Environmental Impact Assessment Report

Teindland Wind Farm

Volume 3

TA A7.2: Collision Risk Modelling Calculations

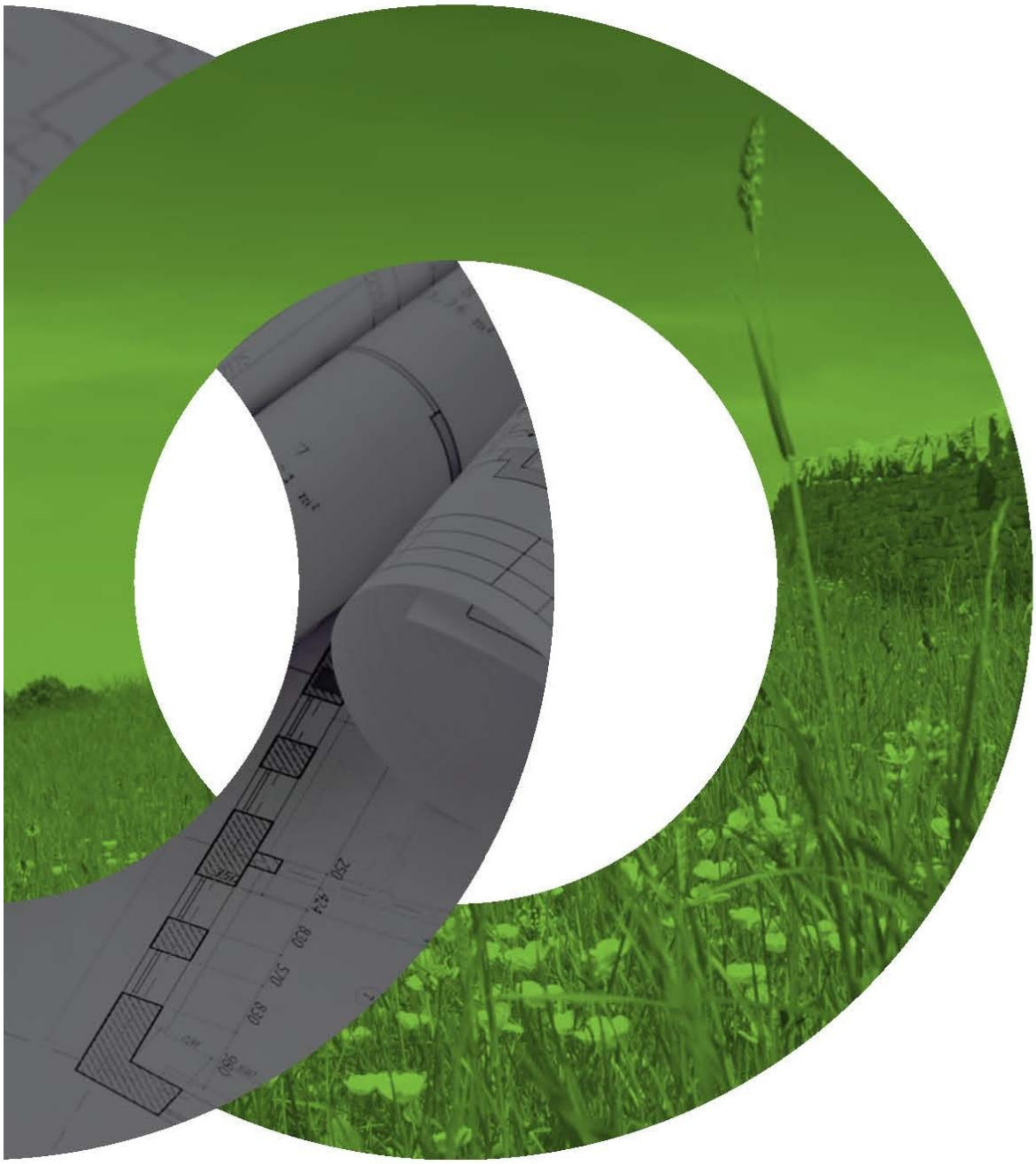
Document prepared by Envams Ltd for: Teindland Wind Farm Ltd

April 2025

Teindland Wind Farm

Environmental Impact Assessment (EIA) Report

Technical Appendix A7.2: Collision Risk Modelling Calculations



avian ecology

CONTENTS

1 INTRODUCTION

1.1.1 This Technical Appendix has been prepared to accompany **Chapter 7: Ornithology** of the Environmental Impact Assessment (EIA) Report for the proposed Teindland Wind Farm ('the Development').

1.1.2 This Technical Appendix presents details of the Collision Risk Modelling (CRM) calculations undertaken to establish the potential impact of collision mortality upon relevant ornithological interests, as a result of the Development.

1.1.3 This Technical Appendix should be read in conjunction with **Technical Appendix A7.1: Ornithology Baseline Report**, which provides full details of baseline survey methods and results, including the Vantage Point (VP) flight activity surveys that informed the CRM calculations.

2 METHODOLOGY

2.1 Background

2.1.1 Baseline ornithology surveys undertaken for the Development included VP flight activity surveys, which recorded flight activity of 'target species' (see **Technical Appendix A7.1: Ornithology Baseline Report**) in the vicinity of proposed turbine locations. The results of the VP flight activity surveys have been used to estimate potential collision mortality risk using CRM analysis.

2.1.2 NatureScot advocate use of the model devised by Band *et al.* (2007[1]) and which has recently been updated (Band, 2024[2]). It should be noted that the CRM reported upon herein was started before the most recent CRM guidance was published and so does not fully follow the methodology set out in Band (2024). However, the main aim of the updated guidance is to standardise the approach to CRM and the previous approach is still considered valid. Band (2024) states that the methods are 'mathematically equivalent' and that the estimates produced using the updated CRM 'should not differ substantially from those deriving from... earlier SNH [now NatureScot] guidance'.

