Technical Appendix 7.3: Collision Risk Modelling (CRM)

7.1 Collision Risk Modelling

Field data on target species were recorded from four vantage points (**Figure 7.1**; excludes the migration vantage point, MIGVP) during the breeding season (March 2017 – August 2017 & March 2018 – August 2018; **Technical Appendix 7.1**) and wintering season (September 2017 – February 2018 & September 2018 – March 2019).

Collision risk modelling (CRM) is a two-stage process (Band et al., 2007[1]) whereby Stage 1 estimates the number of birds that fly through the rotor swept area (RSA) and Stage 2 predicts the proportion of these birds that could theoretically be hit by the rotor blade. The combination of these two stages produces an estimate of collision fatalities in the presumed absence of avoidance behaviour. The model is then adjusted for i) turbine efficiency and ii) avoidance behaviour (set separately at rates of 95%, 98% and 99% successful avoidance) to calculate minimum and maximum likely collision risk.

For the purposes of the models the area of the both the Operational Barnesmore Windfarm and Development infrastructure is initially taken to be the envelope as defined by the turbine locations and the associated turbine plus 500 m buffer for which field data were collected. This equates to an area of 4,783,942 m^2; for the Operational Barnesmore Windfarm, and 5,820,339 m^2 for the Development. These 500 m buffers are utilised to encompass rotor blade length and to minimise spatial error in flight recording accuracy due to the effects of parallax.

The area visible from each vantage point (hereafter referred to as viewshed) was calculated and ground-truthed (i.e. confirmed during field work; **Figures 7.73 & 7.74**) to establish the physical visibility of the viewshed including landscape features (e.g. woodland, spoil heaps etc) that are not accounted for in the computer modelling programme. These viewshed areas were truncated at 2 km as the efficacy of detection rates decline beyond this distance; although varies with size; species; colouration and habitat (Madders & Whitfield, 2006). The viewsheds from the vantage points are considered to have effectively covered the area of the Development turbines to ground level, when truncated at 2 km, and all airspace out to 2 km and beyond was visible.

For the purposes of the modelling process; the bird breeding season is defined as the period March to August inclusive and the non-breeding season as September to February (March) inclusive. Biometric data for each species was derived from Snow & Perrins (1998)[2] and/or published literature review by BTO (2019)[3]. It is assumed in CRM that birds are available to collide with turbines for 365 days per year based on the average monthly day length and activity at the Site (**Table 7.1**), although for some species may not present in the area during the wintering period (**Technical Appendix 7.1**) and adjustments for seasonal occurrence were made accordingly. Bird flight speeds were derived from Provan & Whitfield (2006)[4] and SNH (2014)[5] and Alerstam (2009).

The models were constructed for both the existing and the proposed turbines in order to compare the effects between the Operational Barnesmore Windfarm and the Development. Turbine parameters were entered into the CRM; including the number of turbines (n); hub height (m), rotor diameter (m), rotation period (sec); maximum chord i.e. blade width (m); rotor depth (m); pitch (°) and operation period (%).

The operational turbines have a maximum hub height of 40.5 m with a rotor diameter of 42 m (radius 21 m from the centre of the hub). Whilst pitch (0 - 45 °) and rotation period (30 rpm) are often variable in turbines; where a range is available average

[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., Hanss, G. and Ferrer, M. (eds). Birds and wind farms: Risk assessment and mitigation. pp Quercus.
[2] Snow, D.W. & Perrins, C.M. (1998). The Birds of the Western Palaearctic. Volume I Non-Passerines. Oxford University Press.
[3] BTO (2019). https://www.bto.org/understanding-birds/birdfacts
[4] Provan, S. & Whitfield, D.P. (2006). Avian flight speeds and biometrics for use in collision risk modelling. Report to Scottish Natural Heritage from Natural Research (Projects) Ltd.
[5] SNH (2014b). Flight speeds and biometrics for collision risk modelling. October 2014. Scottish Natural Heritage;

values were utilised in the CRM for pitch (22.5°) and the maximum rotation period at 30 rpm (2 seconds for single revolution) respectively.

Details of the Development turbines are based on a candidate machine assuming worst case parameters (the lowest likely tower height and greatest rotor diameter). The likely candidate turbines have an estimated hub height of 101 m with a rotor diameter of 158 m (radius 79 m from the centre of the hub). Whilst pitch (0 - 45 °) and rotation period (4 – 12 rpm) are often variable in turbines; where a range is available average values were utilised in the CRM for pitch (22.5°) and the maximum rotation period at 12 rpm (five seconds for single revolution) respectively.

Wind turbines were assumed to be operative for 75% of the time due to speed, inclement weather and maintenance. Band et al., (2007) usually considered wind turbine operational time as 75% or greater and in the absence of site-specific wind data the nominal figure of 75% has been utilised.

Each species is considered separately between years of survey 2017 – 2018 and 2018 – 2019 and comparison between Operational Barnesmore Windfarm collision risk estimates and the Development collision risk estimates made. Only those flights which passed through the respective, existing and proposed windfarm (500 m turbine buffer) areas are incorporated to the collision risk modelling (**Figures 7.61 & 7.62**).

The following section sets out collision models and assessment findings for each bird receptor and concludes that the Development presents no significant risk of collision to ornithological receptors. There has been no documented collision recorded at the Operational Barnesmore windfarm as part of on-going monitoring, recording and reporting protocol operated by ScottishPower Renewables since 2010 (see also **Technical Appendix 7.4**). When considering the operational phase of the Development in terms of collision risk, an illustrative 30-year period has been used when considering the magnitude of collision estimates. Flight routes and trajectories under consideration for collision risk modelling are illustrated in **Figures 7.61 & 7.62**.

7.2 Potential effects of collision on birds

There was a maximum of 18 target species detected flying within the 500 m Survey Area during the breeding and/or wintering seasons, buzzard, cormorant, curlew, common sandpiper, golden eagle, golden plover, heron, kestrel, mallard, peregrine, red grouse, raven, sparrowhawk, snipe, teal, white-tailed eagle, wigeon, and whooper swan although the detection rates and occurrence varied between years (**Technical Appendix 7.1**). Some of the detected species were recorded breeding and/or wintering within 500 m of turbines or the wider hinterland of turbines and may therefore have a pathway to collision risk (**Figures 7.20 – 7.26**).

Most frequently occurring species across all years of study were raven, red grouse, golden plover, kestrel snipe and cormorant (**Technical Appendix 7.1**). The ravens were frequently recorded to be present on the Site scavenging on available carrion. There were some raptor species (kestrel) nesting and territorial activity recorded within the 500 m turbine buffers although nest locations will physically be unaffected by the Development as most are associated with the coniferous forest plantation adjacent to the windfarm (**Chapter 7; Figures 7.2; 7.20 – 7.26; 7.39 – 7.45**). Three Target 1 species were recorded within potential collision height bands, golden plover, golden eagle, peregrine and white-tailed eagle.

Golden plover activity was increased over-winter with a small flock that occurred throughout the winter and small numbers of greylag geese and whooper swans were recorded to occasionally pass over or near the Site area during wintering / migration periods and small family parties of whooper swan were recorded roosting and foraging on various loughs within 500 m of turbines however flights passed either beyond the 500 m Survey Areas and from either existing or proposed turbines or below potential collision risk height and therefore no collision is predicted. There were a range of foraging or roosting sites for swans and geese identified within 5 km and beyond for other species including greylag geese, white-fronted geese, light-bellied Brent geese, Canada geese and a migration corridor identified for some of these species along the Barnesmore Gap. Large aggregations of swans using nearest winter roosts on Site or traditional commuting or migratory corridors were not recorded, and all flights were low level which means that collisions are unlikely.

Two eagle species were recorded, with golden eagles known to be breeding beyond 6 km (McLeod et al., 2004; SNH, 2017) and an individual non-breeding white-tailed eagle present during various surveys ranging widely. The Operational Barnesmore Windfarm appears to be within / at the edge of the breeding range of the territorial golden eagles in the Bluestack Mountains.

Hen harrier and raven roost sites were recorded within the wider hinterland (500 m – 5 km Survey Areas (**Technical Appendix7.1; Figures 7.2; 7.20 – 7.26; 7.39 – 7.45**) and these locations, which varied between years, will be unaffected by the existing and/or proposed turbines and associated infrastructure. The harrier and raven wintering locations were utilised throughout the winter although are beyond the Development footprint and beyond the 500 m Survey Area. Hen harrier roosts were all recorded more than 5 km away and in similar areas each year. Raven winter roost sites were identified at several locations in the Killeter Forest and Barnesmore Gap adjacent to the Operational Barnesmore Windfarm and were spatially variable between different days and years and high levels of raven activity was observed within the Site in all years but exhibited considerable evidence of avoidance (**Figures 7.16 & 7.35**)

7.2.1 Collision risk modelling for primary target species

7.2.2 Golden eagle

There was an active golden eagle nest site beyond 7 km, and which was successful in both recent years of survey (**Technical Appendix 7.1**). This is a crag nesting site which is located within the Bluestacks Mountains and successfully fledged one young during both survey years (**Technical Appendix 7.1**; this study). This territory is considered to the origin of all flights (with individual tagged birds identified at the breeding site and over the Operational Barnesmore Windfarm) and post-fledging juvenile birds also observed from vantage point and during wider priority species surveys. Much of the golden eagle flight activity occurred beyond the 500 m turbine buffers and therefore at no risk of collision (**Figure 7.17; 7.18; 7.36; 7.37**). Golden eagle flights occasionally passed through the respective 500 m turbine buffers particularly along the western and northern areas (**Table 7.2; 7.3**) and there was some variation in potential collision risk heights at the existing and proposed turbines given the different turbine metrics. A number of the eagle flights were at very high elevation well above collision risk heights.

The collision risk predicted in 2017-2018 at the Operational Barnesmore Windfarm turbine envelope equates to up to 0.25 golden eagles in the absence of avoidance (**Table 7.18**). This represents approximately 2.5% (i.e. 0.25 divided by 10 – 2 x 5 pairs) from the Ireland population (IRSG, 2017) and 1.25% of the individual (20 – 25) estimated population (GET, 2018). With the recommended avoidance for golden eagles as 99% (Provan & Whitfield, 2006; SNH, 2017), this declines to a negligible 0.002 golden eagles. With no avoidance this equates to approximately one bird every 4.1 years, but with 99% avoidance one bird every 406.3 years.

The collision risk predicted in 2017-2018 for the Development turbine envelope equates to up to 0.37 golden eagles (**Table 7.19**) in the absence of avoidance. This represents approximately 3.7% (i.e. 0.37 divided by 10– 2 x 5 pairs) from the Ireland population (IRSG, 2017) and 1.85% of the individual (20 – 25) estimated population (GET, 2018). With the recommended avoidance, for golden eagles as 99% (Provan & Whitfield, 2006; SNH, 2017) this declines to a negligible 0.004 golden eagles which equates to 0.04% of the Ireland breeding population or 0.02% of the individual population. With no avoidance this equates to approximately one bird every 2.7 years, but with 99% avoidance one bird every 270.6 years.

There was some variation between survey years and activity was all recorded beyond the 500 m turbine buffers during the 2018 – 2019 surveys therefore no collisions are predicted in that year. Average collision risk as predicted by Band et al., (2007) models is lower for golden eagles in the Development (7.8%) compared to the Operational Barnesmore Windfarm (10.4%) (**Table 7.16 – 7.17**).

There have been no collisions recorded of this species at the Operational Barnesmore Windfarm and in conclusion, as shown above, the Development presents no significant risk to golden eagles from collision throughout the operational phase and the repowering the turbines actually lowers individual collision risk per turbine.

7.2.3 Golden plover

Golden plover occurred within the 500 m turbine area most frequently of all species during the vantage point surveys in 2017-2018 (n = 31) and there were fewer detections in 2018-2019 (n = 18). Activity was more frequently recorded in the wintering season although the species was also recorded breeding within 2 km but these breeding birds rarely entered the turbine buffers. Wintering golden plover were recorded during migration and throughout the winter season on Site and were predominantly recorded in one part of the Site with occasional flights through other parts of the Site and spent large amounts of time in flight around operational turbines and roosting in and around tracks and turbine bases (**Technical Appendix 7.1; Figures 7.17 - 7.19; 7.36 – 7.38**).

The activity centres largely correspond an apparently preferred roosting area and flocks make intermittent circuits from the roosting site around the Site and occasionally flew to the north (**Figures 7.61 & 7.62**), and they were frequently recorded to fly within the Operational Barnesmore Windfarm including in close proximity to operational turbines and exhibited notable avoidance flight responses around operational turbines (**Figures 7.61 & 7.62**). Golden plover flights occurred both inside and outside the potential collision risk height (**Table 7.2 & 7.4**) within a range of height bands and were recorded between <10 m and up to 180 m.

The collision risk predicted in 2017-2018 at the Operational Barnesmore Windfarm turbine envelope equates to up to 1.4 golden plover (**Table 7.22**) in the absence of avoidance. This represents approximately 0.5% (i.e. 1.4 divided by 300 birds – 150 x 2 pairs) from the Ireland breeding population (NPWS, 2012) or 0.002% of the wintering population (80,707; NPWS, 2012). With the recommended avoidance for golden plover as 98% (Provan & Whitfield, 2006; SNH 2014; 2017), this declines to 0.03 golden plover. With no avoidance this equates to approximately one bird every 0.7 years, but with 98% avoidance one bird every 34.8 years.

The collision risk predicted in 2017-2018 at the Development turbine envelope equates to up to 2.4 golden plover (**Table 7.23**) in the absence of avoidance. This represents approximately 0.8% (i.e. 2.4 divided by 300 birds – 150 x 2 pairs) from the Ireland breeding population (NPWS, 2012) or 0.003% of the wintering population (80,707; NPWS, 2012). With the recommended avoidance for golden plover as 98% (Provan & Whitfield, 2006; SNH 2014; 2017), this declines to 0.05 golden plover. With no avoidance this equates to approximately one bird every 0.4 years, but with 98% avoidance one bird every 20.6 years.

There was some variation between survey years and activity was lower during 2018 – 2019 surveys although more of the observed flights were recorded within the risk window but no flights were recorded during the breeding season in that year and plover were recorded further away during the breeding season. With no avoidance the activity equates to predicted mortality of approximately one bird every 0.4 years, but with 98% avoidance one bird every 19.3 years for the existing turbine envelope (**Table 7.24**) and approximately one bird every 0.3 years, but with 98% avoidance one bird every 13.8 years for the Development (**Table 7.25**). Average collision risk as predicted by Band et al., (2007) models is lower for golden plover in the Development (4.9%) compared to the Operational Barnesmore Windfarm (6.9%) (**Tables 7.20 & 7.21**).

NPWS (2012) estimated that the Irish breeding population of golden plover was 150 pairs (300 birds) and the wintering population considerably larger within 80,707 individuals in Ireland. On the basis of the above any collision rates at the Development would suggest that a negligible proportion of golden plover may be affected from the Irish population. Low level effects may occur locally (on the circa up to 50-60 birds which are over-wintering here however, no golden plover nested within 200 - 400 m (Pearce-Higgins et al., 2009; Sansom et al., 2016) of existing and/or the proposed turbines and indeed the majority were recorded more than 1 km away, therefore actual risks for this species of displacement and/or collision are considered low, but will continue to be monitored as part of the monitoring protocol outlined here (**Chapter 7; Technical Appendix 7.4**).

Golden plover are not considered vulnerable to collision (Haworth & Fielding, 2015) and any residual effects can be monitored via the operational monitoring programme (**Chapter 7; Technical Appendix 7.4**). Any associated collision risk estimate also does not take into account the spatial preferences and/or usage of the Site which shows that activity is primarily around the area of the existing and proposed turbines (**Technical Appendix 7.1; Figure 7.61 & 7.62**) and the Development will be removing turbines from that preferred roosting area. Similarly it is noted that whilst golden plover were assessed over the duration of a year (since they were recorded during breeding and wintering season) the predominant activity and proximity to / within the Site was during winter season only and therefore collision risk modelling on presence for wintering season only (when risk may be higher) reduces the overall collision risk estimates considerably (**Tables 7.26 – 7.28**) equivalent to 84.2 – 49.9 years for 2017-2018; 42.2 – 30.2 for 2018-2019) and therefore no significant effects are predicted on locally wintering golden plover during the 30 year indicative windfarm lifespan albeit risks may be marginally higher than at the Operational Barnesmore Windfarm for this species across the Site, but given restricted spatial usage of the Site and the reduction of individual turbine risk estimates for Development turbines overall reduces extant risks in the core area utilised by golden plover.

There have been no collisions recorded of this species at the Operational Barnesmore Windfarm and in conclusion, as shown above, the Development presents no significant risk to golden plovers from collision throughout the operational phase. Flight activity and extant risk may be associated with winter roosting and foraging proximity and can be managed via the reduction of turbines (as proposed) and implementation of species management particularly around the roosting and foraging areas at the Site (**Chapter 7**).

7.2.4 Peregrine falcon

There was an active peregrine nest site within 2 km, although which was successful in recent years of survey (**Technical Appendix 7.1**). This is a crag nesting site which is located within the Barnesmore Bog NHA and successfully fledged young during both survey years (**Technical Appendix 7.1**; this study). This territory appears to be the origin of all the peregrine flights observed during vantage points with more observations in later summer after young fledglings began travelling further afield during surveys with juveniles observed from vantage point.

Much of the peregrine flight activity occurred beyond the 500 m turbine buffers and therefore at no risk of collision (**Figures 7.17; 7.18; 7.36; 7.37**). Peregrine flights only occasionally passed through the respective 500 m turbine buffers (**Figures 7.61 & 7.62; Table 7.2; 7.4**) and there was some variation in potential collision risk heights at the existing and proposed turbines given the different turbine metrics.

The collision risk predicted in 2017-2018 at the Operational Barnesmore Windfarm equates to up to 0.1 peregrines (**Table 7.42**) in the absence of avoidance. This represents approximately 0.04% (i.e. 0.06 divided by 850 – 2 x 425 pairs) from the Ireland population (IRSG, 2017). With the recommended avoidance for peregrines as 98% (Provan & Whitfield, 2006), this declines to a negligible 0.003 peregrines. With no avoidance this equates to approximately one bird every 6.9 years, but with 98% avoidance one bird every 345.6 years.

The collision risk predicted in 2017-2018 for the Development equates to up to 0.16 peregrines (**Table 7.43**) in the absence of avoidance. This represents approximately 0.48% (i.e. 0.8 divided by 850– 2 x 425 pairs) from the Ireland adult population (IRSG, 2017). With the recommended avoidance, for peregrines as 98% (Provan & Whitfield, 2006) this declines to a negligible 0.003 peregrines. With no avoidance this equates to approximately one bird every 6.2 years, but with 98% avoidance one bird every 314.2 years.

There was some variation between survey years and activity was all recorded beyond the 500 m turbine buffers during the 2018 – 2019 surveys therefore no collisions are predicted in that year. Average collision risk as predicted by Band et al., (2007) models is actually lower for peregrine falcons in the Development (6.5%) compared to the Operational Barnesmore Windfarm (9.5%) (**Tables 7.40 & 7.41**).

There have been no collisions recorded of this species at the Operational Barnesmore Windfarm and in conclusion, as shown above, the Development presents no significant risk to peregrine falcons from collision throughout the operational phase.

