Technical Appendix

Drummarnock Wind Farm

Technical Appendix 7-2: Collision Risk Modelling

Drummarnock Wind Farm Limited

July 2024

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Glossary of Terms

Term	Definition
Collision Risk Modelling	The approach developed to estimate the number of bird collisions over a period of time
Collision Risk Zone	The three dimensional area around the wind turbines within which birds are at risk of colliding with the blades
Potential Collision Height	This encompasses the rotor swept height (i.e., the lowest height above ground up to tip height)
Wind Farm Polygon	The area encompassing the outer turbine blades buffered by 500m. This is created in GIS, as a convex hull of the turbine locations buffered by the blade length + 500m

List of Abbreviations

Abbreviation	Description
BTO	British Trust for Ornithology
CRM	Collision Risk Modelling
CRZ	Collision Risk Zone
EIAR	Environmental Impact Assessment Report
GIS	Geographic Information System
PCH	Potential Collision Height
SBL	Scottish Biodiversity List
SLR	SLR Consulting Ltd (Ornithology Consultants)
SNH	Scottish Natural Heritage (now NatureScot)
SPA	Special Protection Area
VP	Vantage Point
WP	Windfarm Polygon

1 Executive Summary

Collision Risk Modelling (CRM) was undertaken for six bird species (greylag goose *Anser anser*, red kite *Milvus milvus*, kestrel *Falco tinnunculus*, curlew *Numenius arquata*, golden plover *Pluvialis apricaria* and short-eared owl *Asio flammeus*) to inform ornithological assessment studies at the Proposed Development.

Modelling was based on the use of turbines with a rotor diameter of 163m, tip height of 180m and hub height of 98.5m.

Where there was sufficient bird flight activity within the Collision Risk Zone at Potential Collision Height, collision risk modelling was used to predict the number of individuals per target species that might collide with the wind turbine rotors.

The standard Band CRM (Band *et. al.* 2007) 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.

The results of the CRM were as follows:

- Greylag goose – breeding season rate of 0.0222 (45.01 years per collision);
- Red kite – annual rate of 0.0353 (28.29 years per collision);
- Kestrel – annual rate of 0.3317 (3.01 years per collision);
- Curlew – breeding season rate of 0.0790 (12.66 years per collision);
- Golden plover – non-breeding season rate of 0.1125 (8.89 years per collision; and
- Short-eared owl – breeding season rate of 0.2102 (4.76 years per collision).

The conclusions from the CRM are used in the Ornithology EIAR for the Proposed Development.

2 Introduction

This report presents the results of Collision Risk Modelling (CRM) undertaken for six bird species to inform ornithological assessment studies at the Proposed Development.

The exact make, type and model of turbine to be used as part of the Proposed Development will likely be the result of a future tendering process and therefore an indicative turbine model has been assumed for this assessment, as advised by Wind2 Ltd. Modelling was based on the use of turbines with a rotor diameter of 163m, tip height of 180m and hub height of 98.5m.

Where there was sufficient bird flight activity within the Collision Risk Zone (CRZ) (i.e. within the Wind Farm Polygon (WP)) at Potential Collision Height (PCH), collision risk modelling (CRM) was used to predict the number of individuals per target species that might collide with the wind turbine rotors.

The CRM was undertaken in accordance with current NatureScot (formerly Scottish Natural Heritage (SNH)) guidance, which is recognised as standard best practice guidance through the United Kingdom 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 3**. The monitoring results are presented in Section 3.4 and copies of the modelling calculations for each species modelled are included in Annexes A and B.

2.1 Primary Target Species

Target species for the surveys were defined by legal and/ or conservation status and vulnerability to impacts caused by wind turbines, as defined in NS Guidance (SNH 2017).

There are two Special Protection Areas (SPAs) within 20 km, which are potentially within the core foraging range of qualifying features which may occur on the Site (e.g., as defined by SNH 2016). These are:

- Firth of Forth SPA (migratory wildfowl including pink-footed goose *Anser brachyrhynchus*); and
- Slamannan Plateau SPA (Taiga bean goose *Anser fabalis fabalis*).

No SPA species were recorded during any baseline surveys.

Other bird species of high conservation importance are those which are Annex I and Schedule 1 species and other species of high conservation importance which are considered to be vulnerable to impacts from wind farm developments.

The following species are therefore considered relevant as primary target species:

- Annex I raptor and owl species, plus kestrel;
- Breeding and migratory wildfowl; and
- Breeding and migratory waders.

3 Methods

The standard Band CRM (Band *et. al.* 2007) 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.

3.1 Prediction of Rotor Transits from Vantage Point Survey Data

3.1.1 Survey Data 2019-20 and 2021

The number of birds that fly through the rotor swept area was estimated using flight data gathered during baseline surveys carried out during September 2019 to September 2020, and May 2021 to August 2021.