2.1.3 The NatureScot CRM estimates collision mortality risks in three stages:

- Stage 1: estimation of the number of birds passing through the rotor swept volume of the wind farm, using observed flight activity data, and based on:
    - The amount of flight activity recorded in the vicinity of the wind farm;
    - The area watched (VP-specific viewsheds); and
    - The time spent watching the surveyed area (survey effort per VP per month);
- Stage 2: estimation of collision likelihood, i.e. the probability of a bird flying through the rotor swept volume being hit, based on bird and wind farm parameters (where all collisions are assumed to be fatal). This provides an estimate of how many fatal collisions could occur, in theory, should birds take no avoiding action; and,

[1] 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.F.E. & Ferrer, M. (Eds.) *Birds and Wind Farms: Risk Assessment and Mitigation*, pp. 259- 275. Quercus, Madrid.
[2] Band, W. (2024). *Using a collision risk model to assess bird collision risks for onshore wind farms*. NatureScot Research Report 909.

- Stage 3: application of appropriate avoidance factors, whereby it is assumed birds take action to avoid collision.

2.2 Wind Farm Parameters

2.2.1 The Development comprises 12 wind turbines. Tip height will vary, with eight turbines having a proposed tip height of 230 m and four turbines having a proposed tip height of 200 m. The specifications of the proposed turbines are yet to be determined, with the turbine models under consideration having a minimum rotor diameter of 162 m and a maximum rotor diameter of 173 m. This means that minimum rotor swept height would be 27 m and maximum rotor swept height would be 230 m; and this range that has been applied in the CRM analysis, across all turbine locations. This has resulted in a precautionary approach, as this suggests a rotor diameter of 203 m, which is clearly well above the dimensions of the largest turbine proposed.

2.2.2 All flights recorded in a height band that overlaps with the height range of 27 – 230 m are considered to represent flight activity at potential collision height (PCH) (see **Section 2.5**).

2.2.3 For the purposes of CRM analysis, the flight risk volume (Vw) has been calculated based on applying a single, continuous 300 m buffer around the outermost turbine locations and with a height determined by PCH. Any flights recorded during the VP surveys that passed through the 300 m buffer (the 'collision risk zone' (CRZ)) at PCH were considered to represent flights at risk of collision (hereafter 'at-risk' flights).

2.2.4 The 300 m buffer around the turbine envelope used to determine the CRZ is considered to be a precautionary approach, as in reality only flight activity within rotor radius of proposed turbines (maximum of 86.5 m) would be at-risk flights. The 300 m buffer (rotor radius rounded up to 100 m plus an additional 200 m) more than compensates for any small mapping errors that may have inadvertently occurred during field recording and also allows for turbine micro-siting during the design process without need to rerun the CRM. The area within the CRZ equates to a total of 541.44 ha (turbine envelope without a 300 m buffer applied equals 232.55 ha).

2.2.5 The CRM for 'directional flights' (see below) uses the width of the wind farm to calculate the cross-sectional area through which the birds would pass. The value used for the width of the wind farm is the maximum width of the Development, which is the distance between the northernmost and southernmost turbines (plus a 300 m buffer). This means that birds would actually only be exposed to the full 'risk window' if the directional flight is on an east/west axis.

2.2.6 Turbine parameters used in the analysis are summarised in **Table 2.1**. Where certain details were not available, a representative value has been utilised.

2.2.7 Calculations have assumed an operational downtime for turbines of 15% (average across the year).

Table 2.1: Wind farm parameters used in collision risk model.

Parameter	Value	Unit
Wind farm area (300m turbine buffer)	541.44	hectares
Width of wind farm (maximum) (300m turbine buffer)	2097.85	metres
No. of turbines	12	-
No. of blades (per turbine)	3	-
Tip height	200 - 230	metres
Hub height	113.5 – 149.0	metres
Rotor diameter	162 - 173	metres

Parameter	Value	Unit
Rotor radius	81.0 – 86.5	metres
Max chord	4.3	metres
Pitch	10	degrees
Rotation period	7.0	seconds
Operationally active	85	%

2.3 Viewsheds

2.3.1 Flight activity data of target species for use in the CRM analysis have been obtained using baseline surveys from three VP locations (see **Technical Appendix A7.1: Ornithology Baseline Report**). The same VP locations were used throughout the baseline survey period (April 2021 to March 2023).

2.3.2 The visible survey areas from the VP locations utilised during baseline surveys, using a 2km viewshed radius (detection distance) and a 20 m above the ground cut-off are illustrated in **Figure 7.1**.

2.3.3 For limitations in survey coverage please see **Technical Appendix A7.1: Ornithology Baseline Report**. There are not considered to be any substantive limitations with the data gathered.

2.3.4 Details of the VPs used during the flight activity surveys are presented in **Table 2.2**, and this includes the area of viewshed visibility within the CRZ (300 m buffer around turbines) for each VP, which has been used to determine activity per area in the CRM analysis. Note that prior to analysis, the viewsheds were snipped to remove the small overlap between VPs 1 and 2, with the overlapping area allocated to VP2 and removed from the viewshed of VP1. This was done to prevent any potential duplication in recorded flight activity, as both VPs were occasionally done at the same time. The values for 'visible area within the wind farm' presented in **Table 2.2** account for this.

Table 2.2: VP locations and visibility.

VP name	Grid reference	Visible area within wind farm collision risk zone turbine envelope + 300 m buffer
VP1	NJ 28224 52033	171.65 ha
VP2	NJ 28085 53091	207.93 ha
VP3	NJ 29238 54092	136.83 ha

2.4 Vantage Point Survey Effort

2.4.1 Flight activity per unit of time is a component of the calculations. This requires the inclusion of survey effort (hours completed per VP), as summarised in **Table 2.3**.

Table 2.3: VP flight activity survey effort (hours)

Year 1 (2021-2022)													Total VP hours
VP	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
1	6	6	12	6	9	6	6	6	6	6	6	6	**81**
2	6	6	12	6	9	6	6	6	6	6	6	6	**81**
3	6	6	9	15	6	6	6	6	6	6	3	6	**81**

Year 2 (2022-2023)													Total VP hours
VP	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
1	6	6	12	9	6	6	6	6	6	6	6	6	**81**
2	6	6	12	9	6	6	6	6	6	6	6	6	**81**
3	6	0	18	9	6	6	6	6	6	6	6	6	**81**

2.5 Identification of 'At-Risk' Flight Activity

2.5.1 Full details of all target species flights recorded during the VP flight activity surveys are presented in **Technical Appendix A7.1: Ornithology Baseline Report**. However, only those flights considered to be at-risk are included in the CRM analysis.

2.5.2 During baseline surveys, flight activity of target species was recorded using the height bands (HT) shown in **Table 2.4**.

Table 2.4: Height bands used for recording during baseline surveys.

