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APPENDIX 10.2

Collison Risk Model

Avian Collision Risk Assessment Report

Coumnagappul Wind Farm

Coumnagappul, County Waterford

EMPower, Dublin 1

May 2023

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Project No.	Doc. No.	Rev.	Date	Prepared By	Checked By	Approved By	Status
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MWP, Engineering and Environmental Consultants
Address: Reen Point, Blennerville, Tralee, Co. Kerry, V92 X2TK
www.mwp.ie

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HEALTH & SAFETY
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1. Introduction

1.1 Background

Collision with the turbine rotors of onshore wind farms is a potential source of avian mortality. This document has been prepared to assess that risk by using a Collision Risk Model (CRM) at the proposed Coumnagappul Wind Farm site in upland central County Waterford.

In line with NatureScot (formerly known as Scottish Natural Heritage) (SNH[1], 2000) guidance, the Band Collision Risk Model (Band *et al*., 2007; Band, 2012a) was used in this assessment. The Band model estimates the risk of collision based on a target species' activity levels, flight details, biometrics and behaviour, along with the number, layout and specifications of the proposed turbines. The data for this assessment was obtained from vantage point (VP) surveys carried out on site at Coumnagappul from April 2019 to September 2022, inclusive, at three fixed vantage point locations, and from October 2021 to September 2022, inclusive, at a fourth fixed vantage point.

1.2 Band Modelling Method

The Band modelling method involves two stages:

Stage 1: Establishing the number of birds or flights that pass through the air space swept by the turbine rotors. These transits are determined by using either the 'Regular' or 'Random' flight model depending on flight activity and behaviour.

Stage 2: Calculating the probability of a bird being struck when making a transit through a rotor.

The outputs of each stage are then multiplied together to give a theoretical annual collision mortality rate based on the supposition that birds make no attempt to avoid collision. However, in "real-life" circumstances, birds demonstrate high rates of avoidance – usually 98% to 99.5% according to SNH (2018) – and to account for these evasion measures, avoidance rates are applied as a percentage to the theoretical collision value as a final step.

Band model values are solely speculative and representative of worst-case estimates, only drawing conclusions by assuming likely levels of active avoidance by specific species. Accordingly, results obtained are dependent on the quality of field observation data and accuracy of the avoidance rates used and, therefore, must be interpreted with a certain degree of caution.

2. Statement of Competency

This Collision Risk Modelling Report has been prepared by Úna Williams (BSc. MSc.), Ecologist and Environmental Scientist, at Malachy Walsh and Partners (MWP) Engineering and Environmental Consultants.

Úna has worked with MWP for over three years and is an experienced field ecologist with a BSc in Environmental Science and an MSc in Animal Behaviour. She is familiar with various ecological survey methodologies including habitat/survey mapping and zoological surveys and has worked on research teams both in Ireland and abroad. She has undertaken assessments for a wide variety of projects including renewable energy developments, and infrastructural and coastal development projects. Úna has designed and carried out several Collision Risk Models for proposed wind farms and has authored many ecological reports including Screenings for Appropriate Assessment Reports (Stage 1), Natura Impact Statements (Stage 2), and Ecological Impact Assessments.

[1] All Scottish Natural Heritage (SNH) documents consulted for this assessment were published prior to the organisation's rebrand to NatureScot in August 2020. To avoid confusion, the documents remain referenced as SNH throughout this report.

3. Methodology

3.1 Flight Data

Flight data was recorded from three vantage point (VP) locations – VP1, VP2, and VP3 –from April 2019 to September 2022, inclusive. Data from a fourth VP (VP4) was used in the model period of October 2021 to September 2022, inclusive. A potential collision height (PCH) of between 20 metres and 200 metres above ground level (AGL) was established based on the Coumnagappul Wind Farm turbines having a maximum blade tip height of 185 metres, and a rotor diameter of 162 metres (see **Table 1**, below). This slightly overestimates the risk of collision but ensures that the PCH is easily within the rotor sweep of the turbine. Using recent SNH guidance (2017), VP watches were carried out at each VP location for six hours per month over a 42-month period for VPs 1, 2 and 3, and over a 12-month period for VP4.

Each VP arc measures 180° and has a radius of 2 kilometres from the vantage point location - this represents the theoretical maximum visual coverage of the VP. The viewshed, however, is the actual area visible to the surveyor at a specified height above ground level from the vantage point location within each VP arc. Geographical Information Systems (GIS) computer software was used to generate the viewsheds for each VP. Flight data from the viewshed mapping for each VP was used to inform the CRM.

Table 1 and **Figure 1**, below, provide details of each VP's arc and viewshed extent.

Table 1. Details of each vantage point (VP) and corresponding viewshed

Vantage point	Area of VP arc (ha)	Viewshed area within VP arc (ha)	Viewshed coverage within VP arc (%)	Turbine buffer area within viewshed (ha)	No. of turbines within viewshed	Total survey effort (hrs)
VP1	628	343	91.2	247.37	6	252
VP2	628	441	74.8	306.20	7	252
VP3	628	416	51.3	275.33	6	252
VP4	628	319	50.8	257.14	6	72