The surveys gathered data from one vantage point (VP). The total number of hours are as shown in **Table 7-2-1.**

Table 7-2-1: VP Surveys undertaken at Drummarnock, Sept 2019 – Aug 2021

VP Number	Grid Coordinates (x,y)	Hours of Survey Completed (hrs:mins)				
		Sep 2019-Mar 2020	Apr 2020-Aug 2020	Sep 2020	May 2021-Aug 2021	Total
1	272489, 687728	42:15	48:05	06:00	24:50	121:10

3.1.2 Viewshed Data

The viewshed area from the VP (2,045,632 m²)[1] represents 71.7% of the survey WP (2,852,057 m²). The VP location and viewshed area in relation to the Proposed Development is shown on Figure 7-1-3.

3.2 Flight Selection for CRM

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 around the proposed outermost turbine locations. The size of buffer takes into account rotor blade length and potential spatial errors in flight recording accuracy. It is known that bird detection rates vary between species.

[1] Area calculated in GIS using a surface offset of 17 m.

To ensure the CRM used robust measures of flight activity, a 2km distance truncation was used in the viewshed from each VP, i.e., only flights within 2km of each VP were included (as per NatureScot guidance).

Flights were analysed to identify those that were at PCH and within the WP. Flight times that were used in the CRM were derived from field data 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 following section) was used to determine the period that target species were at risk of collision with the rotors.

3.2.1 Correcting Survey PCH to Actual PCH

The baseline surveys during this period utilised the following height bands:

- 1 = <30m
- 2 = 30-150m
- 3 = >150m

As such, the height bands used to record flight activity do not correspond precisely to PCH for the proposed development (17-180m) (turbine data in Table 7-2-3), i.e., height band 1 overlaps with the lower limit of the actual PCH (17-30m of the 0-30m band) and height band 3 overlaps with the upper limit of the actual PCH (150-180m of the >150m band).

Because of this it was necessary to make assumptions about the distribution of some of the flight heights recorded. Assuming an equal distribution of heights within all height bands, it is assumed that 1) a proportion of the flights within height band 1 will be below risk height and 2) all flights within height band 3 are at risk height.

The model accounts for this by adjusting the proportion of flights included by rotor diameter/ survey risk height (163/150 (108.7%)). Therefore, the CRM presents a worst-case scenario, by including all flightlines in height band 3.

3.2.2 Seasonal Definitions

CRMs were constructed using data from the relevant breeding and non-breeding season periods, dictated by the survey design. As summarised in Table 7-2-1, these are defined as September 2019 – March 2020 (non-breeding season 2019/2020), April – August 2020 (breeding season 2020) and May – August 2021 (breeding season 2021).

Data from September 2020 were included in the overall non-breeding season/ annual calculations, as these are technically outside of the breeding season.

The theoretical time that birds could be active with potential for turbine collisions was assumed to be the period between sunrise and sunset within each survey period using the latitude of the Site (timeanddate.com).

For greylag goose, waders (i.e., curlew and golden plover) and short-eared owl, which all could be active nocturnally, an additional 25% of nocturnal hours were added to the daylight hours to give a more accurate representation of the available hours for these species (as per Band *et al.*, 2007).

3.2.3 Undertaking CRM

CRM employs an estimated three-dimensional risk volume, in keeping with the assumption that flight directions are random in space. For species with non-directional (e.g., random, circling and foraging) flights, the occupancy data are derived by multiplying the numbers of a particular species flying through the survey risk area by the total time spent (as a proportion of the flight length within 500m).

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);
- An estimation of daylight hours (or daylight hours plus 25% nocturnal hours) within the period of analysis;
- Species-specific bird parameters (Table 7-2-2); and
- Wind farm parameters (Table 7-2-3).

The NatureScot (2023) CRM spreadsheet 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.

3.2.4 Bird Biometrics and Avoidance Rates

Measurements and flight speeds of the species for which CRM was undertaken were derived from British Trust for Ornithology (BTO), Provan & Whitfield (2007), Bruderer & Boldt (2001) and Alerstram *et al.* (2007). The avoidance rates for these species are taken from SNH (2018).

Table 7-2-2: Bird biometrics and avoidance rates used in CRM

Species name	Bird length (m)	Wingspan (m)	Flight speed (m/s)	Avoidance rate (%)
Greylag goose	0.83	1.64	17.1	99.8
Red kite	0.63	1.85	10.5	99
Kestrel	0.34	0.8	12.7	95
Curlew	0.55	0.9	13.9	98
Golden Plover	0.28	0.7	18.0	98
Short-eared owl	0.38	1.03	10.0	98

3.2.5 Wind Farm and Turbine Parameters

The wind turbine parameters used in the CRM are detailed in Table 7-2-3 and are based on information provided by Wind 2 for the purposes of this CRM.

Table 7-2-3: Wind farm & turbine parameters

Parameter	Value
Size of survey wind farm polygon (WP)	285.2 ha
Number of turbines	4
Rotor radius/ diameter	81.5m/ 163.0m
Hub height	98.5m
Max. chord	4.15m
Pitch	5°
Rotation period	5.60s (rated 10.7 rpm)
Turbine operation time	85%

3.3 Drummarnock Flightline Data

Table 7-2-4 summarises the primary target species flightline data from VP surveys conducted, presented for each season. For those primary target species with sufficient data to conduct CRM (n=5), Table 7-2-5 to Table 7-2-10 (inclusive) present the seasonal occupancy data within each height band, and the total at-risk occupancy data used in the CRM.