Height band	Height range
1	<25 m
2	25-40 m
3	40-150 m
4	150-180 m
5	>180 m

2.5.3 All target species flights recorded in a height band that overlapped with rotor swept height (27 – 230 m) have been taken to represent at-risk flight activity. Therefore, all flights recorded with time in HT 2 - 5 are considered as being at-risk, with only flights that were exclusively in HT1 initially removed from the CRM analysis. It is highly likely that this approach will have over-estimated risk, however, as many flights recorded at HT5 will actually have been passing high over the Site, and above rotor swept height (200 – 230 m).

2.5.4 Therefore, the survey data was further investigated to identify any records for which it was specifically noted that the flight passed over at high altitude and which could be taken as referring to being above at-risk height. For the large majority of records this information was not noted, but it did lead to the removal of one osprey flight.

2.5.5 In the case of pink-footed goose, where it can reasonably be presumed that the flocks recorded were mostly birds overflying on migration, it was considered appropriate to compensate for HT5 encompassing all flights above 180 m. A NatureScot paper (Patterson, 2015)[3], determined that pink-footed goose flight height in northeast Scotland, for long-distance movements (i.e., flights that were not between roosting and foraging sites), 46.1% of these flights were above 300 m (36.5% were below 200 m). Therefore, a conservative estimate of 50% of the geese recorded at HT5 have been considered as being at-risk, for those flights which were exclusively recorded at HB5. This apportionment was not

[3] Patterson, I.J. 2015. *Goose flight activity in relation to distance from SPAs in Scotland, including an analysis of flight height distribution*. Scottish Natural Heritage Commissioned Report No. 735.

undertaken where only part of the flight was recorded in HB5. The numbers presented for at-risk flights refer to numbers following application of this correction factor.

2.6 Identification of Ornithological Features for Analysis

2.6.1 The target species recorded as having potential at-risk flights (within the CRZ at PCH) are listed in **Table 2.5**. Full details of these flights provided in **Annex 1**.

Table 2.5: Target species flight activity - 'at risk' flights (April 2021 to March 2023)

Species	Number of flights	Number of individuals
Curlew	1	1
Goshawk	14	15
Greylag goose	2	43
Hobby	1	1
Lapwing	1	2
Osprey	70	83
Pink-footed goose	45	4,872

2.6.2 Collision mortality risk estimates have only been calculated for ornithological interests for which there is a potential for a significant effect. For species with few at-risk flights and recorded in very low numbers during baseline surveys, it can reasonably be predicted that the risk of collision mortality would be very small (negligible impact at any population level) and no significant effect can be concluded for these ornithological interests without the requirement for undertaking a detailed assessment.

2.6.3 For the purposes of the analysis, a target species qualified for CRM if there were three or more at-risk flights (or ten or more individuals) within the two year baseline survey period. The species that met these criteria were **pink-footed goose**, **goshawk** and **osprey** (>3 flights and >10 individuals), plus **greylag goose** (>10 individuals).

2.6.4 In accordance with NatureScot guidance**Error! Bookmark not defined.**, CRM analysis is only undertaken for pink-footed goose where a site is considered to have connectivity with a relevant protected area. The wintering foraging range of pink-footed goose is 15 – 20 km (SNH, 2016[4]) and thus the Site has theoretical connectivity with the Moray and Nairn Coast Special Protection Area (SPA), which is 5 km from the Site. Thus, CRM analysis was undertaken for pink-footed goose.

2.7 Species Parameters

2.7.1 The CRM analysis uses parameters for each species to calculate collision risk. The parameters used are presented in **Table 2.6**. Parameters are primarily taken from Snow and Perrins (1998)[5] (biometrics)

---

[4] Available at: https://www.nature.scot/professional-advice/planning-and-development/planning-and-development-advice/renewable-energy/onshore-wind-energy/wind-farm-impacts-birds (Accessed February 2025).

[5] Snow, D. W. & Perrins, C. M. (1998). *The Birds of the Western Palearctic. Concise Edition*. Oxford University Press.

and Alerstam *et al*. (2007)[6] (flight speeds), with avoidance rates taken from NatureScot guidance (SNH, 2018[7]). Biometrics (bird length and wingspan) are average measurements.

Table 2.6: Target species parameters.

Species	Length (m)	Wingspan (m)	Flight Speed (m/s)	'Gliding' or 'flapping' flight	Avoidance Rate (%)
Greylag goose	0.83	1.64	17.1	Flapping	99.8
Pink-footed goose	0.68	1.53	16.8*	Flapping	99.8
Goshawk	0.55	1.50	11.3*	Flapping	98.0
Osprey	0.57	1.58	13.3	Flapping	98.0

*Values not provided in Alerstam *et al*. (2007). Flight speeds are those of congener species: sparrowhawk has been used for goshawk and for pink-footed goose the average has been taken from the flight speeds of greylag goose, white-fronted goose and bean goose.

2.7.2 Based on the flightlines recorded, goshawk and osprey were classified as having 'non-directional' (random) flights; whilst greylag goose and pink-footed goose were classified as having directional flights (commuting on a straight path across the Site).

2.7.3 The time period in which the ornithological features are likely to be present in the vicinity of the Development is considered in the analysis, with mortality estimates presented for each season (breeding and non-breeding), where applicable. The time periods used are species-specific breeding seasons, taken from NatureScot guidance (SNH, 2014[8]). These time periods differ from the more generic breeding and non-breeding seasons used to determine overall survey effort for the VP flight activity surveys.

2.7.4 The seasons used in the calculations for each of the identified species are presented in **Table 2.7**. Note that for goshawk the breeding season is actually given as mid-March to mid-August and for greylag goose it is given as April to mid-August; but complete calendar months have been used in the CRM analysis for ease.

2.7.5 Ospreys are generally only present in Scotland during the breeding season and pink-footed geese are generally only recorded in Scotland in the non-breeding season. For pink-footed goose, the non-breeding season has been taken to include the full period in which this species was recorded during the baseline surveys.

Table 2.7: Species-specific seasons used in the CRM analysis.

