# Earraghail Renewable Energy Development
on behalf of ScottishPower Renewables
## Appendix 9.3: Collision Risk Modelling Analysis

avianecology

# CONTENTS

## ANNEXES

# 1 INTRODUCTION

1.1.1 This Technical Appendix has been prepared to accompany **Chapter 9** of the Environmental Impact Assessment (EIA) Report for ScottishPower Renewables' (SPR) Earraghail Renewable Energy Development (hereafter 'the proposed Development').

1.1.2 It presents the details and result of Collision Risk Modelling (CRM) Analysis, completed to inform the assessment of the proposed Development.

1.1.3 This Technical Appendix is supplementary to **Appendix 9.1** in Volume 4 of the EIA Report. Only common bird species names are referred to within this Appendix. **Appendix 9.1** of the EIAR provides a summary of all bird species referred to herein. Both common and species names, together with a summary of their conservation status as relevant is provided.

# 2 OVERVIEW OF FLIGHT ACTIVITY DATA

2.1.1 The following data has been used for the purposes of CRM Analysis:

- Vantage Point (VP) Flight Activity Survey Data:

   o December 2020 to November 2021 (Year 2).

2.1.2 Given the shortcomings of the VP viewshed coverage in Year 1 as discussed during consultation with NatureScot (see **Chapter 9** for further details) CRM Analysis was not undertaken on Year 1 survey data.

## 2.2 VP Flight Activity Data

2.2.1 Target species flight activity data has been obtained from a total of four VP locations between December 2020 and November 2021 and for which estimated viewshed visible areas are illustrated on **Figure 9.3b** and summarised in **Table 2.1**. Visible areas have been calculated using an observer height of 1 m and a 20 m vertical offset above the ground.

2.2.2 **Table 2.1** also presents the location of the VPs and visible area of each viewshed, which falls within the "wind farm area" constructed using a 290 m turbine buffer for the purposes of collision risk analysis. The total within the wind farm area is 335.33 ha.

2.2.3 It should be noted that VP surveys were undertaken on the basis of a preliminary development area, in the absence of known turbine locations. As such for the purposes of CRM Analysis, VP2 does not provide visual coverage of the wind farm area and therefore flight activity recorded from this VP location has been omitted.

2.2.4 VP7 and VP11 were typically surveyed simultaneously, and given there was slight overlap between the two VP viewsheds, the overlap area was included in the VP11 visible area and not VP7, to avoid a replicated surveyed area being regarded in two viewshed's visible area. No target species were recorded in the overlap area during these surveys from VP7.

*Table 2.1: VP locations and viewshed visible areas*

| VP | Grid Reference | Visible Area (ha) – 290 m |
|----|----------------|---------------------------|
| 2  | NR 87592 65315 | 0                         |
| 3b | NR 90045 61699 | 141.7                     |
| 7  | NR 89175 61367 | 117.58                    |

| 11 | NR 87863 63288 | 80.2 |
|----|----------------|------|

2.2.5    Survey effort completed at each VP location between December 2020 and November 2021 is summarised in **Table 2.2.** Further details of VP flight activity surveys are provided in **Appendix 9.1**.

*Table 3.2: VP flight activity survey effort summary*

| VP | 2020 | 2021 | | | | | | | | | | | Year 2 Total |
|----|------|------|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|--------------|
|    | Dec  | Jan  | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov |              |
| 2  | 6    | 6    | 12  | 6   | 9   | 12  | 6   | 9   | 6   | 6    | 9   | 6   | 93           |
| 3b | 6    | 6    | 12  | 6   | 12  | 9   | 9   | 6   | 6   | 6    | 9   | 6   | 93           |
| 7  | 6    | 6    | 12  | 6   | 12  | 9   | 9   | 6   | 6   | 6    | 9   | 6   | 93           |
| 11 | 6    | 6    | 6   | 12  | 12  | 12  | 6   | 6   | 6   | 6    | 9   | 6   | 93           |

# 3    METHODOLOGY

3.1.1    Where sufficient "at collision risk" flight activity has allowed, collision risk mortality as a result of birds colliding with rotor blades has been assessed using CRM as detailed in Band *et al*. (2007[1]).