Table 7-2-4: Number of target species flights and individuals observed passing through the Drummarnock WP during VP surveys (2019/ 2020 & 2021)

Species name	Period of analysis	Total number of birds recorded in flight	Flights through WP		Flights through WP at PCH	
			Flights	Individuals	Flights	Individuals
Greylag goose	Sep 2019 – Mar 2020	2	0	0	0	0
	Apr 2020 – Aug 2020	10	5	10	5	10
	May 2021 – Aug 2021	16	8	16	8	16
Hen harrier	Apr 2020 – Aug 2020	1	1	1	1	1
	Sep 2020	1	0	0	0	0
	May 2021 – Aug 2021	1	0	0	0	0
Red kite	Sep 2019 – Mar 2020	4	3	3	3	3
	May 2021 – Aug 2021	6	5	5	5	5
Osprey	Apr 2020 – Aug 2020	1	1	1	1	1
Kestrel	Sep 2019 – Mar 2020	4	4	4	4	4
	Apr 2020 – Aug 2020	20	11	12	11	12
	Sep 2020	10	4	6	4	6
Curlew	Apr 2020 – Aug 2020	14	13	14	13	14
	May 2021 – Aug 2021	2	2	2	2	2
Golden plover	Sep 2020	26	1	23	1	23
Short-eared owl	Apr 2020 – Aug 2020	26	25	26	25	26

Table 7-2-5: Details of Greylag Goose Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)			
					<30m	30-150m	>150m	At risk
Apr 2020 – Sep 2020	VP1	5	10	566	30	517	19	566
May 2021 – Aug 2021	VP1	8	16	681	556	125	0	681
Total		13	26	1247	586	642	19	1247

Table 7-2-6: Details of Red Kite Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)			
					<30m	30-150m	>150m	At risk
Sep 2019 – Mar 2020	VP1	3	3	131	32	75	24	131
May 2021 – Aug 2021	VP1	5	5	458	0	309	149	458
Total		8	8	589	32	384	173	589

Table 7-2-7: Details of Kestrel Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)			
					<30m	30-150m	>150m	At risk
Sep 2019 – Mar 2020	VP1	4	4	76	58	18	0	76
Apr 2020 – Aug 2020	VP1	11	12	381	180	181	20	381
Sep 2020	VP1	4	6	590	27	536	27	590
Total		19	22	1047	265	735	47	1047

Table 7-2-8: Details of Curlew Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)			
					<30m	30-150m	>150m	At risk
Apr 2020 – Aug 2020	VP1	13	14	562	156	353	53	562
May 2021 – Aug 2021	VP1	2	2	54	24	30	0	54
Total		15	16	616	180	383	53	616

Table 7-2-9: Details of Golden Plover Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)			
					<30m	30-150m	>150m	At risk
Sep 2020	VP1	1	23	516	0	516	0	516
Total		1	23	516	0	516	0	516

Table 7-2-10: Details of Short-eared Owl Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)			
					<30m	30-150m	>150m	At risk
Apr 2020 – Aug 2020	VP1	25	26	2350	1810	502	38	2350
Total		25	26	2350	1810	502	38	2350

4 Collision Risk Modelling Results

Table 7-2-11 summarises the predicted collision rates for the six species under consideration. Copies of the modelling calculations for each species are included in Annexes A and B.

Table 7-2-11: Summary of CRM Output

Species name	Period of analysis	Modelled collisions per Season	Years per collision
Greylag goose	Breeding season (Apr 2020 – Aug 2020 + May 2021 – Aug 2021)	0.0222	45.01
Red kite	Annual	0.0353	28.29
Kestrel	Annual	0.3317	3.01
Curlew	Breeding season (Apr 2020 – Aug 2020 + May 2021 – Aug 2021)	0.0790	12.66
Golden plover	Non-breeding season (Sep 2019 – Mar 2020; Sep 2020)	0.1125	8.89
Short-eared owl	Breeding season (Apr 2020 – Aug 2020 + May 2021 – Aug 2021)	0.2102	4.76

4.1 Species Summary

4.1.1 Greylag Goose

All greylag goose flights through the WP were in the breeding season (April and May) and involved pairs of birds. There were no flights of migratory flocks of geese. Flightlines were both directional and random in nature.

The predicted breeding season collision rate of 0.0225 (one collision every 44--45 years) is consequently very low.

4.1.2 Red Kite

Red kite flights were irregular, with flights in October, January, March, May and July. Five flights were of the same bird on one day (27 May 2021).

The predicted collision rate of 0.0353 (one collision every 28-29 years) is considered low.