Species	Breeding Season	Non-breeding Season
Greylag goose	April to August	September to March
Pink-footed goose	-	September to May
Goshawk	March to August	September to February
Osprey	April to August	-

[6] Alerstam T., Rosén M., Bäckman J., Ericson P.G.P., and Hellgren O. (2007). Flight speeds among bird species: allometric and phylogenetic effects. *PLoS Biol*, 5, 1656-1662

[7] SNH (2018). *Avoidance Rates for the onshore SNH Wind Farm Collision Risk Model. September 2018 v2*. NatureScot (formerly Scottish Natural Heritage), Inverness.

[8] SNH (2014). https://www.nature.scot/doc/bird-breeding-season-dates-scotland (Accessed February 2024)

2.7.6 For each identified species, the potential number of active hours within each season has been calculated following Forsythe *et al.* (1995[9]), using a latitude of 57.568754 (the latitude of the central part of the Site). For each species, 'active hours' correspond with daylight hours. Although geese may migrate at night, such activity is assumed to happen above at-risk height.

2.7.7 Previous NatureScot guidance (based on Band *et al.*, 2007)[1], used a 'collision probability' value for inclusion in the calculations and this is the approach that has been used in this analysis. These values have been calculated using the previously available NatureScot spreadsheet.

- Greylag goose – 5.4%;
- Pink-footed goose – 5.1%;
- Goshawk – 5.3%; and
- Osprey – 5.2%.

2.7.8 Examples of the collision probability calculations are presented in **Annex 2**, with these shown for pink-footed goose and osprey.

3 COLLISION MORTALITY RISKS

3.1.1 **Table 3.1** presents a summary of the annual collision mortality estimates calculated for the four at-risk species for which CRM analysis was undertaken.

3.1.2 Examples of collision mortality risk calculations are provided in **Annex 3**, covering a species with directional flights, pink-footed goose (calculations provided for one non-breeding season (2021/22) only), and one species with non-directional flights, osprey (both years presented). Full workings for all species can be provided upon request.

3.1.3 In **Table 3.1**, seasons when the species is absent from Scotland are shaded out. Seasons when the species is present, but no at-risk flights were recorded have been given an estimate of 0.000.

3.1.4 Where mortality risks were calculated for both the breeding and non-breeding seasons, both estimates are provided, and these are then summed to provide an annual estimate. Estimates were calculated for both survey years (Year 1: April 2021 to March 2022 and Year 2: April 2022 to March 2023) and an average is presented.

3.1.5 The mortality estimates are considered to be precautionary, based on the approach that has been used, and which is set out in this document.

3.1.6 The collision mortality risk estimates should also not be concluded as the number of bird deaths that will definitely occur as a result of the Development. The estimates are best treated as an indication as to the relative level of risk.

[9] Forsythe, W.C., Rykiel, Jr., E.J., Stahl, R.S., Wu, H. and Schoolfield, R.M. (1995). A Model Comparison for Daylength as a Function of Latitude and Day of the Year. *Ecological modelling*, 80, 87-95.

Table 3.1: Collision mortality estimates.

Species	Occupancy	Collision Mortality Estimate		
		Year 1	Year 2	Average
Greylag goose	Breeding season	0.000	0.000	0.000
	Non-breeding season	0.154	0.000	0.077
	Annual estimate	**0.154**	**0.000**	**0.077**
Pink-footed goose	Breeding season	-	-	-
	Non-breeding season	7.738	6.219	6.979
	Annual estimate	**7.738**	**6.219**	**6.979**
Goshawk	Breeding season	0.021	0.115	0.068
	Non-breeding season	0.042	0.044	0.043
	Annual estimate	**0.063**	**0.159**	**0.111**
Osprey	Breeding season	0.498	0.963	0.731
	Non-breeding season	-	-	-
	Annual estimate	**0.498**	**0.963**	**0.731**

4 COLLISION MORTALITY RISKS FOLLOWING MITIGATION

4.1.1 As set out in **Chapter 7: Ornithology**, mitigation for ospreys would include the relocation of an osprey nest away from the Development. By removing this existing nest (when not in use) and by providing alternative nesting platforms elsewhere in the Site there is a high expectation that the pair would be relocated away from the turbines and so reduce the potential collision risk. The nearest artificial platform to the Development would be sited a minimum of 1 km from the nearest proposed turbine.

4.1.2 The relatively high flight activity recorded for osprey in the vicinity of the Development during baseline surveys was closely associated with active nests (see confidential **Figures 7.6a** and **7.6b**). Relocation of the identified nest would therefore also result in the relocation of the associated flight activity. It is clear that following removal of this nest, the level of flight activity in the vicinity of the Development would no longer be characterised by the flight activity data recorded during baseline surveys.

4.1.3 Therefore, the flight activity recorded during the VP surveys, and which has been used to calculate the mortality risks presented above, does not represent the collision risk to osprey following mitigation.

4.1.4 To provide a more realistic assessment that takes into account the proposed mitigation, the CRM has been rerun for osprey. This allows for the change in flight activity that can reasonably be expected following removal of the nest. The cluster of flights directly associated with the identified nest (the northern of the two flight clusters shown on confidential **Figures 7.6a** and **7.6b**) has been removed from the dataset of at-risk flights. This reduced the number of at-risk osprey flights from 70 flights to 22 flights.

4.1.5 Although the occasional flight from a relocated nest may still pass through the CRZ, the updated collision estimate for osprey is considered to be much more representative of the potential risk following mitigation.

4.1.6 **Table 4.1** presents the updated collision mortality estimates for osprey following mitigation. Note that the estimates for the other species remain unchanged as no mitigation to reduce collision risk is proposed for these species.

Table 4.1: Osprey collision mortality estimates following mitigation.

Species	Occupancy	Collision Mortality Estimate		
		Year 1	Year 2	Average
Osprey	Breeding season	0.271	0.234	0.253
	Non-breeding season	-	-	-
	Annual estimate	**0.271**	**0.234**	**0.253**

ANNEX 1: 'AT RISK' FLIGHT ACTIVITY

Table A1.1 presents all at-risk target species flight activity identified for the Development over the full baseline survey period.

The species, number of individuals, total flight duration (in seconds) and duration spent at each height band (recorded at 15 second intervals) is presented.

At-risk flight activity input into the CRM analysis is calculated as a proportional duration for each flight, based on flock size, flock length and duration at collision risk height.

Note that the table includes all osprey flights (pre-mitigation). However, for pink-footed goose the flights listed follow apportionment based on the methods set out in **Section 2.5**. Those that have been apportioned are highlighted in *italics*.