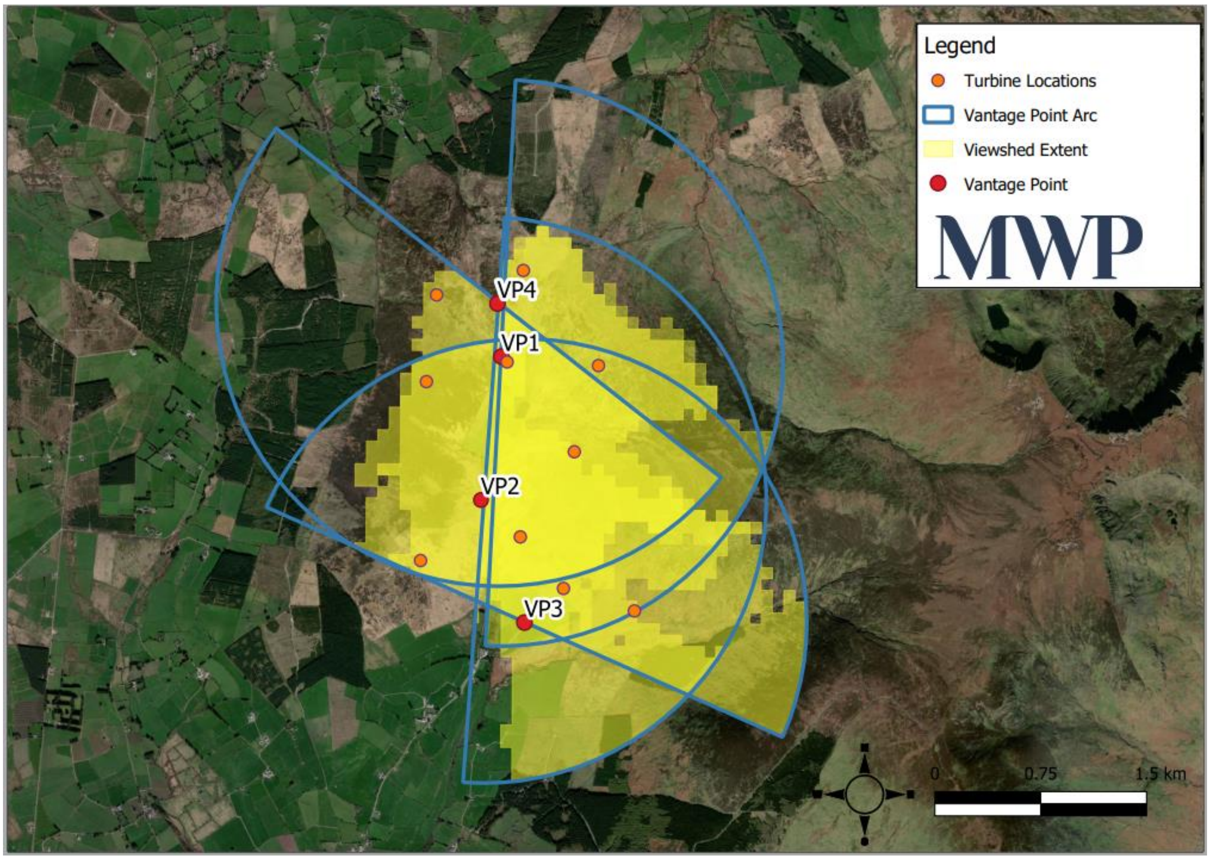

Figure 1. Vantage point arcs and viewshed extents at proposed Coumnagappul Wind Farm site

3.2 Bird Biometrics and Flight Duration at Potential Collision Height (PCH)

Specific species morphometric measurements and flight speeds are shown in **Table 2,** below, while the amount of time a species was observed flying at heights of between 20 and 200 metres, i.e. within the PCH, is presented in **Table 3,** below. Total monthly values of bird-seconds at PCH within all viewsheds are set out in **Table 4**, below**.**

Values for bird length and bird wingspan were retrieved from Welcome to BirdFacts | BTO - British Trust for Ornithology. Values for the mean velocity of a flying bird were taken from Alerstam *et al*. (2007) for all species, apart from merlin which was derived from Cochran & Applegate (1986). Grey plover (*Pluvialis squatarola*) flight speed values were substituted for golden plover as details on the latter were absent from Alerstam *et al*. (2007).

For convenience, species in this report have been listed alphabetically as opposed to taxonomically.

Table 2. Bird species biometrics

Species	Species length (m)	Species wingspan (m)	Mean flight speed (m/s)
Buzzard (*Buteo buteo*)	0.54	1.2	11.6
Golden plover (*Pluvialis apricaria*)	0.28	0.72	17.9
Great black-backed gull (*Larus marinus*)	0.71	1.58	13.7

Species	Species length (m)	Species wingspan (m)	Mean flight speed (m/s)
Hen harrier (*Circus cyaneus*)	0.48	1.1	9.1
Herring gull (*Larus argentatus*)	0.57	1.4	12.8
Kestrel (*Falco tinnunculus*)	0.34	0.76	10.1
Lesser black-backed gull (*Larus fuscus*)	0.58	1.42	13.1
Merlin (*Falco columbarius*)	0.28	0.56	10.9
Peregrine (*Falco peregrinus*)	0.45	1.02	12.1
Snipe (*Gallinago gallinago*)	0.26	0.46	17.1
Sparrowhawk (*Accipiter nisus*)	0.33	0.62	11.3

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Table 3. Bird-seconds spent at Potential Collision Height (20 - 200 metres)

Species	Total bird-secs at PCH over entire survey period	Bird-seconds in flight at PCH (20 – 200 m)									
		2019/2020			2020/2021			2021/2022			2022
		Breeding	Winter	Total	Breeding	Winter	Total	Breeding	Winter	Total	Breeding
Buzzard	2,360	815	455	1,270	195	225	420	110	65	175	495
Golden plover	76,270	0	0	0	0	75,300	75,300	0	970	970	0
Great black-backed gull	25	0	0	0	25	0	25	0	0	0	0
Hen harrier	130	0	0	0	0	0	0	60	0	60	70
Herring gull	150	0	0	0	95	0	95	0	0	0	55
Kestrel	4,151	788	703	1,491	535	420	955	520	450	970	735
Lesser black-backed gull	521	150	96	246	125	0	125	150	0	150	0
Merlin	180	180	0	180	0	0	0	0	0	0	0
Peregrine	110	0	90	90	0	0	0	0	20	20	0
Snipe	43	10	0	10	0	18	18	0	15	15	0
Sparrowhawk	275	215	0	215	0	40	40	0	20	20	0

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Table 4. Species monthly values of bird-seconds spent at Potential Collision Height (20 - 200 metres)

Species	Season(s)	Monthly values of bird-seconds spent at PCH within viewsheds											
		Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Buzzard	2019/20	300	405	0	0	50	60	360	0	0	0	95	0
	2020/21	175	0	0	20	0	0	0	0	25	0	60	140
	2021/22	70	40	0	0	0	0	15	25	0	25	0	0
	2022	45	145	90	90	125	0	-	-	-	-	-	-
Golden plover	2019/20	0	0	0	0	0	0	0	0	0	0	0	0
	2020/21	0	0	0	0	0	0	75,240	0	60	0	0	0
	2021/22	0	0	0	0	0	0	0	375	0	0	0	595
	2022	0	0	0	0	0	0	-	-	-	-	-	-
Great black-backed gull	2019/20	0	0	0	0	0	0	0	0	0	0	0	0
	2020/21	0	0	0	25	0	0	0	0	0	0	0	0
	2021/22	0	0	0	0	0	0	0	0	0	0	0	0
	2022	0	0	0	0	0	0	-	-	-	-	-	-
Hen harrier	2019/20	0	0	0	0	0	0	0	0	0	0	0	0
	2020/21	0	0	0	0	0	0	0	0	0	0	0	0
	2021/22	60	0	0	0	0	0	0	0	0	0	0	0
	2022	0	0	0	0	70	0	-	-	-	-	-	-
Herring gull	2019/20	0	0	0	0	0	0	0	0	0	0	0	0

