APPENDIX 7-6

COLLISION RISK ASSESSMENT

Table of Contents

1. INTRODUCTION 1
2. METHODOLOGY 1
2.1 Modelling Process 1
2.2 Turbine Specifications 1
2.3 Vantage Point Surveys 3
2.4 Species Assessed 6
2.5 Photoperiod 15
3. RESULTS 16
3.1 Stage A Flight Activity 16
3.2 Stage B Number of Flights Through Rotors 18
3.3 Stage C Probability of Collision 20
3.4 Stage D Expected Collisions 22
3.5 Stage E Allowing for Avoidance and Attraction 24
3.6 Stage F Uncertainty 35
3.7 Predicted Collision Rates 39
4. WORKED EXAMPLE 42
4.1 Proposed Development Scenario 42
4.2 Bird Survey Scenario 42
4.3 Stage A: Flight Activity 44
4.4 Stage B: Number of Flights Through Rotors 47
4.5 Stage C: Probability of Collision 47
4.6 Stage D Expected Collisions 49
4.7 Stage E Allowing for Avoidance and Attraction 49
4.8 Stage F: Uncertainty 50
4.9 Worked Example Collision Rates 50
5. BIBLIOGRAPHY 51

1. INTRODUCTION

This document outlines the methodology used to conduct a collision risk assessment of the Crumhach Wind Farm. This assessment calculates an annual collision rate using a mathematical model to predict the number of birds that may be killed by collision with moving wind turbine rotor blades. The modelling method used is the Collision Risk Model provided by Band (2024). This method is recommended by NatureScot and provides a standardised approach to collision risk assessment for onshore wind farms. Note that these are theoretical predictions, therefore the results must be interpreted with a degree of caution.

2. METHODOLOGY

2.1 Modelling Process

The collision risk model estimates the number of collisions through the following stages:

- **Stage A Flight activity** - uses bird survey data to establish the density of flying birds in the vicinity of the turbines, and the proportion flying at a risk height (between the lowest and highest points of the rotors).
- **Stage B Number of flights through rotors** – makes an estimate, based on the bird density and proportion at risk height, of the potential number of bird passages through rotors. The initial assumption is that birds will continue to make flights within the area at the same intensity as before.
- **Stage C Probability of collision** - calculates the probability of collision during a single bird rotor transit.
- **Stage D Expected collisions** - multiplies the outputs of stage B and C to yield the potential collision rate for the bird species, assuming current levels of bird use of the site but allowing for the proportion of time that turbines are not operational.
- **Stage E Allowing for avoidance and attraction** - takes account of the proportion of birds likely to avoid the wind farm or its turbines, either because they have been displaced from the site or because they take evasive action or are attracted to the wind farm.
- **Stage F Uncertainty** - each of these five stages is followed by a further stage, stage F, which describes how to express the uncertainty surrounding a collision risk estimate.

The general features and assumptions of the collision risk model are discussed in further detail in Band (2024). Using the model, a final predicted annual collision rate can be predicted for each species that can be used in the impact assessment

2.2 Turbine Specifications

Three turbine scenarios (Scenario 1, Scenario 2 and Scenario 3) were assessed. The turbine specifications used in each model are provided in Table 7 - 6 - 1 to Table 7 - 6 - 3. The expected operational time of the turbines is 85% according to report by the British Wind Energy Association (BWEA; 2007) which identifies the standard operational period of the wind turbines in the UK.

Table 7 - 6 - 1 Turbine specifications - Scenario 1

Component	Scenario Modelled
Latitude (°N)	54.2075
Turbine model	V150
Number of turbines	17
Hub height (m)	105
Rotor diameter (m)	150

Component	Scenario Modelled
Blade pitch (°)	6
Maximum blade width (m)	4.2
Rotational speed (rpm)	9.35
Number of blades	3

Table 7 - 6 - 2 Turbine specifications - Scenario 2

Component	Scenario Modelled
Latitude (°N)	54.2075
Turbine model	N149
Number of turbines	17
Hub height (m)	105
Rotor diameter (m)	149
Blade pitch (°)	6
Maximum blade width (m)	4.5
Rotational speed (rpm)	9.35
Number of blades	3

Table 7 - 6 - 3 Turbine specifications - Scenario 3

Component	Scenario Modelled
Latitude (°N)	54.2075
Turbine model	N133
Number of turbines	17
Hub height (m)	110
Rotor diameter (m)	133.5
Blade pitch (°)	6
Maximum blade width (m)	4
Rotational speed (rpm)	9.35
Number of blades	3

The turbine blade profile used in the model is presented in Table 7 - 6 - 4. In the absence of a specific blade profile for each turbine model, the blade profile provided in the collision risk model spreadsheet in Band (2024) has been used in the three scenarios. This table provides the chord width values at 20 evenly spaced points along the blade, expressed relative to the maximum chord width. The ratio r/R represents the relative radial position along the blade, where 0 corresponds to the hub and 1 corresponds to the blade tip, while the ratio c/C represents the relative chord width. Further information on blade profiles is in Section 4 'Worked Example'.

Table 7 - 6 - 4 Turbine blade profile

r/R	c/C
0.00	0.690
0.05	0.730
0.10	0.790
0.15	0.880
0.20	0.960
0.25	1.000
0.30	0.980
0.35	0.920

r/R	c/C
0.40	0.850
0.45	0.800
0.50	0.750
0.55	0.700
0.60	0.640
0.65	0.580
0.70	0.520
0.75	0.470
0.80	0.410
0.85	0.370
0.90	0.300
0.95	0.240
1.00	0.000

2.3 Vantage Point Surveys

The assessment is based on vantage point surveys to monitor flight activity undertaken between May 2021 and March 2025. This represents a 46-month period, consisting of four breeding seasons and four winter seasons, which is in full compliance with guidance from NatureScot (formerly Scottish Natural Heritage [SNH]) outlined in SNH (2017), which was revised in NatureScot (2025a). Surveys remain in accordance with the updated guidance.

Surveys were undertaken at eight vantage points. Viewsheds were calculated using the Visibility Analysis plugin (Version 1.8) over a raster digital terrain model (DTM) in QGIS (Version 3.28). A point 1.75m in height (to represent the height of the surveyor) was created on a map using 10m contours terrain data, accounting for the relative height of any surrounding landscape features (e.g., trees). The software produced a 360° viewshed at 30m (Scenario 1), 30.5m (Scenario 2) and 43.4m (Scenario 3) from ground level up to a 2km radius around the vantage point. The combined viewsheds from these vantage points provided coverage to a 500m radius of the potential turbine positions for each scenario. The vantage points and the area watched (i.e., the area of the viewsheds) are listed in Table 7 - 6 - 5 for each scenario.

Table 7 - 6 - 5 Vantage points

Vantage Point	Area Watched (ha)		
	Scenario 1	Scenario 2	Scenario 3
VP1	604	606	637
VP2	242	246	348
VP3	627	628	623
VP4	540	550	586
VP5	561	564	603
VP6	548	548	567
VP7	532	536	577
VP8	579	577	586

Survey methodology followed SNH (2017; revised in NatureScot, 2025). The surveyor collected data on bird observations and flight activity from the scanning arc of 180° to a 2km radius at the fixed vantage point locations for two 3 hour watches separated by a minimum 30 minute break (i.e., 6 hours total) per month. The survey effort is presented in Table 7 - 6 - 6, expressed in terms of hours and seconds per month.

Table 7 - 6 - 6 Survey effort

Vantage Point	Month	Hours Survey	Seconds Survey
VP1	Jan	24.00	86,400
VP2	Jan	30.00	108,000
VP3	Jan	18.00	64,800
VP4	Jan	24.00	86,400
VP5	Jan	18.00	64,800
VP6	Jan	24.00	86,400
VP7	Jan	18.00	64,800
VP8	Jan	27.00	97,200
VP1	Feb	24.00	86,400
VP2	Feb	24.00	86,400
VP3	Feb	18.00	64,800
VP4	Feb	12.00	43,200
VP5	Feb	18.00	64,800
VP6	Feb	24.00	86,400
VP7	Feb	18.00	64,800
VP8	Feb	18.00	64,800
VP1	Mar	24.00	86,400
VP2	Mar	24.00	86,400
VP3	Mar	18.00	64,800
VP4	Mar	24.00	86,400
VP5	Mar	18.00	64,800
VP6	Mar	24.00	86,400
VP7	Mar	18.00	64,800
VP8	Mar	30.00	108,000
VP1	Apr	15.00	54,000
VP2	Apr	15.00	54,000
VP3	Apr	15.00	54,000
VP4	Apr	12.00	43,200
VP5	Apr	12.00	43,200
VP6	Apr	15.00	54,000
VP7	Apr	15.00	54,000
VP8	Apr	12.08	43,488
VP1	May	22.00	79,200
VP2	May	24.00	86,400
VP3	May	12.00	43,200
VP4	May	15.00	54,000
VP5	May	15.00	54,000
VP6	May	9.00	32,400
VP7	May	11.99	43,164
VP8	May	12.00	43,200
VP1	Jun	20.00	72,000
VP2	Jun	15.25	54,900

Vantage Point	Month	Hours Survey	Seconds Survey
VP3	Jun	15.00	54,000
VP4	Jun	14.00	50,400
VP5	Jun	15.00	54,000
VP6	Jun	18.00	64,800
VP7	Jun	18.00	64,800
VP8	Jun	15.00	54,000
VP1	Jul	39.42	141,912
VP2	Jul	25.00	90,000
VP3	Jul	24.00	86,400
VP4	Jul	25.00	90,000
VP5	Jul	24.00	86,400
VP6	Jul	24.00	86,400
VP7	Jul	18.00	64,800
VP8	Jul	21.00	75,600
VP1	Aug	30.25	108,900
VP2	Aug	24.00	86,400
VP3	Aug	24.00	86,400
VP4	Aug	24.00	86,400
VP5	Aug	24.00	86,400
VP6	Aug	24.00	86,400
VP7	Aug	27.00	97,200
VP8	Aug	30.00	108,000
VP1	Sep	19.00	68,400
VP2	Sep	13.00	46,800
VP3	Sep	23.99	86,364
VP4	Sep	24.00	86,400
VP5	Sep	18.00	64,800
VP6	Sep	18.00	64,800
VP7	Sep	18.00	64,800
VP8	Sep	18.00	64,800
VP1	Oct	30.00	108,000
VP2	Oct	24.00	86,400
VP3	Oct	12.00	43,200
VP4	Oct	12.00	43,200
VP5	Oct	18.00	64,800
VP6	Oct	18.00	64,800
VP7	Oct	12.00	43,200
VP8	Oct	18.00	64,800
VP1	Nov	24.00	86,400
VP2	Nov	31.83	114,588
VP3	Nov	16.33	58,788
VP4	Nov	18.17	65,412
VP5	Nov	18.00	64,800

Vantage Point	Month	Hours Survey	Seconds Survey
VP6	Nov	30.00	108,000
VP7	Nov	24.00	86,400
VP8	Nov	30.00	108,000
VP1	Dec	24.00	86,400
VP2	Dec	18.00	64,800
VP3	Dec	20.00	72,000
VP4	Dec	12.00	43,200
VP5	Dec	18.42	66,312
VP6	Dec	24.00	86,400
VP7	Dec	18.58	66,888
VP8	Dec	21.25	76,500

Flight activity of target species was mapped and recorded as per defined flight bands which were chosen in relation to the dimensions of potential turbine models at the outset of surveys as well as turbines in the Existing Wind Farm of Dunneill. As such, there is some overlap in bands, which is accounted for in the model. These heights bands were:

- Band 1 = 0-15m
- Band 2 = 15-23m
- Band 3 = 15-25m
- Band 4 = 23-75m
- Band 5 = 25-200m
- Band 6 = 75-150m
- Band 7 = 150+
- Band 8 = 200+

As the risk height range of the turbines are 30-180m for Scenario 1, 30.5-179.5m for Scenario 2 and 43.4-176.6m for Scenario 3, all flight activity in Bands 4, 5, 6 and 7 are considered to be at potential collision height for all scenarios.

2.4 Species Assessed

Collision rates were estimated for the species listed in Table 7 - 6 - 7. The months included for each species are also presented.

