Oweninny Wind Farm Phase 3

Environmental Impact Assessment Report

# Appendix 8.2 Collision Risk Modelling Report


# Oweninny Wind Farm Phase 3 CRM

Collision Risk Modelling
Updated Results: January 2023

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**Tobin Consulting Engineers**

# Document history

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# 1. Introduction

Collision risk modelling (CRM) has previously been carried out for the proposed Oweninny Wind Farm, Phase 3 Project, using vantage point (VP) data collected between April 2019 and September 2021. The results of this CRM were presented in a short report issued in June 2022. At this time, two scenarios were modelled, representing a 'maximum' scenario (a 158 m diameter turbine model) and a 'minimum' scenario (a 117 m diameter turbine model).

The CRM has now been updated and the results of this new analysis are presented within this report. The rerun of the CRM was undertaken for two reasons.

Firstly, the CRM now includes the full dataset collected during baseline VP surveys. The data used in the model now covers the period April 2019 to September 2022 (inclusive), and so it includes an additional year's worth of baseline data compared to the previous CRM; and therefore, utilises a more comprehensive dataset.

Secondly, this report only presents the results of the CRM undertaken for one project design scenario (using maximum turbine dimensions).

# 2. Methods

Collision risk modelling was carried out according to the Band *et al.* (2007) Collision Risk Model[1]. Data collected during flight activity VP surveys were used to predict the number of individuals per species expected to collide with the turbine rotors per season.

The data used in the model were collected during four breeding seasons (April to September 2019, 2020, 2021 and 2022) and three non-breeding seasons (October 2019 to March 2020, October 2020 to March 2021 and October 2021 to March 2022). The survey effort of each season is provided in Appendix A. Seven VP locations were used during the flight activity surveys, however the data was excluded from 'VP5' for the CRM, as the viewshed covered from this location did not overlap with the collision risk area of the currently proposed development.

Data was examined for those species for which flight activity was recorded in detail during the baseline surveys: i.e. those recorded as 'target species'. Bird flights considered to represent a potential collision risk were those flight lines that passed within the collision risk zone (CRZ) at potential collision height (PCH). The CRZ incorporated a 279 m buffer of the proposed turbine locations, representing half the rotor diameter of the maximum turbine specification proposed at the site (158/2 = 79 m) plus a precautionary surrounding buffer zone of 200 m.

Flightlines recorded passing through the CRZ were examined to determine whether they occurred within PCH: the height range within which the proposed turbine blades will rotate. As flight heights were recorded in height bands during the surveys, any flight within a height band that overlapped with PCH was considered to have passed within PCH. The height bands used during flight activity surveys were:

- Height band 1: 0-25 m
- Height band 2: 26-50 m
- Height band 3: 51-150 m
- Height band 4: 151-200 m
- Height band 5: 201 m+

The proposed rotor swept height covers the range 42 m to 200 m. Thus, all flights within height bands 2, 3 and 4 were considered as being at potential collision risk. Note that the actual height range covered by height bands 2, 3

[1] Band, W., Madders, M. & Whitfield, D.P. (2007) *Developing field and analytical methods to assess avian collision risk at wind farms*. In de Lucas, M., Janss, G. & Ferrer, M. (eds.) Birds and Wind Power. Quercus, Madrid.

and 4 is 25 m to 200 m altitude. Thus, this represents a precautionary approach as any bird flights at a height of 25 m to 41 m would be below PCH but will have been included within the model as being at risk.

A proportionate approach to CRM was followed, whereby it was only run for species that met a specified threshold of flight activity. The threshold used was of three flights, or at least 10 individuals, recorded within the CRZ at PCH within either season, over the course of all survey years. Thus any species which was recorded using the site only very occasionally, and for which a nil or negligible collision impact could therefore be predicted, were excluded.

For species that usually fly in approximately straight lines (commuting flights) the flights observed were extrapolated up in order to estimate the number of individuals likely to pass through the CRZ at PCH per season. A species-specific two-dimensional risk window was constructed based on the mean direction of passage through the site and used to predict the number of passages through the rotor-swept area in each season[1]. This type of analysis was carried out for great black-backed gull, lesser black-backed gull, whooper swan and mallard.

For species that are expected to fly 'randomly' within the site (non-directional) the observed time spent flying within the CRZ at PCH is calculated and extrapolated. Average flight activity per unit effort (measured in minutes of survey time and hectares of area surveyed) is calculated. This metric is then used to extrapolate flight activity across time and across the entirety of the CRZ to estimate the total flight activity across the site per season[1]. This type of analysis was used to estimate collisions for golden plover and kestrel.