Species	Season(s)	Monthly values of bird-seconds spent at PCH within viewsheds											
		Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
	2020/21	0	0	95	0	0	0	0	0	0	0	0	0
	2021/22	0	0	0	0	0	0	0	0	0	0	0	0
	2022	0	0	0	55	0	0	-	-	-	-	-	-
Kestrel	2019/20	0	120	0	40	628	0	558	120	0	0	0	25
	2020/21	40	250	35	0	0	210	320	70	30	0	0	0
	2021/22	0	0	520	0	0	0	110	80	70	55	55	80
	2022	105	95	130	195	120	90	-	-	-	-	-	-
Lesser black-backed gull	2019/20	100	0	0	0	50	0	0	0	0	0	0	96
	2020/21	0	35	50	40	0	0	0	0	0	0	0	0
	2021/22	0	0	150	0	0	0	0	0	0	0	0	0
	2022	0	0	0	0	0	0	-	-	-	-	-	-
Merlin	2019/20	60	120	0	0	0	0	0	0	0	0	0	0
	2020/21	0	0	0	0	0	0	0	0	0	0	0	0
	2021/22	0	0	0	0	0	0	0	0	0	0	0	0
	2022	0	0	0	0	0	0	-	-	-	-	-	-
Peregrine	2019/20	0	0	0	0	0	0	0	0	15	35	40	0
	2020/21	0	0	0	0	0	0	0	0	0	0	0	0
	2021/22	0	0	0	0	0	0	0	0	0	0	20	0

Species	Season(s)	Monthly values of bird-seconds spent at PCH within viewsheds											
		Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
	2022	0	0	0	0	0	0	-	-	-	-	-	-
Snipe	2019/20	0	0	0	0	10	0	0	0	0	0	0	0
	2020/21	0	0	0	0	0	0	0	0	0	18	0	0
	2021/22	0	0	0	0	0	0	0	0	15	0	0	0
	2022	0	0	0	0	0	0	-	-	-	-	-	-
Sparrowhawk	2019/20	0	0	0	0	215	0	0	0	0	0	0	0
	2020/21	0	0	0	0	0	0	0	40	0	0	0	0
	2021/22	0	0	0	0	0	0	20	0	0	0	0	0
	2022	0	0	0	0	0	0	-	-	-	-	-	-

3.3 Band Collision Risk Modelling

3.3.1 Regular and Random Flight Models – Stage 1

Stage 1 calculations use the data recorded during VP surveys to calculate the number of predicted transits of a species through the turbine blade swept areas (see example of Stage 1 calculation spreadsheet for buzzard in Appendix A). Stage 1 calculations are carried out using one of two methods based on whether flight activity follows a regular pattern or is random – the "Regular Flight Model" or the "Random Flight Model", respectively.

For predictable flightlines, like those created by geese following a migratory route or those produced by the regular movement of divers from nest sites to the coast, the "Regular Flight Model" is used. This model involves calculating the number of birds flying through the rotor swept area each year.

The "Random Flight Model" is used in cases of irregular flight activity such as that displayed by raptors occupying a recognised territory, or by waders - this model requires calculation of the proportion of time birds were observed flying per unit of survey area.

More information on both Regular and Random Flight Model calculations are freely available on the NatureScot (formerly known as Scottish National Heritage) website at: https://www.nature.scot/wind-farm-impacts-birds-calculating-theoretical-collision-risk-assuming-no-avoiding-action.

The flights recorded from the four vantage points (VP1, VP2, VP3, and VP4) at the proposed Coumnagappul Wind Farm site were deemed to be randomly distributed – that is, with a potential to occur anywhere within a viewshed, or with no regular patterns observed. Consequently, the "Random Flight Model" was used to determine the predicted number of transits by a species through the site.

The proportion of flight time between 20 metres and 200 metres AGL for each VP was calculated. If multiple birds were observed in one flight, the seconds spent at PCH were calculated by multiplying the number of birds observed per flight by the duration of the flight at PCH (in accordance with SNH (2000) guidelines).

The hours a species may potentially be active in either a breeding or a non-breeding season was calculated to include hours of daylight, one hour before sunrise, and one hour after sunset (dusk). For snipe and golden plover, some nocturnal activity was assumed so the hours of availability for these two species was calculated to include hours of daylight, one hour before sunrise, one hour after sunset (dusk), and 25% of length of the night (Band, 2012b). Calculations to ascertain the numbers of hours potentially available for activity were carried out using values based on data obtained from Wilson *et al.* (2015) and timeanddate.com (2022) using the latitudinal value for Waterford as 52°14'N / 7°09'W.

This flight activity was used to calculate the number of bird passes through the rotor per VP and bird passes through the rotor per turbine within each viewshed before being calculated for the entire 10-turbine wind farm.

3.3.2 Probability of Collision – Stage 2

Stage 2 of the model calculates the probability of a bird being struck were it to fly through the rotor. This is determined using the same method for both regular and random flightlines using a publicly available SNH collision risk probability model spreadsheet available at: https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision.

The spreadsheet provides for a scenario in which the bird is either flapping or gliding, and where the transit is either upwind or downwind. For collision risk assessment, the mean probability of both flapping and gliding behaviour was used (see **Table 8**, below). For a detailed explanation of Stage 2 calculations see Band *et al*. (2007). A completed spreadsheet of Stage 2 calculations for buzzard is included in **Appendix A** as an example.

