Appendix 7.2 Collision Risk Modelling

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Appendix 7.2 Collision Risk Modelling

Introduction

ITPEnergised was appointed by Orkney Islands Council to undertake a series of ornithological surveys in support of a proposed wind farm development at Faray in April 2019. In order to assess the likely impacts of the Proposed Development on the local bird population analysis for the potential for collision risk has been undertaken on certain key species. The analysis has been undertaken using an indicative layout and development boundary, as displayed in Figure 7.1, and a provisional turbine specification as outlined in Table 1.

Table 1 - Candidate Turbine - Vestas V136 4.2MW

Parameter	Value
Collision Risk Area (turbines plus 500m)	296.04
Viewshed Area	589.86 (254.45 N: 239.81 S)
No turbines	6
Rotor diameter	136m
Hub height	82m
Max rotor depth	4.2
Max chord	4.1
Pitch	Variable – use 15
Rotation period	(6-16 rpm, ave = 11 rpm) = 5.45 secs
Turbine 'lifetime'*	25 years

* Although the Applicant is seeking in- perpetuity, in order to create a figure for comparison with other windfarm sites and use in the cumulative assessment a figure for 25 years is used as the 'lifetime' of the Proposed Development

Data Collection and Species Selection

Surveys were undertaken from two VP's at a single location, one facing south and one facing north between April 2019 and March 2020 with 72 hours undertaken per VP, this time period constitutes one complete year.

A total of 19 target species were recorded from the VP surveys and are summarised below in Table 2. All the survey flights were recorded onto ArcGIS and the data entered into an excel spreadsheet and further analysed in order to select all the flights which were recorded at potential collision height ('PCH') within the viewshed the VP. PCH is the height between the low and high points of the rotor sweep of the turbine blades, namely between 14 and 150m, all flights and the total number of individuals recorded at PCH within the viewshed of the VP are displayed below in Table 2. The area covered by the viewshed is larger than the area of the Proposed Development and the collision risk modelling process adjusts the figures to allow for this, calculating the results to give an average amount for the collision risk zone ('CRZ'). The CRZ is a volume which covers the proposed turbines and a 500m buffer at PCH.

Table 2 - Target Species Recorded April 2019 – March 2020

Species	Flights	Total no birds in flights	Flights in Viewshed	Flight in Viewshed @ PCH	Individuals in Viewshed @ PCH	Total No. Of At Risk Flight Sec.	Collison Risk Modelling carried Out
Arctic skua	1	1	1	1	1	55	No
Arctic tern	3	15	3	2	5	195	No
Curlew	24	34	24	12	16	675	Yes
Dunlin	1	1	1	1	1	50	No
Golden plover	21	309	21	12	252	7710	Yes
Great skua	26	26	26	18	18	808	Yes
Greylag goose	42	233	42	28	166	9899	Yes
Hen harrier	7	7	7	2	2	65	No
Lapwing	85	443	85	51	315	10755	Yes
Merlin	4	4	4	1	1	10	No
Oystercatcher	46	117	46	22	74	2099	Yes
Peregrine	3	3	3	2	2	469	No
Pink-footed goose	1	1	1	1	1	60	No
Redshank	11	14	11	3	4	46	No
Red-throated diver	9	9	9	6	6	540	Yes
Ringed plover	2	7	2	1	1	30	No
Snipe	10	15	10	8	13	1511	Yes
Turnstone	4	10	4	2	3	134	No
Whooper swan	1	2	1	1	1	45	No

Methods

Collision risk has been calculated based as an average figure for the area covered by the viewsheds (Figure 7.1) and based on a layout of six wind turbines of the specifications outlined in Table 1. It should be noted that the resultant figures provide an average for the survey area as a whole and does not allow for the potential of configuring a layout in order to minimise the impacts of the proposed turbines.