The risk of collision for an individual was estimated based on the characteristics of the bird species and of the turbines. The bird parameters and wind farm specifications used in the model are provided in Table 2.1 and Table 2.2.

A range of collision estimates were produced for each species, based on a range of avoidance rates. This parameter takes into account the fact that birds take avoiding action when approaching turbines. A species-specific avoidance rate is stated in guidance[2] for many target species, and the estimates produced using these stated avoidance rates are those that should be used in any subsequent impact assessment.

**Table 2.1: Wind farm attributes used in the collision risk analysis**

| Attribute | Value |
|---|---|
| Number of turbines | 18 |
| Number of blades | 3 |
| Maximum chord length (metres) | 4.2 |
| Pitch (degrees) | 6.0 |
| Rotor diameter (metres) | 158 |
| Rotation period (seconds) | 6.19 |

[2] SNH (2017) Avoidance rates for the onshore SNH wind farm collision risk model. SNH Guidance Note, July 2017

Table 2.2: Bird attributes used in the collision risk analysis

| Attribute | Great black-backed gull | Golden plover | Kestrel | Lesser black-backed gull | Mallard | Whooper swan |
|---|---|---|---|---|---|---|
| Bird length (metres)* | 0.71 | 0.29 | 0.34 | 0.58 | 0.58 | 1.60 |
| Wingspan (metres) * | 1.58 | 0.76 | 0.76 | 1.43 | 0.90 | 2.43 |
| Bird speed (metres/second)** | 13.7 | 17.9 | 8.3 | 13.1 | 18.5 | 17.3 |
| Estimated nocturnal activity (as proportion of diurnal activity) | 0 | 0.25 | 0 | 0 | 0 | 0.25 |
| Calculated individual collision risk | 0.062 | 0.042 | 0.065 | 0.059 | 0.048 | 0.080 |

*Sources: *Snow and Perrins (1998)[3]; **Alerstam et al.(2007)[4]*

[3] Snow, D.W. and Perrins, (1998) The birds of the Western Palearctic – concise edition. Volume 1 – Non-passerines. Oxford University Press, UK.

[4] Alerstam, T., Rosén, M., Bäckman, J., Ericson, P.G.P., and Hellgren, O. (2007) Flight speeds among bird species: allometric and phylogenetic effects. PLoS Biology, 5, e197.

# 3. Results

The total number of target species flight lines recorded across all breeding seasons and non-breeding seasons are shown in Table 3.1 and Table 3.2 respectively. The number of flights and individuals observed passing through the CRZ at PCH are also shown. Those species which met the CRM criteria are highlighted in bold.

**Table 3.1: Number of flights and individuals observed passing through the risk area at risk height during breeding season flight activity surveys (April to September inclusive, 2019, 2020, 2021 and 2022)**

| Species | Total Flights* | Risk flights | Risk individuals | CRM carried out |
|---|---|---|---|---|
| Buzzard | 1 | 1 | 1 | No |
| Cormorant | 3 | 1 | 1 | No |
| Common gull | 13 | 1 | 2 | No |
| Common sandpiper | 7 | 0 | 0 | No |
| Egyptian vulture | 1 | 0 | 0 | No |
| Golden eagle | 1 | 1 | 1 | No |
| **Golden plover** | **3** | **2** | **31** | **Yes** |
| **Great black-backed gull** | **13** | **4** | **4** | **Yes** |
| Grey heron | 9 | 1 | 1 | No |
| Hen harrier | 1 | 0 | 0 | No |
| **Kestrel** | **23** | **6** | **6** | **Yes** |
| Lapwing | 1 | 0 | 0 | No |
| **Lesser black-backed gull** | **20** | **8** | **14** | **Yes** |
| Little grebe | 3 | 0 | 0 | No |
| **Mallard** | **20** | **4** | **5** | **Yes** |
| Meadow pipit | 1 | 1 | 6 | No |
| Merlin | 3 | 1 | 1 | No |
| Moorhen | 2 | 0 | 0 | No |
| Peregrine | 1 | 0 | 0 | No |
| Ringed plover | 5 | 0 | 0 | No |
| Sparrowhawk | 7 | 1 | 1 | No |
| Snipe | 7 | 0 | 0 | No |
| Teal | 18 | 0 | 0 | No |
| Whimbrel | 1 | 0 | 0 | No |