For Stage 2, the probability of collision depends on the size of the bird (length and wingspan), the breadth and pitch of the turbine blades, the rotation speed of the turbine, and the flight speed of the bird (Band *et al*., 2007). **Table 5**, below, lists the wind farm and turbine characteristics used in this analysis. Values for the mean pitch of a turbine blade (degrees), the maximum chord (metres), and the rotational speed (rotations per minute (rpm)) were obtained from a senior wind farm engineer with Malachy Walsh and Partners based on knowledge and specifications of the proposed turbine dimensions. Bird biometric parameters (**Table 2**, above) were obtained from Wilson *et al*. (2015), Alerstam *et al*. (2007), and the British Trust for Ornithology (BTO) website[2].

Table 5. Turbine technical parameters

Parameter	Specification
Proposed number of turbines	10
Number of blades per turbine rotor	3
Rotor diameter (metres)	162
Rotor radius (metres)	81
Hub height (metres)	104
Maximum height to blade tip (metres)	185
Minimum height to blade tip (metres)	23
Swept area per turbine (metres^2)	20,612
Mean pitch of blade (degrees)	5
Maximum chord (metres)	4.1
Rotational speed (rotations per minute)	4.3 – 12.1
Mean rotational speed (rotation per minute)	8.572
Mean rotational period (seconds)	7.00
Turbine operational time (%)	85

3.3.3 Calculating Collision Risk

For the purposes of the CRM calculations, each twelve-month cycle was divided into two seasonal periods – the breeding (summer) season running from April to September, inclusive, and the winter season running from October to March, inclusive. Rather than using results from a single entire-year CRM, the predicted annual collision risk was taken as the sum of these separate summer and winter CRM results. This was to minimise, as much as was feasible, any potential underestimation or overestimation for a species' risk of collision i.e. to

[2] https://www.bto.org/understanding-birds/birdfacts Accessed: 28th April 2023

increase the precision of the CRM. For example, kestrel observed at the site during the summer months are likely to be resident birds from the same population. During the winter, however, some kestrel may disperse from the area meaning that a single twelve-month CRM would likely underestimate the risk of collision. Conversely, local golden plover are part of a wintering population so producing a single, all-year CRM would likely overestimate the collision risk of this species.

It is acknowledged that these six-month seasonal divisions are solely approximations since in 'real-life' scenarios the breeding/winter seasons will vary slightly for each species. These six-month divisions of the survey period were used to ensure the efficient incorporation of all available data.

The results of each separate stage - Stage 1 and Stage 2 - were multiplied together to calculate the risk of collision for each species per season. This predicted collision mortality rate assumes a bird takes no action to avoid a collision, yet in practice birds show a very high degree of collision avoidance that dramatically lowers predicted mortality (Band *et al*., 2007). Avoidance rates listed in SNH (2018), Furness (2019) and Gittings (2020) (see Section 4.3.1, below) were applied to the predicted number of collisions for each species to calculate the risk per season.

Finally, all seasons were added together and the mean number of predicted annual collisions for each species was calculated in addition to the mean number of predicted collisions per 40 years (predicted lifespan of the wind farm). See Table 11, below, for the final modelling results.

4. Results

4.1 Results of Stage 1 Calculations

Table 6 and Table 7, below, show the results of Stage 1 calculations – the number of birds estimated to fly through the blades of the proposed turbines at the Coumnagappul Wind Farm. Table 6, below, presents the number of annual transits predicted to occur within the viewshed of each VP during each breeding season and winter season. Table 7, below, gives further details on the mean predicted transits through each turbine per season, and mean predicted transits per season through all turbines across the proposed 10-turbine site.

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Table 6. Predicted transits per turbine within viewsheds of VP1, VP2 and VP3 for the 2019, 2020, 2021 and 2022 breeding (summer) seasons and the 2019/20, 2020/21 and 2021/22 winter seasons, and predicted transits per turbine within viewshed of VP4 for the 2021/22 winter season and the 2022 breeding (summer) season

Species		VP1			VP2			VP3			VP4		
	Year/Season	Breeding	Winter	Total	Breeding	Winter	Total	Breeding	Winter	Total	Breeding	Winter	Total
Buzzard	2019/20	7.96	0	7.96	1.83	2.26	4.09	4.70	2.14	6.84	-	-	-
	2020/21	0.49	0	0.49	0.31	0	0.31	2.43	2.24	4.67	-	-	-
	2021/22	0	0	0	0	0.47	0.47	1.78	0.15	1.93	-	0	0
	2022	0	-	0	3.51	-	3.51	4.29	-	4.29	0	-	0
Golden plover	2019/20	0	0	0	0	0	0	0	0	0	-	-	-
	2020/21	0	44.91	44.91	0	1687.72	1687.72	0	44.98	44.98	-	-	-
	2021/22	0	0	0	0	0.82	0.82	0	23.23	23.23	-	0	0
	2022	0	-	0	0	-	0	0	-	0	0	-	0
Great black-backed gull	2019/20	0	0	0	0	0	0	0	0	0	-	-	-
	2020/21	0.58	0	0.58	0	0	0	0	0	0	-	-	-
	2021/22	0	0	0	0	0	0	0	0	0	-	0	0
	2022	0	-	0	0	-	0	0	-	0	0	-	0
Hen harrier	2019/20	0	0	0	0	0	0	0	0	0	-	-	-
	2020/21	0	0	0	0	0	0	0	0	0	-	-	-
	2021/22	0	0	0	0	0	0	0.76	0	0.76	-	0	0
	2022	0	-	0	0	-	0	0.89	-	0.89	0	-	0
Herring gull	2019/20	0	0	0	0	0	0	0	0	0	-	-	-