7.2.5 White-tailed eagle

There were no active white-tailed eagle breeding or regular roosting sites recorded within 2 km, although the individual bird (identifiable by wing-tags and satellite tag) was recorded in a variety of locations including within 500 m of the Site; fishing at Lough Slug and in the wider hinterland up to 10 km away and the same individual was encountered at Lough Derg, Lough Eske, Barnesmore Gap and near Meenadreen (**Technical Appendix 7.1**) and also known to be recorded at Lough Assaroe and Lough Erne (M. Ruddock, personal observation; www.mountshannoneagles.ie) more than 30 km to the south. This individual was identified as a non-territory holding eagle and was confirmed to subsequently return to Lough Derg, Co. Clare in 2019 (Irish Times, 2019). Usage of the Site by white-tailed eagles was apparently ad-hoc mostly high level flights (above operational turbine height) although was observed to attempt fishing on Lough Slug during other surveys (**Technical Appendix 7.1**) and was chased to lower flight elevation level by a golden eagle during one observation (**Technical Appendix 7.1**; **Figures 7.61 & 7.62**).

Some of the white-tailed eagle flight activity occurred beyond the 500 m turbine buffers including and therefore at no risk of collision (**Figure 7.17; 7.18; 7.36; 7.37**). White-tailed eagle flights occasionally passed through the respective 500 m turbine buffers and in some flights in close proximity to Operational Barnesmore Windfarm (**Figures 7.61 & 7.62; Table 7.2; 7.4**) and there were only flights at collision risk height detected during one year of the survey (2017 – 2018).

The collision risk predicted in 2017-2018 at the Operational Barnesmore Windfarm equates to up to 1.06 eagles (**Table 7.46**) in the absence of avoidance. This represents approximately 5.3% (i.e.1.06 divided by 20 birds – 2 x 10 pairs) from the Ireland population (IRSG, 2019; **Chapter 7**). With the recommended avoidance for white-tailed eagles as 95% (Provan & Whitfield, 2006), this declines to 0.05 eagles. With no avoidance this equates to approximately one bird every 0.9 years, but with 95% avoidance one bird every 18.8 years.

The collision risk predicted in 2017-2018 for the Development equates to up to 1.12 eagles (**Table 7.47**) in the absence of avoidance. This represents approximately 5.6% (i.e. 1.12 divided by 20 birds – 2 x 10 pairs) from the Ireland population (IRSG, 2019). With the recommended avoidance, for white-tailed eagles as 95% (Provan & Whitfield, 2006) this declines to 0.06 eagles. With no avoidance this equates to approximately one bird every 0.9 years, but with 95% avoidance one bird every 17.8 years. The difference between existing and proposed collision risks is therefore negligible.

There was some variation between survey years and activity was all recorded beyond the 500 m turbine buffers and/or below collision risk height during the 2018 – 2019 surveys therefore no collisions are predicted in that year. Average collision risk as predicted by Band et al., (2007) models is considerably lower for white-tailed eagles in the Development (9.3%) compared to the Operational Barnesmore Windfarm (15.5%) (**Tables 7.44 & 7.45**). Collision risk for white-tailed eagles on a per turbine basis and across the windfarm is lower for proposed than existing turbines and a betterment is predicted for this species.

There have been no collisions recorded of this species at the Operational Barnesmore Windfarm and there are also no established breeding / roosting areas for this species and the individual bird involved has left the area and therefore is no longer at risk of collision, in conclusion, as shown above, the Development presents no significant risk to white-tailed eagle from collision throughout the operational phase.

7.2.6 Collision risk modelling for secondary target species

As detailed in the methods section of the technical report (**Technical Appendix 7.1**) certain species are prioritised during vantage point observations for recording purposes (**Chapter 7**; **Table 7.1**). Flight trajectories, duration and heights are recorded in a hierarchical method in order that high risk species e.g. Annex 1; red-listed or species vulnerable to collision are the focus of the observer. Thus, species like hen harrier, eagles and swans are prioritised and observer efforts focussed on these, in particular to avoid long recording periods of more common or less vulnerable species like ravens, or buzzards they are typically treated as secondary species (see both SNH, 2005 & 2013).

It is noted that, as per SNH guidance and general best practice guidance, detailed field monitoring of secondary species can detract and/or distract from the monitoring of primary species and would always caution against observers trying to record too many species. However, as a matter of course observers at Bird Surveyors Ltd record the height band range of all detected species and flight trajectory for the secondary species, particularly raptors (see **Technical Appendix 7.1**) and/or record additional information on maps and recording forms. This information was additionally digitised and has been presented (**Technical Appendix 7.1; Figures 7.14 – 7.16 & 7.33 – 7.35**).

The species priority list utilised in this study are based on composite measures of legislative protection e.g. Annex 1 EU protected species, conservation status (Colhoun & Cummins, 2013; Eaton et al., 2015), vulnerability to collision (e.g. swans with poor manoeuvrability) or displacement and propensity to consume observer observation effort (e.g. buzzards or ravens). Whilst this system does not diminish the importance of each individual species, the methods recognise that observers can realistically only record specific information during each observation. This hierarchical recording methodology is recognised best practice for wind farm vantage point observations (SNH, 2005; 2013; 2017) specifically to minimise observer errors or detections.

Nevertheless, information presented here was extracted and analysed for secondary species which were observed to either regularly utilise the Site and occurred within 500 m of turbines and occurred within collision risk height, namely buzzard, cormorant, heron and kestrel. It is also noted that all of the other secondary species detected including mallard, red grouse, snipe, common sandpiper, sparrowhawk, teal and wigeon were either flying <20 m a.g.l. (**Technical Appendix 7.1**) and therefore there is no associated collision risk for these species and no further collision risk modelling was conducted on these species.

7.2.7 Buzzard

The majority of the buzzard activity originated from the nearest breeding locations west of the Barnesmore Gap and in 2018 there were two additional pairs located west of the Development; **Technical Appendix 7.1; Figure 7.14 & 7.33**) and occasional flights are made into the area by the pairs located to the west (**Figure 7.33**). Some individuals may use the edge of the Barnesmore Gap to obtain lift for foraging, displaying and commuting, but the majority of all buzzard flight activity is in the wider 500 m Survey Area rather than through or over the core Site and existing or proposed turbine locations (**Technical Appendix 7.1**) which minimises extant risk.

Some buzzard flights occurred both inside and outside the potential collision risk height and within the 500 m turbine buffers during 2018 – 2019 survey season (**Tables 7.3 & 7.5**). The collision risk predicted in 2018-2019 at the Operational Barnesmore Windfarm equates to up to 0.7 buzzard (**Table 7.8**) in the absence of avoidance. This represents approximately 0.02% (i.e. 0.7 divided by 3,000 – 2 x 1,500 pairs) from the Ireland population (NPWS, 2012) or 0.002% of the NI population (2,000 pairs / 4000 birds; Musgrave et al., 2013). With the recommended avoidance for buzzard as 98% (Provan & Whitfield, 2006; SNH 2014; 2017), this declines to a negligible 0.014 buzzard. With no avoidance this equates to approximately one bird every 1.5 years, but with 98% avoidance one bird every 73.1 years.

The collision risk predicted in 2018-2019 at the Development equates to up to 0.02 buzzard (**Table 7.9**) in the absence of avoidance. This represents approximately 0.02% of the Ireland population and 0.018% from the Northern Ireland adult population (Musgrove et al., 2013). With the recommended avoidance for buzzard as 98% (Provan & Whitfield, 2006; SNH 2014; 2017), this declines to a negligible 0.014 buzzard. With no avoidance this equates to approximately one bird every 1.4 years, but with 98% avoidance one bird every 69.4 years.

There was some variation between survey years and activity was lower during 2017 – 2018 surveys and there were no flights recorded at risk of collision during the first year of surveys. Average collision risk as predicted by Band et al., (2007) models is lower for buzzards in the Development (11.3%) compared to the Operational Barnesmore Windfarm (7.5%) (**Tables 7.6 & 7.7**).

Buzzards are not considered particularly vulnerable to collision (Whitfield & Madders, 2006) and no specific avoidance measures have been established for them. In Wales, they will breed in close proximity to windfarms although some collisions have occurred (K. Duffy, personal communication & M. Ruddock, personal observation) and equally buzzards have been recorded to display in the vicinity of windfarms and even perch on nacelles when blades are not turning without observations of mortality (M. Ruddock, personal observation).

Pearce-Higgins et al., (2009) indicates that buzzard occurrence in/around windfarms may be altered (displaced) by an average of 41.4% (range 16.0% to 57.8%), therefore indicating that there may be a reduced level of activity (i.e. avoidance), and further reducing collision risk by up to 57%.

On the basis of the above any collision rates within the Development would confirm that a negligible proportion of the buzzards may be affected from the Irish population. Some buzzards nested within 5 km of the Development, and others were recorded within 2 km of the Development, therefore actual risks for this species of displacement and/or collision are considered low, but will continue to be monitored as part of the monitoring protocol outlined here (**Chapter 7; Technical Appendix 7.4).**

Any collision risk estimate for this secondary species does not take into account the spatial preferences and/or usage of the Site which shows that activity is primarily away from the proposed area of the turbines (**Figures 7.14 & 7.33; 7.61 – 7.62**), and located around areas of identified breeding territories (**Technical Appendix 7.1**) therefore collision rates are likely to be considerably lower than any predicted rate (**Tables 7.8 & 7.9**).

There have been no collisions recorded of this species at the Operational Barnesmore Windfarm and in conclusion, as shown above, the Development presents no significant risk to buzzard from collision throughout the operational phase.

7.2.8 Cormorant

Cormorant were recorded during both breeding and wintering season but were not breeding on or near the Site. Birds were recorded regularly utilising the loughs within the Operational Barnesmore Windfarm. Flight activity originated from the east to / from direction of Lough Derg and to / from the direction of Lough Eske; **Technical Appendix 7.1; Figure 7.14 & 7.33**) birds utilised primarily Lough Slug, Lough Golagh and Lough Naweelagh and spent extended periods of time loafing, fishing and making short low level flights across the loughs (**Figures 7.14 & 7.33**). The typical entry / exit point to the Site for flights was the western end of Lough Golagh. The majority of cormorant flight activity is through corridors between turbines and largely associated with Lough Golagh in the wider 500 m Survey Area rather than through or over the existing or proposed turbine locations (**Technical Appendix 7.1**) which minimises extant risk.

Some cormorant flights occurred both inside and outside the potential collision risk height and within the 500 m turbine buffers during 2017 – 2018 survey season (**Tables 7.3 & 7.5**). The collision risk predicted in 2017-2018 at the Operational Barnesmore Windfarm equates to up to 1.1 cormorant (**Table 7.12**) in the absence of avoidance. This represents

approximately 0.01% (i.e. 1.1 divided by 8700 birds) from the Ireland population (NPWS, 2012) or 0.1 – 0.7% of the county population (108 - 803 birds). With the recommended avoidance for cormorant as 98% (Provan & Whitfield, 2006; SNH 2014; 2017), this declines to a negligible 0.02 cormorant. With no avoidance this equates to approximately one bird every 0.9 years, but with 98% avoidance one bird every 47.3 years.

The collision risk predicted in 2017-2018 at the Development equates to up to 0.9 cormorants (**Table 7.13**) in the absence of avoidance. This represents approximately 0.03% of the Ireland population and 0.1 – 0.6 % of the county population. With the recommended avoidance for cormorant as 98% (Provan & Whitfield, 2006; SNH 2014; 2017), this declines to a negligible 0.02 cormorant. With no avoidance this equates to approximately one bird every 1.0 years, but with 98% avoidance one bird every 50.6 years.

There was some variation between survey years and activity was lower during the 2018 – 2019 surveys. With no avoidance the activity during this period equates to predicted mortality of approximately one bird every 2.5 years, but with 98% avoidance one bird every 122.6 years for existing turbines (**Table 7.14**) and approximately one bird every 1.3 years, but with 98% avoidance one bird every 131.4 years for the proposed turbines (**Table 7.15**). Collision estimates here therefore are lower for the Development than the Operational Barnesmore Windfarm and therefore the repowering is a positive effect for cormorant collision risks. Average collision risk as predicted by Band et al., (2007) models is lower for cormorants in the Development (7.2%) compared to the Operational Barnesmore Windfarm (12.4%) (**Tables 7.10 & 7.11**).

Cormorant are not considered particularly vulnerable to collision and no specific avoidance measures have been established for them. Birds locally appeared to be habituated to turbines and infrastructure at the Operational Barnesmore Windfarm and flying around and through turbines to access some of the fishing lakes. Cook et al (2012) indicates that cormorant spent 4 – 33% of time at collision risk height at off-shore windfarms and that avoidance is >99% and other studies, Krijgsveld et al. (2011), reported the majority of birds at heights of less than 5 m.

On the basis of the above any collision rates within the Development would confirm that a negligible proportion of the cormorant may be affected from the Irish population. Some cormorants nested within 5 km – 10 km of the Development, and were recorded on other waterbodies during breeding and wintering surveys, therefore actual risks for this species of displacement and/or collision are considered low, but will continue to be monitored as part of the monitoring protocol outlined here (**Chapter 7; Technical Appendix 7.4**).

Any collision risk estimate for this secondary species does not take into account the spatial preferences and/or usage of the Site which shows that activity is primarily away from the proposed area of the turbines (**Figures 7.14 & 7.33**; **7.61 & 7.62**), and located around areas of identified breeding territories (**Technical Appendix 7.1**) therefore collision rates are likely to be considerably lower than any predicted rate (**Tables 7.12 – 7.16**).

There have been no collisions recorded of this species at the Operational Barnesmore Windfarm and in conclusion, as shown above, the Development presents no significant risk to cormorant from collision throughout the operational phase.

7.2.9 Heron

There were no active heron nest sites recorded within 2 km, although the species was recorded in suitable habitat at along the Mourne Beg River and frequently encountered at Lough Derg and Lough Eske (**Technical Appendix 7.1**; **Figures 7.20 – 7.26**). Usage of the Site by herons is focussed primarily on the usage of Lough Golagh for foraging with entry and exit flights recorded coming from Barnesmore Gap and also to / from the western edge of Golagh, other flights were typically low level and along the length of the loughs whilst moving foraging positions (**Technical Appendix 7.1**; **Figures 7.14 & 7.33**; this study). Extended period of time were spent along lough edges and margins fishing. Flights were recorded during both breeding and wintering seasons.

Some of the heron flight activity occurred beyond the 500 m turbine buffers including along Barnesmore Gap corridor and therefore at no risk of collision (**Figures 7.17; 7.18; 7.36; 7.37**). Heron flights occasionally passed through the respective 500 m turbine buffers and in some flights in close proximity to operational Barnesmore turbines (**Tables 7.3; 7.5**) and there were only flights at collision risk height detected during one year of the survey.

The collision risk predicted in 2018-2019 at the Operational Barnesmore Windfarm equates to up to 0.39 herons (**Table 7.32**) in the absence of avoidance. This represents approximately 0.007% (i.e. 0.4 divided by 6,080 birds) from the Ireland population (NPWS, 2012). With the recommended avoidance for herons as 98% (Provan & Whitfield, 2006), this declines to a

negligible 0.008 herons. With no avoidance this equates to approximately one bird every 2.6 years, but with 98% avoidance one bird every 128.9 years.

The collision risk predicted in 2018-2019 for the Development equates to up to 0.36 herons (**Table 7.33**) in the absence of avoidance. This represents approximately 0.006% (i.e. 0.36 divided by 6,080 birds) from the Ireland population (NPWS, 2012). With the recommended avoidance, for herons as 98% (Provan & Whitfield, 2006) this declines to a negligible 0.007 herons. With no avoidance this equates to approximately one bird every 2.7 years, but with 98% avoidance one bird every 137.2 years.

There was some variation between survey years and activity was all recorded beyond the 500 m turbine buffers and/or below collision risk height during the 2017 – 2018 surveys therefore no collisions are predicted in that year. Average collision risk as predicted by Band et al., (2007) models is lower for herons in the Development (9.9%) compared to the Operational Barnesmore Windfarm (17.1%) (**Tables 7.30 & 7.31**). Collision risk for herons on a per turbine basis and across the windfarm is lower for proposed than existing turbines and a betterment is predicted for herons.

There have been no collisions recorded of this species at the Operational Barnesmore Windfarm and in conclusion, as shown above, the Development presents no significant risk to herons from collision throughout the operational phase

7.2.10 Kestrel

Kestrels occurred within the 500 m turbine area frequently during the vantage point surveys in 2017-2018 (n = 20) although there were fewer detections in 2018-2019 (n = 9) perhaps the reduction of activity since the nearest pair nested further away during 2018. These birds occurred widespread over most parts of the Site and around operational turbines (**Technical Appendix 7.1; Figures 7.15 & 7.34; 7.20 – 7.26**).

The activity centres largely correspond to the proximity and foraging range of nearest known territories at Lough Shivanagh to the north, Barnesmore Gap to the north-west and Keadew Upper to the west. The Site is used for foraging and birds were frequently encountered hunting in and around turbines and were observed capturing lizards on Site and birds appear to be using the areas of the 500 m turbine buffers based on proximity to the nearest nest sites (**Figures 7.14 – 7.33**), and they were frequently recorded to fly within the area of the Operational Barnesmore Windfarm including in close proximity to operational turbines (**Figures 7.14 & 7.33; 7.61 & 7.62**). Kestrel flights occurred both inside and outside the potential collision risk height (**Tables 7.3 & 7.5**) within a range of height bands and were recorded between <10 m and up to 180 m.

The collision risk predicted in 2017-2018 at the Operational Barnesmore Windfarm equates to up to 2.0 kestrel (**Table 7.36**) in the absence of avoidance. This represents approximately 0.02% (i.e. 2.0 divided by 12,100) from the Ireland population (Crowe et al., 2014). With the recommended avoidance for kestrel as 95% (Provan & Whitfield, 2006; SNH 2014; 2017), this declines to 0.1 kestrel. With no avoidance this equates to approximately one bird every 0.5 years, but with 95% avoidance one bird every 9.9 years.

The collision risk predicted in 2017-2018 at the Development equates to up to 2.8 kestrel (**Table 7.37**) in the absence of avoidance. This represents approximately 0.02% (i.e. 2.8 divided by 12,100) from the Ireland population (Crowe et al., 2014). With the recommended avoidance for kestrel as 95% (Provan & Whitfield, 2006; SNH 2014; 2017), this declines to 0.14 kestrel. With no avoidance this equates to approximately one bird every 0.4 years, but with 95% avoidance one bird every 7.2 years.

There was some variation between survey years and activity was lower during 2018 – 2019 surveys. With no avoidance the activity equates to predicted mortality of approximately one bird every 2.6 years, but with 95% avoidance one bird every 52.5 years for the existing turbine envelope (**Table 7.38**) and approximately one bird every 2.2 years, but with 95% avoidance one bird every 44.3 years for the existing turbine envelope (**Table 7.39**). Average collision risk as predicted by Band et al., (2007) models is lower for kestrels in the Development (6.9%) compared to the Operational Barnesmore Windfarm (9.5%) (**Tables 7.34 & 7.35**).

A study by Crowe et al., (2014) estimated that the Irish population of kestrels was 16,470 (12,100 – 21.220) individuals in Ireland. On the basis of the above any collision rates at the Development would suggest that a negligible proportion of kestrels may be affected from the Irish population. No kestrels nested within 600 m (1 year only) of the proposed turbines and indeed the majority were recorded more than 1 km away, therefore actual risks for this species of displacement and/or

collision are considered low, but will continue to be monitored as part of the monitoring protocol outlined here (**Chapter 7; Technical Appendix 7.4**).

Kestrels are considered vulnerable to collision (Whitfield & Madders, 2006) and any effects can be monitored via the operational monitoring programme (**Chapter 7; Technical Appendix 7.4**). Any associated collision risk estimate also does not take into account the spatial preferences and/or usage of the Site which shows that activity is primarily around the area of the existing and proposed turbines (**Technical Appendix 7.1; Figure 7.15 & 7.34**) and activity may be linked to the proximity of the nearest nesting sites and spatial changes in activity were evident when in 2018 the nearest northern pair were not present but a pair was within the landownership to the west.