** Excludes flights recorded from VP5 (see methods)*

Table 3.2: **Number of flights and individuals observed passing through the risk area at risk height during non-breeding season flight activity surveys (October 2019 to March 2020 inclusive, October 2020 to March 2021 inclusive and October 2021 to March 2022 inclusive)**

| Species | Total Flights | Risk flights | Risk individuals | CRM carried out |
|---|---|---|---|---|
| Black-headed gull | 1 | 0 | 0 | No |
| Buzzard | 2 | 0 | 0 | No |
| Great black-backed gull | 3 | 0 | 0 | No |
| Grey heron | 8 | 1 | 1 | No |
| **Golden plover** | **42** | **27** | **911** | **Yes** |
| Hen harrier | 20 | 1 | 1 | No |
| **Kestrel** | **22** | **4** | **4** | **Yes** |
| Lesser black-backed gull | 2 | 0 | 0 | No |
| **Mallard** | **12** | **3** | **10** | **Yes** |
| Merlin | 1 | 1 | 1 | No |
| Peregrine | 5 | 1 | 1 | No |
| Ringed plover | 1 | 1 | 1 | No |
| Snipe | 1 | 0 | 0 | No |
| Teal | 6 | 2 | 4 | No |
| **Whooper swan** | **15** | **5** | **25** | **Yes** |

** Excludes flights recorded from VP5 (see methods)*

Six species fulfilled the criteria for undertaking CRM: great black-backed gull, lesser black-backed gull, whooper swan, mallard, golden plover and kestrel.

The risk of collision for each of these six species, calculated with avoidance factors of 95%, 98%, 99%, 99.2% and 99.8%, are presented in Table 3.3. Values shown in bold represent species-specific avoidance levels recommended for collision risk analysis by NatureScot[2,5,6]. For those species for which a species-specific avoidance rate is not available (mallard and golden plover) the recommended default avoidance rate of 98% has been used. In the case of mallard this can be considered precautionary as this duck species can be expected to have a similar level of avoidance as geese and swans (99.8% and 99.5% respectively)[7].

Details of the calculations used to produce these estimates are provided in Appendix B.

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[5] Furness, R.W (2019) Avoidance rates of herring gull, great black-backed gull and common gull for use in the assessment of terrestrial wind farms in Scotland. Scottish Natural Heritage Research Report No. 1019.

[6] In 2020 SNH was re-branded as **NatureScot**

[7] Graeme Garner (Natural Power) personal comment (2023)

Table 3.3: **Estimated number of collisions during the breeding/summer season (April to September) and non-breeding/wintering season (October to March) – bold, shaded cells represent avoidance rates recommended by NatureScot (SNH, 2017[2]; Furness, 2019[5]). Annual estimates are sums of breeding and non-breeding estimates.**

| Species | Model type | Season | Estimated mortality assuming avoidance of: | | | | |
|---|---|---|---|---|---|---|---|
| | | | 95% | 98% | 99% | 99.5% | 99.8% |
| Great black-backed gull | Commuting | Breeding | 0.10 | 0.04 | 0.02 | **0.01** | 0.00 |
| | | Non-breeding | 0.00 | 0.00 | 0.00 | **0.00** | 0.00 |
| | | Annual | 0.10 | 0.04 | 0.02 | **0.01** | 0.00 |
| Lesser black-backed gull | Commuting | Breeding | 0.30 | 0.12 | 0.06 | **0.03** | 0.01 |
| | | Non-breeding | 0.00 | 0.00 | 0.00 | **0.00** | 0.00 |
| | | Annual | 0.30 | 0.12 | 0.06 | **0.03** | 0.01 |
| Whooper swan | Commuting | Breeding | 0.00 | 0.00 | 0.00 | **0.00** | 0.00 |
| | | Non-breeding | 0.74 | 0.30 | 0.15 | **0.07** | 0.03 |
| | | Annual | 0.74 | 0.30 | 0.15 | **0.07** | 0.03 |
| Mallard | Commuting | Breeding | 0.10 | **0.04** | 0.02 | 0.01 | 0.00 |
| | | Non-breeding | 0.16 | **0.07** | 0.03 | 0.02 | 0.01 |
| | | Annual | 0.26 | **0.11** | 0.05 | 0.03 | 0.01 |
| Golden plover | Non-directional | Breeding | 0.68 | **0.27** | 0.14 | 0.07 | 0.03 |
| | | Non-breeding | 16.26 | **6.50** | 3.25 | 1.63 | 0.65 |
| | | Annual | 16.94 | **6.77** | 3.39 | 1.70 | 0.68 |
| Kestrel | Non-directional | Breeding | **0.06** | 0.03 | 0.01 | 0.01 | 0.00 |
| | | Non-breeding | **0.03** | 0.01 | 0.01 | 0.00 | 0.00 |
| | | Annual | **0.09** | 0.04 | 0.02 | 0.01 | 0.00 |

