APPENDIX 7-7

AVIAN COLLISION RISK MODEL

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Avian Collision Risk Modelling

SEVEN HILLS WIND FARM

Avian Collision Risk Modelling Report

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1.0 Introduction

This report presents the results of Collision Risk Modelling (CRM) undertaken for nine bird species to inform the Environmental Impact Assessment (EIA) for the proposed Seven Hills Wind Farm, which comprises two separate turbine clusters (Wind Farm 1 (WF1) (North) and Wind Farm 2 (WF2) (South)). For the purposes of this report, these two clusters are treated individually and in combination.

The exact make, type and model of turbine to be used as part of the proposed wind farm development will be the result of a future tendering process and therefore an indicative 'candidate' turbine model has been assumed for this assessment. Modelling was therefore based on the use of Vestas V162 6MW turbines, each with a rotor diameter of 162m, tip height of 180m and hub height of 99m, which is consistent with the information outlined in the EIA Report (EIAR).

Where there was sufficient bird flight activity within the respective Collision Risk Zones (CRZs) (i.e., within the respective Wind Farm Polygon (WP[1])) at Potential Collision Height (PCH), CRM was used to predict the number of individuals of each primary target species (see Section 1.1) that might collide with the wind turbine rotors.

Sufficient flight activity was defined as a minimum total of five flights or minimum ten individuals of each primary target species recorded in each CRZ during each season of analysis[2].

The CRM was undertaken in accordance with current NatureScot (NS) (formerly SNH) guidance, which is recognised as standard best practice guidance through the UK and Ireland to inform impact assessment for onshore wind farms. Further details regarding the methodology used, including details of assumptions used and any corrections applied, are provided in Section 2. The monitoring results are presented in Section 3 and copies of the modelling calculations for each species modelled are included in Appendices 01-03.

The results of the CRM, as presented in this report, will be used to inform the EIA for the proposed wind farm. The assessment of significance of potential impacts is beyond the scope of this report and is covered within the EIAR.

1.1 Primary Target Species

The list of primary target species was limited to species upon which effects are most likely to be potentially significant in EIA terms, thereby enabling recording to focus on the species of greatest importance.

NatureScot guidelines state that "*in most circumstances the target species will be limited to those species which are afforded a higher level of legislative protection*." Common kestrel[3], buzzard and sparrowhawk are not subject to a higher level of legislative protection than any other bird species and were therefore not considered as primary target species.

Furthermore, primary target species were specifically limited to species upon which effects are most likely to be potentially significant in EIA terms, e.g., breeding and non-breeding species forming qualifying features for nearby SPAs or species listed on Annex I of the Birds Directive. This enabled recording to focus on the species of greatest importance without the distraction of having to record detailed flight data for a larger number of more common species.

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[1] The Wind Farm Polygon for each cluster includes the area within 500m of the outermost turbine blades in the respective layouts.

[2] Numbers below these thresholds are likely to result in negligible predicted mortality.

[3] Following the publication of the latest Birds of Conservation Concern in Ireland (BoCCI) 4: 2020-2026 (Gilbert *et al*., 2021) in April 2021, common kestrel has been moved to the Red-list. Common kestrel was therefore subsequently included as a primary target species during the breeding season in 2021.

1.1.1 Non-breeding Season Surveys

The primary target species included the following bird species (* excluded in 2019/20):

- Whooper swan *Cygnus cygnus*;
- Greenland white-fronted goose *Anser albifrons flavirostris;*
- Eurasian wigeon *Mareca penelope*;*
- Peregrine falcon *Falco peregrinus*;
- Hen harrier *Circus cyaneus;*
- Merlin *Falco columbarius;*
- Northern lapwing *Vanellus vanellus;*
- European golden plover *Pluvialis apricaria;*
- Eurasian curlew *Numenius arquata*;* and
- Short-eared owl *Asio flammeus*.

1.1.2 Breeding Season Surveys

A precautionary approach was taken to the inclusion of Annex 1 species as primary target species with all Annex 1 raptor/owl species with any realistic potential to be present included as primary target species, although it was recognised that the likelihood of some of these species breeding in the vicinity of the sites was very low. As such, the primary target species for VP surveys during the breeding season included the following bird species (* 2020 and 2021, ** 2021 only):

- Peregrine falcon;
- Hen harrier*;*
- Merlin*;*
- Common kestrel *Falco tinnunculus**;*
- European golden plover*;*
- Eurasian curlew*;*
- Black-headed gull *Chroicocephalus ridibundus**;
- Herring gull *Larus argentatus**; and
- Short-eared owl.

Although northern lapwing, Eurasian curlew, black-headed gull and herring gull are not listed under Annex I of the Birds Directive, they were red-listed in Ireland under the Birds of Conservation Concern 2014-2019[4] as numbers of breeding pairs within the Irish landscape have suffered a serious decline in recent years. As such, Eurasian curlew was recorded as a primary target species in 2019, 2020 and 2021; and northern lapwing and black-headed gull were also included in 2020 and 2021. Herring gull was included as a primary target species in 2020, but not in 2021 owing to its removal from the BoCC red list in April 2021 (Gilbert *et al*., 2021)[5]. Black-headed gull was also removed from the BoCC red list in April 2021 but was retained as a primary target species

[4] Colhoun, K. & Cummins, S. (2013). Birds of Conservation Concern in Ireland 2014–2019. *Irish Birds* 9: 523-544.
[5] Gilbert, G., Stanbury, A. & Lewis, L. (2021). Birds of Conservation Concern in Ireland 4: (2020-2026). *Irish Birds* 43: 1-22.

due to the presence of a breeding colony at Lough Ree. Common kestrel was added to the red list in April 2021 and was therefore classed as a primary target species for breeding season surveys undertaken in 2021.

1.2 Secondary Target Species

Secondary target species included the following and were not subject to CRM:

- Any other wildfowl and wader species not recorded as primary target species;
- Buzzard *Buteo buteo;*
- Sparrowhawk *Accipiter nisus*;
- Common kestrel (other than in 2021 when included as primary target species)*;*
- Raven *Corvus corax*;
- Grey heron *Ardea cinerea;*
- Cormorant *Phalacrocorax carbo;* and
- Gulls *Larus sp*. (where not recorded as primary target species).

2.0 Methods

The standard Band CRM (Band *et al.* 2007[6]) was used to estimate collision risk based on recorded target species activity levels and flight behaviour, proposed turbine numbers and specifications, and the relevant species biometrics and flight characteristics. Modelling collision risk under the Band CRM is a two-stage process. Stage 1 estimates the number of birds that fly through the rotor swept disc. Stage 2 predicts the proportion of these birds that have the potential to be hit by a rotor blade. Combining both stages produces an estimate of collision mortality in the absence of any avoidance action/behaviour by birds. Avoidance rates are then applied to generate predicted rates of collision mortality.

2.1 Prediction of Rotor Transits from Vantage Point Survey Data

The number of birds that fly through the rotor swept area was estimated using flight data gathered during baseline surveys carried out during the period September 2018 to September 2021[7]. These surveys gathered data from the two wind farm clusters using vantage points (VPs). Two VPs were used at WF1 and four VPs were used at WF2.

In order to select flights liable to incur a potential risk of collision; i.e. within the areas occupied by proposed turbines, the CRM used only observations collected within the WP – defined by a 500m buffer (generated from the turbine blades) around the proposed outermost turbine locations (see Figure 1). The size of buffer follows NS guidance, in order to take into account rotor blade length and potential spatial errors in flight recording accuracy[8]. It is known that bird detection rates vary between species. To ensure the CRM used robust measures of flight activity, a 2km distance truncation was used in the viewshed (i.e. the area visible) from each VP (as per NS guidance).

Analysis in GIS identified those flights that were at PCH and over the WP. Flight times that were used in the CRM were derived from field data for each flight. Where only part of the relevant flight line occurred within the WP, the flight time was calculated based on the proportion of the flight recorded within the WP, assuming a constant speed for each flight. Time spent at different flight heights was estimated in a database from interval data for flights that entered the WP. Flying time estimated to occur within the survey recording height bands (see Section 2.1.1) was used to determine the period that target species were at risk of collision with the rotors.

2.1.1 Correcting Survey PCH to Actual PCH

Baseline VP surveys were initiated before candidate turbine details were known. The baseline surveys utilised the following height bands, which evolved over time as likely turbine details became better understood:

Winter 2018/19

- Height Band 1: 0-30m;
- Height Band 2: 30-150m; and

[6] Band, W., Madders, M. and Whitfield, D.P. (2007) Developing Field and Analytical Methods to Assess Avian Collision Risk at Wind Farms. In: De Lucas, M., Janss, G. and Ferrer, M., Eds., *Birds and Wind Power*, Quercus Editions, Madrid, 259-275.
[7] SLR Consulting. (2021). Seven Hills Wind Farm Phase I and II Bird Survey Reports (x6): Winter 2018/19; Breeding Season 2019; Winter 2019/20; Breeding Season 2020; Winter 2020/21; and Breeding Season 2021.
[8] Note that the inclusion of all flights within 500m is a necessarily precautionary approach, primarily to allow for mapping inaccuracies. However, at Seven Hills many of the flights within the 500m buffer occurred close to VPs and are therefore known to be mapped accurately. The inclusion of these flights could therefore result in collision risk being overestimated in some cases, e.g. by the inclusion of flights around Feacle Turlough near WF2 VP3, most of which did enter the rotor swept area.

- Height Band 3: >150m.

Summer 2019

- Height Band 1: 0-30m;
- Height Band 2: 30-150m; and
- Height Band 3: >150m.

Winter 2019/20

- Height Band 1: 0-25m;
- Height Band 2: 25-50m;
- Height Band 3: 50-150m; and
- Height Band 4: >150m.

Summer 2020

- Height Band 1: 0-25m;
- Height Band 2: 25-50m;
- Height Band 3: 50-150m; and
- Height Band 4: >150m.

Winter 2020/21

October only:

- Height Band 1: 0-25m;
- Height Band 2: 25-50m;
- Height Band 3: 50-150m; and
- Height Band 4: >150m.

November – March:

- Height Band 1: 0-15m;
- Height Band 2: 15-30m;
- Height Band 3: 30-150m;
- Height Band 4: 150-200m; and
- Height Band 5: >200m.

Summer 2021

- Height Band 1: 0-15m;
- Height Band 2: 15-30m;
- Height Band 3: 30-150m;
- Height Band 4: 150-200m; and
- Height Band 5: >200m.

As such, the height bands used to record flight activity do not correspond precisely to PCH for the proposed development (18-180m), i.e.:

- Height band 1 overlaps with the lower limit of the actual PCH where it is 0-30m and 0-25m (i.e. prior to November 2020); and
- The 150-180m zone is included within the >150m height bands in all seasons other than during November 2020 – September 2021. Height band 5 in this last period (>200m) is above the tip height of 180m and flights in this height band can therefore be assumed to be above risk height; whereas height band 4 (150-200m) overlaps with the upper limit of the actual PCH.

Because of this it was necessary to make assumptions about the distribution of some of the flight heights recorded. With regard to height band 1, assuming an equal distribution of heights within it, it is clear that a proportion of flights will be below risk height. Therefore, as theoretically only a proportion of flights from 0-30m or 0-25m are at risk, the proportion of flights included within the CRM in height band 1 was assumed to be either 12/30 (where height band 1 was 0-30m) or 7/25 (where height band 1 was 0-25m). With regard to surveys during November 2020 – September 2021 the proportion of flights in height band 2 (15-30m) used was 12/15.

With regard to flights in the >150m height band, these cannot logically be proportioned so a precautionary approach was adopted whereby all flights in this height band were included within the CRM (unless the surveyor noted the estimated height was >180m).

There were no flights in the revised height bands 4 or 5 during the period November 2020-September 2021 therefore no adjustments were necessary.

2.1.2 Seasonal Definitions

For each species modelled, CRMs were constructed using data from the relevant breeding and non-breeding season periods, as defined by NS in relation to Scotland but also broadly applicable to Ireland[9] (Table 2-1).