4.1.3 Kestrel

Kestrel activity peaked in the late and post-breeding season period 2020 (July - September), with up to three individuals foraging inside and outside the WP. As noted for short-eared owl, this activity was probably related to high numbers of voles on site in 2020.

This resulted in a predicted annual collision rate of 0.3317 (one collision every 3 years).

4.1.4 Curlew

Curlews were only present in the breeding season. Activity peaked in June 2020, with 10 out of the total of 15 flights being recorded on one date (24 June 2020).

This resulted in a predicted breeding season collision rate of 0.0790 (one collision every 12-13 years).

4.1.5 Golden Plover

Golden plover was only present on one date (29 September 2020). Flights involving 23 and 3 birds resulted in a predicted non-breeding season collision rate of 0.1125 (one collision every 8-9 years).

4.1.6 Short-eared Owl

Short-eared owls were only present in the breeding season 2020 (May – July), which coincided with a peak vole year on site (as noticed during walkover surveys). No breeding was confirmed. Of the 25 flights, 14 were on one date (14 May). None was present in 2021.

This resulted in a predicted breeding season collision rate of 0.2102 (one collision every 4-5 years).

5 References

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Annex A: Probability of Collision Species Models

Greylag Goose: Probability of Collision

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.15	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.83	m	0.025	0.575	7.48	30.26	0.95	0.00118	29.84	0.93	0.00117
Wingspan	1.64	m	0.075	0.575	2.49	10.22	0.32	0.00240	9.81	0.31	0.00230
F: Flapping (0) or gliding (-	0		0.125	0.702	1.50	7.05	0.22	0.00276	6.54	0.20	0.00256
			0.175	0.860	1.07	5.86	0.18	0.00321	5.24	0.16	0.00287
Bird speed	17.1	m/sec	0.225	0.994	0.83	5.14	0.16	0.00362	4.42	0.14	0.00312
RotorDiam	163	m	0.275	0.947	0.68	4.12	0.13	0.00355	3.43	0.11	0.00296
RotationPeriod	5.60	sec	0.325	0.899	0.58	3.41	0.11	0.00347	2.76	0.09	0.00281
			0.375	0.851	0.50	2.89	0.09	0.00340	2.28	0.07	0.00268
			0.425	0.804	0.44	2.58	0.08	0.00344	2.00	0.06	0.00266
			0.475	0.756	0.39	2.33	0.07	0.00347	1.79	0.06	0.00266
Bird aspect ratioo: β	0.51		0.525	0.708	0.36	2.13	0.07	0.00350	1.62	0.05	0.00266
			0.575	0.660	0.33	1.96	0.06	0.00353	1.48	0.05	0.00266
			0.625	0.613	0.30	1.81	0.06	0.00354	1.37	0.04	0.00268
			0.675	0.565	0.28	1.68	0.05	0.00356	1.27	0.04	0.00269
			0.725	0.517	0.26	1.57	0.05	0.00356	1.19	0.04	0.00271
			0.775	0.470	0.24	1.47	0.05	0.00357	1.13	0.04	0.00274
			0.825	0.422	0.23	1.38	0.04	0.00356	1.07	0.03	0.00277
			0.875	0.374	0.21	1.30	0.04	0.00355	1.03	0.03	0.00281
			0.925	0.327	0.20	1.22	0.04	0.00354	0.98	0.03	0.00285
			0.975	0.279	0.19	1.15	0.04	0.00352	0.95	0.03	0.00290
				Overall p(collision) =			**Upwind**	**6.6%**		**Downwind**	**5.3%**
								Average	**6.0%**		

Red Kite: Probability of Collision

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.15	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.63	m	0.025	0.575	4.59	16.54	0.84	0.00105	16.12	0.82	0.00103
Wingspan	1.85	m	0.075	0.575	1.53	5.65	0.29	0.00216	5.23	0.27	0.00200
F: Flapping (0) or gliding (-	1		0.125	0.702	0.92	4.00	0.20	0.00255	3.49	0.18	0.00223
			0.175	0.860	0.66	3.42	0.17	0.00305	2.79	0.14	0.00250
Bird speed	10.5	m/sec	0.225	0.994	0.51	3.06	0.16	0.00351	2.34	0.12	0.00269
RotorDiam	163	m	0.275	0.947	0.42	2.47	0.13	0.00346	1.78	0.09	0.00250
RotationPeriod	5.60	sec	0.325	0.899	0.35	2.05	0.10	0.00341	1.40	0.07	0.00233
			0.375	0.851	0.31	2.02	0.10	0.00386	1.40	0.07	0.00268
			0.425	0.804	0.27	1.82	0.09	0.00394	1.24	0.06	0.00268
			0.475	0.756	0.24	1.66	0.08	0.00402	1.11	0.06	0.00269
Bird aspect ratioo: β	0.34		0.525	0.708	0.22	1.53	0.08	0.00409	1.01	0.05	0.00272
			0.575	0.660	0.20	1.41	0.07	0.00415	0.94	0.05	0.00275
			0.625	0.613	0.18	1.32	0.07	0.00420	0.87	0.04	0.00279
			0.675	0.565	0.17	1.23	0.06	0.00424	0.82	0.04	0.00283
			0.725	0.517	0.16	1.16	0.06	0.00428	0.78	0.04	0.00289
			0.775	0.470	0.15	1.09	0.06	0.00430	0.75	0.04	0.00296
			0.825	0.422	0.14	1.03	0.05	0.00432	0.72	0.04	0.00303
			0.875	0.374	0.13	0.97	0.05	0.00432	0.70	0.04	0.00311
			0.925	0.327	0.12	0.92	0.05	0.00432	0.68	0.03	0.00321
			0.975	0.279	0.12	0.87	0.04	0.00431	0.66	0.03	0.00331
				Overall p(collision) =			**Upwind**	**7.4%**		**Downwind**	**5.3%**
								Average	**6.3%**		