# 4. Discussion

The more comprehensive dataset upon which the new CRM has been based (longer survey period) has resulted in collision estimates that are very similar to the previous CRM (within 0.01) for great black-backed gull, lesser black-backed gull and kestrel. For whooper swan the new estimate is lower than that calculated previously (0.07 birds per annum compared to a previous estimate of 0.11). Golden plover now has a higher collision estimate (6.77 birds per annum) than that previously presented (5.29). A collision estimate has not been calculated previously for mallard.

For mallard, golden plover and kestrel, the annual collision estimate is the sum of estimates for both the breeding and non-breeding seasons. For great black-backed gull and lesser black-backed gull the breeding season accounts for all flight activity, whilst for whooper swan all flight activity is restricted to the non-breeding season. It is against the appropriate source population (breeding or non-breeding) that impacts will need to be assessed.

This report aims only to present the results of the CRM and an assessment of the potential impacts is not included here. However, the results suggest that for great black-backed gull and lesser black-backed gull the level of collision mortality predicted will be imperceptible against the background level of mortality for these species.

The species of greatest potential concern is golden plover, with an estimated annual mortality of 6.77 individuals at 98% avoidance (of which 6.50 is accounted for by the non-breeding season). This equates to 169.25 birds over a 25-year period. It should be noted that a 98% avoidance rate has been presented for golden plover, but this is likely to be precautionary. There are examples in the UK, where a 99% avoidance rate has been used for golden plover (and considered acceptable by Natural England). Furthermore, studies in North America have estimated avoidance rates for American golden plover (a suitable proxy for the Eurasian golden plover that is found in Ireland) as being in the region of 99.5%[8]. At 99% avoidance, the collision mortality estimate for golden plover falls to 3.39 per annum (and to 1.7 with 99.5% avoidance). The wintering population of golden plover in the Republic of Ireland is estimated at 80,707 birds[9], and so it is considered likely that an assessment of collision impacts will determine a negligible impact upon the wintering population of this species. However, a full ecological impact is recommended, for all the species for which CRM was undertaken.

[8] Whitfield, D.P. (2007) The effects of wind farms on shorebirds (waders: *Charadrii*), especially with regards to wintering golden plover. Natural Research Limited.

[9] Lewis, L., Burke, B., Fitzgerald, N., Tierney, D. & Kelly, S. (2019) Irish Wetland Bird Survey: waterbird status and distribution 2009/10-2015/16. Irish Wildlife Manuals, No. 116. National Parks & Wildlife Service, Department of Culture, Heritage and the Gaeltacht, Ireland.

# Appendices

## A: Vantage Point Survey Effort

The effort carried out during vantage point surveys is presented in Table 4.1.