The predicted level of collision mortality is based on results obtained from a collision risk model which uses flight activity data, species' parameters and turbine specifications to obtain a collision rate as outlined in SNH guidance (SNH, 2000). The collision risk modelling follows two models, firstly the random flight model which is used for foraging or displaying birds and secondly the regular model used for commuting or migrating birds.

The guidance also outlines bird biometrics including bird length and wingspan as well as flight speeds and recommended avoidance rates which are inputs into the model and the figures for the species carried forward for collision risk in this assessment are outlined in Table 3 below.

Table 3 - Target Species Bird Biometrics

Species Name	Bird length (m)	Wingspan (m)	Flight speed (m/s)	Avoidance Rate (%)
Curlew	0.55	0.9	16.3	98
Golden Plover	0.28	0.72	13.7	98
Great skua	0.56	1.635	14.9	99.5
Greylag Goose	0.83	1.64	19.3	99.8
Lapwing	0.30	0.84	12.8	98
Oystercatcher	0.43	0.83	13	98
Red-throated diver	0.61	1.11	19	99.5
Snipe	0.26	0.455	17.1	98

Results

Eight species were taken forward for collision risk modelling, of which seven used the random model (curlew, golden plover, great skua, greylag goose, lapwing, oystercatcher and snipe) as these birds used the site for foraging and breeding display. The seventh species (red-throated diver) commuted through the survey area and therefore the regular model was applied to the analysis for this species.

A full working example for one of the seven random species (curlew) and the only regular species (red-throated diver) are detailed below as well as the results for the other six species are also shown.

A summary of all the results for clarity are shown in Table 4 below.

Table 4 – Collision Risk Modelling Results

Species Name	Annual Collsion rate	Collisions - Scheme Lifetime (using notional 25 years for comparison)	Years per collision
Curlew	0.07	1.94	12.9
Golden Plover	0.49	12.1	2.05
Great skua (breeding season)	0.03	0.65	38.5
Greylag Goose	0.15	4.7	3.85
Lapwing	0.7	17.5	1.42
Oystercatcher	0.19	4.9	5.09
Red-throated diver (breeding season)	0.0333	0.82	30.6
Snipe	0.14	3.64	6.86

CRM calculations

Stage 1: Number of Birds Flying Through the Rotors per Year

Calculate the number of hours of observation expressed in hectare hours.

Hectare hours = viewshed (to 2 km and within 500m of site boundary) * survey duration (hrs)

VP 1 (S) viewshed = 267.84 Ha

VP 2 (N) viewshed = 322.79 Ha

Date	VP	Start Time	End Time	Hours	Ha hours
29-Apr-19	803.52	12:15	15:15	3	719.43
29-Apr-19	803.52	15:45	18:45	3	719.43
30-Apr-19	968.37	12:30	15:30	3	736.35
30-Apr-19	968.37	16:00	19:00	3	736.35
30-May-19	803.52	13:30	16:30	3	719.43
30-May-19	803.52	17:00	20:00	3	719.43
01-Jun-19	968.37	14:00	17:00	3	736.35
01-Jun-19	968.37	17:30	20:30	3	736.35
25-Jun-19	803.52	14:30	17:30	3	719.43
25-Jun-19	968.37	18:00	21:00	3	736.35
26-Jun-19	968.37	13:00	16:00	3	736.35
26-Jun-19	968.37	16:30	19:30	3	736.35
27-Jun-19	803.52	16:30	19:30	3	719.43
25-Jul-19	803.52	11:45	14:45	3	719.43
25-Jul-19	803.52	15:15	18:15	3	719.43
25-Jul-19	968.37	18:45	21:45	3	736.35
26-Jul-19	968.37	12:20	15:20	3	736.35
26-Jul-19	968.37	15:50	18:50	3	736.35
25-Aug-19	968.37	13:00	16:00	3	736.35
25-Aug-19	968.37	16:30	19:30	3	736.35
26-Aug-19	803.52	11:00	14:00	3	719.43
26-Aug-19	803.52	14:30	17:30	3	719.43
27-Aug-19	968.37	13:10	16:10	3	736.35
27-Aug-19	803.52	13:10	16:10	3	719.43
02-Sep-19	803.52	17:05	20:05	3	719.43
02-Sep-19	968.37	17:05	20:05	3	736.35
03-Sep-19	803.52	12:55	15:55	3	719.43
03-Sep-19	968.37	12:55	15:55	3	736.35
01-Sep-19	803.52	09:30	12:30	3	719.43
01-Sep-19	968.37	13:00	16:00	3	736.35
25-Feb-20	968.37	10:00	13:00	3	736.35
25-Feb-20	535.68	13:45	15:45	2	490.9
26-Feb-20	803.52	07:15	10:15	3	719.43
26-Feb-20	803.52	14:30	17:30	3	719.43
27-Feb-20	803.52	07:00	10:00	3	719.43