Table 2-1
Modelled species breeding and non-breeding season periods

Species name	Breeding season start	Breeding season end	Non-breeding season start	Non-breeding season end
Whooper swan	01-Apr	15-Aug	16-Aug	31-Mar
Greenland white-fronted goose	01-Apr	15-Aug	16-Aug	31-Mar
Eurasian wigeon	15-Apr	31-Aug	01-Sep	14-Apr
Peregrine falcon	01-Mar	31-Jul	01-Aug	28-Feb
Common kestrel	01-Mar	15-Aug	16-Aug	28-Feb
European golden plover	01-Apr	15-Aug	16-Aug	31-Mar
Northern lapwing	01-Mar	31-Jul	01-Aug	28-Feb
Eurasian curlew	01-Apr	31-Jul	01-Aug	31-Mar
Black-headed gull	01-Apr	31-Aug	01-Sep	31-Mar

[9] Breeding season dates sourced from NatureScot (https://www.nature.scot/bird-breeding-season-dates-scotland) [Accessed in Dec 2021].

The theoretical time that birds could be active with potential for turbine collisions was assumed to be the period between dawn and dusk within each survey period (determined from civil twilight data for the Site[10]), to account for species which are potentially active during the periods just before sunrise and just after sunset.

2.1.3 Undertaking CRM

The following parameters were entered into a bespoke modelling spreadsheet:

- The total observation effort within the risk volume (V_w) visible from each VP;
- The occupancy total: the total time spent by a particular species flying within the risk volume (V_w) visible from each VP;
- The volume of Vw (m^3) visible from each VP (this is area covered by the outermost turbines without the 500m buffer);
- A calculation of daylight minutes within the season of analysis;
- Species-specific bird parameters (Section 2.1.4); and
- Wind farm parameters (Section 2.1.5).

VP locations, viewsheds (the area visible from each VP at the lowest rotor swept height (18m)) and the 500m buffer around the outermost turbine blades are shown in Figure 1.

The NatureScot CRM spreadsheet[11] calculates the probability of collision for each particular species. The model then combines this probability of collision with the observed flight activity per unit area (hours per hectare) weighted for observation effort from each VP to produce an estimate of the number of transits through the rotor blades. Mortality estimates are then derived by applying species-specific avoidance rates (Section 2.1.4).

2.1.4 Bird Biometrics and Avoidance Rates

Measurements and flight speeds for the species for which CRM was undertaken were derived from British Trust for Ornithology (BTO)[12], SNH (2014[13]), Provan & Whitfield (2006[14]), Bruderer & Boldt (2001[15]) and McDuie *et al.* (2019)[16]. These are detailed in Table 2-2 below, along with the avoidance rate for these species per current NS guidance (SNH 2018[17]).

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[10] https://www.timeanddate.com [Accessed in December 2021].
[11] https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision [Accessed in December 2021].
[12] https://www.bto.org/understanding-birds/birdfacts [Accessed in December 2021].
[13] SNH (2014) Flight speeds and biometrics for collision risk modelling. Scottish Natural Heritage, Inverness.
[14] Provan, S. and Whitfield, D.P. (2006) Avian flight speeds and biometrics for use in collision risk modelling. Unpublished report to Scottish Natural Heritage.
[15] Bruderer, B. and Bolt, A. (2001) Flight characteristics of birds: 1. Radar measurements of speeds, *Ibis*, **143**. 178 – 204.
[16] McDuie, F; Casazza, M.L.; Keiter, D; Overton, C.T.; Herzog, M.P.; Feldheim, C.L. and Ackerman, J.T. (2019). Moving at the speed of flight: dabbling duck-movement rates and the relationship with electronic tracking interval. *Wildlife Research*, **46**, 533-543.
[17] SNH (2018) Avoidance rates for the onshore SNH wind farm collision risk model. https://www.nature.scot/doc/wind-farm-impacts-birds-use-avoidance-rates-naturescot-wind-farm-collision-risk-model#:~:text=2.%20Recommended%20avoidance%20rates%20%20%20Species%20,%20SNH%20%282013%29%20%207%20more%20rows%20

Table 2-2
Bird biometrics and avoidance rates used in CRM

Species name	Bird length (m)	Wingspan (m)	Flight speed (m/s)	Avoidance rate (%)
Whooper swan	1.52	2.3	17.3	99.5
Greenland white-fronted goose	0.72	1.48	16.1	99.8
Eurasian wigeon	0.48	0.8	10.3	98
Peregrine falcon	0.45	1.1	14.0	98
Common kestrel	0.34	0.8	12.7	95
European golden plover	0.28	0.72	17.5	98
Northern lapwing	0.30	0.84	12.3	98
Eurasian curlew	0.55	0.9	13.2	98
Black-headed gull	0.36	1.05	11.2	98

2.1.5 Wind Farm and Turbine Parameters

The north and south wind farm layouts (shown on Figure 1) and wind turbine parameters used in the CRM are detailed in Table 2-3 and are based on the use of Vestas V162 turbines, which are considered likely to represent a reasonable worst-case (in terms of representing the turbine with the longest blade length of the various turbines under consideration).

Table 2-3
Wind farm & turbine parameters

Parameter	Value
Size of wind farm polygons (WP) (ha)	Wind Farm 1 (North): 455.3ha
	Wind Farm 2 (South): 1036.6ha
Wind farm areas (ha) visible within viewshed (v)	Wind Farm 1 (North): 449.6ha
	Wind Farm 2 (South): 914.6ha
Number of turbines	Wind Farm 1 (North): 7
	Wind Farm 2 (South): 13
Rotor diameter	162m
Hub height	99m
Max. chord	4.3m
Pitch	Variable – 0° for modelling purposes
Rotation period	4.96s (max 12.1rpm)
Turbine operation time	95% (estimated by the Client) upper limit considering down-time for maintenance, weather conditions etc.

2.2 Summary Flightline Data

The following sections summarise the available primary target species flightline data from VP surveys conducted at Seven Hills WF1 (north) and WF2 (south), presented for each season (Table 2-4 to Table 2-15). Note that there are some small discrepancies between the total survey hours presented in the baseline survey reports and the survey hours used for CRM in this report. There are two reasons for this:

1. Breeding and non-breeding seasons vary according to species (Table 2-1), therefore the amount of survey effort per season used for CRM does not always correspond with the figures provided in the baseline reports (for example the non-breeding season for wigeon (Table 2-1) begins on 1st September and ends on 14th April whereas the non-breeding season surveys reported in the relevant baseline reports cover the period October to March inclusive); and
2. A small amount of data reported in the baseline reports were unavailable for use in the CRM, due to IT issues. Only flights where the attribute data were available have been used in the CRM, although given the relatively small amount of data affected[18] this is not considered to have significantly affected the outcome of the assessment. It should also be noted that baseline data has been used from three breeding seasons and three non-breeding seasons, which exceeds the requirements of current NS guidance[19].

2.2.1 Wind Farm 1 (North)

Table 2-4
Number of target species flights and individuals observed passing through the CRZ during non-breeding season VP surveys (2018-2019), WF1

Species name	Total number of birds recorded in flight	Flights through WP		CRM carried out	Flights through WP at PCH[20]	
		Flights	Individuals		Flights	Individuals
Whooper swan	21	2	21	Yes	2	21
Greenland white-fronted goose	19	2	19	Yes	2	19
European golden plover	92	1	40	Yes	1	40

[18] The amount of affected data over the two breeding seasons and three non-breeding seasons (where data were affected) is as follows. Northern cluster: VP 1 = 3.2% and VP 2 = 4.8%. Southern cluster: VPs 1 and 2 = 4.8% (each) and VPs 3 and 4 = 13% (each).
[19] Scottish Natural Heritage (2017) Recommended bird survey methods to inform impact assessment of onshore wind farms. Version 2. SNH Guidance.
[20] For the purposes of Tables 2-4 to 2-14 PCH refers to all height bands which include the area at PCH, whether in full or in part.

Table 2-5
Number of target species flights and individuals observed passing through the CRZ during breeding season VP surveys (2019), WF1

Species name	Total number of birds recorded in flight	Flights through WP		CRM carried out	Flights through WP at PCH	
		Flights	Individuals		Flights	Individuals
Peregrine falcon	1	1	1	No	1	1

Table 2-6
Number of target species flights and individuals observed passing through the CRZ during non-breeding season VP surveys (2019-2020), WF1

Species name	Total number of birds recorded in flight	Flights through WP		CRM carried out	Flights through WP at PCH	
		Flights	Individuals		Flights	Individuals
Whooper swan	16	0	0	No	0	0
Greenland white-fronted goose	72	0	0	No	0	0
European golden plover	140	3	92	Yes	3	92
Northern lapwing	25	2	25	Yes	1	10

Table 2-7
Number of target species flights and individuals observed passing through the CRZ during breeding season VP surveys (2020), WF1

Species name	Total number of birds recorded in flight	Flights through WP		CRM carried out	Flights through WP at PCH	
		Flights	Individuals		Flights	Individuals
Hen harrier	1	1	1	No	1	1
Black-headed gull	41	2	7	No	2	7
Herring gull	19	0	0	No	0	0

Table 2-8
Number of target species flights and individuals observed passing through the CRZ during non-breeding season VP surveys (2020-2021), WF1

Species name	Total number of birds recorded in flight	Flights through WP		CRM carried out	Flights through WP at PCH	
		Flights	Individuals		Flights	Individuals
Whooper swan	58	2	13	Yes	2	13
Eurasian wigeon	35	0	0	No	0	0
Peregrine falcon	1	0	0	No	0	0
European golden plover	107	1	17	Yes	1	17
Northern lapwing	60	0	0	No	0	0

Table 2-9
Number of target species flights and individuals observed passing through the CRZ during breeding season VP surveys (2021), WF1

Species name	Total number of birds recorded in flight	Flights through WP		CRM carried out	Flights through WP at PCH	
		Flights	Individuals		Flights	Individuals
Common kestrel	3	0	0	No	0	0
Peregrine falcon	1	1	1	No	1	1
Eurasian curlew	4	0	0	No	0	0
Black-headed gull	51	8	27	Yes	8	27

2.2.2 Wind Farm 2 (South)

Table 2-10
Number of target species flights and individuals observed passing through the CRZ during non-breeding season VP surveys (2018-2019), WF2

Species name	Total number of birds recorded in flight	Flights through WP		CRM carried out	Flights through WP at PCH	
		Flights	Individuals		Flights	Individuals
Whooper swan	33	5	30	Yes	5	30

Species name	Total number of birds recorded in flight	Flights through WP		CRM carried out	Flights through WP at PCH	
		Flights	Individuals		Flights	Individuals
Eurasian wigeon	37	2	37	Yes	2	37
Peregrine falcon	5	4	4	Yes	4	4
European golden plover	11	2	11	Yes	2	11
Northern lapwing	126	8	101	Yes	6	98
Eurasian curlew	212	14	212	Yes	14	212

Table 2-11
Number of target species flights and individuals observed passing through the CRZ during breeding season VP surveys (2019), WF2

Species name	Total number of birds recorded in flight	Flights through WP		CRM carried out	Flights through WP at PCH	
		Flights	Individuals		Flights	Individuals
Peregrine falcon	1	1	1	No	1	1
Eurasian curlew	4	1	4	No	1	4

Table 2-12
Number of target species flights and individuals observed passing through the CRZ during non-breeding season VP surveys (2019-2020), WF2

Species name	Total number of birds recorded in flight	Flights through WP		CRM carried out	Flights through WP at PCH	
		Flights	Individuals		Flights	Individuals
Whooper swan	31	5	31	Yes	5	31
European golden plover	36	3	36	Yes	3	36
Northern lapwing	69	6	69	Yes	6	69

Table 2-13
Number of target species flights and individuals observed passing through the CRZ during breeding season VP surveys (2020), WF2

Species name	Total number of birds recorded in flight	Flights through WP		CRM carried out	Flights through WP at PCH	
		Flights	Individuals		Flights	Individuals
Northern lapwing	23	1	23	Yes	1	23
Black-headed gull	44	16	36	Yes	16	36
Herring gull	5	4	4	No	4	4

Table 2-14
Number of target species flights and individuals observed passing through the CRZ during non-breeding season VP surveys (2020-2021), WF2

Species name	Total number of birds recorded in flight	Flights through WP		CRM carried out	Flights through WP at PCH	
		Flights	Individuals		Flights	Individuals
Whooper swan	35	8	35	Yes	8	35
Greenland white-fronted goose	50	0	0	No	0	0
Eurasian wigeon	291	7	291	Yes	3	158
Peregrine falcon	2	2	2	Yes[21]	2	2
European golden plover	122	5	122	Yes	5	122
Northern lapwing	313	8	313	Yes	8	313

[21] Two flights is below normal threshold for CRM but modelling was carried out in this instance in order to calculate the mean collision risk for peregrine falcon for all years.