Kestrel: Probability of Collision

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.15	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.34	m	0.025	0.575	5.56	17.86	0.75	0.00094	17.44	0.74	0.00092
Wingspan	0.8	m	0.075	0.575	1.85	6.09	0.26	0.00193	5.68	0.24	0.00180
F: Flapping (0) or gliding (-	0		0.125	0.702	1.11	4.36	0.18	0.00230	3.86	0.16	0.00203
			0.175	0.860	0.79	3.77	0.16	0.00278	3.15	0.13	0.00232
Bird speed	12.7	m/sec	0.225	0.994	0.62	3.39	0.14	0.00322	2.67	0.11	0.00254
RotorDiam	163	m	0.275	0.947	0.51	2.72	0.11	0.00316	2.04	0.09	0.00236
RotationPeriod	5.60	sec	0.325	0.899	0.43	2.26	0.10	0.00309	1.60	0.07	0.00220
			0.375	0.851	0.37	1.95	0.08	0.00309	1.34	0.06	0.00211
			0.425	0.804	0.33	1.72	0.07	0.00308	1.13	0.05	0.00203
			0.475	0.756	0.29	1.53	0.06	0.00306	0.98	0.04	0.00196
Bird aspect ratioo: β	0.43		0.525	0.708	0.26	1.37	0.06	0.00304	0.86	0.04	0.00190
			0.575	0.660	0.24	1.24	0.05	0.00300	0.76	0.03	0.00184
			0.625	0.613	0.22	1.12	0.05	0.00296	0.68	0.03	0.00180
			0.675	0.565	0.21	1.03	0.04	0.00292	0.62	0.03	0.00175
			0.725	0.517	0.19	0.94	0.04	0.00287	0.56	0.02	0.00172
			0.775	0.470	0.18	0.86	0.04	0.00280	0.52	0.02	0.00169
			0.825	0.422	0.17	0.79	0.03	0.00274	0.48	0.02	0.00167
			0.875	0.374	0.16	0.72	0.03	0.00266	0.45	0.02	0.00166
			0.925	0.327	0.15	0.66	0.03	0.00258	0.42	0.02	0.00166
			0.975	0.279	0.14	0.61	0.03	0.00249	0.40	0.02	0.00166
				Overall p(collision) =			**Upwind**	**5.5%**		**Downwind**	**3.8%**
								Average	**4.6%**		

Curlew; Probability of Collision

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.15	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.55	m	0.025	0.575	6.08	20.13	0.78	0.00097	19.72	0.76	0.00095
Wingspan	0.9	m	0.075	0.575	2.03	6.85	0.26	0.00198	6.43	0.25	0.00186
F: Flapping (0) or gliding (-	0		0.125	0.702	1.22	4.87	0.19	0.00235	4.37	0.17	0.00210
			0.175	0.860	0.87	4.18	0.16	0.00282	3.56	0.14	0.00240
Bird speed	13.9	m/sec	0.225	0.994	0.68	3.74	0.14	0.00325	3.03	0.12	0.00262
RotorDiam	163	m	0.275	0.947	0.55	3.06	0.12	0.00324	2.37	0.09	0.00251
RotationPeriod	5.60	sec	0.325	0.899	0.47	2.61	0.10	0.00327	1.96	0.08	0.00246
			0.375	0.851	0.41	2.28	0.09	0.00330	1.67	0.06	0.00241
			0.425	0.804	0.36	2.03	0.08	0.00332	1.45	0.06	0.00237
			0.475	0.756	0.32	1.82	0.07	0.00334	1.28	0.05	0.00234
Bird aspect ratioo: β	0.61		0.525	0.708	0.29	1.65	0.06	0.00335	1.14	0.04	0.00231
			0.575	0.660	0.26	1.51	0.06	0.00335	1.03	0.04	0.00229
			0.625	0.613	0.24	1.39	0.05	0.00334	0.94	0.04	0.00228
			0.675	0.565	0.23	1.28	0.05	0.00333	0.87	0.03	0.00227
			0.725	0.517	0.21	1.19	0.05	0.00331	0.81	0.03	0.00227
			0.775	0.470	0.20	1.10	0.04	0.00329	0.76	0.03	0.00227
			0.825	0.422	0.18	1.02	0.04	0.00326	0.72	0.03	0.00229
			0.875	0.374	0.17	0.95	0.04	0.00322	0.68	0.03	0.00230
			0.925	0.327	0.16	0.89	0.03	0.00317	0.65	0.03	0.00233
			0.975	0.279	0.16	0.83	0.03	0.00312	0.63	0.02	0.00236
				Overall p(collision) =			**Upwind**	**6.1%**		**Downwind**	**4.5%**
								Average	**5.3%**		