Table 7 - 6 - 7 Species assessed

Species	Months	Model
White-tailed Eagle	Oct-Sep	nondirectional
Golden Plover	Oct-Sep	nondirectional
Hen Harrier	Oct-Sep	nondirectional
Merlin	Oct-Sep	nondirectional
Peregrine Falcon	Oct-Sep	nondirectional
Whooper Swan	Aug-May	nondirectional
Kestrel	Oct-Sep	nondirectional
Snipe	Oct-Sep	nondirectional
Buzzard	Oct-Sep	nondirectional
Sparrowhawk	Oct-Sep	nondirectional

Species biometrics, such as body length, body width (i.e., wingspan) and flight speed, as well as whether a bird typically flaps or glides in flight, are required to calculate collision risk. This information was sourced from the best available literature.

In addition, a 'nocturnal activity factor is required'. There is considerable uncertainty about levels of bird flight activity by night (Band, 2024). There are no standard expert rankings available for terrestrial species and levels of activity may vary from season to season. Because of this, each species is ranked with a nocturnal activity factor of 0%, 25%, 50%, 75% and 100%. A ranking of 0% is given to represent hardly any flight activity at night and of 100% for much flight activity at night. As such, the figures used in the collision risk model take both day and night flights into account. The biometrics, flight type and nocturnal activity factor used in the model are presented in Table 7 - 6 - 8.

Table 7 - 6 - 8 Species biometrics, flight type and nocturnal activity factor

Species	Length (cm)	Width (cm)	Flight Speed (m/s)	Nocturnal Activity Factor	Flight Type
Buzzard	54	120.5	11.6	0%	gliding
Golden Plover	27.5	71.5	17.9	25%	flapping
Hen Harrier	48	110	8	0%	flapping
Kestrel	33.5	75.5	10.1	0%	flapping
Merlin	27.5	56	10.9	0%	flapping
Peregrine Falcon	44.5	105	12.1	0%	flapping
Snipe	25.5	42	17.1	100%	flapping
Sparrowhawk	33	62.5	10	0%	flapping
White-tailed Eagle	80	220	13.6	0%	flapping
Whooper Swan	150	220	17.3	25%	flapping

To prepare the field survey data for analysis, the number of 'bird-seconds' per month per vantage point was calculated for each observation by multiplying the number of birds aloft by the duration of the flight (in seconds). This included time spent in all recorded height bands, not just those bands within potential collision height. These values are presented per vantage point per month for each species in Table 7 - 6 - 9.

Table 7 - 6 - 9 Bird-seconds per vantage point per month

Species	Month	Vantage Point	Bird-Seconds
Buzzard	Jan	VP1	480
	Feb	VP1	810
	Mar	VP1	1,724
	Apr	VP1	1,074
	May	VP1	1,170
	Jun	VP1	1,340
	Jul	VP1	3,380
	Aug	VP1	4,412
	Sep	VP1	795
	Oct	VP1	467
	Nov	VP1	315
	Dec	VP1	50
	Jan	VP2	40
	Feb	VP2	380
	Mar	VP2	900

Species	Month	Vantage Point	Bird-Seconds
	Apr	VP2	660
	May	VP2	650
	Jun	VP2	215
	Jul	VP2	590
	Aug	VP2	640
	Sep	VP2	860
	Oct	VP2	520
	Nov	VP2	506
	Dec	VP2	90
	Apr	VP3	170
	May	VP3	119
	Jul	VP3	200
	Aug	VP3	329
	Sep	VP3	290
	May	VP4	370
	Jun	VP4	325
	Jul	VP4	420
	Aug	VP4	300
	Sep	VP4	300
	Nov	VP4	451
	Jan	VP5	360
	Feb	VP5	179
	Mar	VP5	175
	Apr	VP5	659
	May	VP5	367
	Jun	VP5	380
	Jul	VP5	36
	Aug	VP5	160
	Jan	VP6	777
	Feb	VP6	60
	Mar	VP6	1,308
	Apr	VP6	9,680
	May	VP6	520
	Jun	VP6	1,353
	Jul	VP6	1,546
	Aug	VP6	2,465
	Sep	VP6	243
	Nov	VP6	1,740
	Dec	VP6	418
	Mar	VP7	93
	Apr	VP7	100
	May	VP7	510
	Aug	VP7	230

Species	Month	Vantage Point	Bird-Seconds
	Sep	VP7	50
	Mar	VP8	1,690
	Apr	VP8	120
	Jun	VP8	821
	Jul	VP8	479
	Aug	VP8	405
	Oct	VP8	60
	Nov	VP8	100
	Dec	VP8	336
Golden Plover	Apr	VP1	754
	Jan	VP2	2,800
	Apr	VP2	390
	Nov	VP2	105
	Jan	VP3	11,880
	Feb	VP3	31,183
	Mar	VP3	72,632
	Apr	VP3	6,670
	May	VP3	36
	Sep	VP3	925
	Oct	VP3	2,836
	Nov	VP3	73,749
	Dec	VP3	11,791
	Jan	VP4	47,700
	Apr	VP4	13,340
	Sep	VP4	102
	Nov	VP4	18,150
	Jan	VP5	5,574
	Nov	VP5	34,500
	Dec	VP5	5,546
	Jan	VP6	9,360
	Mar	VP6	3,526
	Apr	VP6	223,000
	Oct	VP6	4,175
	Jan	VP7	12,423
	Feb	VP7	37,617
	Sep	VP7	6,300
	Oct	VP7	5,306
	Nov	VP7	105,306
	Dec	VP7	19,926
	Jan	VP8	45,150
	Mar	VP8	194,881
	Oct	VP8	11,036
	Nov	VP8	2,824

Species	Month	Vantage Point	Bird-Seconds
Hen Harrier	Jan	VP1	20
	Jan	VP2	594
	Aug	VP2	202
	Nov	VP2	561
	Jan	VP3	785
	Feb	VP3	595
	Dec	VP3	469
	Jan	VP4	21
	Apr	VP4	140
	Jan	VP5	43
	Feb	VP5	142
	Nov	VP5	60
	Jan	VP7	170
	Feb	VP7	168
	Nov	VP7	99
Kestrel	Jan	VP1	200
	Feb	VP1	200
	Mar	VP1	65
	Apr	VP1	653
	May	VP1	360
	Jun	VP1	29
	Jul	VP1	1,087
	Aug	VP1	2,777
	Sep	VP1	315
	Oct	VP1	330
	Dec	VP1	153
	Jan	VP2	140
	Feb	VP2	169
	Mar	VP2	1,371
	Apr	VP2	373
	May	VP2	130
	Jun	VP2	683
	Jul	VP2	420
	Aug	VP2	2,356
	Sep	VP2	750
	Oct	VP2	795
	Nov	VP2	152
	Dec	VP2	120
	Jan	VP3	36
	Mar	VP3	417
	May	VP3	90
	Jul	VP3	960
	Aug	VP3	3,889

Species	Month	Vantage Point	Bird-Seconds
	Sep	VP3	3,465
	Nov	VP3	70
	Dec	VP3	72
	Jan	VP4	80
	Mar	VP4	2,098
	Apr	VP4	800
	Jun	VP4	1,160
	Jul	VP4	3,003
	Aug	VP4	21,420
	Sep	VP4	741
	Nov	VP4	130
	Feb	VP5	250
	Mar	VP5	866
	Apr	VP5	120
	May	VP5	60
	Jun	VP5	212
	Jul	VP5	1,891
	Aug	VP5	2,676
	Sep	VP5	280
	Oct	VP5	420
	Jan	VP6	826
	Feb	VP6	95
	Mar	VP6	496
	Apr	VP6	440
	Jun	VP6	2,228
	Jul	VP6	744
	Aug	VP6	1,200
	Sep	VP6	326
	Oct	VP6	228
	Nov	VP6	13
	Jan	VP7	130
	Mar	VP7	151
	Apr	VP7	120
	May	VP7	92
	Jun	VP7	302
	Jul	VP7	1,890
	Aug	VP7	665
	Sep	VP7	709
	Oct	VP7	118
	Nov	VP7	213
	Jan	VP8	48
	Feb	VP8	19
	Mar	VP8	927

Species	Month	Vantage Point	Bird-Seconds
	Apr	VP8	300
	Jun	VP8	1,548
	Jul	VP8	4,216
	Aug	VP8	4,815
	Sep	VP8	426
	Oct	VP8	330
	Nov	VP8	190
	Dec	VP8	130
Merlin	Apr	VP1	42
	Jun	VP1	15
	Nov	VP1	27
	Dec	VP1	20
	Feb	VP3	10
	Sep	VP3	118
	Oct	VP3	65
	Dec	VP3	40
	Apr	VP4	40
	Aug	VP4	80
	Jan	VP5	97
	Jun	VP5	45
	Jul	VP5	31
	Aug	VP5	55
	Sep	VP5	350
	Oct	VP5	90
	Nov	VP5	13
	Feb	VP7	64
	Dec	VP7	65
	Oct	VP8	15
Peregrine Falcon	Sep	VP3	221
	Dec	VP4	159
	Mar	VP5	39
	Jan	VP6	221
	Jun	VP6	40
	Jul	VP6	1,040
	Aug	VP6	2,390
	Nov	VP6	101
	Feb	VP8	39
	Nov	VP8	70
Snipe	Jan	VP1	39
	Feb	VP1	161
	Mar	VP1	19
	Sep	VP1	80
	Oct	VP1	147

Species	Month	Vantage Point	Bird-Seconds
	Nov	VP1	227
	Dec	VP1	37
	Jan	VP2	75
	Feb	VP2	8
	Mar	VP2	26
	Apr	VP2	14
	May	VP2	6
	Jul	VP2	25
	Sep	VP2	90
	Oct	VP2	41
	Nov	VP2	35
	Jan	VP3	32
	Mar	VP3	20
	May	VP3	805
	Aug	VP3	10
	Oct	VP3	1,860
	Dec	VP3	35
	Nov	VP4	16
	Feb	VP5	9
	Apr	VP5	30
	Aug	VP5	75
	Oct	VP5	65
	Nov	VP5	405
	Jan	VP6	7
	Mar	VP6	44
	Nov	VP6	20
	Dec	VP6	96
	Jan	VP7	27
	Feb	VP7	40
	Apr	VP7	21
	Sep	VP7	2,664
	Nov	VP7	20
	Dec	VP7	106
	Jan	VP8	175
	Mar	VP8	20
	Apr	VP8	17
	Nov	VP8	18
	Dec	VP8	119
Sparrowhawk	Jan	VP1	30
	Feb	VP1	27
	Mar	VP1	15
	Jun	VP1	125
	Aug	VP1	8

Species	Month	Vantage Point	Bird-Seconds
	Sep	VP1	14
	Dec	VP1	45
	Jan	VP2	45
	Feb	VP2	255
	May	VP4	21
	Feb	VP5	32
	Mar	VP5	162
	Jun	VP5	55
	Nov	VP5	6
	Dec	VP5	52
	Jan	VP6	36
	Feb	VP6	168
	Mar	VP6	69
	Apr	VP6	20
	Jul	VP6	101
	Aug	VP6	1,499
	Sep	VP6	132
	Nov	VP6	211
	Dec	VP6	89
	May	VP7	174
White-tailed Eagle	Mar	VP5	137
	Jan	VP6	159
	Dec	VP6	350
	Nov	VP8	78
Whooper Swan	Dec	VP1	800
	Oct	VP2	1,215
	Nov	VP2	662
	Oct	VP3	3,330
	Nov	VP3	4,000
	Dec	VP3	12,288
	Nov	VP5	2,380
	Nov	VP6	1,860
	Dec	VP6	130
	Oct	VP8	840

2.5 Photoperiod

The photoperiod at the latitude of the turbines was acquired for the survey period. The daylight and nighttime hours per month are shown in Table 7 - 6 - 10. The total daylight hours were 4,490 and nighttime hours was 4,270.

Table 7 - 6 - 10 Photoperiod

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daylight hours	247.4	271.7	366.1	420.4	495.3	512.5	514.9	461.7	383.2	328.3	257.7	230.9
Nighttime hours	496.6	400.3	377.9	299.6	248.7	207.5	229.1	282.3	336.8	415.7	462.3	513.1

3. RESULTS

3.1 Stage A Flight Activity

Stage A of the modelling process uses the field survey data to establish the aerial density of flying birds in the vicinity of the turbines and the proportion flying at a risk height (between the lowest and highest points of the rotors). Aerial density was calculated following the formula provided by Band (2024; also see Section 4 'Worked Example'). Similarly, the proportion flying at risk height was calculated following the method in Band (2024; also see Section 4 'Worked Example'). The aerial density per month and the proportion flying at risk height for each species is shown for each scenario in Table 7 - 6 - 11 tTable 7 - 6 - 13.