There have been no collisions recorded of this species at the Operational Barnesmore Windfarm and in conclusion, as shown above, the Development presents no significant risk to kestrel from collision throughout the operational phase. There has been one collision recorded of this species at the SPR Operational Rigged Hill Windfarm, in Northern Ireland, and the collision occurred in the year when nesting was recorded in closer proximity than previous years, flight activity and risk may therefore be associated with nesting proximity and can be managed via the installation of alternative nest sites away from turbine areas (**Chapter 7**) including at Barnesmore.

Table 7.1 Duration of monthly hours and daylight available for collision risk modelling

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Days	31	30	31	30	31	31	30	31	30	31	31	28	31
Total hours	744	720	744	720	744	744	720	744	720	744	744	672	744
Average daylight hours	12	14	13	15	16	16.5	16	10	9	8	9	10	12
Total daylight hours	372	420	403	450	496	512	480	310	270	248	279	280	372

Table 7.2 Details of flights of Target 1 species utilised in collision risk modelling (CRM) 2017 – 2018. [6]

VP No	Month	Day	Year	Species	No	Time 1st detected	Duration (secs)	E	P	<10m	10-20m	20-40m	40-60m	60-100m	100-120m	120-180m	>180m
2	3	23	2017	GP	8	11:27	14	IN	IN	14							
2	3	23	2017	GP	4	13:23	22	IN	IN	22							
2	3	23	2017	GP	3	13:59	158	IN	IN	15	30	83	30				
2	3	23	2017	GP	1	13:59	158	IN	IN	15	30	83	30				
3	3	30	2017	EA	1	14:08	239	IN	IN				30	30			179
3	3	30	2017	GP	30	12:43	46	IN	IN		1	30	15				

6 WS, CU observed in flight and within the windfarm envelope for both existing and proposed turbines but were below potential collision risk height so no CRM completed

VP No	Month	Day	Year	Species	No	Time 1st detected	Duration (secs)	E	P	<10m	10-20m	20-40m	40-60m	60-100m	100-120m	120-180m	>180m
3	3	30	2017	GP	40	13:22	169	OUT	IN		4	30	15		30	15	75
3	3	30	2017	GP	40	13:49	183	IN	IN		18	15	45		60	15	30
2	4	13	2017	GP	15	11:13	32	IN	IN			2	30				
2	4	20	2017	GP	25	19:13	19	IN	IN			4		15			
2	4	20	2017	GP	9	19:13	6	IN	IN		6						
2	4	20	2017	GP	15	19:13	12	IN	IN	12							
2	4	20	2017	GP	15	20:23	29	IN	IN	14			15				
2	4	20	2017	GP	9	20:44	12	IN	IN	12							
2	6	29	2017	GP	2	12:03	137	IN	IN			17	75	45			
4	6	29	2017	PE	1	08:48	67	IN	IN			7	60				
3	7	22	2017	WE	1	12:35	347	IN	IN				315	30	2		
2	10	12	2017	GP	30	10:23	47	IN	IN		32		15				
2	10	12	2017	GP	13	10:26	28	IN	IN	13	15						
4	11	27	2017	GP	35	13:37	41	IN	IN		30	11					
4	11	30	2017	GP	15	10:09	28	IN	IN				15	13			
4	11	30	2017	GP	15	10:18	23	IN	IN			8	15				
4	11	30	2017	GP	12	10:27	16	IN	IN			1	15				
2	11	30	2017	GP	15	10:24	295	IN	IN		200	45	20	30			
2	11	30	2017	GP	8	11:30	34	IN	IN	34							
2	11	30	2017	GP	43	11:51	31	IN	IN		15			16			
3	11	30	2017	WS	3	14:48	105	IN	IN	15	90						
3	12	20	2017	WS	3	09:39	75	IN	IN	45	30						
2	12	21	2017	GP	1	08:44	3	IN	IN	3							
2	12	28	2017	GP	28	15:14	21	IN	IN	6			15				

VP No	Month	Day	Year	Species	No	Time 1st detected	Duration (secs)	E	P	<10m	10-20m	20-40m	40-60m	60-100m	100-120m	120-180m	>180m
2	12	28	2017	GP	8	15:15	12	IN	IN	12							
2	1	12	2018	GP	6	09:43	8	IN	IN	8							
4	1	12	2018	EA	1	11:35	23	IN	IN				8	15			
4	1	12	2018	EA	1	11:45	38	IN	IN			23	15				
4	1	12	2018	WE	1	11:45	38	IN	IN			23	15				
4	1	12	2018	GP	8	11:50	17	IN	IN					2	15		
2	1	25	2018	GP	13	12:08	48	IN	IN		3		30	15			
2	1	25	2018	CU	1	12:53	21	IN	IN	6	15						
2	2	14	2018	GP	11	12:08	23	IN	IN			8	15				
2	2	14	2018	GP	7	12:20	36	IN	IN			15	15	6			
Existing										No	No	Yes	Yes	No	No	No	No
Proposed										No	No	Yes	Yes	Yes	Yes	Yes	No

Table 7.3 Details of flights of Target 2 species utilised in collision risk modelling (CRM) 2017 – 2018. [7]

VP No	Month	Day	Year	Species	No	Time 1st detected	Duration (secs)	E	P	<10m	10-20m	20-40m	40-60m	60-100m	100-120m	120-180m	>180m
3	3	23	2017	RG	2	15:50	3	IN	IN	3							
4	3	29	2017	RG	1	13:20	43	IN	IN	43							
4	3	29	2017	SN	1	12:20	12	IN	IN	12							
3	3	30	2017	K.	1	12:45	84	IN	IN			40	44				
3	3	30	2017	K.	1	13:40	145	IN	IN			75	70				
3	3	30	2017	K.	1	14:55	344	IN	IN		70	100	174				

[7] CS, H., MA, RG, SH, SN, T. WN observed in flight and within the windfarm envelope for both existing and proposed turbines but were below potential collision risk height so no CRM completed

VP No	Month	Day	Year	Species	No	Time 1st detected	Duration (secs)	E	P	<10m	10-20m	20-40m	40-60m	60-100m	100-120m	120-180m	>180m
3	3	30	2017	SH	1	13:05	41	IN	IN	41							
2	4	20	2017	MA	1	19:05	2	IN	IN		2						
1	4	20	2017	RG	2	11:40	4	OUT	IN	4							
1	4	20	2017	RG	2	12:00	4	OUT	IN	4							
2	4	20	2017	RG	1	21:25	13	IN	IN	13							
2	4	20	2017	RG	1	21:30	42	IN	IN	42							
4	4	20	2017	RG	1	21:20	7	IN	IN	7							
4	4	20	2017	RG	2	21:30	4	IN	IN	4							
2	4	20	2017	SN	1	21:15	1	IN	IN	1							
3	5	6	2017	RG	3	21:55	4	IN	IN	4							
3	5	6	2017	SN	2	20:25	9	IN	IN	9							
1	5	7	2017	H.	1	07:50	99	IN	IN	99							
1	5	7	2017	SN	1	07:05	10	OUT	IN	10							
1	5	7	2017	T.	1	08:05	12	OUT	IN	12							
2	5	19	2017	MA	1	18:10	28	IN	IN	28							
3	5	22	2017	H.	2	20:25	96	IN	IN	96							
4	5	24	2017	K.	1	17:05	36	IN	IN			36					
4	5	24	2017	T.	3	15:25	2	IN	IN	2							
2	5	30	2017	CS	1	15:50	12	IN	IN	12							
1	5	30	2017	SN	1	11:05	2	OUT	IN	2							
1	6	7	2017	K.	1	12:15	117	IN	IN		60	57					
2	6	16	2017	CS	1	15:30	9	IN	IN	9							
2	6	16	2017	CS	1	15:50	8	IN	IN	8							
3	6	16	2017	K.	1	19:10	63	IN	IN		20	20	23				

VP No	Month	Day	Year	Species	No	Time 1st detected	Duration (secs)	E	P	<10m	10-20m	20-40m	40-60m	60-100m	100-120m	120-180m	>180m
3	6	16	2017	K.	1	19:15	82	IN	IN		20	40	22				
3	6	16	2017	SN	1	17:15	2	IN	IN	2							
4	6	23	2017	K.	1	18:25	79	IN	IN		79						
3	6	23	2017	K.	1	20:50	140	IN	IN	70	70						
3	6	23	2017	T.	2	20:15	2	IN	IN		2						
2	6	29	2017	K.	1	11:40	76	IN	IN				76				
1	7	9	2017	SN	1	08:40	25	OUT	IN	15	10						
2	7	20	2017	CA	1	11:35	45	IN	IN		25	20					
4	7	20	2017	K.	1	09:25	71	IN	IN			71					
4	7	20	2017	K.	1	09:50	35	IN	IN			35					
3	7	22	2017	K.	2	12:35	115	IN	IN		15	50	50				
3	7	22	2017	K.	1	14:20	58	IN	IN					20	20	18	
3	7	27	2017	SH	1	13:50	13	IN	IN	13							
4	7	31	2017	RG	1	11:35	20	IN	IN	20							
2	7	31	2017	T.	1	11:40	14	IN	IN	14							
1	8	9	2017	CA	1	12:15	102	IN	IN				102				
1	8	9	2017	CA	1	13:05	148	IN	IN				148				
3	8	9	2017	CA	1	09:15	36	IN	IN	36							
3	8	18	2017	CA	1	11:40	25	IN	IN	25							
4	8	18	2017	K.	1	10:20	39	IN	IN		39						
4	8	18	2017	RG	1	08:35	18	IN	IN	18							
3	8	18	2017	SN	1	11:40	11	IN	IN	11							
2	8	31	2017	CA	1	09:30	73	IN	IN		50	23					
2	8	31	2017	K.	1	08:00	63	IN	IN			63					

VP No	Month	Day	Year	Species	No	Time 1st detected	Duration (secs)	E	P	<10m	10-20m	20-40m	40-60m	60-100m	100-120m	120-180m	>180m
1	9	5	2017	CA	1	10:25	11	OUT	IN	11							
1	9	5	2017	K.	1	11:35	95	OUT	IN		50	45					
2	9	19	2017	CA	1	11:20	9	IN	IN			9					
3	9	20	2017	RG	3	07:30	15	OUT	IN	15							
3	9	20	2017	RG	1	07:30	18	IN	IN	18							
1	9	29	2017	K.	1	08:05	86	IN	IN	20	30	36					
2	10	12	2017	CA	1	09:50	6	IN	IN	6							
3	12	20	2017	CA	1	09:40	12	IN	IN	12							
3	12	20	2017	T.	12	10:25	10	IN	IN	10							
2	12	20	2017	RG	1	11:40	12	IN	IN	12							
2	12	21	2017	RG	1	09:10	5	IN	IN	5							
4	12	21	2017	RG	1	11:25	12	IN	IN	12							
4	12	21	2017	RG	1	11:30	7	IN	IN	7							
3	12	28	2017	WN	2	13:15	3	IN	IN	3							
3	12	28	2017	RG	1	15:50	42	IN	IN	42							
1	1	11	2018	K.	1	12:50	80	OUT	IN			80					
2	1	12	2018	H.	1	09:45	84	IN	IN		84						
4	1	12	2018	RG	1	09:30	48	IN	IN	48							
1	1	25	2018	RG	1	09:30	15	OUT	IN		15						
4	2	14	2018	RG	1	14:15	32	IN	IN	32							
3	2	26	2018	RG	1	15:25	27	IN	IN	27							
1	2	27	2018	K.	1	12:05	73	IN	IN		73						
Existing										No	No	Yes	Yes	No	No	No	No
Proposed										No	No	Yes	Yes	Yes	Yes	Yes	No

Table 7.4 Details of flights of Target 1 species utilised in collision risk modelling (CRM) 2018 – 2019.[8]

VP No	Month	Day	Year	Species	No	Time 1st detected	Duration (secs)	E	P	<10m	10-20m	20-40m	40-60m	60-100m	100-120m	120-180m	>180m
1	10	30	2018	WS	4	09:02	47	OUT	IN	47							
2	11	7	2018	GP	5	10:03	12	IN	IN	12							
2	11	21	2018	GP	19	09:43	19	IN	IN	19							
2	11	21	2018	GP	18	09:57	14	IN	IN	14							
2	12	12	2018	GP	19	10:16	110	IN	IN				60	30			20
2	12	12	2018	GP	39	11:29	325	IN	IN	25			120	160			20
3	12	20	2018	GP	37	14:08	153	IN	IN				93	60			
4	12	31	2018	GP	3	16:57	9	IN	IN		9						
2	12	31	2018	GP	3	13:51	7	IN	IN		7						
3	1	23	2019	GP	39	10:07	1680	IN	IN	840			840				
3	1	23	2019	GP	23	11:56	96	IN	IN	51		45					
2	2	14	2019	GP	7	11:56	7	IN	IN	7							
3	2	20	2019	EA	1	14:25	150	IN	IN								150
3	2	20	2019	EA	1	15:10	68	IN	IN								68
1	2	21	2019	GP	50	11:20	184	IN	IN								184
2	2	27	2019	GP	11	07:01	11	IN	IN			11					
2	2	27	2019	GP	6	07:01	32	IN	IN			32					
2	2	27	2019	GP	14	08:22	86	IN	IN	86							
2	2	27	2019	GP	14	08:31	32	IN	IN		18	14					
2	2	27	2019	GP	6	08:47	49	IN	IN		49						

[8] WS observed in flight and within the windfarm envelope for both existing and proposed turbines but were below potential collision risk height so no CRM completed

VP No	Month	Day	Year	Species	No	Time 1st detected	Duration (secs)	E	P	<10m	10-20m	20-40m	40-60m	60-100m	100-120m	120-180m	>180m
3	3	28	2019	GP	1	18:13	27	IN	IN			27					
Existing										No	No	Yes	Yes	No	No	No	No
Proposed										No	No	Yes	Yes	Yes	Yes	Yes	No

Table 7.5 Details of flights of Target 2 species utilised in collision risk modelling (CRM) 2018 – 2019.[9]

VP No	Month	Day	Year	Species	No	Time 1st detected	Duration (secs)	E	P	<10m	10-20m	20-40m	40-60m	60-100m	100-120m	120-180m	>180m
2	3	21	2018	MA	2	13:40	57	IN	IN	57							
4	3	26	2018	RG	1	16:50	16	IN	IN	16							
1	4	25	2018	CA	1	11:25	39	IN	OUT	39							
4	4	26	2018	SN	1	17:35	16	IN	IN	16							
2	4	26	2018	MA	1	18:50	12	IN	IN	12							
2	4	26	2018	RG	2	19:20	7	IN	IN	7							
2	4	26	2018	SN	1	19:40	3	IN	IN	3							
2	4	26	2018	SN	1	20:20	6	IN	IN	6							
2	4	26	2018	RG	1	20:20	17	IN	IN	17							
3	4	27	2018	SN	1	18:20	3	IN	IN	3							
3	4	27	2018	SN	1	18:20	4	IN	IN	4							
5	4	27	2018	K.	1	17:40	71	IN	OUT	71							
5	4	27	2018	K.	1	18:55	283	IN	IN		130	130	23				
2	5	11	2018	SN	1	20:40	2	IN	IN	2							
3	6	7	2018	SN	1	12:25	2	IN	IN	2							
3	6	7	2018	K.	1	13:55	44	IN	IN		44						

[9] CS, MA, RG, SN observed in flight and within the windfarm envelope for both existing and proposed turbines but were below potential collision risk height so no CRM completed

VP No	Month	Day	Year	Species	No	Time 1st detected	Duration (secs)	E	P	<10m	10-20m	20-40m	40-60m	60-100m	100-120m	120-180m	>180m
4	6	7	2018	BZ	1	14:30	67	IN	OUT			40	27				
4	6	7	2018	BZ	1	14:40	9	IN	IN				9				
1	6	13	2018	SN	1	16:25	2	OUT	IN	2							
2	6	13	2018	SN	1	19:05	9	IN	IN	9							
3	6	20	2018	SN	1	13:00	3	IN	IN	3							
2	6	28	2018	CS	2	16:00	8	IN	IN	8							
2	6	28	2018	CS	2	16:00	11	IN	IN	11							
4	7	3	2018	SN	1	20:15	4	IN	IN	4							
4	7	3	2018	SN	1	20:30	2	IN	IN	2							
4	7	3	2018	SN	1	21:05	3	IN	IN	3							
1	7	4	2018	K.	1	12:45	74	IN	IN		34	40					
3	7	30	2018	H.	1	19:15	57	IN	IN	47	10						
3	8	8	2018	K.	1	17:15	54	IN	IN		54						
3	8	8	2018	K.	1	18:40	37	OUT	IN		37						
2	8	31	2018	RG	2	16:05	28	IN	IN	28							
1	9	11	2018	K.	1	16:05	132	IN	IN	70	62						
1	9	11	2018	K.	2	16:30	5	IN	IN			5					
5	9	12	2018	BZ	1	10:35	507	IN	IN		150	100	100	100	57		
3	9	21	2018	CA	1	09:20	14	IN	IN	14							
2	9	21	2018	CA	1	12:15	8	IN	IN	8							
3	9	27	2018	CA	3	16:00	5	IN	IN	5							
3	9	27	2018	CA	1	18:10	82	IN	IN	82							
3	9	27	2018	CA	1	18:15	89	IN	IN	89							
1	10	6	2018	CA	1	11:35	23	OUT	IN		23						

VP No	Month	Day	Year	Species	No	Time 1st detected	Duration (secs)	E	P	<10m	10-20m	20-40m	40-60m	60-100m	100-120m	120-180m	>180m
1	10	6	2018	K.	1	12:50	141	OUT	IN	40	40	40	21				
4	10	15	2018	BZ	1	13:20	63	OUT	IN			3	20	20	20		
4	10	15	2018	SN	1	16:15	8	IN	IN	8							
3	11	14	2018	RG	1	14:40	11	IN	IN	11							
4	11	20	2018	SN	1	10:25	3	IN	IN	3							
4	11	20	2018	SN	1	10:25	3	IN	IN	3							
4	11	20	2018	CS	1	10:25	3	IN	IN	3							
3	12	6	2018	SN	1	08:20	3	IN	IN	3							
2	12	12	2018	CA	1	09:40	97	IN	IN	97							
2	12	12	2018	RG	3	10:10	11	IN	IN	11							
4	12	12	2018	H.	1	15:00	112	IN	IN				112				
4	12	31	2018	RG	1	14:45	15	IN	IN	15							
4	12	31	2018	RG	1	17:00	16	IN	IN	16							
1	1	10	2019	CA	1	09:30	32	IN	IN			32					
4	1	16	2019	CA	1	10:45	68	IN	IN		34	34					
4	1	16	2019	RG	1	11:25	16	IN	IN	16							
2	1	16	2019	RG	1	12:10	5	IN	IN	5							
1	1	27	2019	MA	3	12:55	28	OUT	IN	14	14						
2	2	14	2019	RG	2	11:25	31	IN	IN	31							
4	2	27	2019	RG	1	16:40	5	IN	IN	5							
4	2	27	2019	RG	1	18:30	7	IN	IN	7							
4	2	27	2019	RG	1	18:35	7	IN	IN	7							
4	2	27	2019	RG	1	18:35	4	IN	IN	4							
4	2	27	2019	RG	1	18:50	5	IN	IN	5							