Species	Year/Season	VP1 Breeding	VP1 Winter	VP1 Total	VP2 Breeding	VP2 Winter	VP2 Total	VP3 Breeding	VP3 Winter	VP3 Total	VP4 Breeding	VP4 Winter	VP4 Total
	2020/21	1.52	0	1.52	0	0	0	0.45	0	0.45	-	-	-
	2021/22	0	0	0	0	0	0	0	0	0	-	0	0
	2022	0	-	0	0.93	-	0.93	0	-	0	0	-	0
Kestrel	2019/20	2.74	5.69	8.43	4.11	1.07	5.18	4.50	0.28	4.78	-	-	-
	2020/21	1.28	0.32	1.60	4.06	2.87	6.93	2.19	0.35	2.54	-	-	-
	2021/22	0	1.42	1.42	6.91	1.76	8.67	0	0.87	0.87	-	0	0
	2022	4.36	-	4.36	1.46	-	1.46	2.33	-	2.33	3.77	-	3.77
Lesser black-backed gull	2019/20	0	0	0	0.86	0	0.86	1.83	1.08	2.91	-	-	-
	2020/21	0.78	0	0.78	0.86	0	0.86	0.73	0	0.73	-	-	-
	2021/22	0.67	0	0.67	2.07	0	2.07	0	0	0	-	0	0
	2022	0	-	0	0	-	0	0	-	0	0	-	0
Merlin	2019/20	0	0	0	0.86	0	0.86	1.83	0	1.83	-	-	-
	2020/21	0	0	0	0	0	0	0	0	0	-	-	-
	2021/22	0	0	0	0	0	0	0	0	0	-	0	0
	2022	0	-	0	0	-	0	0	-	0	0	-	0
Peregrine	2019/20	0	0	0	0	0.34	0.34	0	0.57	0.57	-	-	-
	2020/21	0	0	0	0	0	0	0	0	0	-	-	-
	2021/22	0	0	0	0	0.20	0.20	0	0	0	-	0	0
	2022	0	-	0	0	-	0	0	-	0	0	-	0

Species	Year/Season	VP1 Breeding	VP1 Winter	VP1 Total	VP2 Breeding	VP2 Winter	VP2 Total	VP3 Breeding	VP3 Winter	VP3 Total	VP4 Breeding	VP4 Winter	VP4 Total
Snipe	2019/20	0.37	0	0.37	0	0	0	0	0	0	-	-	-
	2020/21	0	0.52	0.52	0	0	0	0	0	0	-	-	-
	2021/22	0	0	0	0	0	0	0	0.36	0.36	-	0	0
	2022	0	-	0	0	-	0	0	-	0	0	-	0
Sparrowhawk	2019/20	0	0	0	2.53	0	2.53	0.71	0	0.71	-	-	-
	2020/21	0	0	0	0	0	0	0	0.39	0.39	-	-	-
	2021/22	0	0	0	0	0	0	0	0.19	0.19	-	0	0
	2022	0	-	0	0	-	0	0	-	0	0	-	0

Table 7. Mean number of predicted transits per turbine per season, and mean number of predicted transits across the entire wind farm site per season

Species		Mean transits per turbine per season			Mean transits predicted across entire proposed wind farm site per season		
	Year/Season	Breeding	Winter	Total	Breeding	Winter	Total
Buzzard	2019/20	4.83	1.47	6.30	48.30	14.67	62.97
	2020/21	1.61	0.75	2.36	16.07	7.48	23.55
	2021/22	0.60	0.62	1.22	5.94	6.20	12.14
	2022	7.81	-	7.81	78.07	-	78.07
Golden plover	2019/20	0	0	0	0	0	0
	2020/21	0	592.53	592.53	0	5925.33	5925.33
	2021/22	0	24.05	24.05	0	240.54	240.54
	2022	0	-	0	0	-	0
Great black-backed gull	2019/20	0	0	0	0	0	0
	2020/21	0.58	0	0.58	5.80	0	5.80
	2021/22	0	0	0	0	0	0
	2022		-			-	
Hen harrier	2019/20	0	0	0	0	0	0
	2020/21	0	0	0	0	0	0
	2021/22	0.25	0	0.25	2.54	0	2.54
	2022	0.89	-	0.89	8.89	-	8.89
Herring gull	2019/20	0	0	0	0	0	0
	2020/21	1.67	0	1.67	16.66	0	16.66

Species		Mean transits per turbine per season			Mean transits predicted across entire proposed wind farm site per season		
	Year/Season	Breeding	Winter	Total	Breeding	Winter	Total
	2021/22	0	0	0	0	0	0
	2022	0.93	-	0.93	9.27	-	9.27
Kestrel	2019/20	3.78	2.35	6.13	37.82	23.46	61.28
	2020/21	6.07	3.30	9.37	60.69	32.98	101.98
	2021/22	6.92	4.05	10.97	69.18	40.51	109.69
	2022	9.09	-	9.09	90.95	-	90.95
Lesser black-backed gull	2019/20	0.90	0.36	1.26	8.97	3.60	12.57
	2020/21	1.88	0	1.88	18.83	0	18.83
	2021/22	2.74	0	2.74	27.36	0	27.36
	2022	0	-	0	0	-	0
Merlin	2019/20	0.90	0	0.90	8.96	0	8.96
	2020/21	0	0	0	0	0	0
	2021/22	0	0	0	0	0	0
	2022	0	-	0	0	-	0
Peregrine	2019/20	0	0.31	0.31	0	3.05	3.05
	2020/21	0	0	0	0	0	0
	2021/22	0	0.20	0.20	0	1.96	1.96
	2022	0	-	0	0	-	0
Snipe	2019/20	0.12	0	0.12	1.23	0	1.23

Species	Year/Season	Mean transits per turbine per season: Breeding	Winter	Total	Mean transits predicted across entire proposed wind farm site per season: Breeding	Winter	Total
	2020/21	0	0.52	0.52	0	5.18	5.18
	2021/22	0	0.36	0.36	0	3.56	3.56
	2022	0	-	0	0	-	0
Sparrowhawk	2019/20	1.08	0	1.08	10.80	0	10.80
	2020/21	0	0.13	0.13	0	1.30	1.30
	2021/22	0	0.19	0.19	0	1.94	1.94
	2022	0	-	0	0	-	0

4.2 Stage 2 Calculations Results

The second stage of calculations determines the percentage risk of collision of a species flying through a rotating turbine, the results of which are presented in **Table 8**, below. Refer also to **Appendix A** for a completed Stage 2 calculations spreadsheet.

The highest values or "worst-case scenario" collision percentages occur when a bird flies upwind using flapping behaviour while the turbine is rotating at its fastest speed. Conversely, "best-case scenario" or lowest collision percentage values occur when a bird flies downwind using a gliding flight while the turbine is rotating at its slowest speed. The Collision Risk Assessment uses the mean of these two scenarios (see **Table 8**, below).