Date	VP	Start Time	End Time	Hours	Ha hours
27-Feb-20	267.84	10:30	11:30	1	245.45
19-Mar-20	803.52	07:35	10:35	3	719.43
19-Mar-20	968.37	07:35	10:35	3	736.35
19-Mar-20	803.52	11:10	14:10	3	719.43
19-Mar-20	968.37	11:10	14:10	3	736.35
19-Mar-20	803.52	14:45	17:45	3	719.43
19-Mar-20	968.37	14:45	17:45	3	736.35
20-Mar-20	968.37	06:20	09:20	3	736.35
20-Mar-20	803.52	09:50	12:50	3	719.43
21-Mar-20	803.52	07:15	10:15	3	719.43
21-Mar-20	968.37	07:15	10:15	3	736.35
21-Mar-20	803.52	10:45	13:45	3	719.43
21-Mar-20	968.37	10:45	13:45	3	736.35
21-Mar-20	968.37	15:45	18:30	3	736.35
Total					42525.36

Calculate hectare seconds = hectare hours * 3600

= 42525.36 * 3600

= 15308496

Calculations species – Random model - full example - Curlew

Calculate the bird observation in all areas and percentage of time birds active in overall observed area.

All Curlew flights April 2019 – March 2020 (highlighted flights not recorded at PCH)

Date	Number	VP	HB1 <PCH (0-14m)	PCH (14-150m)	>PCH (150m+)	Total flight time at PCH in seconds
29-Apr-19	2	1	20	8	0	16
30-Apr-19	2	2	37	0	0	0
30-Apr-19	1	2	49	0	0	0
30-May-19	1	1	17	26	0	26
25-Jun-19	1	1	14	13	0	13
26-Aug-19	1	1	22	34	0	34
27-Aug-19	4	2	0	40	0	160
01-Sep-19	1	1	7	11	0	11
25-Feb-20	1	2	0	65	0	65
19-Mar-20	1	1	45	0	0	0
21-Mar-20	1	2	19	0	0	0
21-Mar-20	1	2	35	0	0	0
21-Mar-20	1	2	11	16	0	16
19-Mar-20	2	2	17	0	0	0
19-Mar-20	1	2	30	0	0	0
19-Mar-20	2	2	30	0	0	0
19-Mar-20	2	2	45	0	0	0
19-Mar-20	1	2	103	197	0	197
19-Mar-20	2	2	15	0	0	0
19-Mar-20	1	2	10	20	0	20
20-Mar-20	2	2	15	0	0	0

Date	Number	VP	HB1 <PCH (0-14m)	PCH (14-150m)	>PCH (150m+)	Total flight time at PCH in seconds
20-Mar-20	1	2	0	40	0	40
20-Mar-20	1	2	13	77	0	77
21-Mar-20	1	2	5	0	0	0
Total						675

Bird Activity = Total bird flight time / hectare seconds

= 675 / 15308496

BA = 0.0000044091

Overall Area covered by VPs = 589.86

Proportion of time potentially active = Area x BA = 0.002600772

Hours potentially active = 4920

Seconds potentially active (4920*3600) = 22026600

Number of seconds of bird occur in airspace = sec potentially active * bird activity