VP No	Month	Day	Year	Species	No	Time 1st detected	Duration (secs)	E	P	<10m	10-20m	20-40m	40-60m	60-100m	100-120m	120-180m	>180m
2	2	27	2019	RG	1	06:45	4	IN	IN	4							
2	2	27	2019	RG	1	06:45	5	IN	IN	5							
2	2	27	2019	RG	1	06:50	5	IN	IN	5							
2	2	27	2019	RG	1	06:50	4	IN	IN	4							
2	2	27	2019	RG	2	08:25	13	IN	IN	13							
2	2	27	2019	RG	1	08:25	10	IN	IN	10							
2	2	27	2019	RG	1	08:35	9	IN	IN	9							
2	2	27	2019	RG	1	08:35	18	IN	IN	18							
2	2	27	2019	RG	1	08:35	19	IN	IN	19							
1	3	15	2019	CA	1	12:15	106	IN	IN	30	30	30	16				
2	3	26	2019	MA	1	10:35	3	IN	IN	3							
2	3	26	2019	CA	1	12:10	45	IN	IN		45						
3	3	28	2019	CA	1	17:15	14	IN	IN	14							
3	3	28	2019	SN	1	19:45	2	IN	IN	2							
3	3	28	2019	SN	1	19:55	3	IN	IN	3							
3	3	28	2019	SN	1	20:00	2	IN	IN	2							
Existing										No	No	Yes	Yes	No	No	No	No
Proposed										No	No	Yes	Yes	Yes	Yes	Yes	No

Table 7.6 Collision Risk Estimate (Band et al., 2007) for the Operational Barnesmore Windfarm and buzzard

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	1.56	m	r/R	c/C	□	collide		contribution	collide		contribution
Pitch (degrees)	22.5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
BirdLength	0.54	m	0.025	0.575	7.88	12.90	1.00	0.00125	12.21	1.00	0.00125
Wingspan	1.2	m	0.075	0.575	2.63	4.53	0.52	0.00392	3.84	0.44	0.00332
F: Flapping (0) or gliding (+1)	1		0.125	0.702	1.58	3.22	0.37	0.00464	2.38	0.27	0.00343
			0.175	0.860	1.13	2.77	0.32	0.00559	1.74	0.20	0.00352
Bird speed	13	m/sec	0.225	0.994	0.88	2.52	0.29	0.00654	1.33	0.15	0.00345
RotorDiam	42	m	0.275	0.947	0.72	2.09	0.24	0.00663	0.96	0.11	0.00305
RotationPeriod	2.00	sec	0.325	0.899	0.61	1.79	0.21	0.00670	0.71	0.08	0.00267
			0.375	0.851	0.53	1.55	0.18	0.00673	0.54	0.06	0.00233
			0.425	0.804	0.46	1.37	0.16	0.00672	0.41	0.05	0.00202
			0.475	0.756	0.41	1.44	0.17	0.00791	0.54	0.06	0.00296
Bird aspect ratio:	0.45		0.525	0.708	0.38	1.35	0.16	0.00815	0.58	0.07	0.00351
			0.575	0.660	0.34	1.26	0.15	0.00836	0.61	0.07	0.00403
			0.625	0.613	0.32	1.18	0.14	0.00854	0.63	0.07	0.00452
			0.675	0.565	0.29	1.12	0.13	0.00868	0.64	0.07	0.00498
			0.725	0.517	0.27	1.05	0.12	0.00880	0.65	0.07	0.00541
			0.775	0.470	0.25	0.99	0.11	0.00888	0.65	0.07	0.00580
			0.825	0.422	0.24	0.94	0.11	0.00892	0.65	0.07	0.00616
			0.875	0.374	0.23	0.88	0.10	0.00893	0.64	0.07	0.00648
			0.925	0.327	0.21	0.84	0.10	0.00891	0.63	0.07	0.00677
			0.975	0.279	0.20	0.79	0.09	0.00886	0.63	0.07	0.00703
				Overall p(collision) =			Upwind	14.4%		Downwind	8.3%
								Average	11.3%		

Table 7.7 Collision Risk Estimate (Band et al., 2007) for the Development and buzzard

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.5	m	r/R	c/C	□	collide		contribution	collide		contribution
Pitch (degrees)	22.5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.54	m	0.025	0.575	5.24	17.51	0.81	0.00101	15.53	0.72	0.00090
Wingspan	1.2	m	0.075	0.575	1.75	6.50	0.30	0.00225	4.52	0.21	0.00156
F: Flapping (0) or gliding (+1)	1		0.125	0.702	1.05	5.06	0.23	0.00292	2.65	0.12	0.00153
			0.175	0.860	0.75	4.73	0.22	0.00382	1.77	0.08	0.00143
Bird speed	13	m/sec	0.225	0.994	0.58	4.56	0.21	0.00474	1.14	0.05	0.00118
RotorDiam	158	m	0.275	0.947	0.48	3.87	0.18	0.00491	0.61	0.03	0.00077
RotationPeriod	5.00	sec	0.325	0.899	0.40	3.59	0.17	0.00539	0.58	0.03	0.00087
			0.375	0.851	0.35	3.24	0.15	0.00561	0.77	0.04	0.00133
			0.425	0.804	0.31	2.95	0.14	0.00579	0.89	0.04	0.00175
			0.475	0.756	0.28	2.71	0.12	0.00594	0.98	0.05	0.00214
Bird aspect ratio:	0.45		0.525	0.708	0.25	2.49	0.12	0.00604	1.03	0.05	0.00248
			0.575	0.660	0.23	2.30	0.11	0.00611	1.05	0.05	0.00279
			0.625	0.613	0.21	2.13	0.10	0.00614	1.06	0.05	0.00306
			0.675	0.565	0.19	1.97	0.09	0.00613	1.06	0.05	0.00329
			0.725	0.517	0.18	1.82	0.08	0.00609	1.04	0.05	0.00349
			0.775	0.470	0.17	1.68	0.08	0.00600	1.02	0.05	0.00364
			0.825	0.422	0.16	1.55	0.07	0.00588	0.99	0.05	0.00376
			0.875	0.374	0.15	1.42	0.07	0.00572	0.95	0.04	0.00384

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
			0.925	0.327	0.14	1.29	0.06	0.00553	0.91	0.04	0.00389
			0.975	0.279	0.13	1.18	0.05	0.00529	0.86	0.04	0.00389
				Overall p(collision) =			Upwind	10.1%		Downwind	4.8%
								Average	7.4%		

Table 7.8 Collision Risk Assessment Operational Barnesmore Windfarm 2018 – 2019: buzzard

Details	Description	Value	Units
Turbine parameters	Number of turbines	25	n
	Hub height	40.5	m
	Rotor diameter	42	m
	Rotor radius	21	m
	Blade maximum chord	1.56	m
	Blade pitch	22.5	°
	Rotor rotation period	2	sec
	Blade depth	1.56	m
	Risk window ceiling height	61.5	m
	Risk window floor height	19.5	m
	Windfarm area	4783942	m2
	Flight risk volume	200925564	m3
	Rotor swept area (single turbine)	1385.44236	m2
	Rotor swept volume (single turbine)	2909.42896	m3
	Rotor swept volume (combined)	72735.7239	m3
	Proportion of flight risk volume with turbines	0.000362	

Details	Description	Value	Units
Bird parameters	Months surveyed	Mar - Mar	months
	Speed of the bird through the rotor	13	m/s
	Length of the bird	0.54	m
	Wingspan of the bird	1.2	m
	Vantage point hours completed	375	hours
	Vantage point seconds completed	1350000	seconds
	Time available for flight activity per year	4892	hours
	Flight seconds per year	17611200	seconds
	Number of birds observed	3	n
	Total time all birds spent in risk window	276	seconds
	Proportional time individual bird spends in risk window	6.8148E-05	
	Average time individual bird in risk window (Mar - Mar)	1200.17067	seconds
	Bird occupancy of flight risk window	3600.512	seconds
	Bird occupancy of rotor swept area	1.30339735	seconds
	Bird transit time through rotors	0.16153846	seconds
	Number of birds passing through rotors (Mar - Mar)	8.06865023	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	11.3	%
	Adjusted collision risk to include turbine efficiency	8.475	%
	No. of collisions with no avoidance (Mar - Mar)	0.68381811	n
	Adjusted for avoidance (95%)	0.03419091	n
	Adjusted for avoidance (98%)	0.01367636	n
	Adjusted for avoidance (99%)	0.00683818	n

Details	Description	Value	Units
	Adjusted for avoidance (99.9%)	0.00068382	n
Frequency of mortality	No avoidance, equivalent to one bird every	1.46237719	years
	98% avoidance, equivalent to one bird every	73.1188593	years

Table 7.9 Collision Risk Assessment Development 2018 – 2019: buzzard

Details	Description	Value	Units
Turbine parameters	Number of turbines	13	n
	Hub height	101	m
	Rotor diameter	158	m
	Rotor radius	79	m
	Blade maximum chord	4.5	m
	Blade pitch	22.5	°
	Rotor rotation period	5	sec
	Blade depth	2.6	m
	Risk window ceiling height	180	m
	Risk window floor height	22	m
	Windfarm area	5820339	m2
	Flight risk volume	919613562	m3
	Rotor swept area (single turbine)	19606.6798	m2
	Rotor swept volume (single turbine)	61564.9744	m3
	Rotor swept volume (combined)	800344.667	m3
	Proportion of flight risk volume with turbines	0.00087031	

Details	Description	Value	Units
Bird parameters	Months surveyed	Mar - Mar	months
	Speed of the bird through the rotor	13	m/s
	Length of the bird	0.54	m
	Wingspan of the bird	1.2	m
	Vantage point hours completed	375	hours
	Vantage point seconds completed	1350000	seconds
	Time available for flight activity per year	4892	hours
	Flight seconds per year	17611200	seconds
	Number of birds observed	3	n
	Total time all birds spent in risk window	276	seconds
	Proportional time individual bird spends in risk window	6.8148E-05	
	Average time individual bird in risk window (Mar - Mar)	1200.17067	seconds
	Bird occupancy of flight risk window	3600.512	seconds
	Bird occupancy of rotor swept area	3.13354511	seconds
	Bird transit time through rotors	0.24153846	seconds
	Number of birds passing through rotors (Mar-Mar)	12.9732759	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	7.4	%
	Adjusted collision risk to include turbine efficiency	5.55	%
	No. of collisions with no avoidance (Mar - Mar)	0.72001681	n
	Adjusted for avoidance (95%)	0.03600084	n
	Adjusted for avoidance (98%)	0.01440034	n
	Adjusted for avoidance (99%)	0.00720017	n

Details	Description	Value	Units
	Adjusted for avoidance (99.9%)	0.00072002	n
Frequency of mortality	No avoidance, equivalent to one bird every	1.38885646	years
	98% avoidance, equivalent to one bird every	69.4428228	years

Table 7.10 Collision Risk Estimate (Band et al., 2007) for the operational windfarm and cormorant

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	1.56	m	r/R	c/C	□	collide		contribution	collide		contribution
Pitch (degrees)	22.5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.9	m	0.025	0.575	10.55	18.82	1.00	0.00125	18.14	1.00	0.00125
Wingspan	1.45	m	0.075	0.575	3.52	6.50	0.56	0.00420	5.82	0.50	0.00376
F: Flapping (0) or gliding (+1)	1		0.125	0.702	2.11	4.50	0.39	0.00485	3.66	0.32	0.00395
			0.175	0.860	1.51	3.77	0.33	0.00569	2.75	0.24	0.00414
Bird speed	17.4	m/sec	0.225	0.994	1.17	3.36	0.29	0.00651	2.17	0.19	0.00421
RotorDiam	42	m	0.275	0.947	0.96	2.76	0.24	0.00654	1.63	0.14	0.00386
RotationPeriod	2.00	sec	0.325	0.899	0.81	2.34	0.20	0.00655	1.26	0.11	0.00354
			0.375	0.851	0.70	2.02	0.17	0.00653	1.00	0.09	0.00325
			0.425	0.804	0.62	2.10	0.18	0.00769	1.14	0.10	0.00417
			0.475	0.756	0.56	1.96	0.17	0.00801	1.05	0.09	0.00431
Bird aspect ratio:	0.62		0.525	0.708	0.50	1.84	0.16	0.00831	0.99	0.09	0.00448
			0.575	0.660	0.46	1.73	0.15	0.00858	0.94	0.08	0.00467
			0.625	0.613	0.42	1.64	0.14	0.00883	0.91	0.08	0.00489

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
			0.675	0.565	0.39	1.56	0.13	0.00905	0.92	0.08	0.00535
			0.725	0.517	0.36	1.48	0.13	0.00925	0.94	0.08	0.00586
			0.775	0.470	0.34	1.41	0.12	0.00943	0.95	0.08	0.00635
			0.825	0.422	0.32	1.35	0.12	0.00958	0.96	0.08	0.00681
			0.875	0.374	0.30	1.29	0.11	0.00970	0.96	0.08	0.00725
			0.925	0.327	0.29	1.23	0.11	0.00980	0.96	0.08	0.00766
			0.975	0.279	0.27	1.18	0.10	0.00988	0.96	0.08	0.00805
				Overall p(collision) =			Upwind	15.0%		Downwind	9.8%
								Average	12.4%		

Table 7.11 Collision Risk Estimate (Band et al., 2007) for the Development and cormorant

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.5	m	r/R	c/C	a	collide		contribution	collide		contribution
Pitch (degrees)	22.5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.9	m	0.025	0.575	7.01	24.22	0.84	0.00104	22.24	0.77	0.00096
Wingspan	1.45	m	0.075	0.575	2.34	8.73	0.30	0.00226	6.75	0.23	0.00175
F: Flapping (0) or gliding (+1)	1		0.125	0.702	1.40	6.59	0.23	0.00284	4.18	0.14	0.00180
			0.175	0.860	1.00	5.99	0.21	0.00361	3.02	0.10	0.00183
Bird speed	17.4	m/sec	0.225	0.994	0.78	5.65	0.19	0.00438	2.23	0.08	0.00173
RotorDiam	158	m	0.275	0.947	0.64	4.73	0.16	0.00448	1.47	0.05	0.00139
RotationPeriod	5.00	sec	0.325	0.899	0.54	4.46	0.15	0.00500	1.37	0.05	0.00153
			0.375	0.851	0.47	4.02	0.14	0.00520	1.09	0.04	0.00141

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
			0.425	0.804	0.41	3.66	0.13	0.00537	0.91	0.03	0.00133
			0.475	0.756	0.37	3.36	0.12	0.00551	1.04	0.04	0.00171
Bird aspect ratio:	0.62		0.525	0.708	0.33	3.10	0.11	0.00562	1.14	0.04	0.00206
			0.575	0.660	0.30	2.87	0.10	0.00570	1.20	0.04	0.00238
			0.625	0.613	0.28	2.67	0.09	0.00575	1.24	0.04	0.00267
			0.675	0.565	0.26	2.48	0.09	0.00578	1.26	0.04	0.00294
			0.725	0.517	0.24	2.31	0.08	0.00578	1.27	0.04	0.00318
			0.775	0.470	0.23	2.15	0.07	0.00575	1.27	0.04	0.00339
			0.825	0.422	0.21	2.00	0.07	0.00569	1.25	0.04	0.00357
			0.875	0.374	0.20	1.86	0.06	0.00560	1.23	0.04	0.00372
			0.925	0.327	0.19	1.72	0.06	0.00548	1.21	0.04	0.00384
			0.975	0.279	0.18	1.59	0.05	0.00534	1.17	0.04	0.00394
				Overall p(collision) =			Upwind	9.6%		Downwind	4.7%
								Average	7.2%		

Table 7.12 Collision Risk Assessment Operational Barnesmore Windfarm 2017 – 2018: cormorant

Details	Description	Value	Units
Turbine parameters	Number of turbines	25	n
	Hub height	40.5	m
	Rotor diameter	42	m
	Rotor radius	21	m
	Blade maximum chord	1.56	m
	Blade pitch	22.5	°
	Rotor rotation period	2	sec

Details	Description	Value	Units
	Blade depth	1.56	m
	Risk window ceiling height	61.5	m
	Risk window floor height	19.5	m
	Windfarm area	4783942	m2
	Flight risk volume	200925564	m3
	Rotor swept area (single turbine)	1385.44236	m2
	Rotor swept volume (single turbine)	3408.18821	m3
	Rotor swept volume (combined)	85204.7052	m3
	Proportion of flight risk volume with turbines	0.00042406	
Bird parameters	Months surveyed	Mar - Feb	months
	Speed of the bird through the rotor	17.4	m/s
	Length of the bird	0.9	m
	Wingspan of the bird	1.45	m
	Vantage point hours completed	360	hours
	Vantage point seconds completed	1296000	seconds
	Time available for flight activity per year	4520	hours
	Flight seconds per year	16272000	seconds
	Number of birds observed	5	n
	Total time all birds spent in risk window	302	seconds
	Proportional time individual bird spends in risk window	4.6605E-05	
	Average time individual bird in risk window (Mar - Feb)	758.35556	seconds
	Bird occupancy of flight risk window	3791.77778	seconds
	Bird occupancy of rotor swept area	1.60795	seconds

Details	Description	Value	Units
	Bird transit time through rotors	0.14138	seconds
	Number of birds passing through rotors (Mar-Feb)	11.37327	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	12.4	%
	Adjusted collision risk to include turbine efficiency	9.3	%
	No. of collisions with no avoidance (Mar - Feb)	1.05771	n
	Adjusted for avoidance (95%)	0.05289	n
	Adjusted for avoidance (98%)	0.02115	n
	Adjusted for avoidance (99%)	0.01058	n
	Adjusted for avoidance (99.9%)	0.00106	n
Frequency of mortality	No avoidance, equivalent to one bird every	0.94543	years
	98% avoidance, equivalent to one bird every	47.27175	years

Table 7.13 Collision Risk Assessment Development 2017 – 2018: cormorant

Details	Description	Value	Units
Turbine parameters	Number of turbines	13	n
	Hub height	101	m
	Rotor diameter	158	m
	Rotor radius	79	m
	Blade maximum chord	4.5	m
	Blade pitch	22.5	°
	Rotor rotation period	5	sec

Details	Description	Value	Units
	Blade depth	2.6	m
	Risk window ceiling height	180	m
	Risk window floor height	22	m
	Windfarm area	5820339	m2
	Flight risk volume	919613562	m3
	Rotor swept area (single turbine)	19606.6798	m2
	Rotor swept volume (single turbine)	68623.3791	m3
	Rotor swept volume (combined)	892103.929	m3
	Proportion of flight risk volume with turbines	0.00097009	
Bird parameters	Months surveyed	Mar - Feb	months
	Speed of the bird through the rotor	17.4	m/s
	Length of the bird	0.9	m
	Wingspan of the bird	1.45	m
	Vantage point hours completed	360	hours
	Vantage point seconds completed	1296000	seconds
	Time available for flight activity per year	4520	hours
	Flight seconds per year	16272000	seconds
	Number of birds observed	5	n
	Total time all birds spent in risk window	302	seconds
	Proportional time individual bird spends in risk window	4.6605E-05	
	Average time individual bird in risk window (Mar - Feb)	758.35556	seconds
	Bird occupancy of flight risk window	3791.77778	seconds
	Bird occupancy of rotor swept area	3.67835	seconds

Details	Description	Value	Units
	Bird transit time through rotors	0.20115	seconds
	Number of birds passing through rotors (Mar-Feb)	18.28665	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	7.2	%
	Adjusted collision risk to include turbine efficiency	5.4	%
	No. of collisions with no avoidance (Mar - Feb)	0.98748	n
	Adjusted for avoidance (95%)	0.04937	n
	Adjusted for avoidance (98%)	0.01975	n
	Adjusted for avoidance (99%)	0.00987	n
	Adjusted for avoidance (99.9%)	0.00099	n
Frequency of mortality	No avoidance, equivalent to one bird every	1.01268	years
	98% avoidance, equivalent to one bird every	50.63398	years

Table 7.14 Collision Risk Assessment Operational Barnesmore Windfarm 2018 – 2019: cormorant

Details	Description	Value	Units
Turbine parameters	Number of turbines	25	n
	Hub height	40.5	m
	Rotor diameter	42	m
	Rotor radius	21	m
	Blade maximum chord	1.56	m
	Blade pitch	22.5	°
	Rotor rotation period	2	sec