3.1.2    As defined within guidance (SNH, 2000[2]) the Collision Risk Window (CRW) is 'equal to the width of the wind farm across the general flight direction of the birds, and of height equal to the maximum height of the highest turbine'. In accordance with this guidance the turbine specification for the proposed Development i.e. up to 180 m tip height and up to 155 m blade diameter, would require a minimum CRW of 155 m diameter and 25-180 m height.

3.1.3    For the purposes of a precautionary assessment and in line with general industry standards, "at collision risk" flight activity (i.e. that within the CRW) is defined as that recorded at collision risk height (between 25-180 m) and within 290 m of proposed turbine locations for all target species. As such this adopts a precautionary approach in relation to the identification of "at collision risk" flights and is considered to be in line with good practice.

3.1.4    Band *et al.* (2007) details two CRMs; one model for directional flights, and another for non-directional (or space-filling) flights. The former model is based upon the total number of birds passing through the CRW, whereas the non-directional model is based upon the total time a bird is recorded within the CRW volume. Target species have therefore been assigned to a single model based on the nature of flight activity data obtained during VP surveys.

3.1.5    Collision risk mortality has subsequently been calculated in three stages:

- Directional: calculating the total number of birds recorded to pass though the CRW. Non-directional: estimating the time an individual bird spent passing through the CRW volume.

- Estimating the probability that a bird will be struck by a rotor blade when passing through the area swept by the rotors.

- Applying an 'avoidance rate', whereby it is assumed that most birds will take action to avoid collision.

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[1] Band, W., Madders, M. and Whitfield, D.P. (2007) Developing field and analytical methods to assess avian collision risk at windfarms. In De Lucas, M., Janss, G. and Ferrer, M. (eds) 'Birds and Wind Power'.
[2] SNH (2000) Windfarms and Birds: Calculating a theoretical collision risk assuming no avoiding action. SNH, Inverness.

## 3.2 "At Collision Risk" Flight Activity

3.2.1 "At collision risk" flight activity recorded during VP flight activity surveys is summarised in **Tables 3.1** (Year 2). The total number of flights, total number of birds and total time spent at collision risk height is presented.

3.2.2 **Annex 1** provides further details of target species "at collision risk" flight activity.

*Table 3.1: "At collision risk" flight activity – Year 2 (December 2020 – November 2021)*

| Species | Total No. of Flights | Total No. of Birds | Total Time at Collision Risk Height (s) |
|---|---|---|---|
| Greylag goose | 1 | 2 | 19 |
| Hen harrier | 7 | 7 | 866 |
| Golden eagle | 44 | 46 | 11,421 |
| White-tailed eagle | 1 | 1 | 180 |
| Merlin | 1 | 1 | 30 |
| Honey buzzard | 2 | 2 | 358 |

## 3.3 CRM Parameters

3.3.1 CRM parameters for the purposes of CRM Analysis are presented in **Tables 3.3** and **3.4**.

3.3.2 CRM Analysis has only been undertaken for golden eagle and hen harrier. No other species had more than two "at collision risk" flights and/or comprised large flocks. In addition, overall flight activity for these species was considered to be very infrequent. As such, annual collision risk mortality can reasonably be predicted to be very small and inconsequential at any population level.

*Table 3.3: Turbine parameters*

| Parameter | Value | Unit |
|---|---|---|
| No. of rotors | 13 | meters |
| No. of blades | 3 | meters |
| Height to tip | 180 | meters |
| Hub height | 102.5 | meters |
| Rotor diameter | 155 | meters |
| Rotor radius | 77.5 | meters |
| Max cord | 4 | meters |
| Pitch | 15 | degrees |
| Rotation period | 6.43[3] | Seconds |
| Downtime | 15 | % |

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[3] Based upon a maximum rotational speed of 11.20 r.p.m taken from a Siemens SWT-DD-142 3.5-4.1MW, with a conservative operating speed estimate derived as 20% of the maximum. https://www.siemensgamesa.com/en-int/-/media/siemensgamesa/downloads/en/products-and-services/archive/swt-dd-142.pdf (Accessed 17th December 2021).