= 22026600* 0.002600772
= 46064.86718

Calculate flight risk volume (Vw)

Vw = 5898573 (m2) * rotor diameter (m)

Vw = 802209600

Calculate combined rotor swept volume

Vr = number of turbines (n) * pi * r2 * (max chord + bird length)
Vr = 6 * (pi * 4624) * (4.1 + 0.55)
Vr = 405090.144

Calculate bird occurrence in swept volume

Occurrence = no of sec of bird occ * combined rotor swept volume/flight risk volume

= 46064.86718* (Vr/Vw)

= 46064.86718* (405090.144/ 802209600)

= 23.26128194

Calculate bird transits time and potential number of transits per year

Transit time = (max chord + bird length) / bird speed (m2)
= (4.1 + 0.55) / 16.3
= 0.28527

No. of transits = occurrence / transit time
= 23.26128194/ 0.28527

= 81.53954743

Stage 2: Collision Risk of Bird Passing through Rotor (Assuming No Avoidance)

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA												
Only enter input parameters in blue											W Band	08/09/2020
K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**									
NoBlades	3					Upwind:			Downwind:			
MaxChord	4.1	m	r/R	c/C	α	collide		contribution	collide		contribution	
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r	
BirdLength	0.55	m	0.025	0.575	8.32	27.03	0.91	0.00114	25.81	0.87	0.00109	
Wingspan	0.9	m	0.075	0.575	2.77	9.42	0.32	0.00239	8.20	0.28	0.00208	
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.66	6.86	0.23	0.00290	5.37	0.18	0.00227	
			0.175	0.860	1.19	6.03	0.20	0.00356	4.20	0.14	0.00248	
Bird speed	16.3	m/sec	0.225	0.994	0.92	5.53	0.19	0.00420	3.42	0.12	0.00260	
RotorDiam	136	m	0.275	0.947	0.76	4.52	0.15	0.00420	2.51	0.08	0.00233	
RotationPeriod	5.45	sec	0.325	0.899	0.64	3.81	0.13	0.00418	1.90	0.06	0.00208	
			0.375	0.851	0.55	3.32	0.11	0.00421	1.52	0.05	0.00192	
			0.425	0.804	0.49	2.96	0.10	0.00425	1.25	0.04	0.00180	
			0.475	0.756	0.44	2.66	0.09	0.00427	1.06	0.04	0.00170	
Bird aspect ratioo: β	0.61		0.525	0.708	0.40	2.41	0.08	0.00428	0.91	0.03	0.00161	
			0.575	0.660	0.36	2.20	0.07	0.00427	0.79	0.03	0.00154	
			0.625	0.613	0.33	2.01	0.07	0.00424	0.71	0.02	0.00149	
			0.675	0.565	0.31	1.84	0.06	0.00419	0.64	0.02	0.00146	
			0.725	0.517	0.29	1.69	0.06	0.00413	0.59	0.02	0.00144	
			0.775	0.470	0.27	1.55	0.05	0.00405	0.55	0.02	0.00144	
			0.825	0.422	0.25	1.42	0.05	0.00395	0.58	0.02	0.00161	
			0.875	0.374	0.24	1.30	0.04	0.00384	0.59	0.02	0.00176	
			0.925	0.327	0.22	1.19	0.04	0.00371	0.61	0.02	0.00189	
			0.975	0.279	0.21	1.08	0.04	0.00356	0.61	0.02	0.00201	
				Overall p(collision) =			**Upwind**	**7.5%**		**Downwind**	**3.7%**	
								Average	**5.6%**			

Annual Collision Rate assuming no avoidance

= No. of transits * Ave probability of collision
= (81.53954743/ 100) x 5.6

= 4.566214656

Corrected for avoidance

= 4.566214656– ((4.566214656/ 100) *98)