The following British Trust for Ornithology (BTO) species codes are used to denote species: *CU – curlew, GI – goshawk, GJ – greylag goose, HY – hobby, L. – lapwing, OP – osprey and PG – pink-footed goose.*

Table A1.1: 'At-risk' flight activity.

Date	VP	Species	No.	Start_Time	Duration	HT1	HT2	HT3	HT4	HT5	Flight Length (m)
28/04/2021	1	OP	1	08:56	105	45	45	15	0	0	687.101
29/04/2021	2	OP	1	10:05	40	25	0	15	0	0	973.677
06/05/2021	2	PG	50	10:12	138	0	138	0	0	0	238.92
28/04/2022	3	OP	1	07:18	85	0	0	85	0	0	1312.43
16/06/2022	3	OP	1	08:35	30	0	0	0	15	15	1430.45
06/05/2021	2	GI	1	13:17	226	30	196	0	0	0	1205.48
22/11/2022	3	PG	87	08:52	122	0	0	0	122	0	745.924
07/10/2021	1	PG	73	13:17	184	0	0	135	49	0	312.983
26/04/2021	2	OP	1	17:01	35	20	15	0	0	0	450.228
28/04/2021	1	OP	1	11:56	430	10	90	165	165	0	1007.98
24/06/2021	2	OP	1	10:53	209	134	75	0	0	0	8682.03
26/07/2021	2	OP	1	17:27	38	8	30	0	0	0	369.864
28/04/2021	1	OP	1	12:20	125	0	50	45	30	0	85.694
15/12/2021	1	GI	1	09:09	47	0	30	17	0	0	585.637
27/04/2022	2	OP	1	17:43	115	0	30	85	0	0	1045.77
01/07/2021	3	OP	1	09:50	90	0	0	90	0	0	1475.47
26/07/2021	1	OP	1	16:49	60	0	0	15	15	30	1924.02
24/03/2022	*3*	*PG*	*47*	*10:05*	*198*	*0*	*0*	*0*	*0*	*198*	*910.966*
04/03/2022	2	PG	110	07:38	75	0	0	75	0	0	1287.55
06/05/2021	2	OP	1	11:31	70	30	40	0	0	0	531.916
06/05/2021	1	OP	3	14:44	130	0	10	0	0	120	1072.34
24/05/2022	1	OP	1	13:03	297	0	0	180	117	0	3079.51
24/03/2022	3	PG	74	06:14	87	0	0	45	30	12	567.957
06/05/2021	2	OP	1	12:14	525	0	270	255	0	0	1893.37
24/06/2021	1	OP	1	10:31	75	15	45	15	0	0	666.245
24/03/2022	3	PG	67	06:24	92	0	0	90	0	2	166.278
04/03/2022	2	PG	60	07:58	70	0	0	70	0	0	1287.55
26/07/2021	2	OP	1	15:55	74	14	30	30	0	0	755.792
11/03/2022	1	GI	1	09:24	140	30	110	0	0	0	202.144
06/05/2021	2	OP	1	13:34	234	0	144	90	0	0	547.288
24/03/2022	3	PG	76	06:20	88	0	0	45	15	28	672.893

Date	VP	Species	No.	Start_Time	Duration	HT1	HT2	HT3	HT4	HT5	Flight Length (m)
24/06/2021	1	OP	2	10:59	420	0	300	60	15	45	3157.35
08/03/2023	3	GI	1	12:53	41	0	41	0	0	0	462.587
28/01/2022	1	PG	45	08:41	205	0	0	0	90	115	1214.93
27/04/2022	2	OP	1	17:42	105	0	0	105	0	0	1426.52
06/05/2021	2	OP	1	13:39	46	16	30	0	0	0	228.734
24/03/2022	3	PG	62	06:34	153	0	0	0	30	123	713.124
28/09/2022	*3*	*PG*	*205*	*12:09*	*189*	*0*	*0*	*0*	*0*	*189*	*1329.72*
24/03/2022	3	PG	3	06:30	75	0	0	45	30	0	567.957
27/04/2022	2	OP	1	14:13	40	0	30	10	0	0	138.364
12/08/2021	1	OP	1	16:04	197	2	195	0	0	0	519.602
01/06/2021	2	OP	1	07:26	155	0	90	65	0	0	469.055
10/08/2022	2	OP	1	13:27	105	0	0	60	45	0	1154.76
27/04/2022	2	OP	2	15:01	205	40	60	105	0	0	2810.99
24/03/2022	3	PG	120	06:32	105	0	0	0	30	75	672.893
01/09/2021	1	GI	1	09:56	83	38	45	0	0	0	672.083
27/04/2022	2	OP	1	15:42	65	5	60	0	0	0	1083.29
24/03/2022	*3*	*PG*	*2*	*07:43*	*24*	*0*	*0*	*0*	*0*	*24*	*401.64*
24/03/2022	3	PG	58	06:37	79	0	0	30	15	34	672.893
05/11/2021	1	PG	650	08:12	154	0	0	154	0	0	1164.93
24/03/2022	*3*	*PG*	*275*	*09:31*	*183*	*0*	*0*	*0*	*0*	*183*	*245.289*
26/07/2021	2	OP	1	17:23	289	19	15	165	90	0	2953.61
26/07/2021	2	OP	1	17:40	48	33	15	0	0	0	323.175
24/03/2022	3	PG	12	08:15	70	0	0	0	15	55	619.396
05/11/2021	1	GJ	29	08:57	139	0	0	139	0	0	421.07
27/04/2022	2	OP	1	14:14	40	0	40	0	0	0	107.878
05/07/2022	2	OP	2	20:57	140	35	105	0	0	0	3579.36
27/04/2022	2	OP	1	15:37	120	60	30	30	0	0	577.276
14/03/2023	2	GI	2	13:17	52	7	30	15	0	0	515.55
24/03/2022	3	PG	20	08:34	80	0	0	15	45	20	567.957
26/07/2021	2	OP	1	18:10	120	75	45	0	0	0	1024.39
05/11/2021	1	GJ	14	10:14	126	0	0	126	0	0	421.07
26/07/2021	2	OP	1	18:12	58	43	15	0	0	0	1362.2
22/11/2022	3	PG	53	09:18	133	0	0	0	133	0	805.795
24/03/2022	3	PG	19	09:12	80	0	0	30	50	0	492.573
27/04/2022	1	OP	1	16:50	50	5	45	0	0	0	920.78
23/05/2022	2	OP	1	12:51	50	5	45	0	0	0	463.917
28/01/2022	1	GI	1	13:21	155	0	65	90	0	0	1453.46
08/03/2023	3	PG	26	09:21	55	0	0	55	0	0	892.278
25/02/2022	2	GI	1	14:45	45	15	30	0	0	0	896.115
24/03/2022	3	PG	115	09:16	147	0	0	105	12	30	614.975
26/07/2021	2	OP	1	19:01	135	45	30	60	0	0	1432.6
05/07/2022	1	OP	1	18:55	253	0	0	28	180	45	678.774
10/08/2022	1	OP	1	12:07	53	0	53	0	0	0	1595.12
05/07/2022	2	OP	1	20:04	110	20	60	30	0	0	1045.45
24/03/2022	*3*	*PG*	*3*	*10:28*	*113*	*0*	*0*	*0*	*0*	*113*	*322.608*
03/06/2022	1	GI	1	10:21	197	0	60	137	0	0	2437.64
26/07/2021	2	OP	1	19:07	93	33	60	0	0	0	900.276