*Table 3.4: Target species parameters*
*As per Proven & Whitfield (2007[4]) and Robinson (2005[5]), unless where otherwise specified.*

| Species | Length | Wingspan | Flight Speed | Collision Probability[6] | Avoidance Rate[7] | Occupancy |
|---------|--------|----------|--------------|--------------------------|-------------------|-----------|
| Golden eagle | 0.82 | 2.12 | 15.0 | 6.2 | 99% | All year |
| Hen harrier | 0.48 | 1.10 | 11.5 | 5.5 | 99% | All year |

## 3.4    Other Model Input

3.4.1    Other inputs used for CRM Analysis were:

- Wind farm area (290 m): 335.33 ha

- Assumed daylight flying hours (potential): 4473.8[8] (Year Round Occupancy)

- Down-time: 15 %

## 3.5    Collision Probability Analysis

3.5.1    **Annex 2** presents collision probability calculations for species listed within **Table 3.4**.

# 4    RESULTS

4.1.1    **Table 3.5** summarises he results of CRM Analysis for golden eagle and hen harrier for Year 2, with the full results shown in **Annex 3**.

*Table 3.5: CRM Analysis results*

| Species | Annual Mortality | 40 Year Mortality | Year for 1 Death |
|---------|------------------|-------------------|------------------|
| Golden eagle | 0.393 | 15.72 | 2.54 |
| Hen harrier | 0.057 | 2.27 | 17.66 |

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[4] Provan, S. & Whitfield, S. (2007) Avian flight speeds and biometrics for use in collision risk modelling. Report to SNH from Natural Research.

[5] Robinson, R.A. (2005) BirdFacts: profiles of birds occurring in Britain & Ireland. BTO, Thetford (http://www.bto.org/birdfacts, Accessed 1st December 2021)

[6] See **Annex 2**.

[7] SNH (2018). Avoidance rates for the onshore SNH wind farm collision risk model. September 2018, v2.

[8] Potentially active hours for golden eagle and hen harrier has been calculated using a latitude of 55.808517 as per 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**, pp. 87-95. Hours exclude 29th February as field surveys were not undertaken over a leap year.

# ANNEX 1 – "AT COLLISION RISK" FLIGHT ACTIVITY

**Table A1-1** present "at collision risk" flight activity for target species recorded between December 2020 and November 2021 (Year 2); the number of birds, flight duration (secs) and time spent (secs) below (HT1), at (HT2 & HT3) and above (HT4) collision risk height is presented.

***Table A1-1: Target species "at collision risk" flight activity (Wind Farm Area: 290 m).***
*HT1 (0 - 20 m); HT2 (20 - 150 m); HT3 (150 - 200 m) & HT4 (>200 m).*