Table 8. Probability of collision - Stage 2 calculation outputs

Species	Flapping Bird		Gliding Bird		Mean Probability of Collision
	Upwind	Downwind	Upwind	Downwind	
Buzzard	6.0%	4.5%	5.8%	4.3%	5.15%
Golden Plover	4.4%	3.5%	4.2%	3.3%	3.85%
Great Black-backed Gull	6.2%	5.0%	6.0%	4.7%	5.45%
Hen Harrier	6.4%	4.5%	6.3%	4.4%	5.35%
Herring Gull	5.9%	4.6%	5.7%	4.3%	5.15%
Kestrel	5.4%	3.7%	5.4%	3.7%	4.55%
Lesser Black-backed Gull	5.9%	4.6%	5.7%	4.3%	5.15%
Merlin	5.0%	3.4%	4.9%	3.4%	4.20%
Peregrine	5.5%	4.1%	5.4%	4.0%	4.75%
Snipe	4.3%	3.3%	4.2%	3.2%	3.75%
Sparrowhawk	5.1%	3.6%	5.1%	3.5%	4.35%

4.3 Collision Rates

The theoretical collision rates for each species per season, based on the assumption that the bird makes no attempt to avoid the moving rotors, are presented in **Table 9,** below. Rates were calculated using VP survey data collected at the proposed Coumnagappul Wind Farm site over 42 consecutive months for VP1, VP2 and VP3 from April 2019 to September 2022, inclusive, and 12 consecutive months for VP4 from October 2021 to September 2022, inclusive.

Table 9. Predicted collision rates per season assuming no avoidance measures taken by bird

Species	Collision Probability	Year/Season	Predicted collisions per season with no avoidance measures applied		
			Breeding	Winter	Total
Buzzard	5.15%	2019/20	2.49	0.76	3.25
		2020/21	0.83	0.39	1.22
		2021/22	0.31	0.32	0.63
		2022	4.02	-	4.02
Golden plover	3.85%	2019/20	0	0	0
		2020/21	0	228.13	228.13
		2021/22	0	9.26	9.26
		2022	0	-	0
Great black-backed gull	5.45%	2019/20	0	0	0
		2020/21	0.32	0	0.32
		2021/22	0	0	0
		2022	0	-	0
Hen harrier	5.35%	2019/20	0	0	0
		2020/21	0	0	0
		2021/22	0.14	0	0.14
		2022	0.48	-	0.48
Herring gull	5.15%	2019/20	0	0	0
		2020/21	0.86	0	0.86
		2021/22	0	0	0
		2022	0.48	-	0.48
Kestrel	4.55%	2019/20	1.72	1.07	2.79

Species	Collision Probability	Year/Season	Predicted collisions per season with no avoidance measures applied		
			Breeding	Winter	Total
		2020/21	2.76	1.50	4.26
		2021/22	3.15	1.82	4.97
		2022	4.09	-	4.09
Lesser black-backed gull	5.15%	2019/20	0.46	0.19	0.60
		2020/21	0.97	0	0.97
		2021/22	1.41	0	1.41
		2022	0	-	0
Merlin	4.20%	2019/20	0.38	0	0.38
		2020/21	0	0	0
		2021/22	0	0	0
		2022	0	-	0
Peregrine	4.75%	2019/20	0	0.14	0.14
		2020/21	0	0	0
		2021/22	0	0.09	0.09
		2022	0	-	0
Snipe	3.75%	2019/20	0.05	0	0.05
		2020/21	0	0.19	0.19
		2021/22	0	0.13	0.13
		2022	0	-	0
Sparrowhawk	4.35%	2019/20	0.47	0	0.47
		2020/21	0	0.06	0.06
		2021/22	0	0.08	0.08
		2022	0	-	0

4.3.1 Collision Rates with Application of Specific Avoidance Rates

The final phase of the collision risk assessment is to apply known avoidance rates to the predicted collision rates from Table 9, above, to correct for a bird's ability to identify and move around turbines. An avoidance rate of between 95% and 99.5% was used as recommended by SNH (2018) and Furness (2019) for all species apart from golden plover where an avoidance rate of 99.8% was applied.

Gittings (2020) deduced this high avoidance rate for golden plover by examining the results of three post-construction winter surveys at wind farms and, from data collected on the species' collision fatality rates, estimating avoidance rates. An avoidance rate of 99.8% was considered by Gittings (2020) to be a suitably robust precautionary estimate since the recommended avoidance rate for whooper swan by SNH (2018) is based on a single study thereby ensuring 'the evidence base for a species-specific avoidance rate is stronger for golden plover then for whooper swan' in this case. Furthermore, Gittings (2020) postulates that the absence of golden plover avoidance rates from SNH (2018) guidance may be associated with the tendency for golden plover conservation concerns at wind farms to focus on breeding populations rather than wintering populations.

Upon application of avoidance rates, the seasonal values for each year were added together to give the predicted number of annual collisions for each 12-month dataset. Finally, the number of collisions predicted to occur over the lifespan of the wind farm (40 years) was calculated (refer to Table 10, below). Table 11, below, presents the final collision risk modelling results for the proposed Coumnagappul Wind Farm.

Table 10. Number of collisions predicted with application of avoidance rates specified by SNH (2018), Furness (2019) and Gittings (2020)

Species	Avoidance Rate		Predicted collisions per season			Predicted collisions per season over 40-year lifetime of proposed wind farm		
		Year/Season	Breeding	Winter	Total	Breeding	Winter	Total
Buzzard	98%	2019/20	0.050	0.015	0.065	1.990	0.605	2.595
		2020/21	0.017	0.008	0.025	0.662	0.308	0.970
		2021/22	0.006	0.006	0.012	0.245	0.255	0.500
		2022	0.080	-	0.080	3.216	-	3.216
Golden Plover	99.8%	2019/20	0	0	0	0	0	0
		2020/21	0	0.456	0.456	0	18.25	18.25
		2021/22	0	0.019	0.019	0	0.741	0.741
		2022	0	-	0	0	-	0
Great Black-backed Gull	99.5%	2019/20	0	0	0	0	0	0
		2020/21	0.002	0	0.002	0.063	0	0.063
		2021/22	0	0	0	0	0	0
		2022	0	-	0	0	-	0
Hen Harrier	99%	2019/20	0	0	0	0	0	0
		2020/21	0	0	0	0	0	0
		2021/22	0.001	0	0.001	0.054	0	0.054
		2022	0.005	-	0.005	0.190	-	0.190
Herring Gull	99.5%	2019/20	0	0	0	0	0	0
		2020/21	0.004	0	0.004	0.172	0	0.172
		2021/22	0	0	0	0	0	0
		2022	0.002	-	0.002	0.096	-	0.096
Kestrel	95%	2019/20	0.086	0.053	0.139	3.442	2.135	5.577
		2020/21	0.138	0.075	0.213	5.523	3.002	8.525
		2021/22	0.157	0.091	0.248	6.295	3.646	9.941
		2022	0.205	-	0.205	8.185	-	8.185
	99.5%	2019/20	0.002	0.001	0.003	0.092	0.037	0.129
		2020/21	0.005	0	0.005	0.194	0	0.194