Golden Plover: Probability of Collision

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.15	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.28	m	0.025	0.575	7.87	22.43	0.67	0.00083	22.02	0.66	0.00082
Wingspan	0.7	m	0.075	0.575	2.62	7.62	0.23	0.00170	7.20	0.21	0.00161
F: Flapping (0) or gliding (-	1		0.125	0.702	1.57	5.52	0.16	0.00205	5.02	0.15	0.00187
			0.175	0.860	1.12	4.81	0.14	0.00251	4.19	0.12	0.00218
Bird speed	18	m/sec	0.225	0.994	0.87	4.35	0.13	0.00291	3.63	0.11	0.00243
RotorDiam	163	m	0.275	0.947	0.72	3.46	0.10	0.00283	2.78	0.08	0.00227
RotationPeriod	5.60	sec	0.325	0.899	0.61	2.85	0.08	0.00275	2.20	0.07	0.00212
			0.375	0.851	0.52	2.39	0.07	0.00267	1.77	0.05	0.00198
			0.425	0.804	0.46	2.04	0.06	0.00257	1.45	0.04	0.00184
			0.475	0.756	0.41	1.75	0.05	0.00248	1.21	0.04	0.00171
Bird aspect ratioo: β	0.40		0.525	0.708	0.37	1.63	0.05	0.00255	1.12	0.03	0.00175
			0.575	0.660	0.34	1.45	0.04	0.00249	0.98	0.03	0.00167
			0.625	0.613	0.31	1.30	0.04	0.00242	0.86	0.03	0.00159
			0.675	0.565	0.29	1.17	0.03	0.00234	0.76	0.02	0.00152
			0.725	0.517	0.27	1.05	0.03	0.00226	0.67	0.02	0.00145
			0.775	0.470	0.25	0.94	0.03	0.00218	0.60	0.02	0.00139
			0.825	0.422	0.24	0.85	0.03	0.00208	0.54	0.02	0.00133
			0.875	0.374	0.22	0.76	0.02	0.00199	0.49	0.01	0.00128
			0.925	0.327	0.21	0.69	0.02	0.00189	0.45	0.01	0.00124
			0.975	0.279	0.20	0.61	0.02	0.00178	0.41	0.01	0.00120
				Overall p(collision) =			**Upwind**	**4.5%**		**Downwind**	**3.3%**
								Average	**3.9%**		

Short-eared Owl: Probability of Collision

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.15	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.38	m	0.025	0.575	4.37	13.47	0.72	0.00090	13.06	0.70	0.00087
Wingspan	1.03	m	0.075	0.575	1.46	4.63	0.25	0.00186	4.21	0.23	0.00169
F: Flapping (0) or gliding (-	1		0.125	0.702	0.87	3.36	0.18	0.00225	2.86	0.15	0.00191
			0.175	0.860	0.62	2.94	0.16	0.00276	2.32	0.12	0.00218
Bird speed	10	m/sec	0.225	0.994	0.49	2.68	0.14	0.00323	1.96	0.10	0.00236
RotorDiam	163	m	0.275	0.947	0.40	2.16	0.12	0.00318	1.47	0.08	0.00217
RotationPeriod	5.60	sec	0.325	0.899	0.34	1.96	0.10	0.00340	1.31	0.07	0.00227
			0.375	0.851	0.29	1.71	0.09	0.00344	1.10	0.06	0.00221
			0.425	0.804	0.26	1.53	0.08	0.00347	0.94	0.05	0.00215
			0.475	0.756	0.23	1.37	0.07	0.00349	0.83	0.04	0.00210
Bird aspect ratioo: β	0.37		0.525	0.708	0.21	1.25	0.07	0.00350	0.73	0.04	0.00206
			0.575	0.660	0.19	1.14	0.06	0.00351	0.66	0.04	0.00203
			0.625	0.613	0.17	1.04	0.06	0.00350	0.60	0.03	0.00201
			0.675	0.565	0.16	0.96	0.05	0.00348	0.55	0.03	0.00200
			0.725	0.517	0.15	0.89	0.05	0.00346	0.52	0.03	0.00200
			0.775	0.470	0.14	0.82	0.04	0.00342	0.48	0.03	0.00201
			0.825	0.422	0.13	0.76	0.04	0.00338	0.46	0.02	0.00203
			0.875	0.374	0.12	0.71	0.04	0.00332	0.44	0.02	0.00205
			0.925	0.327	0.12	0.66	0.04	0.00326	0.42	0.02	0.00209
			0.975	0.279	0.11	0.61	0.03	0.00319	0.41	0.02	0.00213
				Overall p(collision) =			**Upwind**	**6.2%**		**Downwind**	**4.0%**
								Average	**5.1%**		