Details	Description	Value	Units
	Blade depth	1.56	m
	Risk window ceiling height	61.5	m
	Risk window floor height	19.5	m
	Windfarm area	4783942	m2
	Flight risk volume	200925564	m3
	Rotor swept area (single turbine)	1385.44236	m2
	Rotor swept volume (single turbine)	3408.18821	m3
	Rotor swept volume (combined)	85204.7052	m3
	Proportion of flight risk volume with turbines	0.00042406	
Bird parameters	Months surveyed	Mar - Mar	months
	Speed of the bird through the rotor	17.4	m/s
	Length of the bird	0.9	m
	Wingspan of the bird	1.45	m
	Vantage point hours completed	375	hours
	Vantage point seconds completed	1350000	seconds
	Time available for flight activity per year	4892	hours
	Flight seconds per year	17611200	seconds
	Number of birds observed	3	n
	Total time all birds spent in risk window	112	seconds
	Proportional time individual bird spends in risk window	2.7654E-05	
	Average time individual bird in risk window (Mar - Mar)	487.02578	seconds
	Bird occupancy of flight risk window	1461.07733	seconds
	Bird occupancy of rotor swept area	0.61959	seconds

Details	Description	Value	Units
	Bird transit time through rotors	0.14138	seconds
	Number of birds passing through rotors (Mar - Mar)	4.38244	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	12.4	%
	Adjusted collision risk to include turbine efficiency	9.3	%
	No. of collisions with no avoidance (Mar - Mar)	0.40757	n
	Adjusted for avoidance (95%)	0.02038	n
	Adjusted for avoidance (98%)	0.00815	n
	Adjusted for avoidance (99%)	0.00408	n
	Adjusted for avoidance (99.9%)	0.00041	n
Frequency of mortality	No avoidance, equivalent to one bird every	2.45359	years
	98% avoidance, equivalent to one bird every	122.67931	years

Table 7.15 Collision Risk Assessment Development 2018 – 2019: cormorant

Details	Description	Value	Units
Turbine parameters	Number of turbines	13	n
	Hub height	101	m
	Rotor diameter	158	m
	Rotor radius	79	m
	Blade maximum chord	4.5	m
	Blade pitch	22.5	°
	Rotor rotation period	5	sec

Details	Description	Value	Units
	Blade depth	2.6	m
	Risk window ceiling height	180	m
	Risk window floor height	22	m
	Windfarm area	5820339	m2
	Flight risk volume	919613562	m3
	Rotor swept area (single turbine)	19606.6798	m2
	Rotor swept volume (single turbine)	68623.3791	m3
	Rotor swept volume (combined)	892103.929	m3
	Proportion of flight risk volume with turbines	0.00097009	
Bird parameters	Months surveyed	Mar - Mar	months
	Speed of the bird through the rotor	17.4	m/s
	Length of the bird	0.9	m
	Wingspan of the bird	1.45	m
	Vantage point hours completed	375	hours
	Vantage point seconds completed	1350000	seconds
	Time available for flight activity per year	4892	hours
	Flight seconds per year	17611200	seconds
	Number of birds observed	3	n
	Total time all birds spent in risk window	112	seconds
	Proportional time individual bird spends in risk window	2.7654E-05	
	Average time individual bird in risk window (Mar - Mar)	487.02578	seconds
	Bird occupancy of flight risk window	1461.07733	seconds
	Bird occupancy of rotor swept area	1.41737	seconds

Details	Description	Value	Units
	Bird transit time through rotors	0.20115	seconds
	Number of birds passing through rotors (Mar-Mar)	7.04635	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	7.2	%
	Adjusted collision risk to include turbine efficiency	5.4	%
	No. of collisions with no avoidance (Mar - Mar)	0.38050	n
	Adjusted for avoidance (95%)	0.01903	n
	Adjusted for avoidance (98%)	0.00761	n
	Adjusted for avoidance (99%)	0.00381	n
	Adjusted for avoidance (99.9%)	0.00038	n
Frequency of mortality	No avoidance, equivalent to one bird every	2.62810	years
	98% avoidance, equivalent to one bird every	131.40496	years

Table 7.16 Collision Risk Estimate (Band et al., 2007) for the Operational Barnesmore Windfarm and golden eagle

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	1.56	m	r/R	c/C	□	collide		contribution	collide		contribution
Pitch (degrees)	22.5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.82	m	0.025	0.575	9.09	20.15	1.00	0.00125	19.47	1.00	0.00125
Wingspan	2.12	m	0.075	0.575	3.03	6.95	0.69	0.00521	6.26	0.63	0.00470
F: Flapping (0) or gliding (+1)	1		0.125	0.702	1.82	4.71	0.47	0.00589	3.88	0.39	0.00484

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
			0.175	0.860	1.30	3.88	0.39	0.00679	2.85	0.29	0.00499
Bird speed	15	m/sec	0.225	0.994	1.01	3.41	0.34	0.00766	2.22	0.22	0.00499
RotorDiam	42	m	0.275	0.947	0.83	2.81	0.28	0.00772	1.68	0.17	0.00462
RotationPeriod	2.00	sec	0.325	0.899	0.70	2.39	0.24	0.00776	1.31	0.13	0.00427
			0.375	0.851	0.61	2.07	0.21	0.00776	1.05	0.11	0.00395
			0.425	0.804	0.53	1.82	0.18	0.00774	0.86	0.09	0.00366
			0.475	0.756	0.48	1.62	0.16	0.00769	0.72	0.07	0.00340
Bird aspect ratio:	0.39		0.525	0.708	0.43	1.45	0.14	0.00761	0.60	0.06	0.00317
			0.575	0.660	0.40	1.30	0.13	0.00750	0.55	0.06	0.00317
			0.625	0.613	0.36	1.51	0.15	0.00942	0.86	0.09	0.00540
			0.675	0.565	0.34	1.43	0.14	0.00966	0.88	0.09	0.00596
			0.725	0.517	0.31	1.36	0.14	0.00988	0.90	0.09	0.00649
			0.775	0.470	0.29	1.30	0.13	0.01007	0.90	0.09	0.00699
			0.825	0.422	0.28	1.24	0.12	0.01023	0.90	0.09	0.00746
			0.875	0.374	0.26	1.18	0.12	0.01036	0.90	0.09	0.00790
			0.925	0.327	0.25	1.13	0.11	0.01046	0.90	0.09	0.00832
			0.975	0.279	0.23	1.08	0.11	0.01053	0.89	0.09	0.00870
				Overall p(collision) =			Upwind	16.1%		Downwind	10.4%
								Average	13.3%		

Table 7.17 Collision Risk Estimate (Band et al., 2007) for the Development and golden eagle

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.5	m	r/R	c/C	α	collide		contribution	collide		contribution

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
Pitch (degrees)	22.5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.82	m	0.025	0.575	6.04	23.60	0.94	0.00118	21.61	0.86	0.00108
Wingspan	2.12	m	0.075	0.575	2.01	8.53	0.34	0.00256	6.54	0.26	0.00196
F: Flapping (0) or gliding (+1)	1		0.125	0.702	1.21	6.36	0.25	0.00318	3.95	0.16	0.00197
			0.175	0.860	0.86	5.73	0.23	0.00401	2.77	0.11	0.00194
Bird speed	15	m/sec	0.225	0.994	0.67	5.39	0.22	0.00486	1.97	0.08	0.00177
RotorDiam	158	m	0.275	0.947	0.55	4.53	0.18	0.00499	1.27	0.05	0.00140
RotationPeriod	5.00	sec	0.325	0.899	0.46	3.91	0.16	0.00509	0.82	0.03	0.00106
			0.375	0.851	0.40	3.44	0.14	0.00515	0.58	0.02	0.00088
			0.425	0.804	0.36	3.39	0.14	0.00577	1.02	0.04	0.00173
			0.475	0.756	0.32	3.12	0.12	0.00593	1.12	0.04	0.00213
Bird aspect ratioo: β	0.39		0.525	0.708	0.29	2.89	0.12	0.00606	1.19	0.05	0.00250
			0.575	0.660	0.26	2.68	0.11	0.00616	1.24	0.05	0.00284
			0.625	0.613	0.24	2.49	0.10	0.00623	1.26	0.05	0.00315
			0.675	0.565	0.22	2.32	0.09	0.00626	1.27	0.05	0.00342
			0.725	0.517	0.21	2.16	0.09	0.00626	1.26	0.05	0.00366
			0.775	0.470	0.19	2.01	0.08	0.00623	1.25	0.05	0.00387
			0.825	0.422	0.18	1.87	0.07	0.00616	1.23	0.05	0.00404
			0.875	0.374	0.17	1.73	0.07	0.00607	1.20	0.05	0.00419
			0.925	0.327	0.16	1.60	0.06	0.00594	1.16	0.05	0.00429
			0.975	0.279	0.15	1.48	0.06	0.00577	1.12	0.04	0.00437
				Overall p(collision) =			Upwind	10.4%		Downwind	5.2%
								Average	7.8%		

Table 7.18 Collision Risk Assessment Operational Barnesmore Windfarm 2017 – 2018: golden eagle

Details	Description	Value	Units
Turbine parameters	Number of turbines	25	n
	Hub height	40.5	m
	Rotor diameter	42	m
	Rotor radius	21	m
	Blade maximum chord	1.56	m
	Blade pitch	22.5	°
	Rotor rotation period	2	sec
	Blade depth	1.56	m
	Risk window ceiling height	61.5	m
	Risk window floor height	19.5	m
	Windfarm area	4783942	m2
	Flight risk volume	200925564	m3
	Rotor swept area (single turbine)	1385.44236	m2
	Rotor swept volume (single turbine)	3297.352817	m3
	Rotor swept volume (combined)	82433.82043	m3
	Proportion of flight risk volume with turbines	0.00041027	
Bird parameters	Months surveyed	Mar - Feb	months
	Speed of the bird through the rotor	15	m/s
	Length of the bird	0.82	m
	Wingspan of the bird	2.12	m
	Vantage point hours completed	360	hours
	Vantage point seconds completed	1296000	seconds

Details	Description	Value	Units
	Time available for flight activity per year	4520	hours
	Flight seconds per year	16272000	seconds
	Number of birds observed	3	n
	Total time all birds spent in risk window	76	seconds
	Proportional time individual bird spends in risk window	1.9547E-05	
	Average time individual bird in risk window (Mar - Feb)	318.07407	seconds
	Bird occupancy of flight risk window	954.22222	seconds
	Bird occupancy of rotor swept area	0.39149	seconds
	Bird transit time through rotors	0.15867	seconds
	Number of birds passing through rotors (Mar-Feb)	2.46737	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	13.3	%
	Adjusted collision risk to include turbine efficiency	9.975	%
	No. of collisions with no avoidance (Mar - Feb)	0.246120	n
	Adjusted for avoidance (95%)	0.012306	n
	Adjusted for avoidance (98%)	0.004922	n
	Adjusted for avoidance (99%)	0.002461	n
	Adjusted for avoidance (99.9%)	0.000246	n
Frequency of mortality	No avoidance, equivalent to one bird every	4.063058	years
	99% avoidance, equivalent to one bird every	406.305813	years

Table 7.19 Collision Risk Assessment Development 2017 – 2018: golden eagle

Details	Description	Value	Units
Turbine parameters	Number of turbines	13	n
	Hub height	101	m
	Rotor diameter	158	m
	Rotor radius	79	m
	Blade maximum chord	4.5	m
	Blade pitch	22.5	°
	Rotor rotation period	5	sec
	Blade depth	2.6	m
	Risk window ceiling height	180	m
	Risk window floor height	22	m
	Windfarm area	5820339	m2
	Flight risk volume	919613562	m3
	Rotor swept area (single turbine)	19606.67975	m2
	Rotor swept volume (single turbine)	67054.84475	m3
	Rotor swept volume (combined)	871712.9817	m3
	Proportion of flight risk volume with turbines	0.000947912	
Bird parameters	Months surveyed	Mar - Feb	months
	Speed of the bird through the rotor	15	m/s
	Length of the bird	0.82	m
	Wingspan of the bird	2.12	m
	Vantage point hours completed	360	hours
	Vantage point seconds completed	1296000	seconds

Details	Description	Value	Units
	Time available for flight activity per year	4520	hours
	Flight seconds per year	16272000	seconds
	Number of birds observed	3	n
	Total time all birds spent in risk window	121	seconds
	Proportional time individual bird spends in risk window	3.1121E-05	
	Average time individual bird in risk window (Mar - Feb)	506.40741	seconds
	Bird occupancy of flight risk window	1519.22222	seconds
	Bird occupancy of rotor swept area	1.44009	seconds
	Bird transit time through rotors	0.22800	seconds
	Number of birds passing through rotors (Mar-Feb)	6.31618	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	7.8	%
	Adjusted collision risk to include turbine efficiency	5.85	%
	No. of collisions with no avoidance (Mar - Feb)	0.369497	n
	Adjusted for avoidance (95%)	0.018475	n
	Adjusted for avoidance (98%)	0.007390	n
	Adjusted for avoidance (99%)	0.003695	n
	Adjusted for avoidance (99.9%)	0.000369	n
Frequency of mortality	No avoidance, equivalent to one bird every	2.706385	years
	99% avoidance, equivalent to one bird every	270.638470	years

Table 7.20 Collision Risk Estimate (Band et al., 2007) for the Operational Barnesmore Windfarm and golden plover

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	1.56	m	r/R	c/C	□	collide		contribution	collide		contribution
Pitch (degrees)	22.5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.28	m	0.025	0.575	10.85	14.31	1.00	0.00125	13.63	1.00	0.00125
Wingspan	0.72	m	0.075	0.575	3.62	5.00	0.42	0.00314	4.31	0.36	0.00271
F: Flapping (0) or gliding (+1)	1		0.125	0.702	2.17	3.61	0.30	0.00378	2.77	0.23	0.00290
			0.175	0.860	1.55	3.15	0.26	0.00461	2.12	0.18	0.00311
Bird speed	17.9	m/sec	0.225	0.994	1.21	2.87	0.24	0.00542	1.69	0.14	0.00318
RotorDiam	42	m	0.275	0.947	0.99	2.36	0.20	0.00545	1.23	0.10	0.00284
RotationPeriod	2.00	sec	0.325	0.899	0.83	2.00	0.17	0.00545	0.93	0.08	0.00253
			0.375	0.851	0.72	1.73	0.14	0.00543	0.71	0.06	0.00223
			0.425	0.804	0.64	1.51	0.13	0.00538	0.55	0.05	0.00197
			0.475	0.756	0.57	1.34	0.11	0.00532	0.43	0.04	0.00172
Bird aspect ratio:	0.39		0.525	0.708	0.52	1.19	0.10	0.00522	0.34	0.03	0.00150
			0.575	0.660	0.47	1.06	0.09	0.00511	0.27	0.02	0.00131
			0.625	0.613	0.43	0.95	0.08	0.00497	0.22	0.02	0.00113
			0.675	0.565	0.40	0.85	0.07	0.00480	0.19	0.02	0.00110
			0.725	0.517	0.37	0.87	0.07	0.00527	0.31	0.03	0.00188
			0.775	0.470	0.35	0.80	0.07	0.00518	0.32	0.03	0.00210
			0.825	0.422	0.33	0.73	0.06	0.00506	0.33	0.03	0.00229
			0.875	0.374	0.31	0.67	0.06	0.00492	0.34	0.03	0.00246
			0.925	0.327	0.29	0.61	0.05	0.00475	0.34	0.03	0.00261

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
			0.975	0.279	0.28	0.56	0.05	0.00456	0.33	0.03	0.00273
				Overall p(collision) =			Upwind	9.5%		Downwind	4.4%
								Average	6.9%		

Table 7.21 Collision Risk Estimate (Band et al., 2007) for the Development and golden plover

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.5	m	r/R	c/C	□	collide		contribution	collide		contribution
Pitch (degrees)	22.5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.28	m	0.025	0.575	7.21	21.54	0.72	0.00090	19.56	0.66	0.00082
Wingspan	0.72	m	0.075	0.575	2.40	7.84	0.26	0.00197	5.86	0.20	0.00147
F: Flapping (0) or gliding (+1)	1		0.125	0.702	1.44	6.08	0.20	0.00255	3.66	0.12	0.00153
			0.175	0.860	1.03	5.64	0.19	0.00331	2.68	0.09	0.00157
Bird speed	17.9	m/sec	0.225	0.994	0.80	5.39	0.18	0.00407	1.97	0.07	0.00148
RotorDiam	158	m	0.275	0.947	0.66	4.51	0.15	0.00416	1.25	0.04	0.00115
RotationPeriod	5.00	sec	0.325	0.899	0.55	3.88	0.13	0.00422	0.78	0.03	0.00085
			0.375	0.851	0.48	3.39	0.11	0.00426	0.46	0.02	0.00057
			0.425	0.804	0.42	3.00	0.10	0.00427	0.23	0.01	0.00032
			0.475	0.756	0.38	2.77	0.09	0.00442	0.39	0.01	0.00062
Bird aspect ratio:	0.39		0.525	0.708	0.34	2.51	0.08	0.00442	0.49	0.02	0.00086
			0.575	0.660	0.31	2.28	0.08	0.00439	0.56	0.02	0.00107
			0.625	0.613	0.29	2.07	0.07	0.00434	0.60	0.02	0.00126
			0.675	0.565	0.27	1.88	0.06	0.00425	0.63	0.02	0.00142

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
			0.725	0.517	0.25	1.71	0.06	0.00415	0.64	0.02	0.00155
			0.775	0.470	0.23	1.54	0.05	0.00401	0.63	0.02	0.00165
			0.825	0.422	0.22	1.39	0.05	0.00384	0.62	0.02	0.00172
			0.875	0.374	0.21	1.25	0.04	0.00365	0.60	0.02	0.00177
			0.925	0.327	0.19	1.11	0.04	0.00343	0.58	0.02	0.00179
			0.975	0.279	0.18	0.97	0.03	0.00319	0.55	0.02	0.00178
				Overall p(collision) =			Upwind	7.4%		Downwind	2.5%
								Average	5.0%		

Table 7.22 Collision Risk Assessment Operational Barnesmore Windfarm 2017 – 2018: golden plover

Details	Description	Value	Units
Turbine parameters	Number of turbines	25	n
	Hub height	40.5	m
	Rotor diameter	42	m
	Rotor radius	21	m
	Blade maximum chord	1.56	m
	Blade pitch	22.5	°
	Rotor rotation period	2	sec
	Blade depth	1.56	m
	Risk window ceiling height	61.5	m
	Risk window floor height	19.5	m
	Windfarm area	4783942	m2
	Flight risk volume	200925564	m3
	Rotor swept area (single turbine)	1385.44236	m2

Details	Description	Value	Units
	Rotor swept volume (single turbine)	2549.21394	m3
	Rotor swept volume (combined)	63730.3486	m3
	Proportion of flight risk volume with turbines	0.00031718	
Bird parameters	Months surveyed	Mar - Feb	months
	Speed of the bird through the rotor	17.9	m/s
	Length of the bird	0.28	m
	Wingspan of the bird	0.72	m
	Vantage point hours completed	360	hours
	Vantage point seconds completed	1296000	seconds
	Time available for flight activity per year	4520	hours
	Flight seconds per year	16272000	seconds
	Number of birds observed	352	n
	Total time all birds spent in risk window	717	seconds
	Proportional time individual bird spends in risk window	1.5717E-06	
	Average time individual bird in risk window (Mar - Feb)	25.5748106	seconds
	Bird occupancy of flight risk window	9002.33333	seconds
	Bird occupancy of rotor swept area	2.85539495	seconds
	Bird transit time through rotors	0.1027933	seconds
	Number of birds passing through rotors (Mar-Feb)	27.778027	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	6.9	%
	Adjusted collision risk to include turbine efficiency	5.175	%