Table 2-15
Number of target species flights and individuals observed passing through the CRZ during breeding season VP surveys (2021), WF2

Species name	Total number of birds recorded in flight	Flights through WP		CRM carried out	Flights through WP at PCH	
		Flights	Individuals		Flights	Individuals
Common kestrel	9	9	9	Yes	9	9
Peregrine falcon	2	2	2	No	2	2
Northern lapwing	45	4	45	Yes	4	45
Eurasian curlew	3	2	3	No	2	3
Black-headed gull	97	40	64	Yes	40	64

2.3 Species Input Data

2.3.1 Wind Farm 1 (North)

Species input data are detailed in Table 2-16 to Table 2-23 inclusive.

Table 2-16
Whooper Swan Input Data, Non-breeding Season 2018-19 WF1

VP/ Viewshed		Non-breeding season 2018-19		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	330.5	36	270	270
2	174.6	33	565	452
		Non-breeding season = 01 October[22] – 31 March (182 days) Daylight minutes = 116,909		

Table 2-17
Whooper Swan Input Data, Non-breeding Season 2020-21 WF1

VP/ Viewshed		Non-breeding season 2020-21		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)

[22] Surveys only started in October 2018 so 1st October is taken to be the start of the non-breeding season for this year.

VP/ Viewshed		Non-breeding season 2020-21		
1	330.5	36	0	0
2	174.6	36	912	415
		Non-breeding season = 16 August – 31 March (228 days) Daylight minutes = 156,692		

Table 2-18
Greenland White-fronted Goose Input Data, Non-breeding Season 2018-19 WF1

VP/ Viewshed		Non-breeding season 2018-19		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	330.5	36	959	959
2	174.6	33	0	0
		Non-breeding season = 01 October – 31 March (182 days) Daylight minutes = 116,909		

Table 2-19
European Golden Plover Input Data, Non-breeding Season 2018-19 WF1

VP/ Viewshed		Non-breeding season 2018-19		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	330.5	36	0	0
2	174.6	33	235	235
		Non-breeding season = 01 October – 31 March (182 days) Daylight minutes = 116,909		

Table 2-20
European Golden Plover Input Data, Non-breeding Season 2019-20 WF1

VP/ Viewshed		Non-breeding season 2019-20		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	330.5	48	0	0
2	174.6	48	1859	1736
		Non-breeding season = 01 August – 31 March (244 days)		

VP/ Viewshed	Non-breeding season 2019-20
	Daylight minutes = 172,630

Table 2-21
European Golden Plover Input Data, Non-breeding Season 2020-21 WF1

VP/ Viewshed		Non-breeding season 2019-20		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	330.5	48	849	849
2	174.6	48	0	0
		Non-breeding season = 01 August – 31 March (243 days) Daylight minutes = 171,618		

Table 2-22
Northern Lapwing Input Data, Non-breeding Season 2019-20 WF1

VP/ Viewshed		Non-breeding season 2019-20		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	330.5	48	450	450
2	174.6	48	0	0
		Non-breeding season = 01 August – 29 February (213 days) Daylight minutes = 148,282		

Table 2-23
Black-headed Gull Input Data, Breeding Season 2021 WF1

VP/ Viewshed		Breeding season 2021		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	330.5	30	4080	1834
2	174.6	30	0	0
		Breeding season = 01 April – 31 August (153 days) Daylight minutes = 156,993		

2.3.2 Wind Farm 2 (South)

Species input data are detailed in Table 2-24 to Table 2-42 inclusive.

Table 2-24
Whooper Swan Input Data, Non-breeding Season 2018-19 WF2

VP/ Viewshed		Non-breeding season 2018-19		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	36	0	0
2	371.1	36	135	114
3	415.0	27	624	430
4	154.2	33	0	0
		Non-breeding season = 01 October – 31 March (182 days) Daylight minutes = 116,909		

Table 2-25
Whooper Swan Input Data, Non-breeding Season 2019-20 WF2

VP/ Viewshed		Non-breeding season 2019-20		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	39	240	67
2	371.1	39	990	990
3	415.0	42	795	223
4	154.2	39	207	207
		Non-breeding season = 16 August – 31 March (229 days) Daylight minutes = 158,602		

Table 2-26
Whooper Swan Input Data, Non-breeding Season 2020-21 WF2

VP/ Viewshed		Non-breeding season 2020-21		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	36	0	0
2	371.1	36	357	357

VP/ Viewshed		Non-breeding season 2020-21		
3	415.0	36	1696	1428
4	154.2	36	0	0
		Non-breeding season = 16 August – 31 March (228 days) Daylight minutes = 156,692		

Table 2-27
Eurasian Wigeon Input Data, Non-breeding Season 2018-19 WF2

VP/ Viewshed		Non-breeding season 2018-19		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	36	0	0
2	371.1	36	0	0
3	415.0	27	1770	1041
4	154.2	33	0	0
		Non-breeding season = 01 October – 14 April (196 days) Daylight minutes = 129,231		

Table 2-28
Eurasian Wigeon Input Data, Non-breeding Season 2020-21 WF2

VP/ Viewshed		Non-breeding season 2020-21		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	42	0	0
2	371.1	42	0	0
3	415.0	42	20805	13296
4	154.2	42	0	0
		Non-breeding season = 01 September – 31 March[23] (212 days) Daylight minutes = 141,821		

[23] Survey data period ended on 31 March in 2021.

Table 2-29
Peregrine Falcon Input Data, Non-breeding Season 2018-19 WF2

VP/ Viewshed		Non-breeding season 2018-19		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	30	70	70
2	371.1	33	24	15
3	415.0	21	15	6
4	154.2	30	0	0
		Non-breeding season = 01 October – 28 February (151 days) Daylight minutes = 92,661		

Table 2-30
Peregrine Falcon Input Data, Non-breeding Season 2020-21 WF2

VP/ Viewshed		Non-breeding season 2020-21		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	42	165	165
2	371.1	42	0	0
3	415.0	39	0	0
4	154.2	36	23	23
		Non-breeding season = 01 August – 28 February (212 days) Daylight minutes = 147,318		

Table 2-31
Common Kestrel Input Data, Breeding Season 2021 WF2

VP/ Viewshed		Breeding season 2021		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	36	780	780
2	371.1	33	345	334
3	415.0	30	0	0
4	154.2	30	43	18
		Breeding season = 01 March – 15 August (168 days)		

VP/ Viewshed	Breeding season 2021
	Daylight minutes = 166,422

Table 2-32
European Golden Plover Input Data, Non-breeding Season 2018-19 WF2

VP/ Viewshed		Non-breeding season 2018-19		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	33	0	0
2	371.1	36	270	108
3	415.0	36	0	0
4	154.2	36	0	0
		Non-breeding season = 01 October – 31 March (182 days) Daylight minutes = 116,909		

Table 2-33
European Golden Plover Input Data, Non-breeding Season 2019-20 WF2

VP/ Viewshed		Non-breeding season 2019-20		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	45	0	0
2	371.1	45	1575	441
3	415.0	48	1577	1553
4	154.2	45	0	0
		Non-breeding season = 01 August – 31 March (244 days) Daylight minutes = 172,630		

Table 2-34
European Golden Plover Input Data, Non-breeding Season 2020-21 WF2

VP/ Viewshed		Non-breeding season 2020-21	
VP ID			Bird flight occupancy data

VP/ Viewshed		Non-breeding season 2020-21		
	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Total (s)	Risk height (s)
1	489.4	48	0	0
2	371.1	48	0	0
3	415.0	45	15129	13895
4	154.2	42	10	8
		Non-breeding season = 01 August – 31 March (243 days) Daylight minutes = 171,618		

Table 2-35
Northern Lapwing Input Data, Non-breeding Season 2018-19 WF2

VP/ Viewshed		Non-breeding season 2018-19		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	30	1588	1588
2	371.1	33	447	339
3	415.0	21	3147	1826
4	154.2	30	0	0
		Non-breeding season = 01 October – 28 February (181 days) Daylight minutes = 92,661		

Table 2-36
Northern Lapwing Input Data, Non-breeding Season 2019-20 WF2

VP/ Viewshed		Non-breeding season 2019-20		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	39	0	0
2	371.1	45	0	0
3	415.0	48	5115	4118
4	154.2	45	0	0
		Non-breeding season = 01 August – 29 February (213 days) Daylight minutes = 148,282		

Table 2-37
Northern Lapwing Input Data, Breeding Season 2020 WF2

VP/ Viewshed		Breeding season 2020		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	30	0	0
2	371.1	30	0	0
3	415.0	24	690	442
4	154.2	27	0	0
		Breeding season = 01 March – 31 July (153 days) Daylight minutes = 151,538		

Table 2-38
Northern Lapwing Input Data, Non-breeding Season 2020-21 WF2

VP/ Viewshed		Non-breeding season 2020-21		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	30	0	0
2	371.1	30	0	0
3	415.0	24	28050	24240
4	154.2	27	75	60
		Non-breeding season = 01 August – 28 February (212 days) Daylight minutes = 147,3158		

Table 2-39
Northern Lapwing Input Data, Breeding Season 2021 WF2

VP/ Viewshed		Breeding season 2021		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	30	0	0
2	371.1	30	0	0
3	415.0	30	9855	7596
4	154.2	30	0	0
		Breeding season = 01 March – 31 July (153 days)		

VP/ Viewshed	Breeding season 2021
	Daylight minutes = 151,456

Table 2-40
Eurasian Curlew Input Data, Non-breeding Season 2018-19 WF2

VP/ Viewshed		Non-breeding season 2018-19		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	36	0	0
2	371.1	36	0	0
3	415.0	27	9331	5656
4	154.2	33	405	405
		Non-breeding season = 01 October – 31 Mar (182 days) Daylight minutes = 116,909		

Table 2-41
Black-headed Gull Input Data, Breeding Season 2020 WF2

VP/ Viewshed		Breeding season 2020		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	30	0	0
2	371.1	30	90	25
3	415.0	24	1095	544
4	154.2	27	8	8
		Breeding season = 01 April – 31 August (153 days) Daylight minutes = 157,005		

Table 2-42
Black-headed Gull Input Data, Breeding Season 2021 WF2

VP/ Viewshed		Breeding season 2021		
VP ID	Area of CRZ visible from VP (ha)	Survey effort (hrs)	Bird flight occupancy data	
			Total (s)	Risk height (s)
1	489.4	30	30	8

VP/ Viewshed		Breeding season 2021		
2	371.1	30	0	0
3	415.0	30	1696	1215
4	154.2	30	194	159
		Breeding season = 01 April – 31 August (153 days) Daylight minutes = 156,993		

3.0 Collision Risk Modelling Results

3.1 Wind Farm 1 (North)

Results of modelling for each season, where sufficient data are available, are summarised in Table 3-1 to Table 3-5 inclusive. The mean figure (where CRM was conducted for more than one season) is calculated by combining the occupancy data along with the survey effort data for all years where flight data were used in the model, using the mean number of potentially active minutes for all years and running the model again.

Table 3-1
Whooper Swan CRM Output, WF1

Season	Modelled Collisions per Year	Years per Collision
Non-breeding season 2018-19	0.156	6.4
Non-breeding season 2020-21	0.118	8.5
Non-breeding season mean	0.095	10.5

Table 3-2
Greenland White-fronted Goose CRM Output, WF1

Season	Modelled Collisions per Year	Years per Collision
Non-breeding season 2018-19	0.054	18.5

Table 3-3
European Golden Plover CRM Output, WF1

Season	Modelled Collisions per Year	Years per Collision
Non-breeding season 2018-19	0.101	9.9
Non-breeding season 2019-20	0.798	1.3
Non-breeding season 2020-21	0.444	2.3
Non-breeding season mean	0.432	2.3

Table 3-4
Northern Lapwing CRM Output, WF1

Season	Modelled Collisions per Year	Years per Collision
Non-breeding season 2019-20	0.160	6.3

Table 3-5
Black-headed Gull CRM Output, WF1

Season	Modelled Collisions per Year	Years per Collision
Breeding season 2021	0.969	1.0

3.2 Wind Farm 2 (South)

Results of modelling for each season, where sufficient data are available, are summarised in Table 3-6 to Table 3-13 inclusive. As For WF1 (Section 3.1) the mean figure (where CRM was conducted for more than one season) is calculated by combining the occupancy data along with the survey effort data for all years where flight data were used in the model, using the mean number of potentially active minutes for all years and running the model again.