Species	Avoidance Rate	Year/Season	Predicted collisions per season			Predicted collisions per season over 40-year lifetime of proposed wind farm		
			Breeding	Winter	Total	Breeding	Winter	Total
Lesser Black-backed Gull		2021/22	0.007	0	0.007	0.282	0	0.282
		2022	0	-	0	0	-	0
Merlin	98%	2019/20	0.008	0	0.008	0.301	0	0.301
		2020/21	0	0	0	0	0	0
		2021/22	0	0	0	0	0	0
		2022	0	-	0	0	-	0
Peregrine	98%	2019/20	0	0.003	0.003	0	0.116	0.116
		2020/21	0	0	0	0	0	0
		2021/22	0	0.002	0.002	0	0.075	0.075
		2022	0	-	0	0	-	0
Snipe	98%	2019/20	0.001	0	0.001	0.037	0	0.037
		2020/21	0	0.004	0.004	0	0.155	0.155
		2021/22	0	0.003	0.003	0	0.107	0.107
		2022	0	-	0	0	-	0
Sparrowhawk	98%	2019/20	0.009	0	0.009	0.376	0	0.376
		2020/21	0	0.001	0.001	0	0.045	0.045
		2021/22	0	0.002	0.002	0	0.068	0.068
		2022	0	-	0	0	-	0

4.4 Final Outputs of Model

Table 11, below, presents the final collision risk modelling results for each species.

The annual number of collisions predicted to occur each year for all species is less than 0.25 – that is to say, it is predicted that less than one bird will die every four years due to turbine collision. The number of predicted collisions per 40 years is also relatively low – for most species, less than one bird every 40 years is predicted to collide with the turbine rotors. Only two species have a predicted collision rate of more than one bird every 40 years, namely golden plover, kestrel and buzzard.

Table 11. Mean number of predicted collisions per year and per 40 years (the predicted windfarm lifespan) using the application of avoidance rates specified by SNH (2018), Furness (2019) and Gittings (2020)

Species	Mean number of predicted collisions per year	Mean number of predicted collisions per 40 years	Equivalent to 1 bird every x (years)
Buzzard	0.052	2.080	19.231
Golden Plover	0.136	5.429	7.368
Great Black-backed Gull	0.001	0.018	2,222.222
Hen Harrier	0.002	0.069	579.710
Herring Gull	0.002	0.069	579.710
Kestrel	0.230	9.208	4.344
Lesser Black-backed Gull	0.004	0.171	233.918
Merlin	0.002	0.091	439.560
Peregrine	0.001	0.057	701.754
Snipe	0.002	0.914	43.764
Sparrowhawk	0.003	0.137	291.970

5. Conclusion

Using the Band method of collision risk modelling, a CRM has been completed for the proposed Coumnagappul Wind Farm development. The Band model operates using many assumptions, particularly in relation to bird behaviour and characteristics, and relies on accurate information regarding species avoidance rates, turbine specifications, and data recording. As a result of these assumptions and the limitations presented by collision risk modelling, any collision risk predictions are highly precautionary and should only be considered indicative rather than conclusive.

Kestrel, a year-round resident of the area, has a relatively high predicted collision rate of 9 collisions every 40 years. This value, however, is liable to be rather tenuous because the CRM operates on the assumption that all birds are constantly moving when in reality, a large percentage of recorded kestrel flight activity is likely to have involved hovering birds. Therefore, the mean flight speed for kestrel used in the CRM may not be representative of mean flight speed of the kestrels observed during the surveys. Furthermore, kestrels fly relatively quickly between hovering spots which can lead to an underestimation of their speed resulting in a greater predicted risk of collision than would likely occur in "real-life" scenarios. A predicted rate of 5.4 collisions every 40 years for wintering golden plover is particularly low for this species as they tend to move in large flocks and, since the number of seconds spent at PCH during a flight is multiplied by the number of birds completing that flight, high collision rates are often predicted.

The predicted collision risk of less than one collision per year for all species is deemed unlikely to cause significant impacts to the national populations of the species included in the model. However, in view of the assumptions and limitations associated with collision risk modelling, the final predicted collision rates should only be considered indicative and never definitive and used solely as a comparative tool rather than an accurate indicator of mortality risk. Consequently, it is perhaps wisest to interpret the results of CRM analyses as being only an indication of the order of magnitude of predicted collision risk.

6. References

Alerstam, T., Rosén, M., Bäckman, J., Ericson, P.G. and Hellgren, O. (2007). Flight speeds among bird species: allometric and phylogenetic effects. *PLoS biology*, *5*(8), p.197.

Band, B. (2012a). *Using a collision risk model to assess bird collision risks for offshore windfarms.* Report commissioned by The Crown Estate, through the British Trust for Ornithology, via its Strategic Ornithological Support Services (SOSS), Project SOSS-02.

Band, B. (2012b). *Using a collision risk model to assess bird collision risks for offshore windfarms – with extended method: Worked example*. SOSS Report. The Crown Estate.

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 farms: Risk assessment and mitigation*. Madrid: Quercus/Libreria Linneo, pp.259-275.

Cochran, W.W. and Applegate, R.D., (1986). Speed of flapping flight of merlins and peregrine falcons. *The Condor*, 88(3), pp.397-398.

Furness, R.W. (2019). Avoidance Rates of Herring Gull, Great Black-Backed Gull and Common Gull for Use in the Assessment of Terrestrial Wind Farms in Scotland. *Scottish Natural Heritage Research Report No. 1019.*

Gittings, T. (2020). *Ummeras Wind Farm Collision Risk Model (Report Number: 2008-F1, Revision 6).* Appendix 6-4 in Volume III – Appendices (Part 1 of 2) of Ummeras Wind Farm Environmental Impact Assessment Report (Planning Application Number at Kildare County Council: 2184).