| Date | VP | Species | No. of Birds | Start Time | Flight Duration (s) | Time Spent (s) | | | |
|------|-----|---------|--------------|------------|---------------------|-----|-----|-----|-----|
| | | | | | | HT1 | HT2 | HT3 | HT4 |
| 10/02/2021 | 7 | Golden eagle | 1 | 09:41 | 33 | 0 | 33 | 0 | 0 |
| 21/02/2021 | 3 | Golden eagle | 1 | 10:38 | 174 | 0 | 174 | 0 | 0 |
| 22/02/2021 | 11 | Hen harrier | 1 | 14:12 | 45 | 15 | 30 | 0 | 0 |
| 25/02/2021 | 7 | Golden eagle | 1 | 12:06 | 143 | 8 | 135 | 0 | 0 |
| 25/02/2021 | 7 | Golden eagle | 1 | 13:49 | 490 | 45 | 280 | 165 | 0 |
| 25/02/2021 | 7 | Golden eagle | 1 | 11:49 | 418 | 0 | 328 | 90 | 0 |
| 25/02/2021 | 7 | Golden eagle | 1 | 12:08 | 1942 | 0 | 817 | 555 | 570 |
| 25/02/2021 | 7 | Golden eagle | 1 | 12:08 | 1693 | 0 | 523 | 495 | 675 |
| 25/02/2021 | 7 | Golden eagle | 1 | 13:51 | 386 | 0 | 161 | 225 | 0 |
| 01/03/2021 | 11 | Hen harrier | 1 | 13:01 | 120 | 45 | 75 | 0 | 0 |
| 01/03/2021 | 11 | Hen harrier | 1 | 13:42 | 90 | 60 | 30 | 0 | 0 |
| 10/03/2021 | 3 | Golden eagle | 1 | 10:35 | 216 | 45 | 156 | 15 | 0 |
| 10/03/2021 | 3 | Hen harrier | 1 | 11:09 | 372 | 90 | 282 | 0 | 0 |
| 10/03/2021 | 3 | Golden eagle | 1 | 11:16 | 305 | 0 | 305 | 0 | 0 |
| 12/03/2021 | 7 | Golden eagle | 1 | 10:58 | 76 | 45 | 31 | 0 | 0 |
| 12/03/2021 | 7 | Golden eagle | 1 | 12:46 | 365 | 0 | 140 | 120 | 105 |
| 12/03/2021 | 7 | Golden eagle | 1 | 09:02 | 374 | 0 | 254 | 120 | 0 |

| Date | VP | Species | No. of Birds | Start Time | Flight Duration (s) | Time Spent (s) | | | |
|------|----|---------|--------------|------------|---------------------|------|------|------|------|
| | | | | | | HT1 | HT2 | HT3 | HT4 |
| 12/03/2021 | 7 | Golden eagle | 1 | 10:54 | 735 | 30 | 255 | 375 | 75 |
| 12/03/2021 | 7 | Golden eagle | 1 | 12:16 | 186 | 45 | 141 | 0 | 0 |
| 12/03/2021 | 7 | Golden eagle | 1 | 13:03 | 515 | 0 | 20 | 45 | 450 |
| 12/03/2021 | 7 | Golden eagle | 1 | 12:23 | 190 | 15 | 145 | 30 | 0 |
| 07/04/2021 | 3 | Golden eagle | 1 | 13:45 | 330 | 0 | 90 | 150 | 90 |
| 19/04/2021 | 3 | Golden eagle | 1 | 08:26 | 181 | 31 | 150 | 0 | 0 |
| 21/04/2021 | 7 | Merlin | 1 | 17:20 | 94 | 64 | 30 | 0 | 0 |
| 28/04/2021 | 7 | Hen harrier | 1 | 20:08 | 211 | 45 | 166 | 0 | 0 |
| 28/04/2021 | 7 | Hen harrier | 1 | 20:08 | 223 | 45 | 178 | 0 | 0 |
| 25/05/2021 | 11 | Golden eagle | 1 | 11:31 | 35 | 0 | 35 | 0 | 0 |
| 30/05/2021 | 11 | Golden eagle | 1 | 16:14 | 214 | 0 | 124 | 90 | 0 |
| 30/05/2021 | 11 | Greylag goose | 2 | 20:44 | 19 | 0 | 19 | 0 | 0 |
| 08/06/2021 | 7 | Golden eagle | 1 | 15:08 | 294 | 30 | 264 | 0 | 0 |
| 16/06/2021 | 3 | Golden eagle | 1 | 14:51 | 65 | 0 | 65 | 0 | 0 |
| 16/06/2021 | 3 | Golden eagle | 1 | 14:51 | 1560 | 0 | 510 | 120 | 840 |
| 17/06/2021 | 7 | Golden eagle | 1 | 13:36 | 278 | 0 | 135 | 60 | 83 |
| 20/07/2021 | 3 | Golden eagle | 1 | 16:11 | 468 | 0 | 105 | 75 | 288 |
| 10/08/2021 | 2 | Honey buzzard | 1 | 15:14 | 235 | 45 | 190 | 0 | 0 |
| 10/08/2021 | 3 | Golden eagle | 1 | 14:37 | 174 | 0 | 174 | 0 | 0 |
| 10/08/2021 | 3 | Golden eagle | 1 | 14:59 | 510 | 0 | 120 | 120 | 270 |
| 10/08/2021 | 3 | Golden eagle | 1 | 12:29 | 211 | 0 | 46 | 105 | 60 |
| 10/08/2021 | 3 | Golden eagle | 1 | 13:55 | 307 | 0 | 112 | 150 | 45 |