Annex B: CRM Species Models

Greylag Goose: CRM

	Viewsheds								
	1								
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)	1247								
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	73								
Windfarm area (ha) visible within viewshed (*v*)[1]	204.57								
Observation effort (*e***v*)	14916.25								
T_wV rate=$T_wV/e*v$	2.32E-05								
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total survey effort made at the VP	1.000								
Weighted T_wV rate (T_wV rate * weight)	2.32E-05								
Total weighted occupancy rate	0.000023				birds seconds per ha/hour				
Mean % activity hr^-1 in wind farm at risk height	0.662%								

Mean % activity hr^-1 in wind farm at rotor height (z)	0.720%	
Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: breeding season (a) (footnote 2)	2,756	hours
Tw=z*a	19.84	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$ (footnote 3)	464,885,331	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.83	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$ footnote 4	415,675.50	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	63.8500	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	17.1	m/sec
t=(d+L)/s	0.29	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	219	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.060	

STAGE 3: Predicted mortality (birds per year)				
Step 3.1: With no avoidance, turbines operational 85% of the time N*p(collision)*0.85	11.107	collisions		
Step 3.2: Adjusted using a range of avoidance rates:				
99.80%	**0.0222**	**approx one collision every**	**45.01**	**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 daylight hours during the period

[3] A= size of windfarm polygon(ha) h= rotor diameter (m)

[4] N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)

[5]Assumes bird length=0.83m, wingspan 1.64m, flight speed= 17.1m/sec

Red Kite: CRM

	Viewsheds								
	1								
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)	589								
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	115								
Windfarm area (ha) visible within viewshed (*v*)[1]	204.57								
Observation effort (*e*v*)	23559.15								
T_wV rate=$T_wV/e*v$	6.94E-06								
Step 1.3: Weighted occupancy rate (*weighted T_wV rate*)[1]									
Weight: proportion of total survey effort made at the VP	1.000								
Weighted T_wV rate (T_wV rate * weight)	6.94E-06								
Total weighted occupancy rate	0.000007				birds seconds per ha/hour				
Mean % activity hr^-1 in wind farm at risk height	0.198%								

Mean % activity hr^-1 in wind farm at rotor height (z)	0.215%	
Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: annual (a) (footnote 2)	4,502	hours
Tw=z*a	9.69	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$ (footnote 3)	464,885,331	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.63	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$ footnote 4	398,981.70	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	29.9355	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	10.5	m/sec
$t=(d+L)/s$	0.46	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	66	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.063	

STAGE 3: Predicted mortality (birds per year)				
Step 3.1: With no avoidance, turbines operational 85% of the time N*p(collision)*0.85	3.534	collisions		
Step 3.2: Adjusted using a range of avoidance rates:				
99.00%	**0.0353**	**approx one collision every**	**28.29**	**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 daylight hours during the period

[3] A= size of windfarm polygon(ha) h= rotor diameter (m)

[4] N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)

[5]Assumes bird length=0.63m, wingspan 1.85m, flight speed= 10.5m/sec

Kestrel: CRM

	Viewsheds								
	1								
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)	1047								
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	96								
Windfarm area (ha) visible within viewshed (*v*)[1]	204.57								
Observation effort (*e***v*)	19706.50								
T_wV rate=$T_wV/e*v$	1.48E-05								
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total survey effort made at the VP	1.000								
Weighted T_wV rate (T_wV rate * weight)	1.48E-05								
Total weighted occupancy rate	0.000015					birds seconds per ha/hour			
Mean % activity hr^-1 in wind farm at risk height	0.421%								

Mean % activity hr^-1 in wind farm at rotor height (z)	0.457%	
Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: breeding season (a) (footnote 2)	4,502	hours
Tw=z*a	20.59	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$ (footnote 3)	464,885,331	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.34	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$ footnote 4	374,775.70	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	59.7566	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	12.7	m/sec
$t=(d+L)/s$	0.35	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	169	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.046	

STAGE 3: Predicted mortality (birds per year)				
Step 3.1: With no avoidance, turbines operational 85% of the time N*p(collision)*0.85	6.634	collisions		
Step 3.2: Adjusted using a range of avoidance rates:				
95.00%	**0.3317**	**approx one collision every**	**3.01**	**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 daylight hours during the period

[3] A= size of windfarm polygon(ha) h= rotor diameter (m)

[4] N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)

[5]Assumes bird length=0.34m, wingspan 0.8m, flight speed= 12.7m/sec

Curlew: CRM

	Viewsheds								
	1								
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)	616								
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	73								
Windfarm area (ha) visible within viewshed (*v*)[1]	204.57								
Observation effort (*e*v*)	14916.25								
T_wV rate=$T_wV/e*v$	1.15E-05								
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total survey effort made at the VP	1.000	0.000	0.000	0.000	0.000	0.000	0.000		
Weighted T_wV rate (T_wV rate * weight)	1.15E-05	0.00E+00	0.00E+00						
Total weighted occupancy rate	0.000011					birds seconds per ha/hour			
Mean % activity hr^-1 in wind farm at risk height	0.327%								