Details	Description	Value	Units
	No. of collisions with no avoidance (Mar - Feb)	1.43751	n
	Adjusted for avoidance (95%)	0.07188	n
	Adjusted for avoidance (98%)	0.02875	n
	Adjusted for avoidance (99%)	0.01438	n
	Adjusted for avoidance (99.9%)	0.00144	n
Frequency of mortality	No avoidance, equivalent to one bird every	0.69565	years
	98% avoidance, equivalent to one bird every	34.78230	years

Table 7.23 Collision Risk Assessment Development 2017 – 2018: golden plover

Details	Description	Value	Units
Turbine parameters	Number of turbines	13	n
	Hub height	101	m
	Rotor diameter	158	m
	Rotor radius	79	m
	Blade maximum chord	4.5	m
	Blade pitch	22.5	°
	Rotor rotation period	5	sec
	Blade depth	2.6	m
	Risk window ceiling height	180	m
	Risk window floor height	22	m
	Windfarm area	5820339	m2
	Flight risk volume	919613562	m3
	Rotor swept area (single turbine)	19606.6798	m2

Details	Description	Value	Units
	Rotor swept volume (single turbine)	56467.2377	m3
	Rotor swept volume (combined)	734074.09	m3
	Proportion of flight risk volume with turbines	0.00079824	
Bird parameters	Months surveyed	Mar - Feb	months
	Speed of the bird through the rotor	17.9	m/s
	Length of the bird	0.28	m
	Wingspan of the bird	0.72	m
	Vantage point hours completed	360	hours
	Vantage point seconds completed	1296000	seconds
	Time available for flight activity per year	4520	hours
	Flight seconds per year	16272000	seconds
	Number of birds observed	403	n
	Total time all birds spent in risk window	1039	seconds
	Proportional time individual bird spends in risk window	1.9893E-06	
	Average time individual bird in risk window (Mar - Feb)	32.3702785	seconds
	Bird occupancy of flight risk window	13045.2222	seconds
	Bird occupancy of rotor swept area	10.4132432	seconds
	Bird transit time through rotors	0.16089385	seconds
	Number of birds passing through rotors (Mar-Feb)	64.7211988	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	5.0	%
	Adjusted collision risk to include turbine efficiency	3.75	%

Details	Description	Value	Units
	No. of collisions with no avoidance (Mar - Feb)	2.42704	n
	Adjusted for avoidance (95%)	0.12135	n
	Adjusted for avoidance (98%)	0.04854	n
	Adjusted for avoidance (99%)	0.02427	n
	Adjusted for avoidance (99.9%)	0.00243	n
Frequency of mortality	No avoidance, equivalent to one bird every	0.41202	years
	98% avoidance, equivalent to one bird every	20.60118	years

Table 7.24 Collision Risk Assessment Operational Barnesmore Windfarm 2018 – 2019: golden plover

Details	Description	Value	Units
Turbine parameters	Number of turbines	25	n
	Hub height	40.5	m
	Rotor diameter	42	m
	Rotor radius	21	m
	Blade maximum chord	1.56	m
	Blade pitch	22.5	°
	Rotor rotation period	2	sec
	Blade depth	1.56	m
	Risk window ceiling height	61.5	m
	Risk window floor height	19.5	m
	Windfarm area	4783942	m2
	Flight risk volume	200925564	m3
	Rotor swept area (single turbine)	1385.44236	m2

Details	Description	Value	Units
	Rotor swept volume (single turbine)	2549.21394	m3
	Rotor swept volume (combined)	63730.3486	m3
	Proportion of flight risk volume with turbines	0.00031718	
Bird parameters	Months surveyed	Mar - Mar	months
	Speed of the bird through the rotor	17.9	m/s
	Length of the bird	0.28	m
	Wingspan of the bird	0.72	m
	Vantage point hours completed	375	hours
	Vantage point seconds completed	1350000	seconds
	Time available for flight activity per year	4892	hours
	Flight seconds per year	17611200	seconds
	Number of birds observed	189	n
	Total time all birds spent in risk window	1242	seconds
	Proportional time individual bird spends in risk window	4.8677E-06	
	Average time individual bird in risk window (Mar - Mar)	85.7264762	seconds
	Bird occupancy of flight risk window	16202.304	seconds
	Bird occupancy of rotor swept area	5.13910953	seconds
	Bird transit time through rotors	0.1027933	seconds
	Number of birds passing through rotors (Mar - Mar)	49.9945982	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	6.9	%
	Adjusted collision risk to include turbine efficiency	5.175	%

Details	Description	Value	Units
	No. of collisions with no avoidance (Mar - Mar)	2.58722	n
	Adjusted for avoidance (95%)	0.12936	n
	Adjusted for avoidance (98%)	0.05174	n
	Adjusted for avoidance (99%)	0.02587	n
	Adjusted for avoidance (99.9%)	0.00259	n
Frequency of mortality	No avoidance, equivalent to one bird every	0.38652	years
	98% avoidance, equivalent to one bird every	19.32576	years

Table 7.25 Collision Risk Assessment Development 2018 – 2019: golden plover

Details	Description	Value	Units
Turbine parameters	Number of turbines	13	n
	Hub height	101	m
	Rotor diameter	158	m
	Rotor radius	79	m
	Blade maximum chord	4.5	m
	Blade pitch	22.5	°
	Rotor rotation period	5	sec
	Blade depth	2.6	m
	Risk window ceiling height	180	m
	Risk window floor height	22	m
	Windfarm area	5820339	m2
	Flight risk volume	919613562	m3
	Rotor swept area (single turbine)	19606.6798	m2

Details	Description	Value	Units
	Rotor swept volume (single turbine)	56467.2377	m3
	Rotor swept volume (combined)	734074.09	m3
	Proportion of flight risk volume with turbines	0.00079824	
Bird parameters	Months surveyed	Mar - Mar	months
	Speed of the bird through the rotor	17.9	m/s
	Length of the bird	0.28	m
	Wingspan of the bird	0.72	m
	Vantage point hours completed	375	hours
	Vantage point seconds completed	1350000	seconds
	Time available for flight activity per year	4892	0
	Flight seconds per year	17611200	seconds
	Number of birds observed	189	n
	Total time all birds spent in risk window	1492	seconds
	Proportional time individual bird spends in risk window	5.8475E-06	
	Average time individual bird in risk window (Mar - Mar)	102.982208	seconds
	Bird occupancy of flight risk window	19463.6373	seconds
	Bird occupancy of rotor swept area	15.5366911	seconds
	Bird transit time through rotors	0.16089385	seconds
	Number of birds passing through rotors (Mar-Mar)	96.564851	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	5.0	%
	Adjusted collision risk to include turbine efficiency	3.75	%

Details	Description	Value	Units
	No. of collisions with no avoidance (Mar - Mar)	3.62118	n
	Adjusted for avoidance (95%)	0.18106	n
	Adjusted for avoidance (98%)	0.07242	n
	Adjusted for avoidance (99%)	0.03621	n
	Adjusted for avoidance (99.9%)	0.00362	n
Frequency of mortality	No avoidance, equivalent to one bird every	0.27615	years
	98% avoidance, equivalent to one bird every	13.80765	years

Table 7.26 Collision Risk Assessment Operational Barnesmore Windfarm 2017 – 2018: golden plover (winter only)

Details	Description	Value	Units
Turbine parameters	Number of turbines	25	n
	Hub height	40.5	m
	Rotor diameter	42	m
	Rotor radius	21	m
	Blade maximum chord	1.56	m
	Blade pitch	22.5	°
	Rotor rotation period	2	sec
	Blade depth	1.56	m
	Risk window ceiling height	61.5	m
	Risk window floor height	19.5	m
	Windfarm area	4783942	m2
	Flight risk volume	200925564	m3
	Rotor swept area (single turbine)	1385.44236	m2

Details	Description	Value	Units
	Rotor swept volume (single turbine)	2549.21394	m3
	Rotor swept volume (combined)	63730.3486	m3
	Proportion of flight risk volume with turbines	0.00031718	
Bird parameters	Months surveyed	Mar - Feb	months
	Speed of the bird through the rotor	17.9	m/s
	Length of the bird	0.28	m
	Wingspan of the bird	0.72	m
	Vantage point hours completed	360	hours
	Vantage point seconds completed	1296000	seconds
	Time available for flight activity per year	1867	hours
	Flight seconds per year	6721200	seconds
	Number of birds observed	352	n
	Total time all birds spent in risk window	717	seconds
	Proportional time individual bird spends in risk window	1.5717E-06	
	Average time individual bird in risk window	10.5637547	seconds
	Bird occupancy of flight risk window	3718.44167	seconds
	Bird occupancy of rotor swept area	1.17942973	seconds
	Bird transit time through rotors	0.1027933	seconds
	Number of birds passing through rotors	11.4738001	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	6.9	%

Details	Description	Value	Units
	Adjusted collision risk to include turbine efficiency	5.175	%
	No. of collisions with no avoidance	0.59377	n
	Adjusted for avoidance (95%)	0.02969	n
	Adjusted for avoidance (98%)	0.01188	n
	Adjusted for avoidance (99%)	0.00594	n
	Adjusted for avoidance (99.9%)	0.00059	n
Frequency of mortality	No avoidance, equivalent to one bird every	1.68416	years
	98% avoidance, equivalent to one bird every	84.20781	years

Table 7.27 Collision Risk Assessment Development 2017 – 2018: golden plover (winter only)

Details	Description	Value	Units
Turbine parameters	Number of turbines	13	n
	Hub height	101	m
	Rotor diameter	158	m
	Rotor radius	79	m
	Blade maximum chord	4.5	m
	Blade pitch	22.5	°
	Rotor rotation period	5	sec
	Blade depth	2.6	m
	Risk window ceiling height	180	m
	Risk window floor height	22	m
	Windfarm area	5820339	m2
	Flight risk volume	919613562	m3

Details	Description	Value	Units
	Rotor swept area (single turbine)	19606.6798	m2
	Rotor swept volume (single turbine)	56467.2377	m3
	Rotor swept volume (combined)	734074.09	m3
	Proportion of flight risk volume with turbines	0.00079824	
Bird parameters	Months surveyed	Mar - Feb	months
	Speed of the bird through the rotor	17.9	m/s
	Length of the bird	0.28	m
	Wingspan of the bird	0.72	m
	Vantage point hours completed	360	hours
	Vantage point seconds completed	1296000	seconds
	Time available for flight activity per year	1867	hours
	Flight seconds per year	6721200	seconds
	Number of birds observed	403	n
	Total time all birds spent in risk window	1039	seconds
	Proportional time individual bird spends in risk window	1.9893E-06	
	Average time individual bird in risk window	13.3706438	seconds
	Bird occupancy of flight risk window	5388.36944	seconds
	Bird occupancy of rotor swept area	4.30122234	seconds
	Bird transit time through rotors	0.16089385	seconds
	Number of birds passing through rotors	26.7332916	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%

Details	Description	Value	Units
	Average collision risk (Band et al., 2007)	5.0	%
	Adjusted collision risk to include turbine efficiency	3.75	%
	No. of collisions with no avoidance	1.00250	n
	Adjusted for avoidance (95%)	0.05012	n
	Adjusted for avoidance (98%)	0.02005	n
	Adjusted for avoidance (99%)	0.01002	n
	Adjusted for avoidance (99.9%)	0.00100	n
Frequency of mortality	No avoidance, equivalent to one bird every	0.99751	years
	98% avoidance, equivalent to one bird every	49.87539	years

Table 7.28 Collision Risk Assessment Operational Barnesmore Windfarm 2018 – 2019: golden plover (winter only)

Details	Description	Value	Units
Turbine parameters	Number of turbines	25	n
	Hub height	40.5	m
	Rotor diameter	42	m
	Rotor radius	21	m
	Blade maximum chord	1.56	m
	Blade pitch	22.5	°
	Rotor rotation period	2	sec
	Blade depth	1.56	m
	Risk window ceiling height	61.5	m
	Risk window floor height	19.5	m
	Windfarm area	4783942	m2

Details	Description	Value	Units
	Flight risk volume	200925564	m3
	Rotor swept area (single turbine)	1385.44236	m2
	Rotor swept volume (single turbine)	2549.21394	m3
	Rotor swept volume (combined)	63730.3486	m3
	Proportion of flight risk volume with turbines	0.00031718	
Bird parameters	Months surveyed	Mar - Mar	months
	Speed of the bird through the rotor	17.9	m/s
	Length of the bird	0.28	m
	Wingspan of the bird	0.72	m
	Vantage point hours completed	375	hours
	Vantage point seconds completed	1350000	seconds
	Time available for flight activity per year	2239	hours
	Flight seconds per year	8060400	seconds
	Number of birds observed	189	n
	Total time all birds spent in risk window	1242	seconds
	Proportional time individual bird spends in risk window	4.8677E-06	
	Average time individual bird in risk window	39.2358095	seconds
	Bird occupancy of flight risk window	7415.568	seconds
	Bird occupancy of rotor swept area	2.35209858	seconds
	Bird transit time through rotors	0.1027933	seconds
	Number of birds passing through rotors	22.8818286	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%

Details	Description	Value	Units
	Average collision risk (Band et al., 2007)	6.9	%
	Adjusted collision risk to include turbine efficiency	5.175	%
	No. of collisions with no avoidance	1.18413	n
	Adjusted for avoidance (95%)	0.05921	n
	Adjusted for avoidance (98%)	0.02368	n
	Adjusted for avoidance (99%)	0.01184	n
	Adjusted for avoidance (99.9%)	0.00118	n
Frequency of mortality	No avoidance, equivalent to one bird every	0.84450	years
	98% avoidance, equivalent to one bird every	42.22493	years

Table 7.29 Collision Risk Assessment Development 2018 – 2019: golden plover (winter only)

Details	Description	Value	Units
Turbine parameters	Number of turbines	13	n
	Hub height	101	m
	Rotor diameter	158	m
	Rotor radius	79	m
	Blade maximum chord	4.5	m
	Blade pitch	22.5	°
	Rotor rotation period	5	sec
	Blade depth	2.6	m
	Risk window ceiling height	180	m
	Risk window floor height	22	m
	Windfarm area	5820339	m2
	Flight risk volume	919613562	m3
	Rotor swept area (single turbine)	19606.6798	m2
	Rotor swept volume (single turbine)	56467.2377	m3
	Rotor swept volume (combined)	734074.09	m3
	Proportion of flight risk volume with turbines	0.00079824	
Bird parameters	Months surveyed	Mar - Mar	months
	Speed of the bird through the rotor	17.9	m/s

Details	Description	Value	Units
	Length of the bird	0.28	m
	Wingspan of the bird	0.72	m
	Vantage point hours completed	375	hours
	Vantage point seconds completed	1350000	seconds
	Time available for flight activity per year	2239	0
	Flight seconds per year	8060400	seconds
	Number of birds observed	189	n
	Total time all birds spent in risk window	1492	seconds
	Proportional time individual bird spends in risk window	5.8475E-06	
	Average time individual bird in risk window	47.1335168	seconds
	Bird occupancy of flight risk window	8908.23467	seconds
	Bird occupancy of rotor swept area	7.11092629	seconds
	Bird transit time through rotors	0.16089385	seconds
	Number of birds passing through rotors	44.1963822	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	5.0	%
	Adjusted collision risk to include turbine efficiency	3.75	%
	No. of collisions with no avoidance	1.65736	n
	Adjusted for avoidance (95%)	0.08287	n
	Adjusted for avoidance (98%)	0.03315	n
	Adjusted for avoidance (99%)	0.01657	n
	Adjusted for avoidance (99.9%)	0.00166	n
Frequency of mortality	No avoidance, equivalent to one bird every	0.60337	years
	98% avoidance, equivalent to one bird every	30.16838	years

Table 7.30 Collision Risk Estimate (Band et al., 2007) for the Operational Barnesmore Windfarm and heron

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	1.56	m	r/R	c/C	□	collide		contribution	collide		contribution
Pitch (degrees)	22.5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.94	m	0.025	0.575	7.28	14.94	1.00	0.00125	14.26	1.00	0.00125
Wingspan	1.85	m	0.075	0.575	2.43	5.21	0.65	0.00488	4.52	0.57	0.00424
F: Flapping (0) or gliding (+1)	1		0.125	0.702	1.46	3.60	0.45	0.00563	2.77	0.35	0.00432
			0.175	0.860	1.04	3.03	0.38	0.00662	2.00	0.25	0.00437
Bird speed	12	m/sec	0.225	0.994	0.81	2.70	0.34	0.00761	1.52	0.19	0.00427
RotorDiam	42	m	0.275	0.947	0.66	2.25	0.28	0.00772	1.12	0.14	0.00384
RotationPeriod	2.00	sec	0.325	0.899	0.56	1.92	0.24	0.00780	0.85	0.11	0.00344
			0.375	0.851	0.49	2.04	0.26	0.00958	1.03	0.13	0.00481
			0.425	0.804	0.43	1.92	0.24	0.01018	0.96	0.12	0.00508
			0.475	0.756	0.38	1.81	0.23	0.01074	0.97	0.12	0.00578
Bird aspect ratioo: □	0.51		0.525	0.708	0.35	1.72	0.21	0.01126	1.01	0.13	0.00662
			0.575	0.660	0.32	1.64	0.20	0.01175	1.03	0.13	0.00743
			0.625	0.613	0.29	1.56	0.20	0.01221	1.05	0.13	0.00819
			0.675	0.565	0.27	1.50	0.19	0.01263	1.06	0.13	0.00893
			0.725	0.517	0.25	1.44	0.18	0.01301	1.06	0.13	0.00962
			0.775	0.470	0.23	1.38	0.17	0.01336	1.06	0.13	0.01028
			0.825	0.422	0.22	1.33	0.17	0.01367	1.06	0.13	0.01091
			0.875	0.374	0.21	1.28	0.16	0.01395	1.05	0.13	0.01150
			0.925	0.327	0.20	1.23	0.15	0.01419	1.04	0.13	0.01205

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
			0.975	0.279	0.19	1.18	0.15	0.01440	1.03	0.13	0.01257
				Overall p(collision) =			Upwind	20.2%		Downwind	14.0%
								Average	17.1%		

Table 7.31 Collision Risk Estimate (Band et al., 2007) for the Development and heron

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.5	m	r/R	c/C	a	collide		contribution	collide		contribution
Pitch (degrees)	22.5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.94	m	0.025	0.575	4.84	18.24	0.91	0.00114	16.26	0.81	0.00102
Wingspan	1.85	m	0.075	0.575	1.61	6.74	0.34	0.00253	4.76	0.24	0.00179
F: Flapping (0) or gliding (+1)	1		0.125	0.702	0.97	5.17	0.26	0.00323	2.75	0.14	0.00172
			0.175	0.860	0.69	4.76	0.24	0.00417	1.80	0.09	0.00158
Bird speed	12	m/sec	0.225	0.994	0.54	4.57	0.23	0.00514	1.14	0.06	0.00128
RotorDiam	158	m	0.275	0.947	0.44	4.30	0.22	0.00591	1.04	0.05	0.00143
RotationPeriod	5.00	sec	0.325	0.899	0.37	3.88	0.19	0.00630	1.10	0.05	0.00178
			0.375	0.851	0.32	3.55	0.18	0.00665	1.27	0.06	0.00237
			0.425	0.804	0.28	3.27	0.16	0.00696	1.37	0.07	0.00292
			0.475	0.756	0.25	3.04	0.15	0.00722	1.44	0.07	0.00342
Bird aspect ratioo: b	0.51		0.525	0.708	0.23	2.84	0.14	0.00745	1.48	0.07	0.00389
			0.575	0.660	0.21	2.65	0.13	0.00763	1.50	0.08	0.00431
			0.625	0.613	0.19	2.49	0.12	0.00777	1.50	0.08	0.00470
			0.675	0.565	0.18	2.33	0.12	0.00788	1.49	0.07	0.00504