| Date | VP | Species | No. of Birds | Start Time | Flight Duration (s) | Time Spent (s) | | | |
|------|-----|---------|--------------|------------|---------------------|------|------|------|------|
| | | | | | | HT1 | HT2 | HT3 | HT4 |
| 10/08/2021 | 3 | Honey buzzard | 1 | 15:08 | 168 | 0 | 168 | 0 | 0 |
| 11/08/2021 | 7 | Golden eagle | 1 | 16:16 | 400 | 45 | 120 | 205 | 30 |
| 27/09/2021 | 7 | Golden eagle | 1 | 18:31 | 130 | 40 | 90 | 0 | 0 |
| 28/09/2021 | 3 | Golden eagle | 1 | 10:32 | 40 | 15 | 25 | 0 | 0 |
| 04/10/2021 | 7 | White-tailed eagle | 1 | 14:42 | 204 | 24 | 150 | 30 | 0 |
| 05/10/2021 | 3 | Golden eagle | 1 | 11:36 | 192 | 27 | 165 | 0 | 0 |
| 05/10/2021 | 3 | Golden eagle | 1 | 14:36 | 149 | 0 | 149 | 0 | 0 |
| 05/10/2021 | 3 | Golden eagle | 1 | 10:46 | 377 | 2 | 195 | 90 | 90 |
| 05/10/2021 | 3 | Golden eagle | 1 | 15:49 | 73 | 15 | 58 | 0 | 0 |
| 05/10/2021 | 3 | Golden eagle | 1 | 16:12 | 347 | 2 | 75 | 90 | 180 |
| 05/10/2021 | 3 | Golden eagle | 2 | 15:50 | 1124 | 7 | 120 | 210 | 225 |
| 05/10/2021 | 3 | Golden eagle | 1 | 16:27 | 333 | 33 | 300 | 0 | 0 |
| 09/11/2021 | 3 | Hen harrier | 1 | 11:40 | 128 | 23 | 105 | 0 | 0 |
| 09/11/2021 | 3 | Golden eagle | 2 | 10:29 | 183 | 0 | 123 | 60 | 0 |
| 09/11/2021 | 3 | Golden eagle | 1 | 10:36 | 284 | 0 | 104 | 120 | 60 |
| 10/11/2021 | 7 | Golden eagle | 1 | 13:00 | 153 | 78 | 75 | 0 | 0 |
| 10/11/2021 | 11 | Golden eagle | 1 | 13:03 | 114 | 0 | 114 | 0 | 0 |