Table 7 - 6 - 11 Aerial density and proportion flying at risk height – Scenario 1

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Proportion
White-tailed Eagle	0.000042	0	0.0000471	0	0	0	0	0	0	0	0.0000156	0.0000924	0.55
Golden Plover	0.0367	0.0232	0.0622	0.104	0.0000166	0	0	0	0.00253	0.00934	0.0725	0.0121	0.63
Hen Harrier	0.000612	0.000293	0	0.000075	0	0	0	0.000121	0	0	0.0003	0.00013	0.09
Merlin	0.0000334	0.0000263	0	0.0000375	0	0.0000229	0.00000799	0.0000356	0.000148	0.0000659	0.0000109	0.0000387	0.05
Peregrine Falcon	0.0000583	0.000013	0.0000134	0	0	0.0000141	0.000275	0.000631	0.000051	0	0.0000353	0.0000852	0.71
Whooper Swan	0	0	0	0	0	-	-	0	0	0.00254	0.00287	0.00363	0.72
Kestrel	0.000423	0.000266	0.00219	0.00148	0.000288	0.00278	0.00397	0.0107	0.00253	0.000937	0.000237	0.000189	0.73
Snipe	0.000106	0.0000609	0.0000419	0.0000464	0.000375	0	0.0000143	0.0000216	0.00109	0.000933	0.000228	0.000115	0.23
Buzzard	0.000463	0.000499	0.00173	0.00564	0.0017	0.0017	0.00154	0.00221	0.00144	0.00042	0.000851	0.000289	0.75
Sparrowhawk	0.0000382	0.000214	0.0000775	0.00000845	0.000104	0.0000586	0.0000267	0.000397	0.0000507	0	0.0000466	0.0000517	0.22

Table 7 - 6 - 12 Aerial density and proportion flying at risk height – Scenario 2

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Proportion
White-tailed Eagle	0.000042	0	0.0000469	0	0	0	0	0	0	0	0.0000156	0.0000924	0.54
Golden Plover	0.0364	0.0231	0.0623	0.104	0.0000166	0	0	0	0.00251	0.00933	0.0721	0.0121	0.62
Hen Harrier	0.000607	0.000292	0	0.0000737	0	0	0	0.000119	0	0	0.000296	0.00013	0.09
Merlin	0.0000332	0.0000261	0	0.0000371	0	0.0000228	0.00000795	0.0000352	0.000147	0.0000657	0.0000109	0.0000385	0.05
Peregrine Falcon	0.0000583	0.000013	0.0000133	0	0	0.0000141	0.000275	0.000631	0.0000509	0	0.0000354	0.0000836	0.70
Whooper Swan	0	0	0	0	0	-	-	0	0	0.00253	0.00285	0.00362	0.71
Kestrel	0.000421	0.000264	0.00217	0.00147	0.000286	0.00276	0.00394	0.0106	0.00251	0.000929	0.000235	0.000187	0.72
Snipe	0.000105	0.0000606	0.0000416	0.0000461	0.000374	0	0.0000141	0.0000215	0.00108	0.000931	0.000227	0.000115	0.22
Buzzard	0.000462	0.000494	0.00172	0.00562	0.00169	0.00169	0.00153	0.0022	0.00142	0.000415	0.000844	0.000288	0.74
Sparrowhawk	0.0000378	0.000212	0.0000772	0.00000845	0.000103	0.0000584	0.0000267	0.000397	0.0000507	0	0.0000466	0.0000516	0.22

Table 7 - 6 - 13 Aerial density and proportion flying at risk height – Scenario 3

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Proportion
White-tailed Eagle	0.0000406	0	0.0000438	0	0	0	0	0	0	0	0.0000154	0.0000893	0.43
Golden Plover	0.0346	0.0222	0.0619	0.101	0.0000167	0	0	0	0.00235	0.00903	0.0691	0.0115	0.55
Hen Harrier	0.000521	0.000286	0	0.0000691	0	0	0	0.000084	0	0	0.00022	0.000131	0.07
Merlin	0.000031	0.0000245	0	0.000035	0	0.0000214	0.00000744	0.0000329	0.000139	0.0000639	0.0000103	0.0000367	0.04
Peregrine Falcon	0.0000564	0.0000128	0.0000125	0	0	0.0000136	0.000265	0.00061	0.0000513	0	0.0000344	0.0000785	0.62
Whooper Swan	0	0	0	0	0	-	-	0	0	0.00233	0.00271	0.00364	0.64
Kestrel	0.000388	0.000226	0.00187	0.00131	0.000254	0.0025	0.00372	0.00972	0.00223	0.00077	0.000208	0.000158	0.63

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Proportion
Snipe	0.0000929	0.0000561	0.0000365	0.0000405	0.000376	0	0.00000998	0.0000203	0.000983	0.000928	0.00021	0.00011	0.20
Buzzard	0.000436	0.000415	0.00152	0.00526	0.00151	0.00157	0.00139	0.00201	0.00113	0.000321	0.000752	0.000262	0.66
Sparrowhawk	0.000031	0.000165	0.0000728	0.00000817	0.0000956	0.0000552	0.0000258	0.000384	0.0000489	0	0.000045	0.0000492	0.19

3.2 Stage B Number of Flights Through Rotors

Stage B of the modelling process makes an estimate, based on the aerial density and proportion flying at risk height, of the potential number of bird passages through rotors. The projected number of transits through the rotor risk area was calculated following the formula provided by Band (2024; also see Section 4 'Worked Example'). Table 7 - 6 - 14 to Table 7 - 6 - 16 shows the projected number of transits per month for each species for each scenario.

Table 7 - 6 - 14 Projected number of transits – Scenario 1

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
White-tailed Eagle	0.563	0	0.935	0	0	0	0	0	0	0	0.218	1.16	2.87
Golden Plover	1103	699	2319	4185	0.749	0	0	0	95.5	327	2191	352	11271.61
Hen Harrier	0.766	0.402	0	0.159	0	0	0	0.282	0	0	0.391	0.152	2.15
Merlin	0.033	0.028	0	0.063	0	0.047	0.016	0.065	0.224	0.086	0.011	0.035	0.61
Peregrine Falcon	0.89	0.218	0.303	0	0	0.445	8.71	18	1.21	0	0.561	1.21	31.51
Whooper Swan	0	0	0	0	0	-	-	0	0	99.1	96.5	118	313.12
Kestrel	5.53	3.82	42.4	33	7.54	75.4	108	261	51.3	16.3	3.23	2.31	609.74
Snipe	2.18	1.14	0.866	0.93	7.76	0	0.297	0.448	21.8	19.3	4.57	2.37	61.69
Buzzard	7.2	8.51	39.8	149	53	54.7	49.8	64	34.7	8.68	13.8	4.19	487.37
Sparrowhawk	0.152	0.938	0.457	0.057	0.828	0.484	0.221	2.96	0.313	0	0.194	0.193	6.79

Table 7 - 6 - 15 Projected number of transits – Scenario 2

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
White-tailed Eagle	0.549	0	0.906	0	0	0	0	0	0	0	0.213	1.13	2.80
Golden Plover	1073	681	2276	4097	0.733	0	0	0	92.9	32	2134	343	11019.32
Hen Harrier	0.744	0.393	0	0.153	0	0	0	0.272	0	0	0.378	0.148	2.09
Merlin	0.032	0.028	0	0.061	0	0.045	0.016	0.063	0.219	0.084	0.011	0.035	0.59
Peregrine Falcon	0.872	0.214	0.295	0	0	0.436	8.54	17.6	1.18	0	0.551	1.17	30.86
Whooper Swan	0	0	0	0	0	-	-	0	0	96.9	94.4	115	306.50
Kestrel	5.4	3.71	41.1	32	7.34	73.4	105	253	49.8	15.8	3.13	2.24	591.74
Snipe	2.13	1.11	0.844	0.905	7.59	0	0.286	0.437	21.2	18.9	4.46	2.32	60.18
Buzzard	7.04	8.27	38.8	146	51.6	53.4	48.6	62.5	33.6	8.4	13.4	4.1	475.51
Sparrowhawk	0.148	0.908	0.446	0.056	0.804	0.472	0.217	2.9	0.307	0	0.19	0.188	6.63

Table 7 - 6 - 16 Projected number of transits – Scenario 3

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
White-tailed Eagle	0.373	0	0.596	0	0	0	0	0	0	0	0.147	0.766	1.88
Golden Plover	806	518	1786	3123	0.584	0	0	0	68.7	245	1617	258	8421.58
Hen Harrier	0.477	0.287	0	0.108	0	0	0	0.144	0	0	0.21	0.112	1.34
Merlin	0.024	0.021	0	0.046	0	0.034	0.012	0.047	0.166	0.065	0.008	0.026	0.45
Peregrine Falcon	0.673	0.168	0.22	0	0	0.336	6.59	13.6	0.949	0	0.428	0.874	23.81
Whooper Swan	0	0	0	0	0	-	-	0	0	71.2	71.7	92.5	235.49
Kestrel	3.92	2.51	27.9	22.5	5.14	52.3	78.2	183	34.9	10.3	2.18	1.49	424.73
Snipe	1.5	0.819	0.589	0.633	6.08	0	0.161	0.328	15.4	15	3.28	1.78	45.52
Buzzard	5.31	5.55	27.4	109	36.9	39.7	35.2	45.7	21.3	5.19	9.55	2.98	343.68

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Sparrowhawk	0.094	0.552	0.328	0.042	0.583	0.348	0.163	2.18	0.231	0	0.143	0.14	4.80

3.3 Stage C Probability of Collision

Stage C of the modelling process calculates the probability of collision during a single bird rotor transit. The likelihood of a bird colliding with a turbine blade during a single pass through the rotor was calculated using the turbine specifications, species biometrics and flight characteristics outlined in the previous sections.

Collision risk was assessed across different parts of the rotor, as blade speed and width varies from the hub to the tip. Because of the geometry of the blades in relation to the flight direction, the collision risk for upwind flight is higher than for downwind (even if the bird's flight speed relative to the ground is taken to be the same), therefore collision risk probabilities were calculated separately for birds flying upwind and downwind. These were then averaged assuming a 50:50 weighting because both upwind and downwind flights are equally likely (further information in Section 4 'Worked Example'). This produced a probability of collision for a bird during a single transit of the rotor, which is presented for each species for each scenario in Table 7 - 6 - 17 to Table 7 - 6 - 19.

Table 7 - 6 - 17 Probability of collision – Scenario 1

Species	Upwind	Downwind	Average
White-tailed Eagle	0.076	0.06	0.068
Golden Plover	0.05	0.038	0.044
Hen Harrier	0.078	0.05	0.064
Merlin	0.057	0.037	0.047
Peregrine Falcon	0.063	0.045	0.054
Whooper Swan	0.085	0.073	0.079
Kestrel	0.062	0.04	0.051
Snipe	0.049	0.036	0.042
Buzzard	0.067	0.048	0.057
Sparrowhawk	0.062	0.039	0.051

Table 7 - 6 - 18 Probability of collision – Scenario 2

Species	Upwind	Downwind	Average
White-tailed Eagle	0.08	0.062	0.071
Golden Plover	0.053	0.04	0.047
Hen Harrier	0.081	0.052	0.066
Merlin	0.061	0.039	0.05
Peregrine Falcon	0.066	0.047	0.056
Whooper Swan	0.089	0.075	0.082
Kestrel	0.065	0.042	0.054
Snipe	0.052	0.038	0.045
Buzzard	0.07	0.05	0.06
Sparrowhawk	0.065	0.041	0.053

Table 7 - 6 - 19 Probability of collision – Scenario 3

Species	Upwind	Downwind	Average
White-tailed Eagle	0.08	0.065	0.073
Golden Plover	0.053	0.041	0.047
Hen Harrier	0.08	0.053	0.067
Merlin	0.059	0.04	0.05
Peregrine Falcon	0.066	0.048	0.057
Whooper Swan	0.089	0.077	0.083
Kestrel	0.064	0.043	0.054
Snipe	0.051	0.039	0.045
Buzzard	0.069	0.051	0.06
Sparrowhawk	0.064	0.043	0.053

3.4 Stage D Expected Collisions

Stage D of the modelling process multiplies the outputs of stage B and C to yield the expected collision rate for each bird species, accounting for the proportion of time the Proposed Wind Farm is expected to be operational. This is before considering avoidance behaviour, which is stage E. The number of expected collisions per month and the year total for each species are presented for each scenario in Table 7 - 6 - 20 to Table 7 - 6 - 22.