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
			0.725	0.517	0.17	2.19	0.11	0.00794	1.47	0.07	0.00534
			0.775	0.470	0.16	2.05	0.10	0.00796	1.44	0.07	0.00560
			0.825	0.422	0.15	1.92	0.10	0.00794	1.41	0.07	0.00581
			0.875	0.374	0.14	1.80	0.09	0.00787	1.37	0.07	0.00599
			0.925	0.327	0.13	1.68	0.08	0.00777	1.32	0.07	0.00613
			0.975	0.279	0.12	1.56	0.08	0.00762	1.28	0.06	0.00622
				Overall p(collision) =			Upwind	12.7%		Downwind	7.2%
								Average	10.0%		

Table 7.32 Collision Risk Assessment Operational Barnesmore Windfarm 2018 – 2019: heron

Details	Description	Value	Units
Turbine parameters	Number of turbines	25	n
	Hub height	40.5	m
	Rotor diameter	42	m
	Rotor radius	21	m
	Blade maximum chord	1.56	m
	Blade pitch	22.5	°
	Rotor rotation period	2	sec
	Blade depth	1.56	m
	Risk window ceiling height	61.5	m
	Risk window floor height	19.5	m
	Windfarm area	4783942	m2
	Flight risk volume	200925564	m3
	Rotor swept area (single turbine)	1385.44236	m2

Details	Description	Value	Units
	Rotor swept volume (single turbine)	3463.6059	m3
	Rotor swept volume (combined)	86590.1475	m3
	Proportion of flight risk volume with turbines	0.00043096	
Bird parameters	Months surveyed	Mar - Mar	months
	Speed of the bird through the rotor	12	m/s
	Length of the bird	0.94	m
	Wingspan of the bird	1.85	m
	Vantage point hours completed	375	hours
	Vantage point seconds completed	1350000	seconds
	Time available for flight activity per year	4892	hours
	Flight seconds per year	17611200	seconds
	Number of birds observed	1	n
	Total time all birds spent in risk window	112	seconds
	Proportional time individual bird spends in risk window	8.2963E-05	
	Average time individual bird in risk window (Mar - Mar)	1461.07733	seconds
	Bird occupancy of flight risk window	1461.07733	seconds
	Bird occupancy of rotor swept area	0.62966055	seconds
	Bird transit time through rotors	0.20833333	seconds
	Number of birds passing through rotors (Mar - Mar)	3.02237066	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	17.1	%
	Adjusted collision risk to include turbine efficiency	12.825	%

Details	Description	Value	Units
	No. of collisions with no avoidance (Mar - Mar)	0.38761904	n
	Adjusted for avoidance (95%)	0.01938095	n
	Adjusted for avoidance (98%)	0.00775238	n
	Adjusted for avoidance (99%)	0.00387619	n
	Adjusted for avoidance (99.9%)	0.00038762	n
Frequency of mortality	No avoidance, equivalent to one bird every	2.57985265	years
	98% avoidance, equivalent to one bird every	128.992633	years

Table 7.33 Collision Risk Assessment Development 2018 – 2019: heron

Details	Description	Value	Units
Turbine parameters	Number of turbines	13	n
	Hub height	101	m
	Rotor diameter	158	m
	Rotor radius	79	m
	Blade maximum chord	4.5	m
	Blade pitch	22.5	°
	Rotor rotation period	5	sec
	Blade depth	2.6	m
	Risk window ceiling height	180	m
	Risk window floor height	22	m
	Windfarm area	5820339	m2
	Flight risk volume	919613562	m3
	Rotor swept area (single turbine)	19606.6798	m2

Details	Description	Value	Units
	Rotor swept volume (single turbine)	69407.6463	m3
	Rotor swept volume (combined)	902299.402	m3
	Proportion of flight risk volume with turbines	0.00098117	
Bird parameters	Months surveyed	Mar - Mar	months
	Speed of the bird through the rotor	12	m/s
	Length of the bird	0.94	m
	Wingspan of the bird	1.85	m
	Vantage point hours completed	375	hours
	Vantage point seconds completed	1350000	seconds
	Time available for flight activity per year	4892	hours
	Flight seconds per year	17611200	seconds
	Number of birds observed	1	n
	Total time all birds spent in risk window	112	seconds
	Proportional time individual bird spends in risk window	8.2963E-05	
	Average time individual bird in risk window (Mar - Mar)	1461.07733	seconds
	Bird occupancy of flight risk window	1461.07733	seconds
	Bird occupancy of rotor swept area	1.43356868	seconds
	Bird transit time through rotors	0.295	seconds
	Number of birds passing through rotors (Mar-Mar)	4.85955486	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	10.0	%
	Adjusted collision risk to include turbine efficiency	7.5	%

Details	Description	Value	Units
	No. of collisions with no avoidance (Mar - Mar)	0.36446661	n
	Adjusted for avoidance (95%)	0.01822333	n
	Adjusted for avoidance (98%)	0.00728933	n
	Adjusted for avoidance (99%)	0.00364467	n
	Adjusted for avoidance (99.9%)	0.00036447	n
Frequency of mortality	No avoidance, equivalent to one bird every	2.74373553	years
	98% avoidance, equivalent to one bird every	137.186776	years

Table 7.34 Collision Risk Estimate (Band et al., 2007) for the Operational Barnesmore Windfarm and kestrel

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	1.56	m	r/R	c/C	□	collide		contribution	collide		contribution
Pitch (degrees)	22.5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.34	m	0.025	0.575	7.28	9.89	1.00	0.00125	9.21	1.00	0.00125
Wingspan	0.76	m	0.075	0.575	2.43	3.53	0.44	0.00331	2.84	0.35	0.00266
F: Flapping (0) or gliding (+1)	1		0.125	0.702	1.46	2.59	0.32	0.00405	1.76	0.22	0.00274
			0.175	0.860	1.04	2.30	0.29	0.00504	1.28	0.16	0.00280
Bird speed	12	m/sec	0.225	0.994	0.81	2.14	0.27	0.00603	0.96	0.12	0.00269
RotorDiam	42	m	0.275	0.947	0.66	1.79	0.22	0.00614	0.66	0.08	0.00226
RotationPeriod	2.00	sec	0.325	0.899	0.56	1.53	0.19	0.00623	0.46	0.06	0.00187
			0.375	0.851	0.49	1.34	0.17	0.00627	0.32	0.04	0.00151
			0.425	0.804	0.43	1.32	0.16	0.00699	0.36	0.04	0.00189

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
			0.475	0.756	0.38	1.21	0.15	0.00717	0.37	0.05	0.00222
Bird aspect ratio:	0.45		0.525	0.708	0.35	1.12	0.14	0.00733	0.41	0.05	0.00269
			0.575	0.660	0.32	1.04	0.13	0.00744	0.43	0.05	0.00311
			0.625	0.613	0.29	0.96	0.12	0.00752	0.45	0.06	0.00351
			0.675	0.565	0.27	0.90	0.11	0.00757	0.46	0.06	0.00386
			0.725	0.517	0.25	0.84	0.10	0.00758	0.46	0.06	0.00418
			0.775	0.470	0.23	0.78	0.10	0.00755	0.46	0.06	0.00447
			0.825	0.422	0.22	0.73	0.09	0.00749	0.46	0.06	0.00472
			0.875	0.374	0.21	0.68	0.08	0.00739	0.45	0.06	0.00494
			0.925	0.327	0.20	0.63	0.08	0.00726	0.44	0.06	0.00512
			0.975	0.279	0.19	0.58	0.07	0.00709	0.43	0.05	0.00526
				Overall p(collision) =			Upwind	12.7%		Downwind	6.4%
								Average	9.5%		

Table 7.35 Collision Risk Estimate (Band et al., 2007) for the Development and kestrel

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.5	m	r/R	c/C	a	collide		contribution	collide		contribution
Pitch (degrees)	22.5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.34	m	0.025	0.575	4.84	14.89	0.74	0.00093	12.91	0.65	0.00081
Wingspan	0.76	m	0.075	0.575	1.61	5.62	0.28	0.00211	3.64	0.18	0.00137
F: Flapping (0) or gliding (+1)	1		0.125	0.702	0.97	4.50	0.22	0.00281	2.08	0.10	0.00130
			0.175	0.860	0.69	4.29	0.21	0.00375	1.32	0.07	0.00116

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
Bird speed	12	m/sec	0.225	0.994	0.54	4.19	0.21	0.00472	0.77	0.04	0.00086
RotorDiam	158	m	0.275	0.947	0.44	3.70	0.19	0.00509	0.44	0.02	0.00060
RotationPeriod	5.00	sec	0.325	0.899	0.37	3.28	0.16	0.00533	0.50	0.02	0.00081
			0.375	0.851	0.32	2.95	0.15	0.00553	0.67	0.03	0.00125
			0.425	0.804	0.28	2.67	0.13	0.00568	0.77	0.04	0.00164
			0.475	0.756	0.25	2.44	0.12	0.00580	0.84	0.04	0.00200
Bird aspect ratioo: b	0.45		0.525	0.708	0.23	2.24	0.11	0.00587	0.88	0.04	0.00231
			0.575	0.660	0.21	2.05	0.10	0.00591	0.90	0.05	0.00259
			0.625	0.613	0.19	1.89	0.09	0.00590	0.90	0.05	0.00282
			0.675	0.565	0.18	1.73	0.09	0.00585	0.89	0.04	0.00301
			0.725	0.517	0.17	1.59	0.08	0.00576	0.87	0.04	0.00316
			0.775	0.470	0.16	1.45	0.07	0.00563	0.84	0.04	0.00327
			0.825	0.422	0.15	1.32	0.07	0.00546	0.81	0.04	0.00334
			0.875	0.374	0.14	1.20	0.06	0.00525	0.77	0.04	0.00337
			0.925	0.327	0.13	1.08	0.05	0.00499	0.72	0.04	0.00335
			0.975	0.279	0.12	0.96	0.05	0.00470	0.68	0.03	0.00330
				Overall p(collision) =			Upwind	9.7%		Downwind	4.2%
								Average	7.0%		

Table 7.36 Collision Risk Assessment Operational Barnesmore Windfarm 2017 – 2018: kestrel

Details	Description	Value	Units
Turbine parameters	Number of turbines	25	n
	Hub height	40.5	m
	Rotor diameter	42	m

Details	Description	Value	Units
	Rotor radius	21	m
	Blade maximum chord	1.56	m
	Blade pitch	22.5	°
	Rotor rotation period	2	sec
	Blade depth	1.56	m
	Risk window ceiling height	61.5	m
	Risk window floor height	19.5	m
	Windfarm area	4783942	m2
	Flight risk volume	200925564	m3
	Rotor swept area (single turbine)	1385.44236	m2
	Rotor swept volume (single turbine)	2632.34048	m3
	Rotor swept volume (combined)	65808.5121	m3
	Proportion of flight risk volume with turbines	0.00032753	
Bird parameters	Months surveyed	Mar - Feb	months
	Speed of the bird through the rotor	12	m/s
	Length of the bird	0.34	m
	Wingspan of the bird	0.76	m
	Vantage point hours completed	360	hours
	Vantage point seconds completed	1296000	seconds
	Time available for flight activity per year	4520	hours
	Flight seconds per year	16272000	seconds
	Number of birds observed	16	n
	Total time all birds spent in risk window	1082	seconds

Details	Description	Value	Units
	Proportional time individual bird spends in risk window	5.218E-05	
	Average time individual bird in risk window (Mar - Feb)	849.069444	seconds
	Bird occupancy of flight risk window	13585.1111	seconds
	Bird occupancy of rotor swept area	4.44948831	seconds
	Bird transit time through rotors	0.15833333	seconds
	Number of birds passing through rotors (Mar-Feb)	28.1020315	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	9.5	%
	Adjusted collision risk to include turbine efficiency	7.125	%
	No. of collisions with no avoidance (Mar - Feb)	2.00226974	n
	Adjusted for avoidance (95%)	0.10011349	n
	Adjusted for avoidance (98%)	0.04004539	n
	Adjusted for avoidance (99%)	0.02002270	n
	Adjusted for avoidance (99.9%)	0.00200227	n
Frequency of mortality	No avoidance, equivalent to one bird every	0.49943321	years
	95% avoidance, equivalent to one bird every	9.98866416	years

Table 7.37 Collision Risk Assessment Development 2017 – 2018: kestrel

Details	Description	Value	Units
Turbine parameters	Number of turbines	13	n
	Hub height	101	m
	Rotor diameter	158	m

Details	Description	Value	Units
	Rotor radius	79	m
	Blade maximum chord	4.5	m
	Blade pitch	22.5	°
	Rotor rotation period	5	sec
	Blade depth	2.6	m
	Risk window ceiling height	180	m
	Risk window floor height	22	m
	Windfarm area	5820339	m2
	Flight risk volume	919613562	m3
	Rotor swept area (single turbine)	19606.6798	m2
	Rotor swept volume (single turbine)	57643.6385	m3
	Rotor swept volume (combined)	749367.3	m3
	Proportion of flight risk volume with turbines	0.00081487	
Bird parameters	Months surveyed	Mar - Feb	months
	Speed of the bird through the rotor	12	m/s
	Length of the bird	0.34	m
	Wingspan of the bird	0.76	m
	Vantage point hours completed	360	hours
	Vantage point seconds completed	1296000	seconds
	Time available for flight activity per year	4520	hours
	Flight seconds per year	16272000	seconds
	Number of birds observed	17	n
	Total time all birds spent in risk window	1265	seconds

Details	Description	Value	Units
	Proportional time individual bird spends in risk window	5.7416E-05	
	Average time individual bird in risk window (Mar - Feb)	934.281046	seconds
	Bird occupancy of flight risk window	15882.7778	seconds
	Bird occupancy of rotor swept area	12.9424302	seconds
	Bird transit time through rotors	0.245	seconds
	Number of birds passing through rotors (Mar-Feb)	52.8262456	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	7.0	%
	Adjusted collision risk to include turbine efficiency	5.25	%
	No. of collisions with no avoidance (Mar - Feb)	2.77337789	n
	Adjusted for avoidance (95%)	0.13866889	n
	Adjusted for avoidance (98%)	0.05546756	n
	Adjusted for avoidance (99%)	0.02773378	n
	Adjusted for avoidance (99.9%)	0.00277338	n
Frequency of mortality	No avoidance, equivalent to one bird every	0.36057113	years
	95% avoidance, equivalent to one bird every	7.2114226	years

Table 7.38 Collision Risk Assessment Operational Barnesmore Windfarm 2018 – 2019: kestrel

Details	Description	Value	Units
Turbine parameters	Number of turbines	25	n
	Hub height	40.5	m
	Rotor diameter	42	m

Details	Description	Value	Units
	Rotor radius	21	m
	Blade maximum chord	1.56	m
	Blade pitch	22.5	°
	Rotor rotation period	2	sec
	Blade depth	1.56	m
	Risk window ceiling height	61.5	m
	Risk window floor height	19.5	m
	Windfarm area	4783942	m2
	Flight risk volume	200925564	m3
	Rotor swept area (single turbine)	1385.44236	m2
	Rotor swept volume (single turbine)	2632.34048	m3
	Rotor swept volume (combined)	65808.5121	m3
	Proportion of flight risk volume with turbines	0.00032753	
Bird parameters	Months surveyed	Mar - Mar	months
	Speed of the bird through the rotor	12	m/s
	Length of the bird	0.34	m
	Wingspan of the bird	0.76	m
	Vantage point hours completed	375	hours
	Vantage point seconds completed	1350000	seconds
	Time available for flight activity per year	4892	hours
	Flight seconds per year	17611200	seconds
	Number of birds observed	3	n
	Total time all birds spent in risk window	198	seconds

Details	Description	Value	Units
	Proportional time individual bird spends in risk window	4.8889E-05	
	Average time individual bird in risk window (Mar - Mar)	860.992	seconds
	Bird occupancy of flight risk window	2582.976	seconds
	Bird occupancy of rotor swept area	0.84599393	seconds
	Bird transit time through rotors	0.15833333	seconds
	Number of birds passing through rotors (Mar - Mar)	5.34311955	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	9.5	%
	Adjusted collision risk to include turbine efficiency	7.125	%
	No. of collisions with no avoidance (Mar - Mar)	0.38069727	n
	Adjusted for avoidance (95%)	0.01903486	n
	Adjusted for avoidance (98%)	0.00761395	n
	Adjusted for avoidance (99%)	0.00380697	n
	Adjusted for avoidance (99.9%)	0.0003807	n
Frequency of mortality	No avoidance, equivalent to one bird every	2.62675906	years
	95% avoidance, equivalent to one bird every	52.5351813	years

Table 7.39 Collision Risk Assessment Development 2018 – 2019: kestrel

Details	Description	Value	Units
Turbine parameters	Number of turbines	13	n
	Hub height	101	m
	Rotor diameter	158	m

Details	Description	Value	Units
	Rotor radius	79	m
	Blade maximum chord	4.5	m
	Blade pitch	22.5	°
	Rotor rotation period	5	sec
	Blade depth	2.6	m
	Risk window ceiling height	180	m
	Risk window floor height	22	m
	Windfarm area	5820339	m2
	Flight risk volume	919613562	m3
	Rotor swept area (single turbine)	19606.6798	m2
	Rotor swept volume (single turbine)	57643.6385	m3
	Rotor swept volume (combined)	749367.3	m3
	Proportion of flight risk volume with turbines	0.00081487	
Bird parameters	Months surveyed	Mar - Mar	months
	Speed of the bird through the rotor	12	m/s
	Length of the bird	0.34	m
	Wingspan of the bird	0.76	m
	Vantage point hours completed	375	hours
	Vantage point seconds completed	1350000	seconds
	Time available for flight activity per year	4892	hours
	Flight seconds per year	17611200	seconds
	Number of birds observed	4	n
	Total time all birds spent in risk window	198	seconds

Details	Description	Value	Units
	Proportional time individual bird spends in risk window	3.6667E-05	
	Average time individual bird in risk window (Mar - Mar)	645.744	seconds
	Bird occupancy of flight risk window	2582.976	seconds
	Bird occupancy of rotor swept area	2.1047947	seconds
	Bird transit time through rotors	0.245	seconds
	Number of birds passing through rotors (Mar-Mar)	8.59099878	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	7.0	%
	Adjusted collision risk to include turbine efficiency	5.25	%
	No. of collisions with no avoidance (Mar - Mar)	0.45102744	n
	Adjusted for avoidance (95%)	0.02255137	n
	Adjusted for avoidance (98%)	0.00902055	n
	Adjusted for avoidance (99%)	0.00451027	n
	Adjusted for avoidance (99.9%)	0.00045103	n
Frequency of mortality	No avoidance, equivalent to one bird every	2.21716002	years
	95% avoidance, equivalent to one bird every	44.3432005	years

Table 7.40 Collision Risk Estimate (Band et al., 2007) for the Operational Barnesmore Windfarm and peregrine falcon