# ANNEX 2 – COLLISION PROBABILITY CALCULATIONS

## Golden eagle

| CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA | | | | | | Upwind: | | | Downwind: | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K: [1D or [3D] (0 or 1) | 1 | | Calculation of alpha and p(collision) as a function of radius | | | | | | | | |
| No. Blades | 3 | | | | | | | | | | |
| Max Chord | 4 | m | r/R | c/C | a | collide | | contribution | collide | | contribution |
| Pitch (degrees) | 15 | | radius | chord | alpha | length | p (collision) | from radius r | length | p (collision) | from radius r |
| Bird Length | 0.82 | m | 0.025 | 0.575 | 7.92 | 34.99 | 1.00 | 0.00125 | 33.80 | 1.00 | 0.00125 |
| Wingspan | 2.12 | m | 0.075 | 0.575 | 2.64 | 12.06 | 0.38 | 0.00281 | 10.87 | 0.34 | 0.00254 |
| F: Flapping (0) or gliding (+1) | 0 | | 0.125 | 0.702 | 1.58 | 8.38 | 0.26 | 0.00326 | 6.93 | 0.22 | 0.00269 |
| | | | 0.175 | 0.860 | 1.13 | 7.05 | 0.22 | 0.00384 | 5.27 | 0.16 | 0.00287 |
| Bird speed | 15 | m/sec | 0.225 | 0.994 | 0.88 | 6.28 | 0.20 | 0.00439 | 4.22 | 0.13 | 0.00295 |
| Rotor Diam | 155 | m | 0.275 | 0.947 | 0.72 | 5.14 | 0.16 | 0.00440 | 3.18 | 0.10 | 0.00272 |
| Rotation Period | 6.43 | sec | 0.325 | 0.899 | 0.61 | 4.34 | 0.13 | 0.00439 | 2.48 | 0.08 | 0.00251 |
| | | | 0.375 | 0.851 | 0.53 | 3.74 | 0.12 | 0.00436 | 1.98 | 0.06 | 0.00230 |
| | | | 0.425 | 0.804 | 0.47 | 3.27 | 0.10 | 0.00432 | 1.60 | 0.05 | 0.00212 |
| | | | 0.475 | 0.756 | 0.42 | 2.88 | 0.09 | 0.00426 | 1.32 | 0.04 | 0.00195 |
| Bird aspect ratio: b | 0.39 | | 0.525 | 0.708 | 0.38 | 2.59 | 0.08 | 0.00422 | 1.12 | 0.03 | 0.00183 |
| | | | 0.575 | 0.660 | 0.34 | 2.38 | 0.07 | 0.00426 | 1.02 | 0.03 | 0.00182 |
| | | | 0.625 | 0.613 | 0.32 | 2.20 | 0.07 | 0.00429 | 0.94 | 0.03 | 0.00182 |
| | | | 0.675 | 0.565 | 0.29 | 2.05 | 0.06 | 0.00429 | 0.88 | 0.03 | 0.00184 |
| | | | 0.725 | 0.517 | 0.27 | 1.90 | 0.06 | 0.00429 | 0.83 | 0.03 | 0.00187 |
| | | | 0.775 | 0.470 | 0.26 | 1.77 | 0.06 | 0.00427 | 0.84 | 0.03 | 0.00203 |
| | | | 0.825 | 0.422 | 0.24 | 1.65 | 0.05 | 0.00423 | 0.87 | 0.03 | 0.00222 |
| | | | 0.875 | 0.374 | 0.23 | 1.53 | 0.05 | 0.00418 | 0.88 | 0.03 | 0.00240 |
| | | | 0.925 | 0.327 | 0.21 | 1.43 | 0.04 | 0.00411 | 0.89 | 0.03 | 0.00255 |
| | | | 0.975 | 0.279 | 0.20 | 1.33 | 0.04 | 0.00403 | 0.89 | 0.03 | 0.00270 |
| | | | | Overall p(collision) = | | | Upwind | 7.9 % | | Downwind | 4.5 % |
| | | | | | | | | Average | 6.2 % | | |