Table 7 - 6 - 20 Expected collisions without avoidance – Scenario 1

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
White-tailed Eagle	0.0326	0	0.0542	0	0	0	0	0	0	0	0.0126	0.0671	0.167
Golden Plover	41.4	26.2	87	157	0.0281	0	0	0	3.58	12.2	82.2	13.2	423
Hen Harrier	0.0415	0.0218	0	0.00861	0	0	0	0.0153	0	0	0.0212	0.00823	0.117
Merlin	0.00132	0.00112	0	0.00252	0	0.00188	0.000639	0.0026	0.00894	0.00343	0.000439	0.0014	0.0243
Peregrine Falcon	0.0407	0.00996	0.0138	0	0	0.0203	0.398	0.82	0.055	0	0.0256	0.0554	1.44
Whooper Swan	0	0	0	0	0	-	-	0	0	6.65	6.48	7.89	21
Kestrel	0.24	0.166	1.84	1.43	0.327	3.27	4.68	11.3	2.22	0.705	0.14	0.1	26.5
Snipe	0.0782	0.0408	0.031	0.0333	0.278	0	0.0106	0.016	0.781	0.692	0.164	0.085	2.21
Buzzard	0.35	0.414	1.93	7.24	2.58	2.66	2.42	3.11	1.69	0.421	0.669	0.204	23.7
Sparrowhawk	0.00653	0.0403	0.0196	0.00245	0.0356	0.0208	0.00949	0.127	0.0134	0	0.00833	0.00829	0.292

Table 7 - 6 - 21 Expected collisions without avoidance – Scenario 2

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
White-tailed Eagle	0.0331	0	0.0547	0	0	0	0	0	0	0	0.0129	0.068	0.169
Golden Plover	42.7	27.1	90.7	163	0.0292	0	0	0	3.7	12.7	85	13.7	439

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Hen Harrier	0.042	0.0222	0	0.00864	0	0	0	0.0154	0	0	0.0213	0.00836	0.118
Merlin	0.00135	0.00118	0	0.00258	0	0.0019	0.000676	0.00266	0.00925	0.00355	0.000465	0.00148	0.0251
Peregrine Falcon	0.0419	0.0103	0.0142	0	0	0.0209	0.41	0.845	0.0566	0	0.0264	0.056	1.48
Whooper Swan	0	0	0	0	0	-	-	0	0	6.73	6.56	8	21.3
Kestrel	0.247	0.17	1.88	1.46	0.335	3.35	4.8	11.5	2.28	0.721	0.143	0.102	27
Snipe	0.0812	0.0423	0.0322	0.0345	0.29	0	0.0109	0.0167	0.809	0.72	0.17	0.0885	2.29
Buzzard	0.358	0.421	1.97	7.42	2.63	2.72	2.47	3.18	1.71	0.428	0.682	0.209	24.2
Sparrowhawk	0.0067	0.0411	0.0202	0.00253	0.0364	0.0214	0.00982	0.131	0.0139	0	0.0086	0.00851	0.3

Table 7 - 6 - 22 Expected collisions without avoidance – Scenario 3

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
White-tailed Eagle	0.023	0	0.0367	0	0	0	0	0	0	0	0.00906	0.0472	0.116
Golden Plover	32.4	20.8	71.9	126	0.0235	0	0	0	2.77	9.84	65.1	10.4	339
Hen Harrier	0.027	0.0163	0	0.00612	0	0	0	0.00816	0	0	0.0119	0.00635	0.0758
Merlin	0.00101	0.000888	0	0.00194	0	0.00144	0.000507	0.00199	0.00702	0.00275	0.000338	0.0011	0.019
Peregrine Falcon	0.0325	0.00812	0.0106	0	0	0.0162	0.319	0.656	0.0459	0	0.0207	0.0423	1.15
Whooper Swan	0	0	0	0	0	-	-	0	0	5.01	5.04	6.5	16.5
Kestrel	0.179	0.115	1.28	1.03	0.236	2.39	3.58	8.39	1.6	0.473	0.1	0.0681	19.5

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Snipe	0.0573	0.0312	0.0225	0.0242	0.232	0	0.00614	0.0125	0.586	0.572	0.125	0.0679	1.74
Buzzard	0.271	0.283	1.4	5.55	1.88	2.03	1.79	2.33	1.09	0.264	0.487	0.152	17.5
Sparrowhawk	0.00426	0.025	0.0149	0.0019	0.0264	0.0158	0.00738	0.0988	0.0105	0	0.00648	0.00634	0.218

3.5 Stage E Allowing for Avoidance and Attraction

Stage E of the modelling process takes account of the proportion of birds likely to avoid the wind farm or its turbines, either because they have been displaced from the site or because they take evasive action or are attracted to the wind farm. Band (2024) states that the collision rate estimate should show potential collision mortality using a range of assumed avoidance rates. In the absence of specific avoidance information for the species in question, it is recommended that collision risks be evaluated assuming avoidance factors of 95%, 98%, 99%, 99.5% and 99.6%. These are presented for each scenario in Table 7 - 6 – 23 to Table 7 – 6 – 25.

Table 7 - 6 - 23 Expected collisions with avoidance – Scenario 1

Species	Avoidance Factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
White-tailed Eagle	0.95	0.00163	0	0.00271	0	0	0	0	0	0	0	0.00063	0.00335	0.00833
	0.98	0.00065	0	0.00108	0	0	0	0	0	0	0	0.00025	0.00134	0.00333
	0.99	0.00033	0	0.00054	0	0	0	0	0	0	0	0.00013	0.00067	0.00167
	0.995	0.00016	0	0.00027	0	0	0	0	0	0	0	0.00006	0.00034	0.00083
	0.996	0.00013	0	0.00022	0	0	0	0	0	0	0	0.00005	0.00027	0.00067
Golden Plover	0.95	2.07	1.31	4.35	7.85	0.0014	0	0	0	0.179	0.612	4.11	0.661	21.1
	0.98	0.827	0.524	1.74	3.14	0.00056	0	0	0	0.0716	0.245	1.64	0.264	8.45

Species	Avoidance Factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	0.99	0.414	0.262	0.87	1.57	0.00028	0	0	0	0.0358	0.122	0.822	0.132	4.23
	0.995	0.207	0.131	0.435	0.785	0.00014	0	0	0	0.0179	0.0612	0.411	0.0661	2.11
	0.996	0.165	0.105	0.348	0.628	0.00011	0	0	0	0.0143	0.049	0.329	0.0529	1.69
Hen Harrier	0.95	0.00207	0.00109	0	0.00043	0	0	0	0.00076	0	0	0.00106	0.00041	0.00583
	0.98	0.00083	0.00044	0	0.00017	0	0	0	0.00031	0	0	0.00042	0.00016	0.00233
	0.99	0.00041	0.00022	0	0.00009	0	0	0	0.00015	0	0	0.00021	0.00008	0.00117
	0.995	0.00021	0.00011	0	0.00004	0	0	0	0.00008	0	0	0.00011	0.00004	0.00058
	0.996	0.00017	0.00009	0	0.00003	0	0	0	0.00006	0	0	0.00008	0.00003	0.00047
Merlin	0.95	0.00007	0.00006	0	0.00013	0	0.00009	0.00003	0.00013	0.00045	0.00017	0.00002	0.00007	0.00121
	0.98	0.00003	0.00002	0	0.00005	0	0.00004	0.00001	0.00005	0.00018	0.00007	0.00001	0.00003	0.00049
	0.99	0.00001	0.00001	0	0.00003	0	0.00002	0.00001	0.00003	0.00009	0.00003	0	0.00001	0.00024
	0.995	0.00001	0.00001	0	0.00001	0	0.00001	0	0.00001	0.00004	0.00002	0	0.00001	0.00012
	0.996	0.00001	0	0	0.00001	0	0.00001	0	0.00001	0.00004	0.00001	0	0.00001	0.0001
Peregrine Falcon	0.95	0.00203	0.0005	0.00069	0	0	0.00102	0.0199	0.041	0.00275	0	0.00128	0.00277	0.072

Species	Avoidance Factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	0.98	0.00081	0.0002	0.00028	0	0	0.00041	0.00796	0.0164	0.0011	0	0.00051	0.00111	0.0288
	0.99	0.00041	0.0001	0.00014	0	0	0.0002	0.00398	0.0082	0.00055	0	0.00026	0.00055	0.0144
	0.995	0.0002	0.00005	0.00007	0	0	0.0001	0.00199	0.0041	0.00028	0	0.00013	0.00028	0.0072
	0.996	0.00016	0.00004	0.00006	0	0	0.00008	0.00159	0.00328	0.00022	0	0.0001	0.00022	0.00576
Whooper Swan	0.95	0	0	0	0	0	-	-	0	0	0.333	0.324	0.394	1.05
	0.98	0	0	0	0	0	-	-	0	0	0.133	0.13	0.158	0.42
	0.99	0	0	0	0	0	-	-	0	0	0.0665	0.0648	0.0789	0.21
	0.995	0	0	0	0	0	-	-	0	0	0.0333	0.0324	0.0394	0.105
	0.996	0	0	0	0	0	-	-	0	0	0.0266	0.0259	0.0316	0.0841
Kestrel	0.95	0.012	0.00829	0.0921	0.0715	0.0164	0.164	0.234	0.566	0.111	0.0353	0.007	0.005	1.32
	0.98	0.0048	0.00332	0.0368	0.0286	0.00654	0.0654	0.0936	0.227	0.0445	0.0141	0.0028	0.002	0.529
	0.99	0.0024	0.00166	0.0184	0.0143	0.00327	0.0327	0.0468	0.113	0.0222	0.00705	0.0014	0.001	0.265
	0.995	0.0012	0.00083	0.00921	0.00715	0.00164	0.0164	0.0234	0.0566	0.0111	0.00353	0.0007	0.0005	0.132
	0.996	0.00096	0.00066	0.00737	0.00572	0.00131	0.0131	0.0187	0.0453	0.0089	0.00282	0.00056	0.0004	0.106

Species	Avoidance Factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Snipe	0.95	0.00391	0.00204	0.00155	0.00167	0.0139	0	0.00053	0.0008	0.0391	0.0346	0.00819	0.00425	0.11
	0.98	0.00156	0.00082	0.00062	0.00067	0.00556	0	0.00021	0.00032	0.0156	0.0138	0.00327	0.0017	0.0442
	0.99	0.00078	0.00041	0.00031	0.00033	0.00278	0	0.00011	0.00016	0.00781	0.00692	0.00164	0.00085	0.0221
	0.995	0.00039	0.0002	0.00016	0.00017	0.00139	0	0.00005	0.00008	0.00391	0.00346	0.00082	0.00043	0.0111
	0.996	0.00031	0.00016	0.00012	0.00013	0.00111	0	0.00004	0.00006	0.00313	0.00277	0.00065	0.00034	0.00884
Buzzard	0.95	0.0175	0.0207	0.0966	0.362	0.129	0.133	0.121	0.156	0.0843	0.0211	0.0335	0.0102	1.18
	0.98	0.007	0.00827	0.0386	0.145	0.0515	0.0532	0.0484	0.0622	0.0337	0.00843	0.0134	0.00407	0.474
	0.99	0.0035	0.00414	0.0193	0.0724	0.0258	0.0266	0.0242	0.0311	0.0169	0.00421	0.00669	0.00204	0.237
	0.995	0.00175	0.00207	0.00966	0.0362	0.0129	0.0133	0.0121	0.0156	0.00843	0.00211	0.00335	0.00102	0.118
	0.996	0.0014	0.00165	0.00773	0.029	0.0103	0.0106	0.00969	0.0124	0.00674	0.00169	0.00268	0.00081	0.0947
Sparrowhawk	0.95	0.00033	0.00201	0.00098	0.00012	0.00178	0.00104	0.00047	0.00635	0.00067	0	0.00042	0.00041	0.0146
	0.98	0.00013	0.00081	0.00039	0.00005	0.00071	0.00042	0.00019	0.00254	0.00027	0	0.00017	0.00017	0.00584
	0.99	0.00007	0.0004	0.0002	0.00002	0.00036	0.00021	0.00009	0.00127	0.00013	0	0.00008	0.00008	0.00292
	0.995	0.00003	0.0002	0.0001	0.00001	0.00018	0.0001	0.00005	0.00063	0.00007	0	0.00004	0.00004	0.00146