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	1.56	m	r/R	c/C	□	collide		contribution	collide		contribution
Pitch (degrees)	22.5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
BirdLength	0.42	m	0.025	0.575	8.49	12.89	1.00	0.00125	12.20	1.00	0.00125
Wingspan	1.02	m	0.075	0.575	2.83	4.53	0.48	0.00364	3.84	0.41	0.00308
F: Flapping (0) or gliding (+1)	1		0.125	0.702	1.70	3.24	0.35	0.00434	2.40	0.26	0.00321
			0.175	0.860	1.21	2.80	0.30	0.00526	1.78	0.19	0.00333
Bird speed	14	m/sec	0.225	0.994	0.94	2.56	0.27	0.00617	1.37	0.15	0.00330
RotorDiam	42	m	0.275	0.947	0.77	2.12	0.23	0.00624	0.99	0.11	0.00291
RotationPeriod	2.00	sec	0.325	0.899	0.65	1.81	0.19	0.00629	0.73	0.08	0.00255
			0.375	0.851	0.57	1.57	0.17	0.00631	0.55	0.06	0.00222
			0.425	0.804	0.50	1.38	0.15	0.00629	0.42	0.05	0.00193
			0.475	0.756	0.45	1.23	0.13	0.00625	0.33	0.03	0.00166
Bird aspect ratioo: □	0.41		0.525	0.708	0.40	1.26	0.13	0.00706	0.43	0.05	0.00242
			0.575	0.660	0.37	1.17	0.12	0.00718	0.46	0.05	0.00285
			0.625	0.613	0.34	1.09	0.12	0.00727	0.49	0.05	0.00325
			0.675	0.565	0.31	1.01	0.11	0.00733	0.50	0.05	0.00363
			0.725	0.517	0.29	0.95	0.10	0.00736	0.51	0.05	0.00397
			0.775	0.470	0.27	0.89	0.09	0.00735	0.52	0.06	0.00428
			0.825	0.422	0.26	0.83	0.09	0.00732	0.52	0.06	0.00456
			0.875	0.374	0.24	0.77	0.08	0.00726	0.51	0.05	0.00481
			0.925	0.327	0.23	0.72	0.08	0.00716	0.51	0.05	0.00502
			0.975	0.279	0.22	0.67	0.07	0.00704	0.50	0.05	0.00521
				Overall p(collision) =			Upwind	12.4%		Downwind	6.5%
								Average	9.5%		

Table 7.41 Collision Risk Estimate (Band et al., 2007) for the Development and peregrine falcon

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.5	m	r/R	c/C	a	collide		contribution	collide		contribution
Pitch (degrees)	22.5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.42	m	0.025	0.575	5.64	18.14	0.78	0.00097	16.16	0.69	0.00087
Wingspan	1.02	m	0.075	0.575	1.88	6.71	0.29	0.00216	4.73	0.20	0.00152
F: Flapping (0) or gliding (+1)	1		0.125	0.702	1.13	5.23	0.22	0.00280	2.81	0.12	0.00151
			0.175	0.860	0.81	4.89	0.21	0.00366	1.92	0.08	0.00144
Bird speed	14	m/sec	0.225	0.994	0.63	4.71	0.20	0.00454	1.29	0.06	0.00124
RotorDiam	158	m	0.275	0.947	0.51	3.98	0.17	0.00469	0.72	0.03	0.00085
RotationPeriod	5.00	sec	0.325	0.899	0.43	3.45	0.15	0.00481	0.36	0.02	0.00050
			0.375	0.851	0.38	3.22	0.14	0.00517	0.56	0.02	0.00089
			0.425	0.804	0.33	2.91	0.12	0.00530	0.70	0.03	0.00127
			0.475	0.756	0.30	2.65	0.11	0.00540	0.79	0.03	0.00161
Bird aspect ratio:	0.41		0.525	0.708	0.27	2.43	0.10	0.00547	0.85	0.04	0.00191
			0.575	0.660	0.25	2.23	0.10	0.00550	0.88	0.04	0.00218
			0.625	0.613	0.23	2.05	0.09	0.00549	0.90	0.04	0.00241
			0.675	0.565	0.21	1.88	0.08	0.00545	0.90	0.04	0.00261
			0.725	0.517	0.19	1.73	0.07	0.00537	0.89	0.04	0.00277
			0.775	0.470	0.18	1.58	0.07	0.00526	0.87	0.04	0.00290
			0.825	0.422	0.17	1.45	0.06	0.00511	0.85	0.04	0.00299
			0.875	0.374	0.16	1.32	0.06	0.00493	0.81	0.03	0.00305
			0.925	0.327	0.15	1.19	0.05	0.00471	0.78	0.03	0.00307

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
			0.975	0.279	0.14	1.07	0.05	0.00446	0.73	0.03	0.00306
				Overall p(collision) =			Upwind	9.1%		Downwind	3.9%
								Average	6.5%		

Table 7.42 Collision Risk Assessment Operational Barnesmore Windfarm 2017 – 2018: Peregrine falcon

Details	Description	Value	Units
Turbine parameters	Number of turbines	25	n
	Hub height	40.5	m
	Rotor diameter	42	m
	Rotor radius	21	m
	Blade maximum chord	1.56	m
	Blade pitch	22.5	°
	Rotor rotation period	2	sec
	Blade depth	1.56	m
	Risk window ceiling height	61.5	m
	Risk window floor height	19.5	m
	Windfarm area	4783942	m2
	Flight risk volume	200925564	m3
	Rotor swept area (single turbine)	1385.44236	m2
	Rotor swept volume (single turbine)	2743.17587	m3
	Rotor swept volume (combined)	68579.3968	m3
	Proportion of flight risk volume with turbines	0.00034132	
Bird parameters	Months surveyed	Mar - Feb	months

Details	Description	Value	Units
	Speed of the bird through the rotor	14	m/s
	Length of the bird	0.42	m
	Wingspan of the bird	1.02	m
	Vantage point hours completed	360	hours
	Vantage point seconds completed	1296000	seconds
	Time available for flight activity per year	4520	hours
	Flight seconds per year	16272000	seconds
	Number of birds observed	1	n
	Total time all birds spent in risk window	67	seconds
	Proportional time individual bird spends in risk window	5.1698E-05	
	Average time individual bird in risk window (Mar - Feb)	841.222222	seconds
	Bird occupancy of flight risk window	841.222222	seconds
	Bird occupancy of rotor swept area	0.28712381	seconds
	Bird transit time through rotors	0.14142857	seconds
	Number of birds passing through rotors (Mar-Feb)	2.03016832	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	9.5	%
	Adjusted collision risk to include turbine efficiency	7.125	%
	No. of collisions with no avoidance (Mar - Feb)	0.14464949	n
	Adjusted for avoidance (95%)	0.00723247	n
	Adjusted for avoidance (98%)	0.00289299	n
	Adjusted for avoidance (99%)	0.00144649	n
	Adjusted for avoidance (99.9%)	0.00014465	n

Details	Description	Value	Units
Frequency of mortality	No avoidance, equivalent to one bird every	6.91326308	years
	98% avoidance, equivalent to one bird every	345.663154	years

Table 7.43 Collision Risk Assessment Development 2017 – 2018: Peregrine falcon

Details	Description	Value	Units
Turbine parameters	Number of turbines	13	n
	Hub height	101	m
	Rotor diameter	158	m
	Rotor radius	79	m
	Blade maximum chord	4.5	m
	Blade pitch	22.5	°
	Rotor rotation period	5	sec
	Blade depth	2.6	m
	Risk window ceiling height	180	m
	Risk window floor height	22	m
	Windfarm area	5820339	m2
	Flight risk volume	919613562	m3
	Rotor swept area (single turbine)	19606.6798	m2
	Rotor swept volume (single turbine)	59212.1728	m3
	Rotor swept volume (combined)	769758.247	m3
	Proportion of flight risk volume with turbines	0.00083705	
Bird parameters	Months surveyed	Mar - Feb	months

Details	Description	Value	Units
	Speed of the bird through the rotor	14	m/s
	Length of the bird	0.42	m
	Wingspan of the bird	1.02	m
	Vantage point hours completed	360	hours
	Vantage point seconds completed	1296000	seconds
	Time available for flight activity per year	4520	hours
	Flight seconds per year	16272000	seconds
	Number of birds observed	1	n
	Total time all birds spent in risk window	67	seconds
	Proportional time individual bird spends in risk window	5.1698E-05	
	Average time individual bird in risk window (Mar - Feb)	841.222222	seconds
	Bird occupancy of flight risk window	841.222222	seconds
	Bird occupancy of rotor swept area	0.70414114	seconds
	Bird transit time through rotors	0.21571429	seconds
	Number of birds passing through rotors (Mar-Feb)	3.26423046	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	6.5	%
	Adjusted collision risk to include turbine efficiency	4.875	%
	No. of collisions with no avoidance (Mar - Feb)	0.15913123	n
	Adjusted for avoidance (95%)	0.00795656	n
	Adjusted for avoidance (98%)	0.00318262	n
	Adjusted for avoidance (99%)	0.00159131	n
	Adjusted for avoidance (99.9%)	0.00015913	n

Details	Description	Value	Units
Frequency of mortality	No avoidance, equivalent to one bird every	6.28412141	years
	98% avoidance, equivalent to one bird every	314.206071	years

Table 7.44 Collision Risk Estimate (Band et al., 2007) for the Operational Barnesmore Windfarm and white-tailed eagle

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	1.56	m	r/R	c/C	□	collide		contribution	collide		contribution
Pitch (degrees)	22.5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.8	m	0.025	0.575	7.28	16.56	1.00	0.00125	15.88	1.00	0.00125
Wingspan	2.2	m	0.075	0.575	2.43	5.75	0.72	0.00539	5.06	0.63	0.00475
F: Flapping (0) or gliding (+1)	1		0.125	0.702	1.46	3.93	0.49	0.00614	3.09	0.39	0.00483
			0.175	0.860	1.04	3.26	0.41	0.00713	2.23	0.28	0.00488
Bird speed	12	m/sec	0.225	0.994	0.81	2.88	0.36	0.00811	1.70	0.21	0.00477
RotorDiam	42	m	0.275	0.947	0.66	2.39	0.30	0.00823	1.26	0.16	0.00434
RotationPeriod	2.00	sec	0.325	0.899	0.56	2.05	0.26	0.00831	0.97	0.12	0.00395
			0.375	0.851	0.49	1.78	0.22	0.00836	0.77	0.10	0.00359
			0.425	0.804	0.43	1.57	0.20	0.00837	0.62	0.08	0.00327
			0.475	0.756	0.38	1.40	0.18	0.00834	0.57	0.07	0.00339
Bird aspect ratio:	0.36		0.525	0.708	0.35	1.58	0.20	0.01034	0.87	0.11	0.00570
			0.575	0.660	0.32	1.50	0.19	0.01075	0.89	0.11	0.00642
			0.625	0.613	0.29	1.42	0.18	0.01112	0.91	0.11	0.00710
			0.675	0.565	0.27	1.36	0.17	0.01145	0.92	0.11	0.00774

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
			0.725	0.517	0.25	1.30	0.16	0.01174	0.92	0.12	0.00835
			0.775	0.470	0.23	1.24	0.15	0.01201	0.92	0.12	0.00893
			0.825	0.422	0.22	1.19	0.15	0.01223	0.92	0.11	0.00947
			0.875	0.374	0.21	1.14	0.14	0.01242	0.91	0.11	0.00997
			0.925	0.327	0.20	1.09	0.14	0.01257	0.90	0.11	0.01043
			0.975	0.279	0.19	1.04	0.13	0.01269	0.89	0.11	0.01087
				Overall p(collision) =			Upwind	18.7%		Downwind	12.4%
								Average	15.5%		

Table 7.45 Collision Risk Estimate (Band et al., 2007) for the Development and white-tailed eagle

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.5	m	r/R	c/C	a	collide		contribution	collide		contribution
Pitch (degrees)	22.5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.8	m	0.025	0.575	4.84	19.32	0.97	0.00121	17.34	0.87	0.00108
Wingspan	2.2	m	0.075	0.575	1.61	7.10	0.36	0.00266	5.12	0.26	0.00192
F: Flapping (0) or gliding (+1)	1		0.125	0.702	0.97	5.38	0.27	0.00336	2.97	0.15	0.00185
			0.175	0.860	0.69	4.92	0.25	0.00430	1.96	0.10	0.00171
Bird speed	12	m/sec	0.225	0.994	0.54	4.69	0.23	0.00527	1.26	0.06	0.00142
RotorDiam	158	m	0.275	0.947	0.44	3.98	0.20	0.00547	0.72	0.04	0.00098
RotationPeriod	5.00	sec	0.325	0.899	0.37	3.46	0.17	0.00562	0.68	0.03	0.00110
			0.375	0.851	0.32	3.41	0.17	0.00639	1.13	0.06	0.00211
			0.425	0.804	0.28	3.13	0.16	0.00666	1.23	0.06	0.00262

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
			0.475	0.756	0.25	2.90	0.15	0.00689	1.30	0.07	0.00309
Bird aspect ratio:	0.36		0.525	0.708	0.23	2.70	0.13	0.00708	1.34	0.07	0.00352
			0.575	0.660	0.21	2.51	0.13	0.00723	1.36	0.07	0.00391
			0.625	0.613	0.19	2.35	0.12	0.00734	1.36	0.07	0.00426
			0.675	0.565	0.18	2.19	0.11	0.00740	1.35	0.07	0.00456
			0.725	0.517	0.17	2.05	0.10	0.00743	1.33	0.07	0.00483
			0.775	0.470	0.16	1.91	0.10	0.00741	1.30	0.07	0.00505
			0.825	0.422	0.15	1.78	0.09	0.00736	1.27	0.06	0.00524
			0.875	0.374	0.14	1.66	0.08	0.00726	1.23	0.06	0.00538
			0.925	0.327	0.13	1.54	0.08	0.00712	1.18	0.06	0.00548
			0.975	0.279	0.12	1.42	0.07	0.00694	1.14	0.06	0.00554
				Overall p(collision) =			Upwind	12.0%		Downwind	6.6%
								Average	9.3%		

Table 7.46 Collision Risk Assessment Operational Barnesmore Windfarm 2017 – 2018: white-tailed eagle

Details	Description	Value	Units
Turbine parameters	Number of turbines	25	n
	Hub height	40.5	m
	Rotor diameter	42	m
	Rotor radius	21	m
	Blade maximum chord	1.56	m
	Blade pitch	22.5	°
	Rotor rotation period	2	sec
	Blade depth	1.56	m

Details	Description	Value	Units
	Risk window ceiling height	61.5	m
	Risk window floor height	19.5	m
	Windfarm area	4783942	m2
	Flight risk volume	200925564	m3
	Rotor swept area (single turbine)	1385.44236	m2
	Rotor swept volume (single turbine)	3269.64397	m3
	Rotor swept volume (combined)	81741.0993	m3
	Proportion of flight risk volume with turbines	0.00040682	
Bird parameters	Months surveyed	Mar - Feb	months
	Speed of the bird through the rotor	12	m/s
	Length of the bird	0.8	m
	Wingspan of the bird	2.2	m
	Vantage point hours completed	360	hours
	Vantage point seconds completed	1296000	seconds
	Time available for flight activity per year	4520	hours
	Flight seconds per year	16272000	seconds
	Number of birds observed	2	n
	Total time all birds spent in risk window	353	seconds
	Proportional time individual bird spends in risk window	0.00013619	
	Average time individual bird in risk window (Mar - Feb)	2216.05556	seconds
	Bird occupancy of flight risk window	4432.11111	seconds
	Bird occupancy of rotor swept area	1.80308382	seconds
	Bird transit time through rotors	0.19666667	seconds

Details	Description	Value	Units
	Number of birds passing through rotors (Mar-Feb)	9.16822283	n
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	15.5	%
	Adjusted collision risk to include turbine efficiency	11.625	%
	No. of collisions with no avoidance (Mar - Feb)	1.0658059	n
	Adjusted for avoidance (95%)	0.0532903	n
	Adjusted for avoidance (98%)	0.02131612	n
	Adjusted for avoidance (99%)	0.01065806	n
	Adjusted for avoidance (99.9%)	0.00106581	n
Frequency of mortality	No avoidance, equivalent to one bird every	0.93825714	years
	95% avoidance, equivalent to one bird every	18.7651428	years

Table 7.47 Collision Risk Assessment Development 2017 – 2018: white-tailed eagle

Details	Description	Value	Units
Turbine parameters	Number of turbines	13	n
	Hub height	101	m
	Rotor diameter	158	m
	Rotor radius	79	m
	Blade maximum chord	4.5	m
	Blade pitch	22.5	°
	Rotor rotation period	5	sec
	Blade depth	2.6	m
	Risk window ceiling height	180	m

Details	Description	Value	Units
	Risk window floor height	22	m
	Windfarm area	5820339	m2
	Flight risk volume	919613562	m3
	Rotor swept area (single turbine)	19606.6798	m2
	Rotor swept volume (single turbine)	66662.7112	m3
	Rotor swept volume (combined)	866615.245	m3
	Proportion of flight risk volume with turbines	0.00094237	
Bird parameters	Months surveyed	Mar - Feb	months
	Speed of the bird through the rotor	12	m/s
	Length of the bird	0.8	m
	Wingspan of the bird	2.2	m
	Vantage point hours completed	360	hours
	Vantage point seconds completed	1296000	seconds
	Time available for flight activity per year	4520	hours
	Flight seconds per year	16272000	seconds
	Number of birds observed	2	n
	Total time all birds spent in risk window	385	seconds
	Proportional time individual bird spends in risk window	0.00014853	
	Average time individual bird in risk window (Mar - Feb)	2416.94444	seconds
	Bird occupancy of flight risk window	4833.88889	seconds
	Bird occupancy of rotor swept area	4.55530668	seconds
	Bird transit time through rotors	0.28333333	seconds
	Number of birds passing through rotors (Mar-Feb)	16.077553	n

Details	Description	Value	Units
Collision Assessment	Estimated turbine efficiency (Band et al., 2007)	75	%
	Average collision risk (Band et al., 2007)	9.3	%
	Adjusted collision risk to include turbine efficiency	6.975	%
	No. of collisions with no avoidance (Mar - Feb)	1.12140932	n
	Adjusted for avoidance (95%)	0.05607047	n
	Adjusted for avoidance (98%)	0.02242819	n
	Adjusted for avoidance (99%)	0.01121409	n
	Adjusted for avoidance (99.9%)	0.00112141	n
Frequency of mortality	No avoidance, equivalent to one bird every	0.89173505	years
	95% avoidance, equivalent to one bird every	17.834701	years

Table 7.48 Summary of collision risk for 2017 – 2018 between existing and Development turbines

Species	Existing			Proposed			Change		
	Upwind %	Downwind %	Average %	Upwind %	Downwind %	Average %	Upwind change	Downwind change	Average change
BZ	14.4	8.3	11.3	10.13	4.76	7.45	-4.2	-3.5	-3.9
CA	15.0	9.8	12.4	9.62	4.71	7.16	-5.4	-5.1	-5.2
EA	16.1	10.4	13.3	10.39	5.23	7.81	-5.7	-5.2	-5.5
GP	9.5	4.4	6.9	7.38	2.53	4.95	-2.1	-1.8	-2.0
H.	20.2	14.0	17.1	12.71	7.23	9.97	-7.5	-6.7	-7.1
K.	12.7	6.4	9.5	9.71	4.23	6.97	-3.0	-2.1	-2.6
PE	12.4	6.5	9.5	9.13	3.86	6.50	-3.3	-2.7	-3.0
WE	18.7	12.4	15.5	12.04	6.57	9.30	-6.7	-5.8	-6.2

Table 7.49 Summary of collision risk for 2017 – 2018 between existing and Development turbines.

Species	Existing (one bird every)	Proposed (one bird every)	
BZ	NA	NA	years
CA	47.3	50.6	years
EA	406.3	270.6	years
GP	34.8 (84.2)*[10]	20.6 (49.9)*	years
H.	NA	NA	years
K.	10.0	7.2	years
PE	345.7	314.2	years
WE	18.8	17.8	years

Table 7.50 Summary of collision risk for 2018 – 2019 between existing and Development turbines.

Species	Existing (one bird every)	Proposed (one bird every)	
BZ	73.1	69.4	years
CA	122.7	131.4	years
EA	NA	NA	years
GP	19.3 (42.2)*	13.8 (30.2)*	years
H.	129.0	137.2	years
K.	52.5	44.3	years
PE	NA	NA	years
WE	NA	NA	years

[10] * Indicates the collision risk estimate for models on wintering season only presence of golden plover