Table 3-6
Whooper Swan CRM Output, WF2

Season	Modelled Collisions per Year	Years per Collision
Non-breeding season 2018-19	0.052	19.2
Non-breeding season 2019-20	0.161	6.2
Non-breeding season 2020-21	0.211	4.7
Non-breeding season mean	0.133	7.5

Table 3-7
Eurasian Wigeon CRM Output, WF2

Season	Modelled Collisions per Year	Years/ months per Collision
Non-breeding season 2018-19	0.182	5.5 years
Non-breeding season 2020-21	2.013	6 months
Non-breeding season mean	0.794	1.3 years

Table 3-8
Peregrine Falcon CRM Output, WF2

Season	Modelled Collisions per Year	Years per Collision
Non-breeding season 2018-19	0.016	62.5
Non-breeding season 2020-21	0.036	27.8
Non-breeding season mean	0.017	58.8

Table 3-9
Common Kestrel CRM Output, WF2

Season	Modelled Collisions per Year	Years per Collision
Breeding season 2021	0.637	1.6

Table 3-10
European Golden Plover CRM Output, WF2

Season	Modelled Collisions per Year	Years/ months per Collision
Non-breeding season 2018-19	0.021	47.6 years
Non-breeding season 2019-20	0.528	1.9 years
Non-breeding season 2020-21	2.756	4-5 months
Non-breeding season mean	0.847	1.2 years

Table 3-11
Northern Lapwing CRM Output, WF2

Season	Modelled Collisions per Year	Years/ months per Collision
Non-breeding season 2018-19	0.520	1.9 years
Non-breeding season 2019-20	0.587	1.7 years
Non-breeding season 2020-21	3.726	3-4 months
Non-breeding season mean	1.509	7-8 months
Breeding season 2020	0.101	9.9 years
Breeding season 2021	1.512	8 months
Breeding season mean	0.855	1.2 years

Table 3-12
Eurasian Curlew CRM Output, WF2

Season	Modelled Collisions per Year	Months per Collision
Non-breeding season 2018-19	1.171	10

Table 3-13
Black-headed Gull CRM Output, WF2

Season	Modelled Collisions per Year	Years per Collision
Breeding season 2020	0.138	7.2
Breeding season 2021	0.287	3.5
Breeding season mean	0.217	4.6

3.3 Wind Farms 1 & 2 Combined

The CRM outputs for WF1 and WF2 combined are summarised in Table 3-14 to Table 3-22.

Table 3-14
Whooper Swan CRM Output, WF1 & WF2 Combined

Season	Modelled Collisions per Year	Years per Collision
Non-breeding season 2018-19	0.208	4.8
Non-breeding season 2019-20	0.161	6.2
Non-breeding season 2020-21	0.329	3.0
Non-breeding season mean	0.228	4.4

Table 3-15
Greenland White-fronted Goose CRM Output, WF1 & WF2 Combined

Season	Modelled Collisions per Year	Years per Collision
Non-breeding season 2018-19	0.054	18.5

Table 3-16
Eurasian Wigeon CRM Output, WF1 & WF2 Combined

Season	Modelled Collisions per Year	Years/ months per Collision
Non-breeding season 2018-19	0.182	5.5 years
Non-breeding season 2020-21	2.013	6 months
Non-breeding season mean	0.794	1.3 years

Table 3-17
Peregrine Falcon CRM Output, WF1 & WF2 Combined

Season	Modelled Collisions per Year	Years per Collision
Non-breeding season 2018-19	0.016	62.5
Non-breeding season 2020-21	0.036	27.8
Non-breeding season mean	0.017	58.8

Table 3-18
Common Kestrel, WF1 & WF2 Combined

Season	Modelled Collisions per Year	Years per Collision
Breeding season 2021	0.637	1.6

Table 3-19
European Golden Plover CRM Output, WF1 & WF2 Combined

Season	Modelled Collisions per Year	Years/ months per Collision
Non-breeding season 2018-19	0.122	8.2 years
Non-breeding season 2019-20	1.326	9 months
Non-breeding season 2020-21	3.2	4 months
Non-breeding season mean	1.279	9 months

Table 3-20
Northern Lapwing CRM Output, WF1 & WF2 Combined

Season	Modelled Collisions per Year	Years/ months per Collision
Non-breeding season 2018-19	0.520	1.9 years
Non-breeding season 2019-20	0.747	1.3 years
Non-breeding season 2020-21	3.726	3-4 months
Non-breeding season mean	1.66	7 months
Breeding season 2020	0.101	9.9 years
Breeding season 2021	1.512	8 months
Breeding season mean	0.855	1.2 years

Table 3-21
Eurasian Curlew CRM Output, WF1 & WF2 Combined

Season	Modelled Collisions per Year	Months per Collision
Non-breeding season 2018-19	1.171	10

Table 3-22
Black-headed Gull CRM Output, WF1 & WF2 Combined

Season	Modelled Collisions per Year	Years/ months per Collision
Breeding season 2020	0.138	7.2 years
Breeding season 2021	1.256	9.6 months
Breeding season mean	0.697	1.4 years

3.3.1 Notes on Distribution of Flightlines

As stated in Section 2.1 (footnote[8]), the inclusion of all flights within 500m is a necessarily precautionary approach (to take into account spatial errors in mapping), but at Seven Hills, many flights occurred close to VPs and are therefore known to be mapped accurately. Collision risk for some species could therefore be overestimated here, e.g. by the inclusion of flights around landscape features such as Feacle Turlough near WF2 VP3 (where birds gather for roosting and foraging), most of which were not recorded entering the rotor swept area. The result of this is that collision risk for some species may have been over-estimated. Specific examples are as follows:

- Eurasian curlew: the majority of flightlines were concentrated around Feacle Turlough (2018/19 survey report Figures 4, 5, 7 & 8);
- Northern lapwing: many flightlines were concentrated around Feacle Turlough (2019/20 survey report Figure 3, and 2020/21 survey report Figure 6);
- European golden plover: the majority of flightlines were concentrated around Feacle Turlough (2020/21 survey report Figure 5);
- Eurasian wigeon: activity was focussed at Feacle Turlough (2020/21 survey report Figure 7); and

Black-headed gull: activity was focussed at Feacle Turlough and Four Roads Turlough (2020 survey report Figure 3 and 2021 survey report Figure 3).

FIGURES

584000 586000 588000 590000 592000 594000

750000 748000 746000

N

WIND FARM 1

WIND FARM 2

Lough Croon
Culleenirwon Lough
Dysart
Curraghboy
County Roscommon
County Galway

R357 R363 R362 L2013 L2014 L2015 L2016 L2018 L2025 L2028

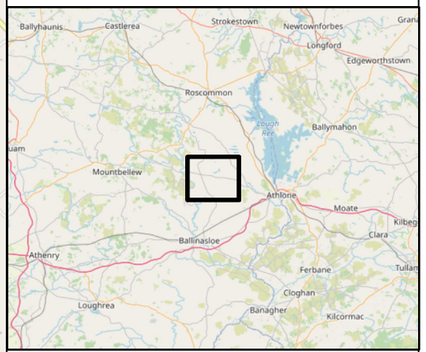
0 1 2
Kilometres

NOTE

1. The Zones of Theoretical Visibility (ZTV) was calculated using ArcMAP 10.5.1 Spatial Analyst. The ZTV is calculated with a surface offset 18m & from a viewing height of 1.8m above ground level. The terrain model is derived from EU-DEM data with a vertical accuracy of ± 7m.

LEGEND

- Turbine Location
- Site Infrastructure
- Vantage Point
- Theoretical Visibility from Wind Farm 1 VP1
- Theoretical Visibility from Wind Farm 1 VP2
- Theoretical Visibility from Wind Farm 2 VP1
- Theoretical Visibility from Wind Farm 2 VP2
- Theoretical Visibility from Wind Farm 2 VP3
- Theoretical Visibility from Wind Farm 2 VP4
- Collision Risk Zones



7 DUNDRUM BUSINESS PARK
WINDY ARBOUR
DUBLIN 14
IRELAND
T: 0129 64667
www.slrconsulting.com

SEVEN HILLS WIND FARM

AVIAN COLLISION RISK MODELLING REPORT

VANTAGE POINT LOCATIONS, VIEWSHEDS AND COLLISION RISK ZONES

FIGURE 1

Scale 1:35,000 @ A3

Date MAY 2022

02036.00633.0035.0 Figure 1 Vantage Point Locations Viewsheds and Collision Risk Zones

APPENDIX 01

Collision Probability Calculations

Whooper Swan

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	0		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	1.52	m	0.025	0.575	6.74	32.19	1.00	0.00125	32.19	1.00	0.00125
Wingspan	2.3	m	0.075	0.575	2.25	10.73	0.38	0.00281	10.73	0.38	0.00281
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.35	7.17	0.25	0.00313	7.17	0.25	0.00313
			0.175	0.860	0.96	5.78	0.20	0.00354	5.78	0.20	0.00354
Bird speed	17.3	m/sec	0.225	0.994	0.75	4.93	0.17	0.00388	4.93	0.17	0.00388
RotorDiam	162	m	0.275	0.947	0.61	4.02	0.14	0.00386	4.02	0.14	0.00386
RotationPeriod	4.96	sec	0.325	0.899	0.52	3.53	0.12	0.00401	3.53	0.12	0.00401
			0.375	0.851	0.45	3.17	0.11	0.00415	3.17	0.11	0.00415
			0.425	0.804	0.40	2.89	0.10	0.00430	2.89	0.10	0.00430
			0.475	0.756	0.35	2.67	0.09	0.00444	2.67	0.09	0.00444
Bird aspect ratioo: β	0.66		0.525	0.708	0.32	2.50	0.09	0.00458	2.50	0.09	0.00458
			0.575	0.660	0.29	2.35	0.08	0.00473	2.35	0.08	0.00473
			0.625	0.613	0.27	2.23	0.08	0.00487	2.23	0.08	0.00487
			0.675	0.565	0.25	2.13	0.07	0.00502	2.13	0.07	0.00502
			0.725	0.517	0.23	2.04	0.07	0.00516	2.04	0.07	0.00516
			0.775	0.470	0.22	1.96	0.07	0.00531	1.96	0.07	0.00531
			0.825	0.422	0.20	1.89	0.07	0.00545	1.89	0.07	0.00545
			0.875	0.374	0.19	1.83	0.06	0.00560	1.83	0.06	0.00560
			0.925	0.327	0.18	1.78	0.06	0.00574	1.78	0.06	0.00574
			0.975	0.279	0.17	1.73	0.06	0.00589	1.73	0.06	0.00589
				Overall p(collision) =			**Upwind**	**8.8%**		**Downwind**	**8.8%**
								Average	**8.8%**		

Greenland White-fronted Goose

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**									
NoBlades	3					Upwind:			Downwind:			
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution	
Pitch (degrees)	0		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r	
BirdLength	0.72	m	0.025	0.575	6.28	24.81	0.93	0.00116	24.81	0.93	0.00116	
Wingspan	1.48	m	0.075	0.575	2.09	8.27	0.31	0.00233	8.27	0.31	0.00233	
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.26	5.64	0.21	0.00265	5.64	0.21	0.00265	
			0.175	0.860	0.90	4.64	0.17	0.00305	4.64	0.17	0.00305	
Bird speed	16.1	m/sec	0.225	0.994	0.70	4.01	0.15	0.00339	4.01	0.15	0.00339	
RotorDiam	162	m	0.275	0.947	0.57	3.17	0.12	0.00327	3.17	0.12	0.00327	
RotationPeriod	4.96	sec	0.325	0.899	0.48	2.59	0.10	0.00316	2.59	0.10	0.00316	
			0.375	0.851	0.42	2.25	0.08	0.00317	2.25	0.08	0.00317	
			0.425	0.804	0.37	2.00	0.07	0.00319	2.00	0.07	0.00319	
			0.475	0.756	0.33	1.79	0.07	0.00320	1.79	0.07	0.00320	
Bird aspect ratioo: β	0.49		0.525	0.708	0.30	1.63	0.06	0.00321	1.63	0.06	0.00321	
			0.575	0.660	0.27	1.49	0.06	0.00323	1.49	0.06	0.00323	
			0.625	0.613	0.25	1.38	0.05	0.00324	1.38	0.05	0.00324	
			0.675	0.565	0.23	1.28	0.05	0.00326	1.28	0.05	0.00326	
			0.725	0.517	0.22	1.20	0.05	0.00327	1.20	0.05	0.00327	
			0.775	0.470	0.20	1.13	0.04	0.00329	1.13	0.04	0.00329	
			0.825	0.422	0.19	1.07	0.04	0.00330	1.07	0.04	0.00330	
			0.875	0.374	0.18	1.01	0.04	0.00332	1.01	0.04	0.00332	
			0.925	0.327	0.17	0.96	0.04	0.00333	0.96	0.04	0.00333	
			0.975	0.279	0.16	0.91	0.03	0.00334	0.91	0.03	0.00334	
				Overall p(collision) =			**Upwind**	**6.1%**		**Downwind**	**6.1%**	
								Average	**6.1%**			