Species	Avoidance Factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	0.996	0.00003	0.00016	0.00008	0.00001	0.00014	0.00008	0.00004	0.00051	0.00005	0	0.00003	0.00003	0.00117

Table 7 - 6 - 24 Expected collisions with avoidance – Scenario 2

Species	Avoidance Factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
White-tailed Eagle	0.95	0.00166	0	0.00273	0	0	0	0	0	0	0	0.00064	0.0034	0.00843
	0.98	0.00066	0	0.00109	0	0	0	0	0	0	0	0.00026	0.00136	0.00337
	0.99	0.00033	0	0.00055	0	0	0	0	0	0	0	0.00013	0.00068	0.00169
	0.995	0.00017	0	0.00027	0	0	0	0	0	0	0	0.00006	0.00034	0.00084
	0.996	0.00013	0	0.00022	0	0	0	0	0	0	0	0.00005	0.00027	0.00067
Golden Plover	0.95	2.14	1.36	4.53	8.16	0.00146	0	0	0	0.185	0.637	4.25	0.684	21.9
	0.98	0.855	0.543	1.81	3.26	0.00058	0	0	0	0.074	0.255	1.7	0.274	8.78
	0.99	0.427	0.271	0.907	1.63	0.00029	0	0	0	0.037	0.127	0.85	0.137	4.39
	0.995	0.214	0.136	0.453	0.816	0.00015	0	0	0	0.0185	0.0637	0.425	0.0684	2.19
	0.996	0.171	0.109	0.363	0.653	0.00012	0	0	0	0.0148	0.0509	0.34	0.0547	1.76
Hen Harrier	0.95	0.0021	0.00111	0	0.00043	0	0	0	0.00077	0	0	0.00107	0.00042	0.0059

Species	Avoidance Factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	0.98	0.00084	0.00044	0	0.00017	0	0	0	0.00031	0	0	0.00043	0.00017	0.00236
	0.99	0.00042	0.00022	0	0.00009	0	0	0	0.00015	0	0	0.00021	0.00008	0.00118
	0.995	0.00021	0.00011	0	0.00004	0	0	0	0.00008	0	0	0.00011	0.00004	0.00059
	0.996	0.00017	0.00009	0	0.00003	0	0	0	0.00006	0	0	0.00009	0.00003	0.00047
Merlin	0.95	0.00007	0.00006	0	0.00013	0	0.0001	0.00003	0.00013	0.00046	0.00018	0.00002	0.00007	0.00125
	0.98	0.00003	0.00002	0	0.00005	0	0.00004	0.00001	0.00005	0.00018	0.00007	0.00001	0.00003	0.0005
	0.99	0.00001	0.00001	0	0.00003	0	0.00002	0.00001	0.00003	0.00009	0.00004	0	0.00001	0.00025
	0.995	0.00001	0.00001	0	0.00001	0	0.00001	0	0.00001	0.00005	0.00002	0	0.00001	0.00013
	0.996	0.00001	0	0	0.00001	0	0.00001	0	0.00001	0.00004	0.00001	0	0.00001	0.0001
Peregrine Falcon	0.95	0.00209	0.00051	0.00071	0	0	0.00105	0.0205	0.0422	0.00283	0	0.00132	0.0028	0.0741
	0.98	0.00084	0.00021	0.00028	0	0	0.00042	0.0082	0.0169	0.00113	0	0.00053	0.00112	0.0296
	0.99	0.00042	0.0001	0.00014	0	0	0.00021	0.0041	0.00845	0.00057	0	0.00026	0.00056	0.0148
	0.995	0.00021	0.00005	0.00007	0	0	0.0001	0.00205	0.00422	0.00028	0	0.00013	0.00028	0.00741
	0.996	0.00017	0.00004	0.00006	0	0	0.00008	0.00164	0.00338	0.00023	0	0.00011	0.00022	0.00592

Species	Avoidance Factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Whooper Swan	0.95	0	0	0	0	0	-	-	0	0	0.336	0.328	0.4	1.06
	0.98	0	0	0	0	0	-	-	0	0	0.135	0.131	0.16	0.426
	0.99	0	0	0	0	0	-	-	0	0	0.0673	0.0656	0.08	0.213
	0.995	0	0	0	0	0	-	-	0	0	0.0336	0.0328	0.04	0.106
	0.996	0	0	0	0	0	-	-	0	0	0.0269	0.0262	0.032	0.0852
Kestrel	0.95	0.0123	0.00848	0.0939	0.0731	0.0168	0.168	0.24	0.577	0.114	0.0361	0.00715	0.00512	1.35
	0.98	0.00493	0.00339	0.0376	0.0292	0.0067	0.067	0.0961	0.231	0.0455	0.0144	0.00286	0.00205	0.541
	0.99	0.00247	0.0017	0.0188	0.0146	0.00335	0.0335	0.0481	0.115	0.0228	0.00721	0.00143	0.00102	0.27
	0.995	0.00123	0.00085	0.00939	0.00731	0.00168	0.0168	0.024	0.0577	0.0114	0.00361	0.00072	0.00051	0.135
	0.996	0.00099	0.00068	0.00751	0.00585	0.00134	0.0134	0.0192	0.0462	0.00911	0.00288	0.00057	0.00041	0.108
Snipe	0.95	0.00406	0.00212	0.00161	0.00173	0.0145	0	0.00055	0.00083	0.0404	0.036	0.00849	0.00443	0.115
	0.98	0.00162	0.00085	0.00064	0.00069	0.00579	0	0.00022	0.00033	0.0162	0.0144	0.0034	0.00177	0.0459
	0.99	0.00081	0.00042	0.00032	0.00035	0.0029	0	0.00011	0.00017	0.00809	0.0072	0.0017	0.00089	0.0229
	0.995	0.00041	0.00021	0.00016	0.00017	0.00145	0	0.00005	0.00008	0.00404	0.0036	0.00085	0.00044	0.0115

Species	Avoidance Factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	0.996	0.00032	0.00017	0.00013	0.00014	0.00116	0	0.00004	0.00007	0.00323	0.00288	0.00068	0.00035	0.00918
Buzzard	0.95	0.0179	0.021	0.0987	0.371	0.131	0.136	0.124	0.159	0.0855	0.0214	0.0341	0.0104	1.21
	0.98	0.00717	0.00842	0.0395	0.148	0.0525	0.0544	0.0495	0.0636	0.0342	0.00855	0.0137	0.00417	0.484
	0.99	0.00358	0.00421	0.0197	0.0742	0.0263	0.0272	0.0247	0.0318	0.0171	0.00428	0.00682	0.00209	0.242
	0.995	0.00179	0.0021	0.00987	0.0371	0.0131	0.0136	0.0124	0.0159	0.00855	0.00214	0.00341	0.00104	0.121
	0.996	0.00143	0.00168	0.0079	0.0297	0.0105	0.0109	0.00989	0.0127	0.00684	0.00171	0.00273	0.00083	0.0968
Sparrowhawk	0.95	0.00033	0.00205	0.00101	0.00013	0.00182	0.00107	0.00049	0.00655	0.00069	0	0.00043	0.00043	0.015
	0.98	0.00013	0.00082	0.0004	0.00005	0.00073	0.00043	0.0002	0.00262	0.00028	0	0.00017	0.00017	0.006
	0.99	0.00007	0.00041	0.0002	0.00003	0.00036	0.00021	0.0001	0.00131	0.00014	0	0.00009	0.00009	0.003
	0.995	0.00003	0.00021	0.0001	0.00001	0.00018	0.00011	0.00005	0.00066	0.00007	0	0.00004	0.00004	0.0015
	0.996	0.00003	0.00016	0.00008	0.00001	0.00015	0.00009	0.00004	0.00052	0.00006	0	0.00003	0.00003	0.0012

Table 7 - 6 - 25 Expected collisions with avoidance – Scenario 3

Species	Avoidance Factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
White-tailed Eagle	0.95	0.00115	0	0.00184	0	0	0	0	0	0	0	0.00045	0.00236	0.0058
	0.98	0.00046	0	0.00073	0	0	0	0	0	0	0	0.00018	0.00094	0.00232
	0.99	0.00023	0	0.00037	0	0	0	0	0	0	0	0.00009	0.00047	0.00116
	0.995	0.00011	0	0.00018	0	0	0	0	0	0	0	0.00005	0.00024	0.00058
	0.996	0.00009	0	0.00015	0	0	0	0	0	0	0	0.00004	0.00019	0.00046
Golden Plover	0.95	1.62	1.04	3.59	6.28	0.00118	0	0	0	0.138	0.492	3.25	0.52	16.9
	0.98	0.649	0.417	1.44	2.51	0.00047	0	0	0	0.0553	0.197	1.3	0.208	6.78
	0.99	0.324	0.208	0.719	1.26	0.00024	0	0	0	0.0277	0.0984	0.651	0.104	3.39
	0.995	0.162	0.104	0.359	0.628	0.00012	0	0	0	0.0138	0.0492	0.325	0.052	1.69
	0.996	0.13	0.0834	0.287	0.503	0.00009	0	0	0	0.0111	0.0394	0.26	0.0416	1.36
Hen Harrier	0.95	0.00135	0.00081	0	0.00031	0	0	0	0.00041	0	0	0.00059	0.00032	0.00379
	0.98	0.00054	0.00033	0	0.00012	0	0	0	0.00016	0	0	0.00024	0.00013	0.00152
	0.99	0.00027	0.00016	0	0.00006	0	0	0	0.00008	0	0	0.00012	0.00006	0.00076
	0.995	0.00014	0.00008	0	0.00003	0	0	0	0.00004	0	0	0.00006	0.00003	0.00038

Species	Avoidance Factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	0.996	0.00011	0.00007	0	0.00002	0	0	0	0.00003	0	0	0.00005	0.00003	0.0003
Merlin	0.95	0.00005	0.00004	0	0.0001	0	0.00007	0.00003	0.0001	0.00035	0.00014	0.00002	0.00005	0.00095
	0.98	0.00002	0.00002	0	0.00004	0	0.00003	0.00001	0.00004	0.00014	0.00005	0.00001	0.00002	0.00038
	0.99	0.00001	0.00001	0	0.00002	0	0.00001	0.00001	0.00002	0.00007	0.00003	0	0.00001	0.00019
	0.995	0.00001	0	0	0.00001	0	0.00001	0	0.00001	0.00004	0.00001	0	0.00001	0.00009
	0.996	0	0	0	0.00001	0	0.00001	0	0.00001	0.00003	0.00001	0	0	0.00008
Peregrine Falcon	0.95	0.00163	0.00041	0.00053	0	0	0.00081	0.0159	0.0328	0.00229	0	0.00103	0.00211	0.0576
	0.98	0.00065	0.00016	0.00021	0	0	0.00032	0.00637	0.0131	0.00092	0	0.00041	0.00085	0.023
	0.99	0.00033	0.00008	0.00011	0	0	0.00016	0.00319	0.00656	0.00046	0	0.00021	0.00042	0.0115
	0.995	0.00016	0.00004	0.00005	0	0	0.00008	0.00159	0.00328	0.00023	0	0.0001	0.00021	0.00576
	0.996	0.00013	0.00003	0.00004	0	0	0.00006	0.00127	0.00263	0.00018	0	0.00008	0.00017	0.00461
Whooper Swan	0.95	0	0	0	0	0	-	-	0	0	0.25	0.252	0.325	0.827
	0.98	0	0	0	0	0	-	-	0	0	0.1	0.101	0.13	0.331
	0.99	0	0	0	0	0	-	-	0	0	0.0501	0.0504	0.065	0.165