Masden, E. A. and Cook, A. S. C. P. (2016). Avian collision risk models for wind energy impact assessments. *Environmental Impact Assessment Review*, 56, 43-49.

Scottish Natural Heritage (2000). *Windfarms and Birds - Calculating a theoretical collision risk assuming no avoiding action. SNH Guidance Note*. Available at: Microsoft Word - COLLIS.DOC (nature.scot)

Scottish Natural Heritage (2017). *Recommended Bird Survey Methods to Inform Impact Assessment on Onshore Wind Farms*. Version 2. Available at: Background and Purpose (nature.scot)

Scottish Natural Heritage (2018). *Use of avoidance rates in the SNH wind farm Collision Risk Model*. Available at: https://www.nature.scot/wind-farm-impacts-birds-use-avoidance-rates-snh-wind-farm-collision-risk-model.

timeanddate.com (2022). *Waterford, Ireland – Sunrise, Sunset, and Daylength*. Available at: Sunrise and sunset times in County Waterford (timeanddate.com).

Wilson, M., Fernández-Bellon, D., Irwin, S. & O'Halloran, J. (2015). *The interactions between Hen Harriers and wind turbines: WINDHARRIER - Final Project Report*. School of Biological Earth & Environmental Sciences at University College Cork (BEES). Available at: https://www.ucc.ie/en/media/research/planforbio/forestecology/WINDHARRIERFinalProjectReport.pdf

Appendix A

Calculation Spreadsheets

Buzzard Biometrics and Stage 1 Calculations for Summer 2022

Measurements	Code	Value
Rotor radius (metres)	r	81
Rotor diameter (metres)	D	162
Max chord width of turbine blades (metres)	d	4.1
Buzzard length (metres)	l	0.54
Average flight speed of Buzzard (m/s)	v	11.6
Wingspan (m)		1.2
Mean pitch of blade (degrees)		5
Rotors per turbine		3
Rotational period (seconds)		7
Turbine operational time (%)		85

		Vantage Point			
		1	2	3	4
Survey time over 6 months (secs)	s	129600	129600	129600	129600
Total flight-time between 20 - 200 m (bird-secs)	PCH	0	230	265	0
No. of turbines in viewshed	x	6	7	6	6
Survey area visible from VP (hectares)	Avp	343	441	416	319
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk	247.37	306.2	275.33	257.14
Availability of species activity during survey period (hours)	Ba	2745	2745	2745	2745

Stage 1 Calculations

Measurements	Code	Calculation	1	2	3	4
Proportion of flight-time betwen 20 - 200 m	t1	PCH/s	0.0000	0.0018	0.0020	0.0000
Flight activity per visible unit of area	F	t1/Avp	0	4.024E-06	4.915E-06	0
Proportion of time in risk area	Trisk	F*Arisk	0	0.0012322	0.0013533	0
Bird occupancy of risk area	n	Trisk*Ba	0	3.3824531	3.7148683	0
Risk volume	Vw	(Arisk*D)*10000	400739400	496044000	446034600	416566800
Actual volume of air swept by rotors	o	x*(Pi*r^2(d+l))	404218.9824	471588.81	404218.98	404218.98
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	0	11.576508	12.119762	0
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.4	0.4	0.4	0.4
Number of bird passes through rotor during survey period	N	b/t2	0	28.94127	30.299404	0
Total transits adjusted for max operation of turbines (85%)	Tn	N*0.85	0	24.600079	25.754494	0
Number of transits per turbine within viewshed	TnT	Tn/x	0	3.5142971	4.2924156	0
Average TnT of all VP's	ATnT	(TnT_1+TnT_2+TnT_3+.....)/4	7.80671266			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	78.0671266			
		Collision Probability (Stage 2)	**5.15%**			
		Collisions during study period	T*Collision Probability	4.020457		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.0804091		
		Over 40-year duration of WF	*40	**3.2163656**		

Stage 2 Calculations for Buzzard

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4.1	m
Pitch (degrees)	5	
BirdLength	0.54	m
Wingspan	1.2	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	11.6	m/sec
RotorDiam	162	m
RotationPeriod	7.00	sec
Bird aspect ratio: β	0.45	

Calculation of alpha and p(collision) as a function of radius

			Upwind:			Downwind:		
r/R radius	c/C chord	α alpha	collide length	p(collision)	contribution from radius r	collide length	p(collision)	contribution from radius r
0.025	0.575	6.38	22.85	0.84	0.00106	22.44	0.83	0.00104
0.075	0.575	2.13	7.75	0.29	0.00215	7.34	0.27	0.00203
0.125	0.702	1.28	5.44	0.20	0.00251	4.94	0.18	0.00228
0.175	0.860	0.91	4.60	0.17	0.00298	3.99	0.15	0.00258
0.225	0.994	0.71	4.09	0.15	0.00340	3.38	0.12	0.00281
0.275	0.947	0.58	3.28	0.12	0.00333	2.60	0.10	0.00264
0.325	0.899	0.49	2.71	0.10	0.00326	2.07	0.08	0.00249
0.375	0.851	0.43	2.32	0.09	0.00322	1.72	0.06	0.00238
0.425	0.804	0.38	2.06	0.08	0.00323	1.48	0.05	0.00233
0.475	0.756	0.34	1.85	0.07	0.00324	1.31	0.05	0.00229
0.525	0.708	0.30	1.67	0.06	0.00324	1.17	0.04	0.00226
0.575	0.660	0.28	1.52	0.06	0.00324	1.05	0.04	0.00224
0.625	0.613	0.26	1.40	0.05	0.00323	0.96	0.04	0.00222
0.675	0.565	0.24	1.29	0.05	0.00321	0.88	0.03	0.00220
0.725	0.517	0.22	1.19	0.04	0.00319	0.82	0.03	0.00220
0.775	0.470	0.21	1.10	0.04	0.00316	0.77	0.03	0.00220
0.825	0.422	0.19	1.02	0.04	0.00312	0.72	0.03	0.00220
0.875	0.374	0.18	0.95	0.04	0.00308	0.68	0.03	0.00221
0.925	0.327	0.17	0.89	0.03	0.00303	0.65	0.02	0.00223
0.975	0.279	0.16	0.83	0.03	0.00298	0.63	0.02	0.00226

Overall p(collision) = **Upwind** **6.0%** **Downwind** **4.5%**

Average **5.2%**

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