**Table 4.1: Survey effort carried out across VPs**

| | Hours of effort | | | | | | |
|---|---|---|---|---|---|---|---|
| **Month and year** | **VP1** | **VP2** | **VP3** | **VP4** | **VP5*** | **VP6** | **VP7** |
| Apr-19 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| May-19 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 3.0 | 3.0 |
| Jun-19 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 9.0 | 9.0 |
| Jul-19 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Aug-19 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Sep-19 | 6.0 | 6.0 | 6.0 | 6.0 | 6.2 | 6.0 | 6.0 |
| **Breeding 2019** | **36.0** | **36.0** | **36.0** | **36.0** | **36.2** | **36.0** | **36.0** |
| Oct-19 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Nov-19 | 6.0 | 6.0 | 6.0 | 6.0 | 6.3 | 6.0 | 6.0 |
| Dec-19 | 6.0 | 6.0 | 7.0 | 6.0 | 5.8 | 6.0 | 6.0 |
| Jan-20 | 6.0 | 6.0 | 6.0 | 6.0 | 6.3 | 6.0 | 6.0 |
| Feb-20 | 6.0 | 6.0 | 6.0 | 6.0 | 6.3 | 6.0 | 6.0 |
| Mar-20 | 6.0 | 6.0 | 6.0 | 6.0 | 9.0 | 6.0 | 6.0 |
| **Winter 2019/2020** | **36.0** | **36.0** | **37.0** | **36.0** | **39.6** | **36.0** | **36.0** |
| Apr-20 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 |
| May-20 | 9.0 | 9.0 | 9.0 | 9.0 | 12.0 | 9.0 | 9.0 |
| Jun-20 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 |
| Jul-20 | 8.7 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 |
| **Breeding 2020** | **35.7** | **36.0** | **36.0** | **36.0** | **39.0** | **36.0** | **36.0** |
| Oct-20 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Nov-20 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Dec-20 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Jan-21 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Feb-21 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Mar-21 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| **Winter 2020/2021** | **36.0** | **36.0** | **36.0** | **36.0** | **36.0** | **36.0** | **36.0** |
| Apr-21 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| May-21 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Jun-21 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Jul-21 | 0.0 | 6.0 | 12.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Aug-21 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Sep-21 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |

| | Hours of effort | | | | | | |
|---|---|---|---|---|---|---|---|
| **Month and year** | **VP1** | **VP2** | **VP3** | **VP4** | **VP5*** | **VP6** | **VP7** |
| **Breeding 2021** | **30.0** | **36.0** | **42.0** | **36.0** | **36.0** | **36.0** | **36.0** |
| Oct-21 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Nov-21 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Dec-21 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Jan-22 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Feb-22 | 3.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Mar-22 | 9.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| **Winter 2020/2021** | **36.0** | **36.0** | **36.0** | **36.0** | **36.0** | **36.0** | **36.0** |
| Apr-22 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| May-22 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Jun-22 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Jul-22 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Aug-22 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Sep-22 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| **Breeding 2022** | **36.0** | **36.0** | **36.0** | **36.0** | **36.0** | **36.0** | **36.0** |

**Data collected from VP 5 were excluded from the analysis as the viewshed did not overlap with the risk zone.*

## B: Details of CRM Parameters

The parameters used in the models of each species are presented in the following tables.

**Table B.1: Collision Risk Model run for Great black-backed gull (Commuting)***

| Parameter | Unit | Breeding | Non-breeding |
|---|---|---|---|
| Total number of birds flying through wind farm polygon (a) | birds | 4 | 0 |
| Mean survey effort (b) | minutes | 8637 | 6490 |
| Daylight during survey period, based on civil twilight (c) | minutes | 167194 | 102202 |
| Estimate of nocturnal activity as a proportion of daytime activity (d) | | 0 | 0 |
| Time of potential activity during survey period (e = c * (1+d)) | minutes | 167194 | 102202 |
| Rate of birds recorded during survey period (f = a/b) | birds per minute | 0.0005 | 0.0000 |
| Estimate of number of birds during season (g = e * f) | birds | 77.43 | 0.00 |
| Risk window length (h) | metres | 4411 | 4411 |
| Turbine blade length (i) | metres | 79 | 79 |
| Number of turbines (j) | | 18 | 18 |
| Risk window (k = h * i * 2) | square metres | 696988 | 696988 |
| Rotor-swept area (l = pi * i^2 * j) | square metres | 352920 | 352920 |
| Proportion of risk area that is rotor-swept (m = l/k) | | 0.506 | 0.506 |
| Estimate of number of birds flying through rotor-swept area during season (n = g * m) | birds | 39.2 | 0.0 |
| Probability of collision for a bird flying through rotors (estimated using SNH spreadsheet) (o) | | 0.062 | 0.062 |
| Predicted mortality with no avoidance - turbines operational 85% of the time (p = n * o * 0.85) | collisions per season | 2.06 | 0.00 |

** Figures have been rounded for presentation purposes. Following the calculations using rounded figures may yield slightly different results.*