= 0.091324293

Corrected for downtime

= 0.091324293* 0.85

= 0.077625649 collisions per year (12.8 years per collision)

Over notional lifetime of the scheme

0.077625649 * 25 = **1.940641229**

Golden Plover Results

	hectare secs		153091296
	total bird flight time		7710
	mean bird activity		0.0000503621
	Overall Area covered by VPs (excluding overlap) =		589.86
	proportion of time active in area =		0.029706592
	hrs potentially active		4920
	seconds potentially active		4920*3600
			17712000
	no of seconds of bird occ in airspace = sec potentially active * bird activity		526163.1495
	Calculate flight risk volume (Vw		Vw = 5898573 (m^2) * rotor diameter (m)
			802205928
	Calculate combined rotor swept volume		Vr = number of turbines (n) * pi * r^2 * (max chord + bird length)
			381133.2
	Calculate bird occurrence in swept volume		Occurrence
			249.9834991
	Calculate bird transits time and potential number of transits per year		max chord+bird length / bir
			0.438
	No. of transits occurrence / transit time		570.7385825
	Annual Collision Rate assuming no avoidance		28.53692912
	Corrected for avoidance		0.570738582
	Corrected for downtime		0.485127795
			2.061312524
	Over lifetime of the scheme		12.12819488
			12.13

Lapwing Results

	hectare secs		153091296
	total bird flight time		10755
	bird activity		0.0000702522
	Overall Area covered by VPs (excluding overlap) =		589.86
	proportion of time active in area =		0.041438961
	hrs potentially active		4920
	seconds potentially active		4920*3600
			17712000
	no of seconds of bird occ in airspace = sec potentially active * bird activity		733966.8837
	Calculate flight risk volume (Vw		Vw = 5898573 (m^2) * rotor diameter (m)
			802205928
	Calculate combined rotor swept volume		Vr = number of turbines (n) * pi * r^2 * (max chord + bird length)
			383311.104
	Calculate bird occurrence in swept volume		Occurrence
			350.705033
	Calculate bird transits time and potential number of transits per year		max chord+bird length / bir
			0.45
	No. of transits occurrence / transit time		779.3445178
	Annual Collision Rate assuming no avoidance		41.30525945
	Corrected for avoidance		0.826105189
	Corrected for downtime		0.702189411
			1.424117175
	Over lifetime of the scheme		17.55473526

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Oystercatcher Results

	hectare secs		153091296
	total bird flight time		2099
	bird activity		0.0000137108
	Overall Area covered by VPs (excluding overlap) =		589.86
	proportion of time active in area =		0.008087437
	hrs potentially active		4920
	seconds potentially active		4920*3600
			17712000
	no of seconds of bird occ in airspace = sec potentially active * bird activity		143244.6759
	Calculate flight risk volume (Vw		Vw = 5898573 (m^2) * rotor diameter (m)
			802205928
	Calculate combined rotor swept volume		Vr = number of turbines (n) * pi * r^2 * (max chord + bird length)
			394636.2048
	Calculate bird occurrence in swept volume		Occurrence
			70.46761095
	Calculate bird transits time and potential number of transits per year		max chord+bird length / bir
			0.348461538
	No. of transits occurrence / transit time		202.2249321
	Annual Collision Rate assuming no avoidance		11.52682113
	Corrected for avoidance		0.230536423
	Corrected for downtime		0.195955959
			5.103187492
	Over lifetime of the scheme		4.89889898