Species	Avoidance Factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	0.995	0	0	0	0	0	-	-	0	0	0.025	0.0252	0.0325	0.0827
	0.996	0	0	0	0	0	-	-	0	0	0.02	0.0202	0.026	0.0662
Kestrel	0.95	0.00897	0.00575	0.064	0.0516	0.0118	0.12	0.179	0.42	0.08	0.0237	0.005	0.0034	0.973
	0.98	0.00359	0.0023	0.0256	0.0207	0.00471	0.0479	0.0716	0.168	0.032	0.00946	0.002	0.00136	0.389
	0.99	0.00179	0.00115	0.0128	0.0103	0.00236	0.0239	0.0358	0.0839	0.016	0.00473	0.001	0.00068	0.195
	0.995	0.0009	0.00057	0.0064	0.00516	0.00118	0.012	0.0179	0.042	0.008	0.00237	0.0005	0.00034	0.0973
	0.996	0.00072	0.00046	0.00512	0.00413	0.00094	0.00958	0.0143	0.0336	0.0064	0.00189	0.0004	0.00027	0.0778
Snipe	0.95	0.00286	0.00156	0.00112	0.00121	0.0116	0	0.00031	0.00063	0.0293	0.0286	0.00626	0.00339	0.0868
	0.98	0.00115	0.00062	0.00045	0.00048	0.00464	0	0.00012	0.00025	0.0117	0.0114	0.0025	0.00136	0.0347
	0.99	0.00057	0.00031	0.00022	0.00024	0.00232	0	0.00006	0.00013	0.00586	0.00572	0.00125	0.00068	0.0174
	0.995	0.00029	0.00016	0.00011	0.00012	0.00116	0	0.00003	0.00006	0.00293	0.00286	0.00063	0.00034	0.00868
	0.996	0.00023	0.00012	0.00009	0.0001	0.00093	0	0.00002	0.00005	0.00234	0.00229	0.0005	0.00027	0.00695
Buzzard	0.95	0.0135	0.0141	0.0699	0.278	0.094	0.101	0.0897	0.117	0.0543	0.0132	0.0243	0.00758	0.876
	0.98	0.00541	0.00565	0.0279	0.111	0.0376	0.0405	0.0359	0.0466	0.0217	0.00529	0.00973	0.00303	0.35

Species	Avoidance Factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	0.99	0.00271	0.00283	0.014	0.0555	0.0188	0.0203	0.0179	0.0233	0.0109	0.00264	0.00487	0.00152	0.175
	0.995	0.00135	0.00141	0.00699	0.0278	0.0094	0.0101	0.00897	0.0117	0.00543	0.00132	0.00243	0.00076	0.0876
	0.996	0.00108	0.00113	0.00559	0.0222	0.00752	0.0081	0.00717	0.00932	0.00435	0.00106	0.00195	0.00061	0.0701
Sparrowhawk	0.95	0.00021	0.00125	0.00074	0.0001	0.00132	0.00079	0.00037	0.00494	0.00052	0	0.00032	0.00032	0.0109
	0.98	0.00009	0.0005	0.0003	0.00004	0.00053	0.00032	0.00015	0.00198	0.00021	0	0.00013	0.00013	0.00435
	0.99	0.00004	0.00025	0.00015	0.00002	0.00026	0.00016	0.00007	0.00099	0.0001	0	0.00006	0.00006	0.00218
	0.995	0.00002	0.00012	0.00007	0.00001	0.00013	0.00008	0.00004	0.00049	0.00005	0	0.00003	0.00003	0.00109
	0.996	0.00002	0.0001	0.00006	0.00001	0.00011	0.00006	0.00003	0.0004	0.00004	0	0.00003	0.00003	0.00087

3.6 Stage F Uncertainty

There are many sources of variability or uncertainty in the output of the Collision Risk Model. The main sources of uncertainty outlined in Band (2024) are:

- survey data is sampled, often both in time and space, and usually exhibits a high degree of variability. Mean estimates can only be representative of flight activity;
- survey data is unavailable for certain conditions, including nighttime and storm conditions;
- natural variability in bird populations, over time and space, for ecological reasons;
- flight height information may be subject to observer bias;
- the collision risk model uses a simplified geometry for turbine blades and bird shape;
- it does not include any risk of collision with turbine towers;
- details of blade dimension and pitch may be unavailable when making the estimate;
- turbines deployed may differ from those used in the collision risk analysis;
- bird parameters (length, wingspan, flight speed) are not fixed but have a distribution;

- bird speed is not a constant but is dependent on wind speed;
- insufficient knowledge about bird displacement and attraction effects;
- there is limited firm information on bird avoidance behaviour.

Because of this, a range of uncertainty is calculated for the predicted collision rates. The range of uncertainty should reflect:

- uncertainty or variability in flight activity data (including imprecision on flight height estimates and lack of knowledge about night-time behaviour);
- uncertainty due to the limitations of the collision model, including the variability of bird dimensions and flight speed, the simplification in shape of a bird and turbine blades;
- uncertainty arising from turbine options yet to be decided, in number, size and speed. These options should include a 'worst case' in terms of the option likely to present greatest bird collision risk.

To provide a measure of uncertainty in aerial density, the mean, standard deviation and relative standard deviation for the monthly values was calculated (see Section 4 'Worked Example'). Uncertainty due to simplifications in the collision risk model was assumed to be 0.20 (Band, 2024). Finally, uncertainty due to design options (including the blade profile, pitch, rotational speed and expected time operational) was considered to be 0.28. The overall range of uncertainty for each species is presented in for each scenario in Table 7 - 6 - 26 to Table 7 - 6 - 28.

Table 7 - 6 - 26 Range of uncertainty – Scenario 1

Species	Months	Model	Mean	Standard Deviation	Relative Standard Deviation	Uncertainty
White-tailed Eagle	Oct-Sep	non-directional	0.00002	0.00003	1.5000	1.54
Golden Plover	Oct-Sep	non-directional	0.02693	0.03351	1.2443	1.29
Hen Harrier	Oct-Sep	non-directional	0.00013	0.00018	1.3846	1.43
Merlin	Oct-Sep	non-directional	0.00004	0.00004	1.0000	1.06
Peregrine Falcon	Oct-Sep	non-directional	0.0001	0.00018	1.8000	1.83
Whooper Swan	Aug-May	non-directional	0.0009	0.0014	1.5556	1.59
Kestrel	Oct-Sep	non-directional	0.00217	0.00283	1.3041	1.35
Snipe	Oct-Sep	non-directional	0.00025	0.00036	1.4400	1.48
Buzzard	Oct-Sep	non-directional	0.00154	0.00138	0.8961	0.96
Sparrowhawk	Oct-Sep	non-directional	0.00009	0.00011	1.2222	1.27

Table 7 - 6 - 27 Range of uncertainty – Scenario 2

Species	Months	Model	Mean	Standard Deviation	Relative Standard Deviation	Uncertainty
White-tailed Eagle	Oct-Sep	non-directional	0.00002	0.00003	1.5000	1.54
Golden Plover	Oct-Sep	non-directional	0.02685	0.03344	1.2454	1.29
Hen Harrier	Oct-Sep	non-directional	0.00013	0.00018	1.3846	1.43
Merlin	Oct-Sep	non-directional	0.00004	0.00004	1.0000	1.06
Peregrine Falcon	Oct-Sep	non-directional	0.0001	0.00018	1.8000	1.83
Whooper Swan	Aug-May	non-directional	0.0009	0.0014	1.5556	1.59

Species	Months	Model	Mean	Standard Deviation	Relative Standard Deviation	Uncertainty
Kestrel	Oct-Sep	non-directional	0.00215	0.0028	1.3023	1.35
Snipe	Oct-Sep	non-directional	0.00025	0.00035	1.4000	1.44
Buzzard	Oct-Sep	non-directional	0.00153	0.00138	0.9020	0.97
Sparrowhawk	Oct-Sep	non-directional	0.00009	0.00011	1.2222	1.27

Table 7 - 6 - 28 Range of uncertainty – Scenario 3

Species	Months	Model	Mean	Standard Deviation	Relative Standard Deviation	Uncertainty
White-tailed Eagle	Oct-Sep	non-directional	0.00002	0.00003	1.5000	1.54
Golden Plover	Oct-Sep	non-directional	0.02595	0.03236	1.2470	1.29
Hen Harrier	Oct-Sep	non-directional	0.00011	0.00015	1.3636	1.41
Merlin	Oct-Sep	non-directional	0.00003	0.00004	1.3333	1.38
Peregrine Falcon	Oct-Sep	non-directional	0.00009	0.00017	1.8889	1.92
Whooper Swan	Aug-May	non-directional	0.00087	0.00136	1.5632	1.60
Kestrel	Oct-Sep	non-directional	0.00195	0.00259	1.3282	1.37
Snipe	Oct-Sep	non-directional	0.00024	0.00034	1.4167	1.46
Buzzard	Oct-Sep	non-directional	0.00138	0.0013	0.9420	1.00
Sparrowhawk	Oct-Sep	non-directional	0.00008	0.0001	1.2500	1.30

3.7 Predicted Collision Rates

To provide a best estimate of the collision rate for each species, the guidance on avoidance rates provided in NatureScot (2025b) was consulted. This guidance suggests the most appropriate avoidance rate for each species; however it should be noted that the lack of research on most species' avoidance rates means that the confidence interval of the prediction may extend from the lowest to the highest avoidance rate in Table 7 – 6 – 23 to Table 7 - 6 - 25. For each species and scenario, the predicted number of collisions corresponding to the recommended avoidance rate was identified. These are presented in Table 7 - 6 - 29 to Table 7 - 6 - 31, along with the range of uncertainty, the predicted number of collisions over the operational lifetime of the facility and an estimation of the number of years for one collision to occur (details on these calculations are shown in Section 4 'Worked Example').

Table 7 - 6 - 29 to Table 7 - 6 - 31 presents the final predicted annual collision rate used for the assessment. The results should be considered as a best estimate of collision risk, rather than a precise figure.

Table 7 - 6 - 29 Predicted collision rates – Scenario 1

Species	Months	Model	Avoidance Factor	Annual Collision Rate	Range of Uncertainty	Collisions Over Lifetime	Years to One Collision
White-tailed Eagle	Oct-Sep	non-directional	0.95	0.008	0-0.020	0.28	>35
Golden Plover	Oct-Sep	non-directional	0.996	1.691	0-3.874	59.185	<1
Hen Harrier	Oct-Sep	non-directional	0.99	0.001	0-0.002	0.035	>35
Merlin	Oct-Sep	non-directional	0.98	0.0005	0-0.001	0.0175	>35
Peregrine Falcon	Oct-Sep	non-directional	0.98	0.029	0-0.082	1.015	34
Whooper Swan	Aug-May	non-directional	0.995	0.105	0-0.272	3.675	10
Kestrel	Oct-Sep	non-directional	0.95	1.323	0-3.107	46.305	<1
Snipe	Oct-Sep	non-directional	0.98	0.044	0-0.109	1.54	23

Species	Months	Model	Avoidance Factor	Annual Collision Rate	Range of Uncertainty	Collisions Over Lifetime	Years to One Collision
Buzzard	Oct-Sep	non-directional	0.98	0.474	0.019-0.929	16.59	2
Sparrowhawk	Oct-Sep	non-directional	0.98	0.006	0-0.014	0.21	>35

Table 7 - 6 - 30 Predicted collision rates – Scenario 2

Species	Months	Model	Avoidance Factor	Annual Collision Rate	Range of Uncertainty	Collisions Over Lifetime	Years to One Collision
White-tailed Eagle	Oct-Sep	non-directional	0.95	0.008	0-0.020	0.28	>35
Golden Plover	Oct-Sep	non-directional	0.996	1.755	0-4.023	61.425	<1
Hen Harrier	Oct-Sep	non-directional	0.99	0.001	0-0.002	0.035	>35
Merlin	Oct-Sep	non-directional	0.98	0.0005	0-0.001	0.0175	>35
Peregrine Falcon	Oct-Sep	non-directional	0.98	0.03	0-0.085	1.05	33
Whooper Swan	Aug-May	non-directional	0.995	0.106	0-0.275	3.71	9
Kestrel	Oct-Sep	non-directional	0.95	1.352	0-3.173	47.32	<1
Snipe	Oct-Sep	non-directional	0.98	0.046	0-0.112	1.61	22
Buzzard	Oct-Sep	non-directional	0.98	0.484	0.017-0.951	16.94	2
Sparrowhawk	Oct-Sep	non-directional	0.98	0.006	0-0.014	0.21	>35