Eurasian Wigeon

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	0		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.48	m	0.025	0.575	4.02	13.14	0.77	0.00096	13.14	0.77	0.00096
Wingspan	0.8	m	0.075	0.575	1.34	4.38	0.26	0.00193	4.38	0.26	0.00193
F: Flapping (0) or gliding (+1)	0		0.125	0.702	0.80	3.06	0.18	0.00225	3.06	0.18	0.00225
			0.175	0.860	0.57	2.60	0.15	0.00267	2.60	0.15	0.00267
Bird speed	10.3	m/sec	0.225	0.994	0.45	2.39	0.14	0.00315	2.39	0.14	0.00315
RotorDiam	162	m	0.275	0.947	0.37	1.97	0.12	0.00317	1.97	0.12	0.00317
RotationPeriod	4.96	sec	0.325	0.899	0.31	1.67	0.10	0.00319	1.67	0.10	0.00319
			0.375	0.851	0.27	1.46	0.09	0.00321	1.46	0.09	0.00321
			0.425	0.804	0.24	1.30	0.08	0.00323	1.30	0.08	0.00323
			0.475	0.756	0.21	1.17	0.07	0.00325	1.17	0.07	0.00325
Bird aspect ratioo: β	0.60		0.525	0.708	0.19	1.06	0.06	0.00327	1.06	0.06	0.00327
			0.575	0.660	0.17	0.98	0.06	0.00329	0.98	0.06	0.00329
			0.625	0.613	0.16	0.90	0.05	0.00331	0.90	0.05	0.00331
			0.675	0.565	0.15	0.84	0.05	0.00333	0.84	0.05	0.00333
			0.725	0.517	0.14	0.79	0.05	0.00335	0.79	0.05	0.00335
			0.775	0.470	0.13	0.74	0.04	0.00337	0.74	0.04	0.00337
			0.825	0.422	0.12	0.70	0.04	0.00339	0.70	0.04	0.00339
			0.875	0.374	0.11	0.66	0.04	0.00341	0.66	0.04	0.00341
			0.925	0.327	0.11	0.63	0.04	0.00343	0.63	0.04	0.00343
			0.975	0.279	0.10	0.60	0.04	0.00345	0.60	0.04	0.00345
				Overall p(collision) =			**Upwind**	**6.1%**		**Downwind**	**6.1%**
								Average	**6.1%**		

Peregrine Falcon

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**									
NoBlades	3					Upwind:			Downwind:			
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution	
Pitch (degrees)	0		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from r	
BirdLength	0.45	m	0.025	0.575	5.46	19.50	0.84	0.00105	19.50	0.84	0.00105	
Wingspan	1.1	m	0.075	0.575	1.82	6.50	0.28	0.00211	6.50	0.28	0.00211	
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.09	4.49	0.19	0.00243	4.49	0.19	0.00243	
			0.175	0.860	0.78	3.74	0.16	0.00283	3.74	0.16	0.00283	
Bird speed	14	m/sec	0.225	0.994	0.61	3.26	0.14	0.00317	3.26	0.14	0.00317	
RotorDiam	162	m	0.275	0.947	0.50	2.57	0.11	0.00305	2.57	0.11	0.00305	
RotationPeriod	4.96	sec	0.325	0.899	0.42	2.08	0.09	0.00293	2.08	0.09	0.00293	
			0.375	0.851	0.36	1.78	0.08	0.00289	1.78	0.08	0.00289	
			0.425	0.804	0.32	1.56	0.07	0.00286	1.56	0.07	0.00286	
			0.475	0.756	0.29	1.38	0.06	0.00284	1.38	0.06	0.00284	
Bird aspect ratioo: β	0.41		0.525	0.708	0.26	1.24	0.05	0.00282	1.24	0.05	0.00282	
			0.575	0.660	0.24	1.12	0.05	0.00279	1.12	0.05	0.00279	
			0.625	0.613	0.22	1.03	0.04	0.00277	1.03	0.04	0.00277	
			0.675	0.565	0.20	0.94	0.04	0.00274	0.94	0.04	0.00274	
			0.725	0.517	0.19	0.87	0.04	0.00272	0.87	0.04	0.00272	
			0.775	0.470	0.18	0.81	0.03	0.00270	0.81	0.03	0.00270	
			0.825	0.422	0.17	0.75	0.03	0.00267	0.75	0.03	0.00267	
			0.875	0.374	0.16	0.70	0.03	0.00265	0.70	0.03	0.00265	
			0.925	0.327	0.15	0.66	0.03	0.00263	0.66	0.03	0.00263	
			0.975	0.279	0.14	0.62	0.03	0.00260	0.62	0.03	0.00260	
				Overall p(collision) =			**Upwind**	**5.3%**		**Downwind**	**5.3%**	
								Average	**5.3%**			

Common Kestrel

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	0		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.34	m	0.025	0.575	4.95	16.20	0.77	0.00096	16.20	0.77	0.00096
Wingspan	0.8	m	0.075	0.575	1.65	5.40	0.26	0.00193	5.40	0.26	0.00193
F: Flapping (0) or gliding (+1)	0		0.125	0.702	0.99	3.78	0.18	0.00225	3.78	0.18	0.00225
			0.175	0.860	0.71	3.18	0.15	0.00265	3.18	0.15	0.00265
Bird speed	12.7	m/sec	0.225	0.994	0.55	2.79	0.13	0.00299	2.79	0.13	0.00299
RotorDiam	162	m	0.275	0.947	0.45	2.19	0.10	0.00287	2.19	0.10	0.00287
RotationPeriod	4.96	sec	0.325	0.899	0.38	1.81	0.09	0.00280	1.81	0.09	0.00280
			0.375	0.851	0.33	1.55	0.07	0.00276	1.55	0.07	0.00276
			0.425	0.804	0.29	1.35	0.06	0.00272	1.35	0.06	0.00272
			0.475	0.756	0.26	1.19	0.06	0.00268	1.19	0.06	0.00268
Bird aspect ratioo: β	0.43		0.525	0.708	0.24	1.06	0.05	0.00265	1.06	0.05	0.00265
			0.575	0.660	0.22	0.95	0.05	0.00261	0.95	0.05	0.00261
			0.625	0.613	0.20	0.86	0.04	0.00257	0.86	0.04	0.00257
			0.675	0.565	0.18	0.79	0.04	0.00253	0.79	0.04	0.00253
			0.725	0.517	0.17	0.72	0.03	0.00249	0.72	0.03	0.00249
			0.775	0.470	0.16	0.66	0.03	0.00245	0.66	0.03	0.00245
			0.825	0.422	0.15	0.61	0.03	0.00241	0.61	0.03	0.00241
			0.875	0.374	0.14	0.57	0.03	0.00237	0.57	0.03	0.00237
			0.925	0.327	0.13	0.53	0.03	0.00233	0.53	0.03	0.00233
			0.975	0.279	0.13	0.49	0.02	0.00229	0.49	0.02	0.00229
				Overall p(collision) =			**Upwind**	**4.9%**		**Downwind**	**4.9%**
								Average	**4.9%**		

European Golden Plover

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	0		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.28	m	0.025	0.575	6.82	21.78	0.75	0.00094	21.78	0.75	0.00094
Wingspan	0.72	m	0.075	0.575	2.27	7.26	0.25	0.00188	7.26	0.25	0.00188
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.36	5.10	0.18	0.00220	5.10	0.18	0.00220
			0.175	0.860	0.97	4.31	0.15	0.00260	4.31	0.15	0.00260
Bird speed	17.5	m/sec	0.225	0.994	0.76	3.79	0.13	0.00294	3.79	0.13	0.00294
RotorDiam	162	m	0.275	0.947	0.62	2.97	0.10	0.00282	2.97	0.10	0.00282
RotationPeriod	4.96	sec	0.325	0.899	0.52	2.41	0.08	0.00270	2.41	0.08	0.00270
			0.375	0.851	0.45	1.99	0.07	0.00258	1.99	0.07	0.00258
			0.425	0.804	0.40	1.68	0.06	0.00246	1.68	0.06	0.00246
			0.475	0.756	0.36	1.45	0.05	0.00238	1.45	0.05	0.00238
Bird aspect ratioo: β	0.39		0.525	0.708	0.32	1.27	0.04	0.00230	1.27	0.04	0.00230
			0.575	0.660	0.30	1.12	0.04	0.00223	1.12	0.04	0.00223
			0.625	0.613	0.27	1.00	0.03	0.00216	1.00	0.03	0.00216
			0.675	0.565	0.25	0.89	0.03	0.00209	0.89	0.03	0.00209
			0.725	0.517	0.24	0.80	0.03	0.00201	0.80	0.03	0.00201
			0.775	0.470	0.22	0.72	0.03	0.00194	0.72	0.03	0.00194
			0.825	0.422	0.21	0.66	0.02	0.00187	0.66	0.02	0.00187
			0.875	0.374	0.19	0.59	0.02	0.00180	0.59	0.02	0.00180
			0.925	0.327	0.18	0.54	0.02	0.00172	0.54	0.02	0.00172
			0.975	0.279	0.17	0.49	0.02	0.00165	0.49	0.02	0.00165
				Overall p(collision) =			**Upwind**	**4.3%**		**Downwind**	**4.3%**
								Average	**4.3%**		

Northern Lapwing

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	0		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.3	m	0.025	0.575	4.79	15.88	0.78	0.00098	15.88	0.78	0.00098
Wingspan	0.84	m	0.075	0.575	1.60	5.29	0.26	0.00195	5.29	0.26	0.00195
F: Flapping (0) or gliding (+1)	0		0.125	0.702	0.96	3.70	0.18	0.00227	3.70	0.18	0.00227
			0.175	0.860	0.68	3.11	0.15	0.00268	3.11	0.15	0.00268
Bird speed	12.3	m/sec	0.225	0.994	0.53	2.73	0.13	0.00302	2.73	0.13	0.00302
RotorDiam	162	m	0.275	0.947	0.44	2.14	0.11	0.00289	2.14	0.11	0.00289
RotationPeriod	4.96	sec	0.325	0.899	0.37	1.74	0.09	0.00277	1.74	0.09	0.00277
			0.375	0.851	0.32	1.47	0.07	0.00271	1.47	0.07	0.00271
			0.425	0.804	0.28	1.27	0.06	0.00266	1.27	0.06	0.00266
			0.475	0.756	0.25	1.12	0.06	0.00262	1.12	0.06	0.00262
Bird aspect ratioo: β	0.36		0.525	0.708	0.23	1.00	0.05	0.00257	1.00	0.05	0.00257
			0.575	0.660	0.21	0.89	0.04	0.00252	0.89	0.04	0.00252
			0.625	0.613	0.19	0.81	0.04	0.00248	0.81	0.04	0.00248
			0.675	0.565	0.18	0.73	0.04	0.00243	0.73	0.04	0.00243
			0.725	0.517	0.17	0.67	0.03	0.00238	0.67	0.03	0.00238
			0.775	0.470	0.15	0.61	0.03	0.00233	0.61	0.03	0.00233
			0.825	0.422	0.15	0.56	0.03	0.00229	0.56	0.03	0.00229
			0.875	0.374	0.14	0.52	0.03	0.00224	0.52	0.03	0.00224
			0.925	0.327	0.13	0.48	0.02	0.00219	0.48	0.02	0.00219
			0.975	0.279	0.12	0.45	0.02	0.00215	0.45	0.02	0.00215
				Overall p(collision) =			**Upwind**	**4.8%**		**Downwind**	**4.8%**
								Average	**4.8%**		