Snipe Results

	hectare secs		153091296
	total bird flight time		1511
	bird activity		0.0000098699
	Overall Area covered by VPs (excluding overlap) =		589.86
	proportion of time active in area =		0.005821875
	hrs potentially active		4920
	seconds potentially active		4920*3600
			17712000
	no of seconds of bird occ in airspace = sec potentially active * bird activity		103117.0582
	Calculate flight risk volume (Vw		Vw = 5898573 (m^2) * rotor diameter (m)
			802205928
	Calculate combined rotor swept volume		Vr = number of turbines (n) * pi * r^2 * (max chord + bird length)
			379826.4576
	Calculate bird occurrence in swept volume		Occurrence
			48.82360698
	Calculate bird transits time and potential number of transits per year		max chord+bird length / bir
			0.256470588
	No. of transits occurrence / transit time		190.3672749
	Annual Collision Rate assuming no avoidance		8.566527371
	Corrected for avoidance		0.171330547
	Corrected for downtime		0.145630965
			6.866671507
	Over lifetime of the scheme		3.640774133

Great Skua Results

	hectare secs		153091296
	total bird flight time		943
	bird activity		0.0000061597
	Overall Area covered by VPs (excluding overlap) =		589.86
	proportion of time active in area =		0.003633374
	hrs potentially active (April - September)		2333
	seconds potentially active		2333*3600
			8398800
	no of seconds of bird occ in airspace = sec potentially active * bird activity		30515.98405
	Calculate flight risk volume (Vw		Vw = 5898573 (m^2) * rotor diameter (m)
			402614400
	Calculate combined rotor swept volume		Vr = number of turbines (n) * pi * r^2 * (max chord + bird length)
			405961.3056
	Calculate bird occurrence in swept volume		Occurrence
			30.76966131
	Calculate bird transits time and potential number of transits per year		max chord+bird length / bir
			0.312751678
	No. of transits occurrence / transit time		98.383681
	Annual Collision Rate assuming no avoidance		6.099788222
	Corrected for avoidance		0.030498941
	Corrected for downtime		0.0259241
			38.57414538
	Over lifetime of the scheme		0.648102499
			0.65

Greylag Goose Results

	hectare secs		153091296
	total bird flight time		9899
	mean bird activity		0.0000646608
	Overall Area covered by VPs (excluding overlap) =		589.86
	proportion of time active in area =		0.038140798
	hrs potentially active		4920
	seconds potentially active		4920*3600
			17712000
	no of seconds of bird occ in airspace = sec potentially active * bird activity		675549.8077
	Calculate flight risk volume (Vw		Vw = 5898573 (m^2) * rotor diameter (m)
			802205928
	Calculate combined rotor swept volume		Vr = number of turbines (n) * pi * r^2 * (max chord + bird length)
			429482.6688
	Calculate bird occurrence in swept volume		Occurrence
			361.6738847
	Calculate bird transits time and potential number of transits per year		max chord+bird length / bird speed
			0.255440415
	No. of transits occurrence / transit time		1415.883565
	Annual Collision Rate assuming no avoidance		90.61654815
	Corrected for avoidance		0.181233096
	Corrected for downtime		0.154048132
			6.491477618
	Over lifetime of the scheme		3.851203296
			3.85

Species Using linear Model: Red-throated diver

Stage 1: Number of Birds Flying Through the Rotors per Year

1. Calculation of the 'risk window'; Cross section area equal to the width of the wind farm across the general direction of flight multiplied by the height of turbine to rotor tip. Width of wind farm was determined using GIS.

   Width of transit flight (Ws) = 2520m

   Turbine height (th) = 150m

   Risk Window (W) = Ws * th

   = 2520m * 150m

   = 378000 m^2

2. Calculate the area occupied by rotor blades (A)

   Number of turbine (n) = 6

   Rotor radius (r) = 68

   A = n * π *r2

   A = 6 * 3.14* 4624

   A = 87,116.16m^2

3. Express the area occupied by rotor blades (A) as a proportion of the risk window (W)

   Proportion (P) = A/W

   = 87,116.16/378000

   = 0.23046

4. Calculate the number of bird potentially flying through the site per year (N)

   N = number of red-throated diver transits at PCH per year

   = hourly rate of transit * available hours for flight

   Hours surveyed between April 2019 and August 2019

   = hectare hours (correcting for overlap) / hectares visible in Study area

   = 21,262.68 / 589.86

   = 36.04

   Number of divers observed in the same period = 7

   Hourly rate of transit = 7/36.04

   = 0.194

Hours available for flight are equal to number of daylight hours in the same period plus 25% of night hours.