Date	VP	Species	No.	Start_Time	Duration	HT1	HT2	HT3	HT4	HT5	Flight Length (m)
03/06/2022	1	OP	1	11:24	156	0	15	141	0	0	718.419
26/07/2021	2	OP	1	19:38	210	75	60	75	0	0	2196.07
04/11/2021	2	PG	65	11:27	92	0	0	92	0	0	1103.01
04/11/2021	2	PG	100	11:47	89	0	0	89	0	0	1103.01
04/11/2021	*2*	*PG*	*70*	*11:50*	*123*	*0*	*0*	*0*	*0*	*123*	*1103.01*
15/06/2022	1	GI	1	08:59	185	50	60	75	0	0	1932.89
04/11/2021	*2*	*PG*	*45*	*11:52*	*98*	*0*	*0*	*0*	*0*	*98*	*1103.01*
15/06/2022	1	OP	1	10:16	390	30	30	330	0	0	1957.08
05/07/2022	1	OP	1	16:54	58	0	43	15	0	0	741.241
04/03/2022	2	PG	350	07:56	105	0	0	105	0	0	575.052
04/03/2022	2	PG	125	10:34	125	0	125	0	0	0	1309.31
05/07/2022	1	OP	1	19:16	109	0	15	90	4	0	305.985
27/04/2022	2	OP	2	14:23	85	10	15	60	0	0	1674.4
27/04/2022	2	OP	1	14:26	70	0	0	70	0	0	1062.47
05/07/2022	1	OP	1	19:17	64	4	30	30	0	0	275.451
27/04/2022	2	OP	1	15:56	130	45	55	30	0	0	207.586
10/08/2022	1	OP	1	11:15	358	30	120	75	133	0	808.736
27/04/2022	2	OP	1	15:48	50	15	30	5	0	0	274.289
27/04/2022	2	OP	1	18:45	35	5	15	15	0	0	218.572
01/09/2022	1	GI	1	13:24	643	0	88	210	165	180	3213.86
10/11/2022	1	PG	694	09:29	378	0	0	378	0	0	1045.51
27/04/2022	2	OP	1	17:16	50	35	15	0	0	0	223.388
28/09/2022	3	PG	138	12:03	176	0	0	0	176	0	181.534
10/11/2022	1	PG	127	11:08	64	0	15	30	19	0	604.416
27/04/2022	2	OP	1	17:27	40	15	15	10	0	0	318.5
24/10/2022	*3*	*PG*	*44*	*10:38*	*104*	*0*	*0*	*0*	*0*	*104*	*740.1*
14/03/2023	1	GI	1	13:38	245	0	0	35	180	30	1009.71
27/04/2022	2	OP	1	17:58	210	15	0	195	0	0	2905.18
14/03/2023	1	GI	1	16:03	70	25	45	0	0	0	287.981
27/04/2022	2	OP	1	18:32	40	0	30	10	0	0	196.772
22/11/2022	3	PG	33	08:28	120	0	0	0	120	0	384.1
14/03/2023	1	GI	1	16:04	40	10	30	0	0	0	333.17
15/06/2022	2	OP	4	09:00	180	0	90	30	60	0	560.761
03/06/2022	1	OP	1	09:53	419	0	74	135	210	0	1116.83
22/11/2022	3	PG	108	09:13	129	0	0	0	129	0	655.076
03/06/2022	2	OP	1	07:28	462	15	60	345	42	0	3198.56
05/07/2022	2	OP	1	15:43	230	5	15	210	0	0	2435.05
22/11/2022	3	PG	34	09:51	117	0	0	0	117	0	716.234
05/07/2022	2	OP	1	19:45	146	26	45	75	0	0	191.878
05/07/2022	2	OP	1	20:04	110	5	75	30	0	0	1427.91
22/11/2022	3	PG	140	09:55	125	0	0	0	125	0	25.9493
05/07/2022	2	OP	2	20:22	115	10	105	0	0	0	765.297
05/07/2022	2	OP	2	20:24	285	15	30	240	0	0	412.182
05/07/2022	2	OP	2	21:09	155	15	45	95	0	0	1067.78
16/12/2022	3	PG	32	11:02	69	0	0	0	69	0	47.022
10/08/2022	2	OP	1	10:22	430	30	130	270	0	0	3236.69
10/08/2022	2	OP	1	10:22	690	0	0	120	240	330	287.157

Date	VP	Species	No.	Start_Time	Duration	HT1	HT2	HT3	HT4	HT5	Flight Length (m)
10/11/2022	2	PG	45	09:20	260	0	260	0	0	0	1404.41
10/11/2022	2	PG	130	09:25	230	0	0	230	0	0	1404.41
10/11/2022	2	PG	26	09:31	200	0	200	0	0	0	1404.41
10/11/2022	2	PG	240	09:33	220	0	0	220	0	0	1404.41
10/11/2022	2	PG	9	10:24	170	0	0	170	0	0	1404.41
05/07/2022	2	OP	2	20:07	230	0	45	185	0	0	714.115

ANNEX 2: COLLISION PROBABILITY CALCULATIONS

Two examples are presented. Calculations for other species can be provided upon request.