Eurasian Curlew

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	0		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.55	m	0.025	0.575	5.15	17.35	0.80	0.00099	17.35	0.80	0.00099
Wingspan	0.9	m	0.075	0.575	1.72	5.78	0.27	0.00199	5.78	0.27	0.00199
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.03	4.03	0.18	0.00231	4.03	0.18	0.00231
			0.175	0.860	0.74	3.38	0.15	0.00271	3.38	0.15	0.00271
Bird speed	13.2	m/sec	0.225	0.994	0.57	2.99	0.14	0.00309	2.99	0.14	0.00309
RotorDiam	162	m	0.275	0.947	0.47	2.45	0.11	0.00309	2.45	0.11	0.00309
RotationPeriod	4.96	sec	0.325	0.899	0.40	2.08	0.10	0.00310	2.08	0.10	0.00310
			0.375	0.851	0.34	1.81	0.08	0.00310	1.81	0.08	0.00310
			0.425	0.804	0.30	1.60	0.07	0.00311	1.60	0.07	0.00311
			0.475	0.756	0.27	1.43	0.07	0.00311	1.43	0.07	0.00311
Bird aspect ratioo: β	0.61		0.525	0.708	0.25	1.30	0.06	0.00312	1.30	0.06	0.00312
			0.575	0.660	0.22	1.19	0.05	0.00312	1.19	0.05	0.00312
			0.625	0.613	0.21	1.09	0.05	0.00313	1.09	0.05	0.00313
			0.675	0.565	0.19	1.01	0.05	0.00313	1.01	0.05	0.00313
			0.725	0.517	0.18	0.94	0.04	0.00314	0.94	0.04	0.00314
			0.775	0.470	0.17	0.89	0.04	0.00314	0.89	0.04	0.00314
			0.825	0.422	0.16	0.83	0.04	0.00315	0.83	0.04	0.00315
			0.875	0.374	0.15	0.79	0.04	0.00315	0.79	0.04	0.00315
			0.925	0.327	0.14	0.75	0.03	0.00316	0.75	0.03	0.00316
			0.975	0.279	0.13	0.71	0.03	0.00316	0.71	0.03	0.00316
				Overall p(collision) =			**Upwind**	**5.8%**		**Downwind**	**5.8%**
								Average	**5.8%**		

Black-headed Gull

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**									
NoBlades	3					Upwind:			Downwind:			
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution	
Pitch (degrees)	0		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r	
BirdLength	0.36	m	0.025	0.575	4.37	15.38	0.83	0.00104	15.38	0.83	0.00104	
Wingspan	1.05	m	0.075	0.575	1.46	5.13	0.28	0.00208	5.13	0.28	0.00208	
F: Flapping (0) or gliding (+1)	0		0.125	0.702	0.87	3.55	0.19	0.00240	3.55	0.19	0.00240	
			0.175	0.860	0.62	2.96	0.16	0.00280	2.96	0.16	0.00280	
Bird speed	11.2	m/sec	0.225	0.994	0.49	2.58	0.14	0.00314	2.58	0.14	0.00314	
RotorDiam	162	m	0.275	0.947	0.40	2.03	0.11	0.00302	2.03	0.11	0.00302	
RotationPeriod	4.96	sec	0.325	0.899	0.34	1.66	0.09	0.00291	1.66	0.09	0.00291	
			0.375	0.851	0.29	1.43	0.08	0.00289	1.43	0.08	0.00289	
			0.425	0.804	0.26	1.25	0.07	0.00286	1.25	0.07	0.00286	
			0.475	0.756	0.23	1.11	0.06	0.00284	1.11	0.06	0.00284	
Bird aspect ratioo: β	0.34		0.525	0.708	0.21	0.99	0.05	0.00282	0.99	0.05	0.00282	
			0.575	0.660	0.19	0.90	0.05	0.00279	0.90	0.05	0.00279	
			0.625	0.613	0.17	0.82	0.04	0.00277	0.82	0.04	0.00277	
			0.675	0.565	0.16	0.75	0.04	0.00274	0.75	0.04	0.00274	
			0.725	0.517	0.15	0.69	0.04	0.00272	0.69	0.04	0.00272	
			0.775	0.470	0.14	0.64	0.03	0.00270	0.64	0.03	0.00270	
			0.825	0.422	0.13	0.60	0.03	0.00267	0.60	0.03	0.00267	
			0.875	0.374	0.12	0.56	0.03	0.00265	0.56	0.03	0.00265	
			0.925	0.327	0.12	0.53	0.03	0.00263	0.53	0.03	0.00263	
			0.975	0.279	0.11	0.49	0.03	0.00260	0.49	0.03	0.00260	
				Overall p(collision) =			**Upwind**	**5.3%**		**Downwind**	**5.3%**	
								Average	**5.3%**			

APPENDIX 02

Wind Farm 1 (North) CRM Calculations

	Viewsheds							
	1	**2**						
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	270	452						
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	2,160	1,980						
Windfarm area (ha) visible within viewshed (*v*)	330.5	174.6						
T_wV rate=$T_wV/e/v$	3.78E-04	1.31E-03						
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	713,794	345,787						
Weight: proportion of total effort made at the VP	0.674	0.326						
Weighted T_wV rate (T_wV rate * weight)	2.55E-04	4.27E-04						
Total weighted occupancy rate (*z*)	0.000682 birds per metre per ha/minute							
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]	116,909							
Total area of windfarm (survey WP, in ha)[1]	455.3							

Tw=z*a*WP	36,282 seconds
Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	36,282 seconds
Step 1.6: Flight risk volume (V_w)	
Actual WP indfarm area *(A)*[3]	1,344,583 m^2
Height of rotors *(h)*	180 m
Actual risk volume: $V_w=A*h$	242,024,873 m^3

Step 1.7: Volume swept by windfarm rotors (V_r)	
Number of turbines *(N)*	7
π	3.14159
Rotor radius *(R)*	81 m
Rotor blade width *(d)*	4.3 m
WS length (L)	1.52 m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	839,732.4 m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)	
T_r=adj$T_w*(V_r/Vw)$	125.9 seconds
Step 1.9: Time taken to transit rotor *(t)*	
Flight speed *(s)*	17.3 m/sec
$t_r=(d+L)/s$	0.34 sec
Step 1.10: Number of rotor transits (N)	
$N=T_r/t$	374 rotor transits

STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.088
STAGE 3: Predicted mortality (birds per year)	
Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	31.28 collisions
Step 3.2: Adjusted using a range of avoidance rates:	
99.50%	**0.156 (approx. one collision every 6-7 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=1.52m, wingspan 2.3m, flight speed= 17.3m/sec

	Viewsheds							
	1	**2**						
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	0	415						
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	2,160	2,160						
Windfarm area (ha) visible within viewshed (*v*)	330.5	174.6						
T_wV rate=$T_wV/e/v$	0.00E+00	1.10E-03						
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	713,794	377,222						
Weight: proportion of total effort made at the VP	0.654	0.346						
Weighted T_wV rate (T_wV rate * weight)	0.00E+00	3.80E-04						
Total weighted occupancy rate (*z*)					0.000380			birds per metre per ha/minute
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]					157,658			
Total area of windfarm (survey WP, in ha)[1]					455.3			
Tw=z*a*WP					27,289			seconds
Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))					27,289			seconds

Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	1,344,583	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	242,024,873	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	7	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
WS length (L)	1.52	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	839,732.4	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	94.7	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	17.3	m/sec
$t_r=(d+L)/s$	0.34	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	281	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.088	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	23.53	collisions
Step 3.2: Adjusted using a range of avoidance rates:		
99.50%	**0.118**	**(approx. one collision every 9 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=1.52m, wingspan 2.3m, flight speed= 17.3m/sec

	Viewsheds							
	1	**2**						
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	959	0						
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	2,160	1,980						
Windfarm area (ha) visible within viewshed (*v*)	330.5	174.6						
T_wV rate=$T_wV/e/v$	1.34E-03	0.00E+00						
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)* [1]								
Effort in hectare-minutes (ve)	713,794	345,787						
Weight: proportion of total effort made at the VP	0.674	0.326						
Weighted T_wV rate (T_wV rate * weight)	9.05E-04	0.00E+00						
Total weighted occupancy rate (*z*)	0.000905 birds per metre per ha/minute							
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: breeding season (a)[2]	116,909							
Total area of windfarm (survey WP, in ha)[1]	455.3							
Tw=z*a*WP	48,166 seconds							
Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	48,166 seconds							

Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	1,344,583	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	242,024,873	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	7	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
WG length (L)	0.72	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	724,305.3	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	144.1	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	16.1	m/sec
$t_r=(d+L)/s$	0.31	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	462	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.061	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, tubines operational 95% of the time N*p(collision)*0.95	26.79	collisions
Step 3.2: Adjusted using a range of avoidance rates:		

99.80%	**0.054**	**(approx. one collision every 18-19 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.72m, wingspan 1.48m, flight speed= 16.1m/sec

	Viewsheds							
	1	**2**						
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	0	235						
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	2,160	1,980						
Windfarm area (ha) visible within viewshed (*v*)	330.5	174.6						
T_wV rate=T_wV/*e*/*v*	0.00E+00	6.79E-04						
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	713,794	345,787						
Weight: proportion of total effort made at the VP	0.674	0.326						
Weighted T_wV rate (T_wV rate * weight)	0.00E+00	2.22E-04						
Total weighted occupancy rate (*z*)	0.000222	birds per metre per ha/minute						
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]	116,909							
Total area of windfarm (survey WP, in ha)[1]	455.3							
Tw=z*a*WP	11,794	seconds						
Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	11,794	seconds						

Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	1,344,583	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	242,024,873	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	7	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
GP length (L)	0.28	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	660,820.4	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	32.2	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	17.5	m/sec
$t_r=(d+L)/s$	0.26	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	123	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.043	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	5.03	collisions
Step 3.2: Adjusted using a range of avoidance rates:		
98%	**0.101**	**(approx one collision every 10 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.28m, wingspan 0.72m, flight speed= 17.5m/sec

	Viewsheds							
	1	**2**						
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	0	1,736						
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	2,880	2,880						
Windfarm area (ha) visible within viewshed (*v*)	330.5	174.6						
T_wV rate=$T_wV/e/v$	0.00E+00	3.45E-03						
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	951,725	502,963						
Weight: proportion of total effort made at the VP	0.654	0.346						
Weighted T_wV rate (T_wV rate * weight)	0.00E+00	1.19E-03						
Total weighted occupancy rate (*z*)					0.001193		birds per metre per ha/minute	
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]					172,360			
Total area of windfarm (survey WP, in ha)[1]					455.3			
Tw=z*a*WP					93,635	seconds		
Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))					93,635	seconds		

Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	1,344,583	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	242,024,873	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	7	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
GP length (L)	0.28	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	660,820.4	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	255.7	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	17.5	m/sec
$t_r=(d+L)/s$	0.26	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	977	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.043	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	39.90	collisions
Step 3.2: Adjusted using a range of avoidance rates:		
98%	**0.798**	**(approx one collision every 1-2 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.28m, wingspan 0.72m, flight speed= 17.5m/sec

	Viewsheds							
	1	**2**						
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	849	0						
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	2,520	2,520						
Windfarm area (ha) visible within viewshed (*v*)	330.5	174.6						
T_wV rate=T_wV/*e*/*v*	1.02E-03	0.00E+00						
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	832,759	440,093						
Weight: proportion of total effort made at the VP	0.654	0.346						
Weighted T_wV rate (T_wV rate * weight)	6.67E-04	0.00E+00						
Total weighted occupancy rate (*z*)	0.000667 birds per metre per ha/minute							
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]	171,618							
Total area of windfarm (survey WP, in ha)[1]	455.3							
Tw=z*a*WP	52,105 seconds							
Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	52,105 seconds							

Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	1,344,583	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	242,024,873	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	7	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
GP length (L)	0.28	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	660,820.4	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	142.3	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	17.5	m/sec
$t_r=(d+L)/s$	0.26	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	544	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.043	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	22.21	collisions
Step 3.2: Adjusted using a range of avoidance rates:		
98%	**0.444**	**(approx one collision every 2 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.28m, wingspan 0.72m, flight speed= 17.5m/sec