Hours available = 2768

N = 2768 * 0.194

= 537.62

1. Calculate the number of birds flights (Nf) to fly through the rotor (P)

Nf = N * P

= 537.62* 0.23046

= 123.901

Stage 2: Collision Risk of Bird Passing Through Rotor (Assuming No Avoidance)

Stage 2 was calculated using the prepopulated spreadsheet provided by Scottish Natural Heritage (SNH) for calculating the probability of collision for any species (available at: http://www.snh.gov.uk/docs/C234672.xls)

Variable highlighted in blue where entered into the spreadsheet. Bird biometrics where determined using the British Trust for Ornithology website (http://www.bto.org/about-birds/birdfacts) bird flight speeds were assumed using the flight speeds characterised by Bruderer and Boldt (2001).

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA												
Only enter input parameters in blue											W Band	29/09/2020
K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**									
NoBlades	3						Upwind:				Downwind:	
MaxChord	4.1	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.55	m	0.025	0.575	6.63	21.68	0.92	0.00115	20.46	0.87	0.00108
Wingspan	0.9	m	0.075	0.575	2.21	7.63	0.32	0.00242	6.41	0.27	0.00204
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.33	5.62	0.24	0.00298	4.14	0.18	0.00219
			0.175	0.860	0.95	4.99	0.21	0.00370	3.17	0.13	0.00235
Bird speed	13	m/sec	0.225	0.994	0.74	4.62	0.20	0.00440	2.51	0.11	0.00239
RotorDiam	136	m	0.275	0.947	0.60	3.82	0.16	0.00444	1.81	0.08	0.00210
RotationPeriod	5.45	sec	0.325	0.899	0.51	3.32	0.14	0.00457	1.41	0.06	0.00194
			0.375	0.851	0.44	2.94	0.12	0.00467	1.14	0.05	0.00181
			0.425	0.804	0.39	2.64	0.11	0.00476	0.94	0.04	0.00169
			0.475	0.756	0.35	2.40	0.10	0.00482	0.79	0.03	0.00159
Bird aspect ratioo: β	0.61		0.525	0.708	0.32	2.19	0.09	0.00486	0.68	0.03	0.00152
			0.575	0.660	0.29	2.01	0.08	0.00488	0.60	0.03	0.00147
			0.625	0.613	0.27	1.84	0.08	0.00488	0.56	0.02	0.00147
			0.675	0.565	0.25	1.70	0.07	0.00486	0.60	0.03	0.00171
			0.725	0.517	0.23	1.57	0.07	0.00481	0.63	0.03	0.00194
			0.775	0.470	0.21	1.45	0.06	0.00475	0.65	0.03	0.00213
			0.825	0.422	0.20	1.33	0.06	0.00466	0.66	0.03	0.00231
			0.875	0.374	0.19	1.23	0.05	0.00455	0.67	0.03	0.00247
			0.925	0.327	0.18	1.13	0.05	0.00442	0.66	0.03	0.00260
			0.975	0.279	0.17	1.03	0.04	0.00427	0.66	0.03	0.00272
				Overall p(collision) =			**Upwind**	**8.5%**		**Downwind**	**4.0%**	
								Average	**6.2%**			

Calculation of collision rate

Collision rate = Nf * average probability of collision

= 123.901*0.062

= 7.682

Calculation of collision rate applying 99.5% avoidance rate

= 7.8296*0.005

= 0.0384

1. Correct collision rate for down time (assuming wind farm operates at 85%)

= (0.198/ 100)*85

= 0.0326

2. Calculate the number of year per collision

= 1 / 0.0326

= 30.6

3. Calculate the number of collisions per lifetime of the scheme (given a 25 value for comparison)

= 0.22 * 25

= 0.82

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