Table B.2: Collision Risk Model run for Lesser black-backed gull (Commuting)

| Parameter | Unit | Breeding | Non-breeding |
|---|---|---|---|
| Total number of birds flying through wind farm polygon (a) | birds | 14 | 0 |
| Mean survey effort (b) | minutes | 8637 | 6490 |
| Daylight during survey period, based on civil twilight (c) | minutes | 167194 | 102202 |
| Estimate of nocturnal activity as a proportion of daytime activity (d) | | 0 | 0 |
| Time of potential activity during survey period (e = c * (1+d)) | minutes | 167194 | 102202 |
| Rate of birds recorded during survey period (f = a/b) | birds per minute | 0.0016 | 0.0000 |
| Estimate of number of birds during season (g = e * f) | birds | 271.02 | 0.00 |
| Risk window length (h) | metres | 5025 | 5025 |
| Turbine blade length (i) | metres | 79 | 79 |
| Number of turbines (j) | | 18 | 18 |
| Risk window (k = h * i * 2) | square metres | 793928 | 793928 |
| Rotor-swept area (l = pi * i^2 * j) | square metres | 352920 | 352920 |
| Proportion of risk area that is rotor-swept (m = l/k) | | 0.445 | 0.445 |
| Estimate of number of birds flying through rotor-swept area during season (n = g * m) | birds | 120.5 | 0 |
| Probability of collision for a bird flying through rotors (estimated using SNH spreadsheet) (o) | | 0.059 | 0.059 |
| Predicted mortality with no avoidance - turbines operational 85% of the time (p = n * o * 0.85) | collisions per season | 6.00 | 0.00 |

** Figures have been rounded for presentation purposes. Following the calculations using rounded figures may yield slightly different results.*

**Table B.3: Collision Risk Model run for Whooper swan (Commuting)**

| Parameter | Unit | Breeding | Non-breeding |
|---|---|---|---|
| Total number of birds flying through wind farm polygon (a) | birds | 0 | 25 |
| Mean survey effort (b) | minutes | 8637 | 6490 |
| Daylight during survey period, based on civil twilight (c) | minutes | 167194 | 102202 |
| Estimate of nocturnal activity as a proportion of daytime activity (d) | | 0.25 | 0.25 |
| Time of potential activity during survey period (e = c * (1+d)) | minutes | 208993 | 127752 |
| Rate of birds recorded during survey period (f = a/b) | birds per minute | 0.0000 | 0.0039 |
| Estimate of number of birds during season (g = e * f) | birds | 0.0 | 492.1 |
| Risk window length (h) | metres | 5043 | 5043 |
| Turbine blade length (i) | metres | 79 | 79 |
| Number of turbines (j) | | 18 | 18 |
| Risk window (k = h * i * 2) | square metres | 796831 | 796831 |
| Rotor-swept area (l = pi * i^2 * j) | square metres | 352920 | 352920 |
| Proportion of risk area that is rotor-swept (m = l/k) | | 0.443 | 0.443 |
| Estimate of number of birds flying through rotor-swept area during season (n = g * m) | birds | 0 | 218 |
| Probability of collision for a bird flying through rotors (estimated using SNH spreadsheet) (o) | | 0.08 | 0.08 |
| Predicted mortality with no avoidance - turbines operational 85% of the time (p = n * o * 0.85) | collisions per season | 0.00 | 14.86 |

** Figures have been rounded for presentation purposes. Following the calculations using rounded figures may yield slightly different results.*

Table B.4: Collision Risk Model run for Mallard (Commuting)

| Parameter | Unit | Breeding | Non-breeding |
| --- | --- | --- | --- |
| Total number of birds flying through wind farm polygon (a) | birds | 5 | 10 |
| Mean survey effort (b) | minutes | 8637 | 6490 |
| Daylight during survey period, based on civil twilight (c) | minutes | 167194 | 102202 |
| Estimate of nocturnal activity as a proportion of daytime activity (d) | | 0 | 0 |
| Time of potential activity during survey period (e = c * (1+d)) | minutes | 167194 | 102202 |
| Rate of birds recorded during survey period (f = a/b) | birds per minute | 0.0006 | 0.0015 |
| Estimate of number of birds during season (g = e * f) | birds | 96.79 | 157.47 |
| Risk window length (h) | metres | 4408 | 4408 |
| Turbine blade length (i) | metres | 79 | 79 |
| Number of turbines (j) | | 18 | 18 |
| Risk window (k = h * i * 2) | square metres | 696386 | 696386 |
| Rotor-swept area (l = pi * i^2 * j) | square metres | 352920 | 352920 |
| Proportion of risk area that is rotor-swept (m = l/k) | | 0.507 | 0.507 |
| Estimate of number of birds flying through rotor-swept area during season (n = g * m) | birds | 49.1 | 79.8 |
| Probability of collision for a bird flying through rotors (estimated using SNH spreadsheet) (o) | | 0.048 | 0.048 |
| Predicted mortality with no avoidance - turbines operational 85% of the time (p = n * o * 0.85) | collisions per season | 2.00 | 3.26 |