	Viewsheds							
	1	**2**						
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	450	0						
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	2,520	2,520						
Windfarm area (ha) visible within viewshed (*v*)	330.5	174.6						
T_wV rate=$T_wV/e/v$	5.40E-04	0.00E+00						
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	832,759	440,093						
Weight: proportion of total effort made at the VP	0.654	0.346						
Weighted T_wV rate (T_wV rate * weight)	3.54E-04	0.00E+00						
Total weighted occupancy rate (*z*)	0.000354	birds per metre per ha/minute						
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]	148,282							
Total area of windfarm (survey WP, in ha)[1]	455.3							
Tw=z*a*WP	23,868	seconds						
Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	23,868	seconds						

Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	1,344,583	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	242,024,873	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	7	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
L. length (L)	0.3	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	663,706.1	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	65.5	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	12.3	m/sec
$t_r=(d+L)/s$	0.37	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	175	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.048	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	7.98	collisions
Step 3.2: Adjusted using a range of avoidance rates:		
98%	**0.160**	**(approx one collision every 6-7 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.30m, wingspan 0.84m, flight speed= 12.3m/sec

	Viewsheds							
	1	**2**						
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	1,834	0						
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	1,800	1,800						
Windfarm area (ha) visible within viewshed (*v*)	330.5	174.6						
T_wV rate=$T_wV/e/v$	3.08E-03	0.00E+00						
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	594,828	314,352						
Weight: proportion of total effort made at the VP	0.654	0.346						
Weighted T_wV rate (T_wV rate * weight)	2.02E-03	0.00E+00						
Total weighted occupancy rate (*z*)					0.002017		birds per metre per ha/minute	
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]					156,993			
Total area of windfarm (survey WP, in ha)[1]					455.3			
Tw=z*a*WP					144,187	seconds		
Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))					144,187	seconds		

Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	1,344,583	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	242,024,873	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	7	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
BH length (L)	0.36	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	672,363.1	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	400.6	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	11.2	m/sec
$t_r=(d+L)/s$	0.42	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	963	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.053	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	48.47	collisions
Step 3.2: Adjusted using a range of avoidance rates:		
98%	**0.969**	**(approx one collision every 1 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.36m, wingspan 1.05m, flight speed= 11.2m/sec

APPENDIX 03

Wind Farm 2 (South) CRM Calculations

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	0	114	430	0				
Step 1.2: Unweighted occupancy rate each viewshed (T_wVrate)								
Minutes survey effort (*e*)	2,160	2,160	1,620	1,980				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=*T_wV/e/v*	0.00E+00	1.42E-04	6.39E-04	0.00E+00				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	1,057,050	801,608	672,298	305,225				
Weight: proportion of total effort made at the VP	0.373	0.283	0.237	0.108				
Weighted T_wV rate (*T_wV* rate * weight)	0.00E+00	4.01E-05	1.51E-04	0.00E+00				
Total weighted occupancy rate (*z*)				0.000192	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]				116,909				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				23,214	seconds			

Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	23,214	seconds
Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
WS length (L)	1.52	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,559,503.1	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	42.0	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	17.3	m/sec
$t_r=(d+L)/s$	0.34	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	125	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.088	
STAGE 3: Predicted mortality (birds per year)		

Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95		10.43	collisions
Step 3.2: Adjusted using a range of avoidance rates:			
99.50%		**0.052**	**(approx. one collision every 19-20 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=1.52m, wingspan 2.3m, flight speed= 17.3m/sec

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	67	990	223	207				
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	2,340	2,340	2,520	2,340				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=*T_wV/e/v*	5.87E-05	1.14E-03	2.13E-04	5.74E-04				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	1,145,138	868,409	1,045,797	360,720				
Weight: proportion of total effort made at the VP	0.335	0.254	0.306	0.105				
Weighted T_wV rate (*T_wV* rate * weight)	1.96E-05	2.89E-04	6.51E-05	6.05E-05				
Total weighted occupancy rate (*z*)				0.000435	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]				158,602				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				71,470	seconds			

Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	71,470	seconds
Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
WS length (L)	1.52	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,559,503.1	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	129.3	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	17.3	m/sec
$t_r=(d+L)/s$	0.34	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	384	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.088	
STAGE 3: Predicted mortality (birds per year)		

Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95		32.12	collisions
Step 3.2: Adjusted using a range of avoidance rates:			
99.50%		**0.161**	**(approx. one collision every 6 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=1.52m, wingspan 2.3m, flight speed= 17.3m/sec

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	0	357	1,428	0				
Step 1.2: Unweighted occupancy rate each viewshed (T_wVrate)								
Minutes survey effort (*e*)	2,160	2,160	2,160	2,160				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=$T_wV/e/v$	0.00E+00	4.45E-04	1.59E-03	0.00E+00				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	1,057,050	801,608	896,398	332,973				
Weight: proportion of total effort made at the VP	0.342	0.260	0.290	0.108				
Weighted T_wV rate (T_wV rate * weight)	0.00E+00	1.16E-04	4.63E-04	0.00E+00				
Total weighted occupancy rate (*z*)				0.000578	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]				156,692				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				93,909	seconds			

Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	93,909	seconds
Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
WS length (L)	1.52	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,559,503.1	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	169.9	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	17.3	m/sec
$t_r=(d+L)/s$	0.34	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	505	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.088	
STAGE 3: Predicted mortality (birds per year)		

Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	42.21	collisions
Step 3.2: Adjusted using a range of avoidance rates:		
99.50%	**0.211**	**(approx. one collision every 4-5 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=1.52m, wingspan 2.3m, flight speed= 17.3m/sec

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	0	0	1,041	0				
Step 1.2: Unweighted occupancy rate each viewshed (T_wVrate)								
Minutes survey effort (*e*)	2,160	2,160	1,620	1,980				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=*T_wV/e/v*	0.00E+00	0.00E+00	1.55E-03	0.00E+00				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	1,057,050	801,608	672,284	305,225				
Weight: proportion of total effort made at the VP	0.373	0.283	0.237	0.108				
Weighted T_wV rate (*T_wV* rate * weight)	0.00E+00	0.00E+00	3.67E-04	0.00E+00				
Total weighted occupancy rate (*z*)				0.000367	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]				129,231				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				49,170	seconds			

Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	49,170	seconds
Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
L. length (L)	0.48	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,280,829.0	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	73.0	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	10.3	m/sec
$t_r=(d+L)/s$	0.46	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	157	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.061	
STAGE 3: Predicted mortality (birds per year)		

Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	9.12	collisions
Step 3.2: Adjusted using a range of avoidance rates:		
98%	**0.182**	**(approx one collisions every 5-6 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.48m, wingspan 0.8m, flight speed= 10.3m/sec

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	0	0	13,296	0				
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	2,520	2,520	2,520	2,520				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=*T_wV/e/v*	0.00E+00	0.00E+00	1.27E-02	0.00E+00				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	1,233,225	935,210	1,045,775	388,468				
Weight: proportion of total effort made at the VP	0.342	0.260	0.290	0.108				
Weighted T_wV rate (*T_wV* rate * weight)	0.00E+00	0.00E+00	3.69E-03	0.00E+00				
Total weighted occupancy rate (*z*)				0.003691	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]				141,821				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				542,559	seconds			
Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))				542,559	seconds			

Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
L. length (L)	0.48	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,280,829.0	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	806.0	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	10.3	m/sec
$t_r=(d+L)/s$	0.46	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	1,737	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.061	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	100.64	collisions
Step 3.2: Adjusted using a range of avoidance rates:		

98%	**2.013**	**(approx 2 collisions per yr)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.
[2] The total number of daytime minutes during the period (based on Civil Twilight).
[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).
[4]Assumes bird length=0.48m, wingspan 0.8m, flight speed= 10.3m/sec

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	780	334	0	18				
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	2,160	1,980	1,800	1,800				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=*$T_wV/e/v$*	7.38E-04	4.55E-04	0.00E+00	6.60E-05				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	1,057,050	734,808	746,982	277,477				
Weight: proportion of total effort made at the VP	0.375	0.261	0.265	0.099				
Weighted T_wV rate (*T_wV* rate * weight)	2.77E-04	1.19E-04	0.00E+00	6.50E-06				
Total weighted occupancy rate (*z*)				0.000402	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: breeding season (a)[2]				166,422				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				69,359	seconds			

Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	69,359	seconds
Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
K. length (L)	0.34	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,243,315.2	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	100.0	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	12.7	m/sec
$t_r=(d+L)/s$	0.37	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	274	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.049	
STAGE 3: Predicted mortality (birds per year)		

Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	12.74	collisions
Step 3.2: Adjusted using a range of avoidance rates:		
95%	**0.637**	**(approx. one collision every 1-2 years)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.36m, wingspan 1.05m, flight speed= 11.2m/sec

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	70	15	6	0				
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	1,800	1,980	1,260	1,800				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=$T_wV/e/v$	7.99E-05	1.97E-05	1.15E-05	0.00E+00				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	880,875	734,808	522,887	277,477				
Weight: proportion of total effort made at the VP	0.365	0.304	0.216	0.115				
Weighted T_wV rate (T_wV rate * weight)	2.91E-05	6.00E-06	2.48E-06	0.00E+00				
Total weighted occupancy rate (*z*)				0.000038	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]				92,661				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				3,614	seconds			

Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	3,614	seconds
Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
PE length (L)	0.45	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,272,790.3	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	5.3	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	14	m/sec
$t_r=(d+L)/s$	0.34	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	16	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.053	
STAGE 3: Predicted mortality (birds per year)		

Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	0.79	collisions
Step 3.2: Adjusted using a range of avoidance rates:		
98%	**0.016**	**(approx one collision every 62 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.45m, wingspan 1.1m, flight speed= 14.0m/sec

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	165	0	0	23				
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	2,520	2,520	2,340	2,160				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=$T_wV/e/v$	1.34E-04	0.00E+00	0.00E+00	6.84E-05				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	1,233,225	935,210	971,077	332,973				
Weight: proportion of total effort made at the VP	0.355	0.269	0.280	0.096				
Weighted T_wV rate (T_wV rate * weight)	4.75E-05	0.00E+00	0.00E+00	6.56E-06				
Total weighted occupancy rate (*z*)				0.000054	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]				147,318				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				8,258	seconds			

Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	8,258	seconds
Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
PE length (L)	0.45	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,272,790.3	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	12.2	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	14	m/sec
$t_r=(d+L)/s$	0.34	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	36	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.053	
STAGE 3: Predicted mortality (birds per year)		

Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	1.81	collisions
Step 3.2: Adjusted using a range of avoidance rates:		
98%	**0.036**	**(approx one collision every 28 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.45m, wingspan 1.1m, flight speed= 14.0m/sec

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	0	0	108	0				
Step 1.2: Unweighted occupancy rate each viewshed (T_wVrate)								
Minutes survey effort (*e*)	2,160	2,160	1,620	1,980				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=*T_wV/e/v*	0.00E+00	0.00E+00	1.61E-04	0.00E+00				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	1,057,050	801,608	672,298	305,225				
Weight: proportion of total effort made at the VP	0.373	0.283	0.237	0.108				
Weighted T_wV rate (*T_wV* rate * weight)	0.00E+00	0.00E+00	3.81E-05	0.00E+00				
Total weighted occupancy rate (*z*)				0.000038	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]				116,909				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				4,615	seconds			

Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	4,615	seconds
Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
GP length (L)	0.28	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,227,237.8	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	6.6	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	17.5	m/sec
$t_r=(d+L)/s$	0.26	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	25	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.043	
STAGE 3: Predicted mortality (birds per year)		

Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	1.03	collisions
Step 3.2: Adjusted using a range of avoidance rates:		
98%	**0.021**	**(approx one collision every 47-48 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.28m, wingspan 0.72m, flight speed= 17.5m/sec

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	0	441	1,553	0				
Step 1.2: Unweighted occupancy rate each viewshed (T_wVrate)								
Minutes survey effort (*e*)	2,700	2,700	2,880	2,700				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=*T_wV/e/v*	0.00E+00	4.40E-04	1.30E-03	0.00E+00				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	1,321,313	1,002,011	1,195,197	416,216				
Weight: proportion of total effort made at the VP	0.336	0.255	0.304	0.106				
Weighted T_wV rate (*T_wV* rate * weight)	0.00E+00	1.12E-04	3.95E-04	0.00E+00				
Total weighted occupancy rate (*z*)				0.000507	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]				172,630				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				90,669	seconds			

Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	90,669	seconds
Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
GP length (L)	0.28	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,227,237.8	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	129.1	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	17.5	m/sec
$t_r=(d+L)/s$	0.26	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	493	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.043	
STAGE 3: Predicted mortality (birds per year)		

Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	20.14	collisions
Step 3.2: Adjusted using a range of avoidance rates:		
98%	**0.403**	**(approx one collision every 2-3 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.28m, wingspan 0.72m, flight speed= 17.5m/sec

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	0	0	13,895	8				
Step 1.2: Unweighted occupancy rate each viewshed (T_wVrate)								
Minutes survey effort (*e*)	2,880	2,880	2,700	2,520				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=*T_wV/e/v*	0.00E+00	0.00E+00	1.24E-02	1.98E-05				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	1,409,400	1,068,811	1,120,497	388,468				
Weight: proportion of total effort made at the VP	0.353	0.268	0.281	0.097				
Weighted T_wV rate (*T_wV* rate * weight)	0.00E+00	0.00E+00	3.48E-03	1.92E-06				
Total weighted occupancy rate (*z*)				0.003487	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]				171,618				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				620,269	seconds			

Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	620,269	seconds
Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
GP length (L)	0.28	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,227,237.8	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	882.9	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	17.5	m/sec
$t_r=(d+L)/s$	0.26	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	3,373	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.043	
STAGE 3: Predicted mortality (birds per year)		

Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	137.80	collisions
Step 3.2: Adjusted using a range of avoidance rates:		
98%	**2.756**	**(approx three collisions every year)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.28m, wingspan 0.72m, flight speed= 17.5m/sec

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	1,588	339	1,826	0				
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	1,800	1,980	1,260	1,800				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=$T_wV/e/v$	1.80E-03	4.62E-04	3.49E-03	0.00E+00				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	880,875	734,808	522,887	277,477				
Weight: proportion of total effort made at the VP	0.365	0.304	0.216	0.115				
Weighted T_wV rate (T_wV rate * weight)	6.57E-04	1.40E-04	7.56E-04	0.00E+00				
Total weighted occupancy rate (*z*)				0.001553	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]				92,661				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				149,203	seconds			

Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	149,203	seconds
Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
L. length (L)	0.3	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,232,597.0	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	213.3	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	12.3	m/sec
$t_r=(d+L)/s$	0.37	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	570	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.048	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	26.01	collisions

Step 3.2: Adjusted using a range of avoidance rates:	
98%	**0.520 (approx one collision every 2 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.30m, wingspan 0.84m, flight speed= 12.3m/sec

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	0	0	4,118	0				
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	2,340	2,700	2,880	2,700				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=$T_wV/e/v$	0.00E+00	0.00E+00	3.45E-03	0.00E+00				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	1,145,138	1,002,011	1,195,171	416,216				
Weight: proportion of total effort made at the VP	0.305	0.267	0.318	0.111				
Weighted T_wV rate (T_wV rate * weight)	0.00E+00	0.00E+00	1.10E-03	0.00E+00				
Total weighted occupancy rate (*z*)				0.001096	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]				148,282				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				168,393	seconds			

Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	168,393	seconds
Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
L. length (L)	0.3	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,232,597.0	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	240.7	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	12.3	m/sec
$t_r=(d+L)/s$	0.37	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	644	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.048	
STAGE 3: Predicted mortality (birds per year)		

Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	29.35	collisions
Step 3.2: Adjusted using a range of avoidance rates:		
98%	**0.587**	**(approx one collision every 1-2 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.30m, wingspan 0.84m, flight speed= 12.3m/sec

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	0	0	442	0				
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	1,800	1,800	1,440	1,620				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=$T_wV/e/v$	0.00E+00	0.00E+00	7.39E-04	0.00E+00				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	880,875	668,007	597,586	249,729				
Weight: proportion of total effort made at the VP	0.368	0.279	0.249	0.104				
Weighted T_wV rate (T_wV rate * weight)	0.00E+00	0.00E+00	1.84E-04	0.00E+00				
Total weighted occupancy rate (*z*)				0.000184	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: breeding season (a)[2]				151,538				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				28,949	seconds			

Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	28,949	seconds
Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
L. length (L)	0.3	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,232,597.0	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	41.4	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	12.3	m/sec
$t_r=(d+L)/s$	0.37	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	111	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.048	
STAGE 3: Predicted mortality (birds per year)		

Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	5.05	collisions
Step 3.2: Adjusted using a range of avoidance rates:		
98%	**0.101**	**(approx one collision every 10 yrs)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.30m, wingspan 0.84m, flight speed= 12.3m/sec

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	0	0	24,240	60				
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	2,520	2,520	2,340	2,160				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=$T_wV/e/v$	0.00E+00	0.00E+00	2.50E-02	1.81E-04				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	1,233,225	935,210	971,077	332,973				
Weight: proportion of total effort made at the VP	0.355	0.269	0.280	0.096				
Weighted T_wV rate (T_wV rate * weight)	0.00E+00	0.00E+00	6.98E-03	1.74E-05				
Total weighted occupancy rate (*z*)				0.006998	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]				147,318				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				1,068,659	seconds			
Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))				1,068,659	seconds			

Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
L. length (L)	0.3	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,232,597.0	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	1527.7	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	12.3	m/sec
$t_r=(d+L)/s$	0.37	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	4,085	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.048	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	186.28	collisions
Step 3.2: Adjusted using a range of avoidance rates:		

98%	**3.726**	**(approx four collisions per yr)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.
[2] The total number of daytime minutes during the period (based on Civil Twilight).
[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).
[4]Assumes bird length=0.30m, wingspan 0.84m, flight speed= 12.3m/sec

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	0	0	7,596	0				
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	2,160	1,800	1,800	1,800				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=*T_wV/e/v*	0.00E+00	0.00E+00	1.02E-02	0.00E+00				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	1,057,050	668,007	746,982	277,477				
Weight: proportion of total effort made at the VP	0.384	0.243	0.272	0.101				
Weighted T_wV rate (*T_wV* rate * weight)	0.00E+00	0.00E+00	2.76E-03	0.00E+00				
Total weighted occupancy rate (*z*)				0.002763	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: breeding season (a)[2]				151,456				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				433,737	seconds			

Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	433,737	seconds
Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
L. length (L)	0.3	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,232,597.0	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	620.1	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	12.3	m/sec
$t_r=(d+L)/s$	0.37	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	1,658	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.048	
STAGE 3: Predicted mortality (birds per year)		

Step 3.1: With no avoidance, turbines operational 95% of the time	N*p(collision)*0.95	75.60	collisions
Step 3.2: Adjusted using a range of avoidance rates:			
98%		**1.512**	**(approx one collision every 8 months)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.30m, wingspan 0.84m, flight speed= 12.3m/sec

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	0	0	5,656	405				
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	2,160	2,160	1,620	1,980				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=$T_wV/e/v$	0.00E+00	0.00E+00	8.41E-03	1.33E-03				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	1,057,050	801,608	672,284	305,225				
Weight: proportion of total effort made at the VP	0.373	0.283	0.237	0.108				
Weighted T_wV rate (T_wV rate * weight)	0.00E+00	0.00E+00	1.99E-03	1.43E-04				
Total weighted occupancy rate (*z*)				0.002137	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: non-breeding season (a)[2]				116,909				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				258,983	seconds			
Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))				258,983	seconds			

Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
L. length (L)	0.55	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,299,585.9	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	390.4	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	13.2	m/sec
$t_r=(d+L)/s$	0.37	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	1,062	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.058	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	58.54	collisions
Step 3.2: Adjusted using a range of avoidance rates:		

98%	**1.171**	**(approx 1.2 collision every yr)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.
[2] The total number of daytime minutes during the period (based on Civil Twilight).
[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).
[4]Assumes bird length=0.55m, wingspan 0.9m, flight speed= 11.2m/sec

Black-headed Gull 2020

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	0	25	544	8				
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)								
Minutes survey effort (*e*)	1,800	1,800	1,440	1,620				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=$T_wV/e/v$	0.00E+00	3.77E-05	9.11E-04	3.36E-05				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	880,875	668,007	597,586	249,729				
Weight: proportion of total effort made at the VP	0.368	0.279	0.249	0.104				
Weighted T_wV rate (T_wV rate * weight)	0.00E+00	1.05E-05	2.27E-04	3.51E-06				
Total weighted occupancy rate (*z*)				0.000241	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: breeding season (a)[2]				157,005				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				39,245	seconds			

Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))	39,245	seconds
Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
L. length (L)	0.36	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,248,674.3	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	56.8	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	11.2	m/sec
$t_r=(d+L)/s$	0.42	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	137	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.053	
STAGE 3: Predicted mortality (birds per year)		

Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	6.88	collisions
Step 3.2: Adjusted using a range of avoidance rates:		
98%	**0.138**	**(approx one collision every 7-8 yr)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.36m, wingspan 1.05m, flight speed= 11.2m/sec

	Viewsheds							
	1	**2a**	**3**	**4**				
STAGE 1: Estimation of rotor transits								
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	8	0	1,215	159				
Step 1.2: Unweighted occupancy rate each viewshed (T_wVrate)								
Minutes survey effort (*e*)	2,160	1,800	1,800	1,800				
Windfarm area (ha) visible within viewshed (*v*)	489.4	371.1	415.0	154.2				
T_wV rate=$T_wV/e/v$	7.57E-06	0.00E+00	1.63E-03	5.73E-04				
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]								
Effort in hectare-minutes (ve)	1,057,050	668,007	746,982	277,477				
Weight: proportion of total effort made at the VP	0.384	0.243	0.272	0.101				
Weighted T_wV rate (T_wV rate * weight)	2.91E-06	0.00E+00	4.42E-04	5.78E-05				
Total weighted occupancy rate (*z*)				0.000503	birds per metre per ha/minute			
Step 1.4: Total occupancy of risk volume during surveys (T_w)								
Potentially active minutes: breeding season (a)[2]				156,993				
Total area of windfarm (survey WP, in ha)[1]				1,036.6				
Tw=z*a*WP				81,798	seconds			
Step 1.5: T_w adjusted from survey PCH band to actual PCH (adjT^w * (not entered))				81,798	seconds			

Step 1.6: Flight risk volume (V_w)		
Actual WP indfarm area *(A)*[3]	4,790,107	m^2
Height of rotors *(h)*	180	m
Actual risk volume: $V_w=A*h$	862,219,334	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Number of turbines *(N)*	13	
π	3.14159	
Rotor radius *(R)*	81	m
Rotor blade width *(d)*	4.3	m
BH length (L)	0.36	m
Rotor-swept bvolume: $V_r=N*\pi*R^2*(d+L)$	1,248,674.3	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
T_r=adj$T_w*(V_r/Vw)$	118.5	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	11.2	m/sec
$t_r=(d+L)/s$	0.42	sec
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	285	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadhseet[4]	0.053	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 95% of the time N*p(collision)*0.95	14.34	collisions
Step 3.2: Adjusted using a range of avoidance rates:		

98%	**0.287**	**(approx one collision every 5 yr)**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime minutes during the period (based on Civil Twilight).

[3] Area of WP as defined by the outermost rotors (excluding the 500m buffer).

[4]Assumes bird length=0.36m, wingspan 1.05m, flight speed= 11.2m/sec

EUROPEAN OFFICES

United Kingdom

AYLESBURY
T: +44 (0)1844 337380

BELFAST
belfast@slrconsulting.com

BRADFORD-ON-AVON
T: +44 (0)1225 309400

BRISTOL
T: +44 (0)117 906 4280

CARDIFF
T: +44 (0)29 2049 1010

CHELMSFORD
T: +44 (0)1245 392170

EDINBURGH
T: +44 (0)131 335 6830

EXETER
T: + 44 (0)1392 490152

GLASGOW
glasgow@slrconsulting.com

GUILDFORD
guildford@slrconsulting.com

LONDON
T: +44 (0)203 805 6418

MAIDSTONE
T: +44 (0)1622 609242

MANCHESTER (Denton)
T: +44 (0)161 549 8410

MANCHESTER (Media City)
T: +44 (0)161 872 7564

NEWCASTLE UPON TYNE
T: +44 (0)191 261 1966

NOTTINGHAM
T: +44 (0)115 964 7280

SHEFFIELD
T: +44 (0)114 245 5153

SHREWSBURY
T: +44 (0)1743 23 9250

STIRLING
T: +44 (0)1786 239900

WORCESTER
T: +44 (0)1905 751310

Ireland

DUBLIN
T: + 353 (0)1 296 4667

France

GRENOBLE
T: +33 (0)6 23 37 14 14