## Hen harrier

| CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | m | r/R | c/C | a | collide | | contribution | collide | | contribution |
| Pitch (degrees) | 15 | | radius | chord | alpha | length | p (collision) | from radius r | length | p (collision) | from radius r |
| Bird Length | 0.48 | m | 0.025 | 0.575 | 6.07 | 20.77 | 0.84 | 0.00105 | 19.58 | 0.79 | 0.00099 |
| Wingspan | 1.1 | m | 0.075 | 0.575 | 2.02 | 7.32 | 0.30 | 0.00223 | 6.13 | 0.25 | 0.00187 |
| F: Flapping (0) or gliding (+1) | 0 | | 0.125 | 0.702 | 1.21 | 5.36 | 0.22 | 0.00272 | 3.90 | 0.16 | 0.00198 |
| | | | 0.175 | 0.860 | 0.87 | 4.73 | 0.19 | 0.00336 | 2.95 | 0.12 | 0.00209 |
| Bird speed | 11.5 | m/sec | 0.225 | 0.994 | 0.67 | 4.36 | 0.18 | 0.00398 | 2.31 | 0.09 | 0.00210 |
| Rotor Diam | 155 | m | 0.275 | 0.947 | 0.55 | 3.61 | 0.15 | 0.00402 | 1.65 | 0.07 | 0.00184 |
| Rotation Period | 6.43 | sec | 0.325 | 0.899 | 0.47 | 3.07 | 0.12 | 0.00404 | 1.21 | 0.05 | 0.00159 |
| | | | 0.375 | 0.851 | 0.40 | 2.69 | 0.11 | 0.00410 | 0.93 | 0.04 | 0.00142 |
| | | | 0.425 | 0.804 | 0.36 | 2.42 | 0.10 | 0.00417 | 0.76 | 0.03 | 0.00131 |
| | | | 0.475 | 0.756 | 0.32 | 2.20 | 0.09 | 0.00423 | 0.63 | 0.03 | 0.00122 |
| Bird aspect ratio:  b | 0.44 | | 0.525 | 0.708 | 0.29 | 2.00 | 0.08 | 0.00427 | 0.54 | 0.02 | 0.00115 |
| | | | 0.575 | 0.660 | 0.26 | 1.84 | 0.07 | 0.00429 | 0.49 | 0.02 | 0.00114 |
| | | | 0.625 | 0.613 | 0.24 | 1.69 | 0.07 | 0.00428 | 0.54 | 0.02 | 0.00137 |
| | | | 0.675 | 0.565 | 0.22 | 1.56 | 0.06 | 0.00426 | 0.57 | 0.02 | 0.00157 |
| | | | 0.725 | 0.517 | 0.21 | 1.43 | 0.06 | 0.00422 | 0.60 | 0.02 | 0.00176 |
| | | | 0.775 | 0.470 | 0.20 | 1.32 | 0.05 | 0.00416 | 0.61 | 0.02 | 0.00192 |
| | | | 0.825 | 0.422 | 0.18 | 1.22 | 0.05 | 0.00407 | 0.62 | 0.03 | 0.00206 |
| | | | 0.875 | 0.374 | 0.17 | 1.12 | 0.05 | 0.00397 | 0.62 | 0.03 | 0.00219 |
| | | | 0.925 | 0.327 | 0.16 | 1.03 | 0.04 | 0.00385 | 0.61 | 0.02 | 0.00229 |
| | | | 0.975 | 0.279 | 0.16 | 0.94 | 0.04 | 0.00370 | 0.60 | 0.02 | 0.00238 |
| | | | | Overall p(collision) = | | | Upwind | 7.5 % | | Downwind | 3.4 % |
| | | | | | | | | Average | 5.5 % | | |

# ANNEX 3 – CRM ANALYSIS RESULTS

*Golden eagle - Year 2 (December 2020 – November 2021)*

| VP | Watch data | | | Flying time (s) | Flying time hahr-1 | Weighted flying time ha hr^-1 | |
|---|---|---|---|---|---|---|---|
| | Area (ha) | Time (hrs) | HaHr | Risk height | Risk height | Weighting | Risk height |
| 3b | 141.70 | 93.0 | 13178.10 | 798.52 | 0.0000168317 | 0.417403087 | 0.0000070256 |
| 7 | 117.58 | 93.0 | 10934.94 | 1260.39 | 0.0000320174 | 0.346353246 | 0.0000110893 |
| 11 | 80.20 | 93.0 | 7458.60 | 159.38 | 0.0000059357 | 0.236243667 | 0.0000014023 |
| Totals | 339.48 | 279.0 | 31571.64 | 2218.28 | 0.0000547848 | 1.0000000000 | 0.0000195172 |