Mean % activity hr^-1 in wind farm at rotor height (z)	0.356%	
Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: breeding season (a) (footnote 2)	2,756	hours
Tw=z*a	9.80	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$ (footnote 3)	464,885,331	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.55	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$ footnote 4	392,304.18	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	29.7676	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	13.9	m/sec
$t=(d+L)/s$	0.34	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	88	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.053	

STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 85% of the time N*p(collision)*0.85	3.950	collisions			
Step 3.2: Adjusted using a range of avoidance rates:					
98.00%	**0.0790**	**approx one collision every**		**12.66**	**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 daylight hours + 25% nocturnal hours during the period

[3] A= size of windfarm polygon(ha) h= rotor diameter (m)

[4] N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)

[5]Assumes bird length=0.55m, wingspan 0.9m, flight speed= 13.9m/sec

Golden Plover: CRM

	Viewsheds								
	1								
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)	516								
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	42								
Windfarm area (ha) visible within viewshed (*v*)[1]	204.57								
Observation effort (*e***v*)	8642.90								
T_wV rate=$T_wV/e*v$	1.66E-05								
Step 1.3: Weighted occupancy rate (*weighted T_wV rate*)[1]									
Weight: proportion of total survey effort made at the VP	1.000								
Weighted T_wV rate (T_wV rate * weight)	1.66E-05								
Total weighted occupancy rate	0.000017				birds seconds per ha/hour				
Mean % activity hr^-1 in wind farm at risk height	0.473%								

Mean % activity hr^-1 in wind farm at rotor height (z)	0.514%	
Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: non-breeding season (a) (footnote 2)	2,818	hours
Tw=z*a	14.48	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w = A*h$ (footnote 3)	464,885,331	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.28	m
Rotor-swept volume: $V_r = N*\pi*r^2*(d+L)$ footnote 4	369,767.56	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r = T_w*(V_r/Vw)$	41.47	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	18	m/sec
$t=(d+L)/s$	0.25	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	168	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.039	

STAGE 3: Predicted mortality (birds per year)				
Step 3.1: With no avoidance, turbines operational 85% of the time N*p(collision)*0.85	5.624	collisions		
Step 3.2: Adjusted using a range of avoidance rates:				
98.00%	**0.1125**	**approx one collision every**	**8.89**	**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 daylight hours + 25% nocturnal hours during the period

[3] A= size of windfarm polygon(ha) h= rotor diameter (m)

[4] N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)

[5]Assumes bird length=0.28m, wingspan 0.7m, flight speed= 18m/sec

Short-eared Owl: CRM

	Viewsheds								
	1								
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)	2350								
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	73								
Windfarm area (ha) visible within viewshed (*v*)[1]	204.57								
Observation effort (*e*v*)	14916.25								
T_wV rate=$T_wV/e*v$	4.38E-05								
Step 1.3: Weighted occupancy rate (*weighted T_wV rate*)[1]									
Weight: proportion of total survey effort made at the VP	1.000								
Weighted T_wV rate (T_wV rate * weight)	4.38E-05	0.00E+00	0.00E+00						
Total weighted occupancy rate	0.000044					birds seconds per ha/hour			
Mean % activity hr^-1 in wind farm at risk height	1.248%								
Mean % activity hr^-1 in wind farm at rotor height (z)	1.356%								
Step 1.4: Total occupancy of risk volume during surveys (T_w)									
Hours potentially active: breeding season (a) (footnote 2)	2,756					hours			
Tw=z*a	37.38					hours			
Step 1.6: Flight risk volume (V_w)									
Risk volume: $V_w=A*h$ (footnote 3)	464,885,331					m^3			
Step 1.7: Volume swept by windfarm rotors (V_r)									
Bird length (L)	0.38					m			
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$ footnote 4	378,114.46					m^3			
Step 1.8: Bird occupancy of rotor-swept volume (Tr)									

$T_r=T_w*(V_r/Vw)$	109.4539	seconds		
Step 1.9: Time taken to transit rotor *(t)*				
Flight speed *(s)*	10	m/sec		
$t=(d+L)/s$	0.45	seconds		
Step 1.10: Number of rotor transits (N)				
$N=T_r/t$	242	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.051			
STAGE 3: Predicted mortality (birds per year)				
Step 3.1: With no avoidance, turbines operational 85% of the time N*p(collision)*0.85	10.511	collisions		
Step 3.2: Adjusted using a range of avoidance rates:				
98.00%	**0.2102**	**approx one collision every**	**4.76**	**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 daylight hours during the period + 25% nocturnal hours during the period

[3] A= size of windfarm polygon(ha) h= rotor diameter (m)

[4] N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)

[5]Assumes bird length=0.38m, wingspan 1.03m, flight speed= 10.0m/sec