** Figures have been rounded for presentation purposes. Following the calculations using rounded figures may yield slightly different results.*

**Table B.5: Collision Risk Model run for Golden plover (Non-directional)**

| Parameter | Unit | Breeding | Non-breeding |
|---|---|---|---|
| Occupancy of risk volume (a) | seconds | 2865 | 84393 |
| Survey effort (b) | hectare-minutes | 6224644 | 4689249 |
| Observed occupancy rate for site (c = a / b) | seconds per hectare-minute | 0.0005 | 0.0180 |
| Daylight minutes (d) | minutes | 167194 | 102202 |
| Potentially active period (e = d*1.25) | minutes | 208993 | 127752 |
| Area of the wind farm polygon (f) | hectares | 427.78 | 427.78 |
| Total occupancy of risk volume during period of interest (g = c * e * f) | seconds | 41153 | 983528 |
| Rotor diameter (h) | metres | 158 | 158 |
| Risk volume (i = f * h * 10,000) | cubic metres | 675886843 | 675886843 |
| Number of turbines (j) | turbines | 18 | 18 |
| Rotor blade width (k) | metres | 4.2 | 4.2 |
| Length of bird of interest (l) | metres | 0.29 | 0.29 |
| Rotor-swept volume (m = j * pi * (h/2)^2 * (k + l)) | cubic metres | 1584612 | 1584612 |
| Bird occupancy of rotor-swept volume (n = g * m / i) | seconds | 96.5 | 2305.9 |
| Bird flight speed (o) | metres per second | 17.9 | 17.9 |
| Time taken for bird to transit rotor (p = (k + l) / o) | seconds | 0.25 | 0.25 |
| Number of rotor transits (q = n / p) | rotor transits | 385 | 9193 |
| Probability of collision for a bird flying through rotors (estimated using SNH spreadsheet) (r) | | 0.042 | 0.042 |
| Predicted mortality with no avoidance - turbines operational 85% of the time (y = q * r * 0.85) | collisions per season | 13.61 | 325.17 |

** Figures have been rounded for presentation purposes. Following the calculations using rounded figures may yield slightly different results.*

Table B.6: Collision Risk Model run for Kestrel (Non-directional)

| Parameter | Unit | Breeding | Non-breeding |
|---|---|---|---|
| Occupancy of risk volume (a) | seconds | 472 | 295 |
| Survey effort (b) | hectare-minutes | 6224644 | 4689249 |
| Observed occupancy rate for site (c = a / b) | seconds per hectare-minute | 0.0001 | 0.0001 |
| Daylight minutes (d) | minutes | 167194 | 102202 |
| Potentially active period (e = d*1) | minutes | 167194 | 102202 |
| Area of the wind farm polygon (f) | hectares | 427.78 | 427.78 |
| Total occupancy of risk volume during period of interest (g = c * e * f) | seconds | 5425 | 2753 |
| Rotor diameter (h) | metres | 158 | 158 |
| Risk volume (i = f * h * 10,000) | cubic metres | 675886843 | 675886843 |
| Number of turbines (j) | turbines | 18 | 18 |
| Rotor blade width (k) | metres | 4.2 | 4.2 |
| Length of bird of interest (l) | metres | 0.34 | 0.34 |
| Rotor-swept volume (m = j * pi * (h/2)^2 * (k + l)) | cubic metres | 1602258 | 1602258 |
| Bird occupancy of rotor-swept volume (n = g * m / i) | seconds | 12.9 | 6.5 |
| Bird flight speed (o) | metres per second | 8.3 | 8.3 |
| Time taken for bird to transit rotor (p = (k + l) / o) | seconds | 0.55 | 0.55 |
| Number of rotor transits (q = n / p) | rotor transits | 24 | 12 |
| Probability of collision for a bird flying through rotors (estimated using SNH spreadsheet) (r) | | 0.065 | 0.065 |
| Predicted mortality with no avoidance - turbines operational 85% of the time (y = q * r * 0.85) | collisions per season | 1.29 | 0.65 |

** Figures have been rounded for presentation purposes. Following the calculations using rounded figures may yield slightly different results.*

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