Table 7 - 6 - 31 Predicted collision rates – Scenario 3

Species	Months	Model	Avoidance Factor	Annual Collision Rate	Range of Uncertainty	Collisions Over Lifetime	Years to One Collision
White-tailed Eagle	Oct-Sep	non-directional	0.95	0.006	0-0.015	0.21	>35
Golden Plover	Oct-Sep	non-directional	0.996	1.356	0-3.110	47.46	<1
Hen Harrier	Oct-Sep	non-directional	0.99	0.001	0-0.002	0.035	>35
Merlin	Oct-Sep	non-directional	0.98	0.0004	0-0.001	0.014	>35
Peregrine Falcon	Oct-Sep	non-directional	0.98	0.023	0-0.067	0.805	>35
Whooper Swan	Aug-May	non-directional	0.995	0.083	0-0.216	2.905	12
Kestrel	Oct-Sep	non-directional	0.95	0.973	0-2.308	34.055	1
Snipe	Oct-Sep	non-directional	0.98	0.035	0-0.086	1.225	29
Buzzard	Oct-Sep	non-directional	0.98	0.35	0-0.701	12.25	3
Sparrowhawk	Oct-Sep	non-directional	0.98	0.004	0-0.009	0.14	>35

4. WORKED EXAMPLE

This section provides a worked example of the collision rate prediction for sparrowhawk at an imaginary facility. This example is deliberately simplified to assist readers with following the steps. The prediction is made using a short imaginary dataset presented in Section 4.2.

4.1 Proposed Development Scenario

In this example, a wind farm is proposed in farmland at a latitude of 53.4°N. The development consists of seven turbines. Each turbine has a hub height of 105m and rotor diameter of 150m, giving a rotor-swept height range of 30-180m. The turbines have a blade radius (R) of 75m, a blade pitch (λ) of 6°, and a maximum blade chord width (C) of 4.2m. Each turbine has 3 blades (b) and operates at an average rotational speed (Ω) of 11.4rpm. The proposed operational lifetime of 35 years, with turbines expected to be operational approximately 85% of the time.

The blade profile of the turbines is presented in Table 7 - 6 - 32. This table provides the chord width values at 20 evenly spaced points along the blade, expressed relative to the maximum chord width. In this context, r denotes the distance from the hub, and R represents the total blade length (i.e., the rotor radius). The ratio r/R therefore represents the relative radial position along the blade, where 0 corresponds to the hub and 1 corresponds to the blade tip. Similarly, c represents the chord width at a given distance (r) from the hub, and C is the maximum chord width of the blade. Therefore, the ratio c/C represents the relative chord width.

Table 7 - 6 - 32 Blade profile of the turbines

r/R	c/C
0.00	0.690
0.05	0.730
0.10	0.790
0.15	0.880
0.20	0.960
0.25	1.000
0.30	0.980
0.35	0.920
0.40	0.850
0.45	0.800
0.50	0.750
0.55	0.700
0.60	0.640
0.65	0.580
0.70	0.520
0.75	0.470
0.80	0.410
0.85	0.370
0.90	0.300
0.95	0.240
1.00	0.000

4.2 Bird Survey Scenario

In this example, bird surveys were conducted at the proposed wind farm site for a two year period (April 2023 to March 2025). Vantage point surveys to monitor flight activity were undertaken at two vantage

points. The combined viewsheds from these vantage points provided at least 500m coverage around all turbines in addition to coverage of the site and surrounds (Figure 7 - 6 - 1). The total viewshed area was 5.23km² for VP1 and 5.92km² for VP2.

Both vantage points were surveyed for 6 hours per month throughout the survey period, totalling 144 hours of survey at each location. For each recorded flight, the duration (in seconds) that bird spent within pre-defined height bands was recorded. These heights bands were:

- Band 1 = 0-15m
- Band 2 = 15-25m
- Band 3 = 25-200m
- Band 4 = 200m+

As the risk height range of the turbine is 30-180m, all flight activity in Band 3 is considered to be at potential collision height.

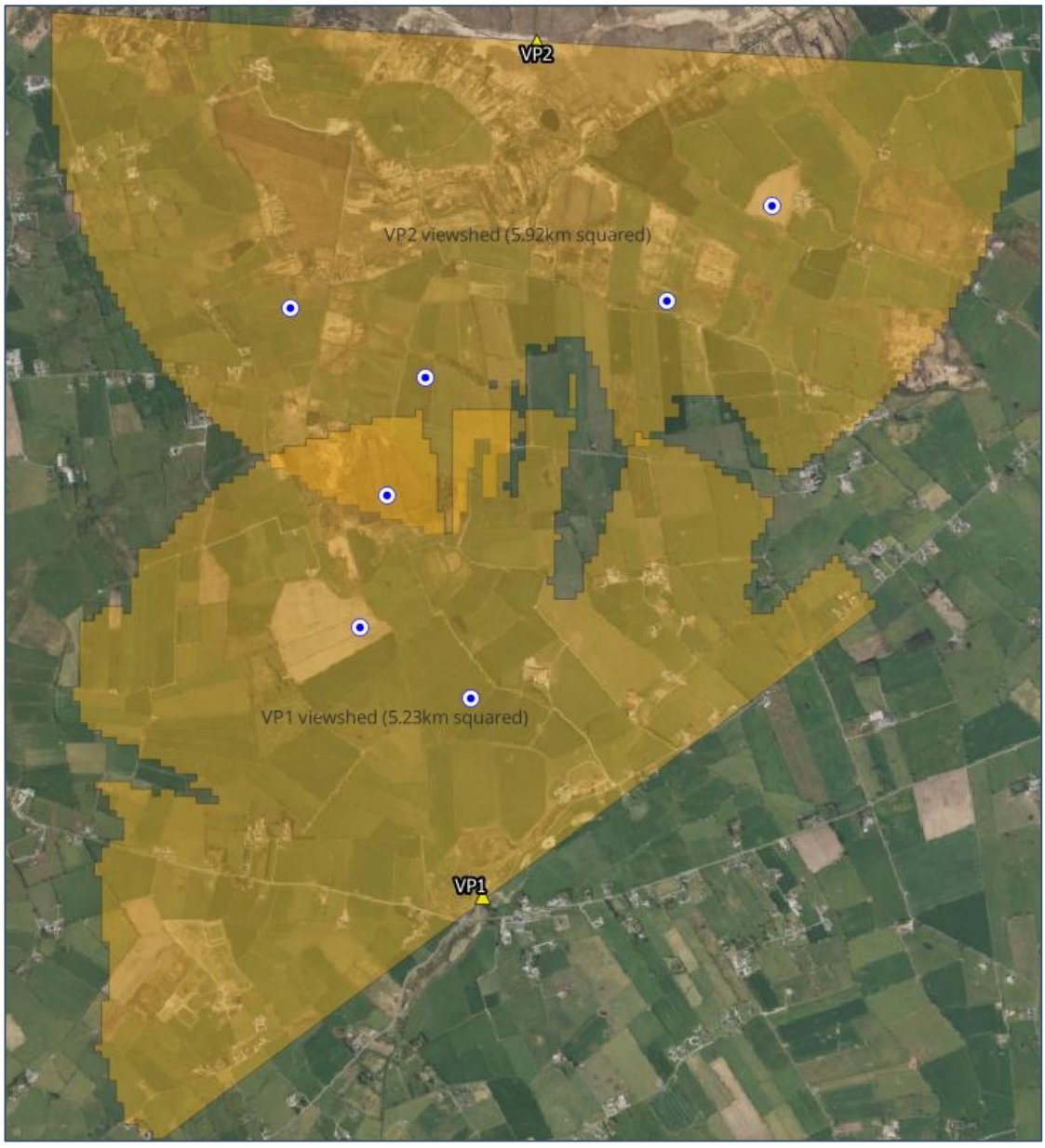

Figure 7 - 6 - 1 Vantage point survey locations and viewshed areas

In this example, a collision risk model will be conducted for the species sparrowhawk. All records for sparrowhawk collected during vantage point surveys are presented in Table 7 - 6 - 33. Records denoted '-' represent non-flight activity, for example when a bird is perched.

The data in Table 7 - 6 - 33 shows that sparrowhawk was present at the site throughout the survey period, in both the breeding and winter season. Therefore, all months of the year will be modelled.

Table 7 - 6 - 33 Sparrowhawk records from vantage point surveys

VP	Date	Time	Species	Number	Band 1	Band 2	Band 3	Band 4
VP2	17/11/2023	07:36	Sparrowhawk	1	17	0	0	0
VP2	17/11/2023	07:43	Sparrowhawk	1	-	-	-	-
VP1	12/12/2023	11:24	Sparrowhawk	1	-	-	-	-
VP1	12/01/2024	12:14	Sparrowhawk	2	14	0	15	0
VP2	30/01/2024	11:34	Sparrowhawk	1	87	0	0	0
VP2	21/02/2024	16:19	Sparrowhawk	1	35	0	0	0
VP1	14/03/2024	11:48	Sparrowhawk	1	50	12	0	0
VP1	03/05/2024	11:25	Sparrowhawk	2	19	0	0	0
VP2	09/05/2024	09:56	Sparrowhawk	1	6	0	0	0
VP1	19/06/2024	10:14	Sparrowhawk	1	15	3	0	0
VP1	19/06/2024	14:22	Sparrowhawk	1	0	0	139	0
VP1	09/07/2024	16:56	Sparrowhawk	1	21	0	0	0
VP2	26/07/2024	13:37	Sparrowhawk	1	17	0	0	0
VP1	03/10/2024	14:02	Sparrowhawk	1	32	9	0	0
VP1	06/11/2024	12:15	Sparrowhawk	1	14	4	0	0
VP1	29/11/2024	13:09	Sparrowhawk	1	0	18	81	0
VP1	29/11/2024	15:57	Sparrowhawk	1	16	0	0	0
VP2	31/01/2025	13:07	Sparrowhawk	1	20	48	0	0
VP2	13/03/2025	08:46	Sparrowhawk	1	0	83	0	0

4.3 Stage A: Flight Activity

Aerial bird density

In order to calculate the aerial bird density (D_A) for sparrowhawk, the following formula was used:

$$DA = b / (t \times A) \text{ bird-seconds } m^2$$

To calculate parameter b, the number of 'bird-seconds' per month per vantage point was calculated by multiplying the number of birds aloft by the duration of the flight (in seconds). This included time spent in all recorded height bands, not just those bands within potential collision height. These values are presented in Table 7 - 6 - 34. Note that sparrowhawk was not recorded in every month, therefore some months are not present in the table.

Table 7 - 6 - 34 Bird-seconds per vantage point per month

Month	Vantage Point	Bird-Seconds
Jan	VP1	58
Mar	VP1	62
May	VP1	38
Jun	VP1	157
Jul	VP1	21

Month	Vantage Point	Bird-Seconds
Oct	VP1	41
Nov	VP1	133
Jan	VP2	155
Feb	VP2	35
Mar	VP2	83
May	VP2	6
Jul	VP2	17
Nov	VP2	17

Parameter t, the time that the vantage point was watched, was obtained from the survey effort. The breakdown of survey time at each vantage point is presented in Table 7 - 6 - 35.