Pink-footed goose

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
No. Blades	3						Upwind:			Downwind:	
Max Chord	4.3	m	r/R	c/C	α	collide		contribution from radius	collide		contribution from radius
Pitch (degrees)	10		radius	chord	alpha	length	p (collision)	r	length	p (collision)	r
Bird Length	0.68	m	0.025	0.575	8.66	34.75	0.89	0.00111	33.89	0.86	0.00108
Wingspan	1.53	m	0.075	0.575	2.89	11.87	0.30	0.00227	11.01	0.28	0.00211
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.73	8.31	0.21	0.00265	7.27	0.19	0.00232
			0.175	0.860	1.24	7.04	0.18	0.00314	5.75	0.15	0.00257
Bird speed	16.8	m/sec	0.225	0.994	0.96	6.26	0.16	0.00359	4.78	0.12	0.00274
Rotor Diam	173	m	0.275	0.947	0.79	5.06	0.13	0.00355	3.65	0.09	0.00256
Rotation Period	7.00	sec	0.325	0.899	0.67	4.22	0.11	0.00350	2.88	0.07	0.00239
			0.375	0.851	0.58	3.60	0.09	0.00344	2.33	0.06	0.00223
			0.425	0.804	0.51	3.11	0.08	0.00337	1.91	0.05	0.00207
			0.475	0.756	0.46	2.72	0.07	0.00330	1.59	0.04	0.00193
Bird aspect ratio: β	0.44		0.525	0.708	0.41	2.44	0.06	0.00327	1.39	0.04	0.00186
			0.575	0.660	0.38	2.23	0.06	0.00326	1.24	0.03	0.00182
			0.625	0.613	0.35	2.04	0.05	0.00325	1.12	0.03	0.00179
			0.675	0.565	0.32	1.87	0.05	0.00322	1.03	0.03	0.00177
			0.725	0.517	0.30	1.72	0.04	0.00318	0.95	0.02	0.00175
			0.775	0.470	0.28	1.59	0.04	0.00314	0.88	0.02	0.00175
			0.825	0.422	0.26	1.46	0.04	0.00308	0.83	0.02	0.00175
			0.875	0.374	0.25	1.35	0.03	0.00302	0.79	0.02	0.00177
			0.925	0.327	0.23	1.25	0.03	0.00294	0.76	0.02	0.00179
			0.975	0.279	0.22	1.15	0.03	0.00286	0.73	0.02	0.00183
				Overall p(collision) =			Upwind	6.1%		Downwind	4.0%
								Average	5.1%		

Osprey

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
No. Blades	3						Upwind:			Downwind:	
Max Chord	4.3	m	r/R	c/C	α	collide		contribution from radius	collide		contribution from radius
Pitch (degrees)	10		radius	chord	alpha	length	p (collision)	r	length	p (collision)	r
Bird Length	0.57	m	0.025	0.575	6.85	27.94	0.90	0.00113	27.08	0.87	0.00109
Wingspan	1.58	m	0.075	0.575	2.28	9.60	0.31	0.00232	8.74	0.28	0.00211
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.37	6.76	0.22	0.00272	5.71	0.18	0.00230
			0.175	0.860	0.98	5.75	0.19	0.00324	4.47	0.14	0.00252
Bird speed	13.3	m/sec	0.225	0.994	0.76	5.15	0.17	0.00373	3.67	0.12	0.00266
Rotor Diam	173	m	0.275	0.947	0.62	4.19	0.13	0.00371	2.77	0.09	0.00246
Rotation Period	7.00	sec	0.325	0.899	0.53	3.51	0.11	0.00368	2.17	0.07	0.00227
			0.375	0.851	0.46	3.00	0.10	0.00363	1.73	0.06	0.00209
			0.425	0.804	0.40	2.61	0.08	0.00357	1.41	0.05	0.00193
			0.475	0.756	0.36	2.29	0.07	0.00350	1.16	0.04	0.00178
Bird aspect ratio: β	0.36		0.525	0.708	0.33	2.08	0.07	0.00351	1.02	0.03	0.00173
			0.575	0.660	0.30	1.90	0.06	0.00351	0.91	0.03	0.00169
			0.625	0.613	0.27	1.74	0.06	0.00350	0.82	0.03	0.00166
			0.675	0.565	0.25	1.60	0.05	0.00348	0.76	0.02	0.00164
			0.725	0.517	0.24	1.47	0.05	0.00344	0.70	0.02	0.00164
			0.775	0.470	0.22	1.36	0.04	0.00340	0.66	0.02	0.00165
			0.825	0.422	0.21	1.26	0.04	0.00334	0.63	0.02	0.00166
			0.875	0.374	0.20	1.16	0.04	0.00327	0.60	0.02	0.00169
			0.925	0.327	0.19	1.07	0.03	0.00319	0.58	0.02	0.00174
			0.975	0.279	0.18	0.99	0.03	0.00310	0.57	0.02	0.00179
				Overall p(collision) =			Upwind	6.5%		Downwind	3.8%
								Average	5.2%		

ANNEX 3: COLLISION RISK MORTALITY CALCULATIONS

Two examples are presented. Full calculations for all species that underwent CRM analysis can be provided upon request.

Pink-footed goose (non-breeding season 2021/22) – VP1

Stage 1

Step 1

Identify a Risk window

Width of Windfarm	2097.85	*Includes 300m buffer*
Height of Rotor sweep	173	
Cross Sectional	362928.05	

Step 2

Estimate number of birds flying through the Risk window

Potential Active	2,295.40

Month	No. hours VP survey effort	No. of birds recorded	No. of birds per hr of observation
Sep-21	6	0	0
Oct-21	6	73	12.16667
Nov-21	6	650	108.3333
Dec-21	6	0	0
Jan-22	6	45	7.5
Feb-22	6	0	0
Mar-22	6	0	0
Apr-21	6	0	0
May-21	6	0	0
Total	54	**Activity pr Hour**	14.22

n	32645.69

Step 3

Calculate proportion of area present by the wind farm rotors (A)

A	282110.75
Radius	86.50
Pi R2	23509.23
No. Rotors	12
Proportion A/W	0.78

Step 4

Calculate number of birds passing through rotors

N	25376.10

Stage 2

Step 1

SNH Probability	5.10%	0.05
Collisions no	1294.18	

Stage 3

Step 1

Apply an avoidance factor

Downtime %		15	0.85
Avoidance	**98%**	25.88	
	99%	12.94	
	99.50%	6.47	
	99.80%	2.59	
Avoidance with Downtime			
	98%	22.00	
	99%	11.00	
	99.50%	5.50	
	99.80%	**2.20**	