| Mean activity hr^-1 in wind farm | | | | WIND FARM DATA | | | | |
|---|---|---|---|---|---|---|---|---|
| Risk height | 0.00654 | 0.6545 % | | Wind farm area (ha) | | 335.33 | | |
| Daylight hours | | | 4473.8 | | | | | |
| Downtime | | | 15 | 0.85 | | | D | 155.0 |
| Vw = | | | 519761500 | | | | L + d | 4.82 |
| Vr = | | | 1181744 | No. of turbines | | 13 | R | 77.5 |
| Vr/Vw = | | | 0.0022736 | | | | | |
| Speed | | | 15 | | | | | |
| Vw Occupancy = | | | 29.280 | 105406.9 | | | | |
| Vr Occupancy = | | | 0.067 | 239.7 | | | | |
| Transit time = | | | 0.321 | | | | | |
| Transits = | | | 745.818 | | | | | |
| Collision probability from NatureScot sheet | | | 0.062 | | | | | |
| Collisions with no avoidance | | | 46.241 | | | | | |
| Collisions with 99% avoidance | | | 0.462 | | | | | |
| Collisions with 99% avoidance & downtime | | | 0.393 | | | | | |
| 40 year mortality | | | 18.496 | | | | | |
| 40 year mortality with 15% downtime etc | | | 15.722 | | | | | |
| Years for 1 death | | | 2.544 | | | | | |

*Hen harrier - Year 2 (December 2020 – November 2021)*

| VP | Watch data | | | Flying time (s) | Flying time hahr-1 | Weighted flying time ha hr^-1 | |
| | Area (ha) | Time (hrs) | HaHr | Risk height | Risk height | Weighting | Risk height |
|---|---|---|---|---|---|---|---|
| 3b | 141.70 | 93.0 | 13178.10 | 246.62 | 0.0000051984 | 0.417403087 | 0.0000021698 |
| 7 | 117.58 | 93.0 | 10934.94 | 105.35 | 0.0000026761 | 0.346353246 | 0.0000009269 |
| 11 | 80.20 | 93.0 | 7458.60 | 117.92 | 0.0000043915 | 0.236243667 | 0.0000010375 |
| Totals | 339.48 | 279.0 | 31571.64 | 469.88 | 0.0000122660 | 1.0000000000 | 0.0000041342 |

| Mean activity hr^-1 in wind farm | | | | WIND FARM DATA | | | |
|---|---|---|---|---|---|---|---|
| Risk height | 0.00139 | 0.1386 % | | Wind farm area (ha) | 335.33 | | |

| Daylight hours | | | 4473.8 | | | | | |
|---|---|---|---|---|---|---|---|---|
| Downtime | | | 15 | 0.85 | | | D | 155.0 |
| Vw = | | | 519761500 | | | | L + d | 4.48 |
| Vr = | | | 1098385 | No. of turbines | | 13 | R | 77.5 |
| Vr/Vw = | | | 0.0021132 | | | | | |
| Speed | | | 11.5 | | | | | |
| Vw Occupancy = | | | 6.202 | 22327.5 | | | | |
| Vr Occupancy = | | | 0.013 | 47.2 | | | | |
| Transit time = | | | 0.390 | | | | | |
| Transits = | | | 121.119 | | | | | |
| Collision probability from SNH sheet | | | 0.055 | | | | | |
| Collisions with no avoidance | | | 6.662 | | | | | |
| Collisions with 99% avoidance | | | 0.067 | | | | | |
| Collisions with 99% avoidance & downtime | | | 0.057 | | | | | |
| 40 year mortality | | | 2.665 | | | | | |
| 40 year mortality with 15% downtime etc | | | 2.265 | | | | | |
| Years for 1 death | | | 17.661 | | | | | |