Table 7 - 6 - 35 Survey time at each vantage point in hours and seconds according to month

Vantage Point	Month	Time in hours	Time in seconds
VP1	Jan	12	43200
VP2	Jan	12	43200
VP1	Feb	12	43200
VP2	Feb	12	43200
VP1	Mar	12	43200
VP2	Mar	12	43200
VP1	Apr	12	43200
VP2	Apr	12	43200
VP1	May	12	43200
VP2	May	12	43200
VP1	Jun	12	43200
VP2	Jun	12	43200
VP1	Jul	12	43200
VP2	Jul	12	43200
VP1	Aug	12	43200
VP2	Aug	12	43200
VP1	Sep	12	43200
VP2	Sep	12	43200
VP1	Oct	12	43200
VP2	Oct	12	43200
VP1	Nov	12	43200
VP2	Nov	12	43200
VP1	Dec	12	43200
VP2	Dec	12	43200

Parameter A is the entire area of the vantage point viewsheds. As described above, these were:

- VP1 = 5.23km^2
- VP2 = 5.92km^2

The aerial bird density (D_A) was calculated for all vantage points, and then a mean value was obtained for each month. For example, D_A for January was calculated as:

VP1
b = 58
t = 43200
A = 5.23
D_A = 0.0002563467

VP2
b = 155
t = 43200
A = 5.92
D_A = 0.0006055715

Mean D_A for the month of January

(0002563467 X 0.0006055715)/2 = 0.0004309591

D_A for all months is presented in Table 7 - 6 - 36. Zero is input for months in which sparrowhawk was not recorded.

Table 7 - 6 - 36 Aerial bird density

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.0004	0.0001	0.0003	0	0.0001	0.0003	0.0001	0	0	0.0001	0.0003	0

Proportion of birds flying at risk height

The proportion of sparrowhawk flying at risk height (Q_AR) was calculated from the survey data in Table 7 - 6 - 33. Note that non-flight records are excluded from this calculation.

First, for each height band, the proportion of flights within that band relative to the total number of flights was calculated. Second, the proportion of each height band overlapping the rotor risk height (30-180m) was determined. Finally, these two proportions were multiplied. The workings for Band 3 (25-200m) are below.

Band 3
Total number of sparrowhawk flights = 17
Total number of sparrowhawk flights in band = 3
Proportion of flights in band = 0.176
Proportion of band overlapping rotor risk height = 0.858
0.176 X 0.858 = 0.151

This calculation was made for all bands. Then, the result from each band was summed to provide a total proportion of birds flying at risk height. Note that the result for bands that do not overlap with rotor risk height will be 0. Because Band 3 was the only band that overlapped with rotor risk height in this example, the final proportion of birds flying at risk height (Q_AR) was 0.151 or 15.1%.

Photoperiod

The photoperiod at the latitude of the site was acquired for the survey period. The daylight and nighttime hours per month (tday and tnight respectively) are shown in Table 7 - 6 - 37. The total daylight hours was 4,487.093 and night-time hours was 4,272.907.

Table 7 - 6 - 37 Photoperiod

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daylight Hours	251.5	273.7	366.3	418.6	491.5	507.3	510.3	459.0	382.6	329.7	261.0	235.6
Nighttime Hours	492.5	398.3	377.7	301.4	252.5	212.7	233.7	285.0	337.4	414.3	459.0	508.4

4.4 Stage B: Number of Flights Through Rotors

To estimate the number of sparrowhawk flights through the rotors, firstly the total rotor frontal area for all turbines was calculated as:

$$\text{rotor frontal area} = T\ \pi R^2$$

where T is the number of turbines. In this example, that is 7 X π X 75^2 = 123700.2m^2

Sparrowhawk biometrics were taken from the best available literature:

- Length (l) = 0.33m
- Wingspan (w) = 0.625m
- Flight speed (v) = 10m/s
- Flight type = flapping
- Nocturnal activity ranking (fnight) = 1 (0% nighttime activity)

Using the values from previous sections, the density (D_v) for each month was calculated as:

$$Dv = (D_\lambda * Q_2R)/(2*R)$$

Then the projected number of transits through the rotor risk area was calculated as:

$$\text{transits} = v * Dv * \text{rotor frontal area} * ((tday + (tnight * (fnight/100))) * 3600)$$

In this example, the density for the month of January was (0.0004 X 0.151)/(2 X 75) = 4.349921^{-13}

The number of transits for the month of January was 10 X 4.349921^{-13} X 123700.2 X ((251.519 + (492.481 X (0/100))) X 3600) = 0.4872201. Table 7 - 6 - 38 shows the projected number of transits for all months. Note that a zero is input for months in which sparrowhawk was not recorded.

Table 7 - 6 - 38 Number of transits per month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.487	0.084	0.493	0	0.211	0.791	0.183	0	0	0.134	0.384	0

4.5 Stage C: Probability of Collision

The probability of a sparrowhawk collision during a single rotor transit was calculated. Sparrowhawk biometrics, flight behaviour and the turbine specifications outlined in the previous sections were used to define how the bird interacts with the moving blades and derive the geometric parameters described below. Collision probability was determined separately for upwind and downwind flight directions. It was calculated as a function of radial position across the rotor disc, at increments of 0.05 from 0.05 to 1.0 (excluding the rotor centre).

At each radial position, collision probability was calculated for flight angles at increments of 10° from 0° to 180°, which assumes a uniform distribution of bird approach angles. For each flight angle, the flight angle (Φ) was converted from degrees to radians and turbine rotation speed (Ω) was converted from rpm to radians per second. The dimensionless radial position (radius) was converted to an absolute distance from the hub in metres. Then, the blade chord width at the radial position was estimated by interpolating the blade profile and scaling it by the maximum chord width, to reflect blade width changes from hub to tip. Flight direction (d) was set as 1 for upwind flight directions and -1 for downwind.

A standard dimensionless blade encounter rate multiplier was defined as:

$$b\ \Omega/2\ \pi v$$

where b is number of blades, Ω is rotation speed (now in rad s^{-1}), and v is bird flight speed.

The ratio of bird speed to blade tangential speed (α) was calculated as:

$$\alpha = v/\text{radius}\ \Omega$$

The blade pitch (λ) was converted from degrees to radians to obtain the blade tilt angle (θ) relative to the rotor plane:

$$\theta = \lambda\pi/180$$

Using these values, two collision lengths were calculated. The first was a blade-related component (accounting for blade chord width [c], blade tilt [θ], bird flight direction [d] and the ratio of bird speed to blade tangential speed [α]), which represents the effective 'interaction length' associated with blade motion and geometry:

$$|\ d\ c\ \sin(\theta)+\alpha\ c\ \cos(\theta)|$$

The second was a bird-size-related component (accounting for body length [l], wingspan [w] and flight type):

$$\max(l, w_{eff}\ \alpha)$$

Here, w_{eff} is the effective wingspan. For flapping flight, the full wingspan was used, but for gliding flight, the wingspan would be reduced by the absolute value of the cosine of the flight angle relative to the rotor plane (Φ) to represent the reduced projected cross-section when the bird's wings are angled relative to the rotor plane.

Finally, the collision probability was calculated as the blade encounter rate multiplier multiplied by the sum of the two collision lengths. The result is capped at a maximum of 1 so that probabilities cannot exceed 100%. This collision probability was then averaged over the flight angles at the radial position. The upwind and downwind collision probabilities calculated for each radial position for sparrowhawk are presented in Table 7 - 6 - 39.

Table 7 - 6 - 39 Upwind and downwind collision probabilities

Radial Position	Upwind	Downwind
0.05	0.486082	0.449547
0.1	0.269631	0.230093
0.15	0.204551	0.160508
0.2	0.171557	0.123511
0.25	0.1502	0.100152
0.3	0.130199	0.081152
0.35	0.11173	0.065686
0.4	0.096588	0.054047
0.45	0.086103	0.046065
0.5	0.077465	0.039929
0.55	0.070171	0.035137
0.6	0.06319	0.031159
0.65	0.057052	0.028024
0.7	0.051576	0.025551

Radial Position	Upwind	Downwind
0.75	0.047235	0.023713
0.8	0.042698	0.022178
0.85	0.039644	0.021126
0.9	0.035181	0.020167
0.95	0.031534	0.019522
1	0.01881	0.01881

Next, the collision probabilities were averaged for flights through the rotor disk for upwind values and downwind values as follows:

$$P = 2[(i=1\sum n-1 r_i p_i)+2p_n]\Delta r$$

Where P is the mean single-transit collision probability (upwind or downwind), r_i is the radial position, p_i is the collision probability at radial position r_i, p_n is the collision probability at the outermost radial position (i.e., the blade tip), $\Delta r = 0.05$ (i.e., the radial increments) and n is the number of evaluated radial positions

The average collision risk for flights through the rotor when moving upwind was calculated as 0.0672, and for downwind as 0.0402. A 50:50 weighting of upwind and downwind flight was assumed. Thus, the final probability of a sparrowhawk collision during a single rotor transit was calculated as the weighted average of these two estimates. The estimated probability of collision for a sparrowhawk during a single rotor transit was 0.0537.

4.6 Stage D Expected Collisions

The outputs of stage B and C were multiplied to yield the expected collision rate for sparrowhawk, and the product was multiplied by the proportion of time the wind farm is expected to be operational. In this example, the expected collisions for January was calculated as:

$$0.487 \text{ X } 0.0537 \text{ X } 0.85 = 0.02224467$$

The predicted number of collisions for each month is presented in Table 7 - 6 - 40. Note that these rates assume no avoidance of turbines or wind farms by sparrowhawk.

Table 7 - 6 - 40 Expected collisions per month (without avoidance)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.022	0.004	0.023	0.000	0.010	0.036	0.008	0.000	0.000	0.006	0.018	0.000

4.7 Stage E Allowing for Avoidance and Attraction

Stage E of the modelling process takes account of the proportion of sparrowhawk likely to avoid the wind farm or its turbines. This is calculated for a range of avoidance factors: 95%, 98%, 99% and 99.5%. The expected collisions per month calculated in stage D are multiplied by the avoidance rates to provide a collision rate with avoidance. These values are presented in Table 7 - 6 - 41.

Table 7 - 6 - 41 Expected collisions per month (with avoidance)

Avoidance Factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.95	0.0011	0.0002	0.0011	0.0000	0.0005	0.0018	0.0004	0.0000	0.0000	0.0003	0.0009	0.0000

Avoidance Factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.98	0.0004	0.0001	0.0005	0.0000	0.0002	0.0007	0.0002	0.0000	0.0000	0.0001	0.0004	0.0000
0.99	0.0002	0.0000	0.0002	0.0000	0.0001	0.0004	0.0001	0.0000	0.0000	0.0001	0.0002	0.0000
0.995	0.0001	0.0000	0.0001	0.0000	0.0001	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000

4.8 Stage F: Uncertainty

To provide a measure of uncertainty in aerial density (u1), the relative standard deviation for the monthly values was used. First, the mean aerial density ($\overline{D_\lambda}$) for all months was calculated to be 0.0001445. Then, the relative standard deviation (RSD) was calculated as:

$$RSD = s / \overline{D_\lambda}$$

where s is the standard deviation of the monthly values. In this example:

$$0.00015/0.0001445 = 1.038062$$

Note that zero values (i.e., months in which the sparrowhawk was not recorded, such as April) were retained in this equation as they may represent true absence or intermittent use of the site.

Uncertainty due to simplifications in the collision risk model (u2) was assumed to be 20% (Band, 2024). Finally, uncertainty due to design options (u3) was considered to be 28%, as 4 of 14 turbine specifications were either not finalised or were approximate (blade profile, pitch, rotational speed and expected time operational). The overall range of uncertainty (u) was thus:

$$\sqrt{(u1^2 + u2^2 + u3^2)}$$

In this example, that is:

$$\sqrt{(1.038062^2 + 0.2^2 + 0.28^2)} = 1.093605$$

4.9 Worked Example Collision Rates

To provide a best estimate of the collision rate for sparrowhawk, the guidance on avoidance rates provided by NatureScot in NatureScot (2025b) was consulted. This guidance recommends a 98% avoidance rate for sparrowhawk. As such the predicted number of collisions corresponding to a 98% avoidance rate was identified and is presented in Table 7 - 6 - 42, along with the range of uncertainty and an estimation of the number of years for one collision to occur.

The column 'Annual Collision Rate' in Table 7 - 6 - 42 presents the final predicted annual collision rate for sparrowhawk that would be used in the impact assessment for this proposed development scenario: 0.0025 sparrowhawk per year. Due to the uncertainties discussed in stage F, this may range up to 0.0052 sparrowhawk per year. Dividing 1 by 0.0025 provides the number of years it would be expected for a collision to occur based on the model predictions.

Table 7 - 6 - 42 Predicted annual collision rate

Species	Annual Collision Rate	Range of Uncertainty	Years to one collision
Sparrowhawk	0.0025	0-0.0052	395

5. BIBLIOGRAPHY

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