Pink-footed goose (non-breeding season 2021/22) – VP2

Stage 1

Step 1

Identify a Risk window

Width of Windfarm	2097.85	*Includes 300m buffer*
Height of Rotor sweep	173	
Cross Sectional	362928.05	

Step 2

Estimate number of birds flying through the Risk window

Potential Active	2,295.40

Month	No. hours VP survey effort	No. of birds recorded	No. of birds per hr of observation
Sep-21	6	0	0
Oct-21	6	0	0
Nov-21	6	280	46.66667
Dec-21	6	0	0
Jan-22	6	0	0
Feb-22	6	0	0
Mar-22	6	645	107.5
Apr-21	6	0	0
May-21	6	50	8.333333
Total	54	**Activity pr Hour**	18.06

n	41444.72

Step 3

Calculate proportion of area present by the wind farm rotors (A)

A	282110.75
Radius	86.50
Pi R2	23509.23
No. Rotors	12
Proportion A/W	0.78

Step 4

Calculate number of birds passing through rotors

N	32215.76

Stage 2

Step 1

SNH Probability	5.10%	0.05
Collisions no	1643.00	

Stage 3

Step 1

Apply an avoidance factor

Downtime %		15	0.85
Avoidance	**98%**	32.86	
	99%	16.43	
	99.50%	8.22	
	99.80%	3.29	
Avoidance with Downtime			
	98%	27.93	
	99%	13.97	
	99.50%	6.98	
	99.80%	**2.79**	

Pink-footed goose (non-breeding season 2021/22) – VP3

Stage 1

Step 1

Identify a Risk window

Width of Windfarm	2097.85	*Includes 300m buffer*
Height of Rotor sweep	173	
Cross Sectional	362928.05	

Step 2

Estimate number of birds flying through the Risk window

Potential Active	2,295.40

Month	No. hours VP survey effort	No. of birds recorded	No. of birds per hr of observation
Sep-21	6	0	0
Oct-21	6	0	0
Nov-21	6	0	0
Dec-21	6	0	0
Jan-22	6	0	0
Feb-22	3	0	0
Mar-22	6	958	159.6667
Apr-21	6	0	0
May-21	6	0	0
Total	51	**Activity pr Hour**	17.74

n	40722.10

Step 3

Calculate proportion of area present by the wind farm rotors (A)

A	282110.75
Radius	86.50
Pi R2	23509.23
No. Rotors	12
Proportion A/W	0.78

Step 4

Calculate number of birds passing through rotors

N	31654.05

Stage 2

Step 1

SNH Probability	5.10%	0.05
Collisions no	1614.36	

Stage 3

Step 1

Apply an avoidance factor

Downtime %		15	0.85
Avoidance	**98%**	32.29	
	99%	16.14	
	99.50%	8.07	
	99.80%	3.23	
Avoidance with Downtime			
	98%	27.44	
	99%	13.72	
	99.50%	6.86	
	99.80%	**2.74**	

Osprey (Breeding Season, Year 1) (pre-mitigation)

Per VP calculation based on a weighted per unit area per unit time

	Watch data			Flying time (s)	Flying time hahr-1	Weighted flying time ha hr^-1	
VP	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height	Weighting	Risk height
1	**171.650**	**39.0**	6694.4	**1050**	0.0000435720	0.325751515	0.000014194
2	**207.930**	**39.0**	8109.3	**1089**	0.0000373084	0.394602462	0.000014722
3	**136.830**	**42.0**	5746.9	**111**	0.0000053622	0.279646023	0.000001500
Totals	516.4	120.0	20550.5	2250	0.0000287475	1.000000000	0.000030415

Mean activity hr^-1 in wind farm		
Risk height	0.01647	1.6468%

WIND FARM DATA	
Wind farm area (ha)	**541.44**

	Daylight hours	**2373.5**				
	Downtime	**15**	0.85		D	**173**
Flight risk volume	Vw =	936691200			L + d	**4.87**
Rotor swept volume	Vr =	1373701	No.turbines	**12**	R	**86.5**
	Vr/Vw =	0.0014665				
	Speed	**13.3**				
	Vw Occupancy =	39.0867	140712.2	*Column C is hours D is seconds*		
	Vr Occupancy =	0.0573	206.4	*Column C is hours D is seconds*		
	Transit time =	0.3662				
	Transits =	563.573				
Collision probability from SNH sheet		**0.052**				
Collisions with no avoidance		29.306				

Collisions with 98% avoidance	0.586
Collisions with 98% avoidance & downtime	**0.498**

Osprey (Breeding Season, Year 2) (pre-mitigation)

Per VP calculation based on a weighted per unit area per unit time

	Watch data			Flying time (s)	Flying time hahr-1	Weighted flying time ha hr^-1	
VP	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height	Weighting	Risk height
1	**171.650**	**39.0**	6694.4	**893**	0.0000370339	0.332390930	0.000012310
2	**207.930**	**39.0**	8109.3	**3165**	0.0001084187	0.402645185	0.000043654
3	**136.830**	**39.0**	5336.4	**206**	0.0000107351	0.264963885	0.000002844
Totals	516.4	117.0	20140.0	4264	0.0000520626	1.000000000	0.000058808

Mean activity hr^-1 in wind farm		
Risk height	0.03184	3.1841%

WIND FARM DATA	
Wind farm area (ha)	**541.44**

	Daylight hours	**2373.5**				
	Downtime	**15**	0.85		D	**173**
Flight risk volume	Vw =	936691200			L + d	**4.87**
Rotor swept volume	Vr =	1373701	No.turbines	**12**	R	**86.5**
	Vr/Vw =	0.0014665				
	Speed	**13.3**				
	Vw Occupancy =	75.5752	272070.6	*Column C is hours D is seconds*		
	Vr Occupancy =	0.1108	399.0	*Column C is hours D is seconds*		
	Transit time =	0.3662				
	Transits =	1089.683				
	Collision probability from SNH sheet	**0.052**				
	Collisions with no avoidance	56.664				
	Collisions with 98% avoidance		1.133			
	Collisions with 98% avoidance & downtime		**0.963**			