APPENDIX 7.2

Collision Risk Model Report

FEHILY TIMONEY

CONSULTANTS IN ENGINEERING, ENVIRONMENTAL SCIENCE & PLANNING

Collision Risk Modelling Calculations for target species at the proposed Tullaghmore Wind Farm (Winter 2019/2020 to Winter 2021/2022)

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1. INTRODUCTION

This report presents the results of the collision risk modelling for the proposed Tullaghmore wind farm, Co. Galway. This modelling used data from vantage point (VP) surveys carried out in the summers of 2020 and 2021 and winters of 2019/2020, 2020/2021 and 2021/2022. VP surveys were SNH (Scottish Natural Heritage) compliant (SNH 2017a). Fifteen target species were recorded in flight within the study area during survey work. Of these, twelve (buzzard, common gull, cormorant, great black-backed gull, grey heron, greylag goose, hen harrier, herring gull, kestrel, lesser black-backed gull, mallard, and snipe) occurred at collision height and thus proceeded to the modelling stage. Of these twelve target species, five occurred in winter and summer (buzzard, common gull, cormorant, great black-backed gull, and grey heron), four occurred in winter only (greylag goose, herring, gull, mallard, and snipe), and three (hen harrier, kestrel, and lesser black-backed gull) occurred in summer only. Not all target species were recorded at the site across all 2.5 years of survey work.

The modelling was carried out using the Scottish Natural Heritage Collision Risk Model (Scottish Natural Heritage 2000; Band *et al.,* 2007). The bird occupancy method (SNH 2000) was used to calculate the number of bird transits through the rotors, and the spreadsheet accompanying the SNH report was used to calculate collision probabilities for birds transiting the rotors.

2. DATA SOURCES

The following data and information were provided for this assessment:

- Spreadsheet data listing all observations of flight activity recorded during the VP surveys;
- GIS mapping of flight lines recorded during the summers of 2020 and 2021 and winters of 2019/2020, 2020/2021 and 2021/2022;
- Mapping of the VP locations;
- Mapping of the constructed turbine locations;
- Technical specifications for the constructed and permitted turbines;
- Various clarifications about the survey methodology.

3. REVIEW AND ANALYSIS OF THE VP SURVEY COVERAGE AND RESULTS

VP locations and viewshed coverage

Initially, three VP locations were selected to cover the site (VP1 – VP3). In May 2020 an additional VP (VP4) was added to the east of the site to increase the observable area of the flight activity survey area, in response to the addition of Coillte lands by the client to the east of the original site. VP3 was also moved slightly to the west of the site to account for the larger site at the time. VP3 was dropped in April 2021 to reflect a reduction in the site area, following a subsequent dropping of the aforementioned Coillte lands. The area of landholding for the proposed wind farm site is 95.3 ha while the area of the landholding for the larger site including Coillte lands was 528.52 ha.

As a result of the reduction in site area, additional hours were not required to make up for the later addition of a fourth VP (with the total number of VPs once again being reduced to three). Thus, survey effort across all VP locations exceeded the recommended amount stated in SNH (2017) guidance.

For the purposes of collision risk modelling, a 500 m radius buffer was drawn around each of the proposed turbine locations. This buffer was used as the flight activity survey area, following SNH (2017a) guidance.

A total of 95.46 percent of the total flight activity survey area (500m radius buffers surrounding the turbine locations) was visible from the VP locations (VPs 1-4), which is marginally less than the 97% recommended by SNH (2017a) guidance. For the purposes of collision risk analysis, a correction factor has been applied to the flight durations recorded to account for the disparity in viewshed coverage. This provides a more conservative estimate of collision risk at the site.

Table 3-1: VPs Used for Avian Surveys

VP Number	Grid Reference (ITM)
1	50374, 74723
2	50121, 74632
3	50345, 74936
3a	50362, 74775
4	50294, 74576

VP survey effort

VP surveys were carried out at the site monthly from October 2019 to March 2022 inclusive. The winter season was defined as running from October to March inclusive (six months) for 2019/20, 2020/21 and 2021/22 and the summer season from April to September inclusive (six months) for both 2020 and 2021. Therefore, over the entire survey period, two summer surveys were completed and three winter surveys. Watches were 2 * 3 hours = 6 hours per VP per month. Thus, the following survey effort was completed for the following seasons:

- Winter 2019/2020: 3 VPs * 6 hours / VP / month * 6 months = 108 hours or 388,800 seconds.
- Summer 2020: 4 VPs * 6 hours / VP / month * 6 months = 144 hours or 518,400 seconds.
- Winter 2020/2021: 4 VPs * 6 hours / VP / month * 6 months = 144 hours or 518,400 seconds.
- Summer 2021: 3 VPs * 6 hours / VP / month * 6 months = 180 hours or 648,000 seconds. Note that an additional 45 minutes was completed at VP1, and extra 15 minutes at VP2, with 45 minutes less conducted at VP (this was made up in the following season), thus the total for the season was 108 hours and 15 minutes or 389,700 seconds.
- Winter 2021/2022: 3 VPs * 6 hours / VP / month * 6 months = 108 hours or 388,800 seconds. Note that an extra 1.5 hours were conducted at VP4, thus the total for the season was 109.5 hours or 394,200 seconds.

The total survey effort over the entire period was 613.75 hours or 2,209,500 seconds. Thus, while VP4 fell short of the required 36 hours of survey effort per season by 0.75 hours in summer 2021, the following winter season saw VP4 exceed requirements by 1.5 hours meaning the survey effort required for the season exceeds that required by SNH guidance (SNH, 2017a).

VP survey protocol

The VP surveys recorded flight activity of all target species within fixed visual envelopes. For the first winter season, flight durations were recorded separately for the following vertical distance bands: 0-30m, 30-50m, 50-150m, > 150m. For summer 2020, winter 2020/21, summer 2021, and winter 2021/22 seasons, flight durations were recorded separately for the following vertical distance bands: 0-10m, 10-20m, 20-30m, 30-50m, 50-100m, 100-185m, and > 185m. Flight durations were not classified in the field as inside and outside of the 500 m buffer boundary surrounding the turbines. Following a more conservative approach, the total duration of any flightline which intersects the boundary of the site is included in full regardless of the percentage time the flightline was outside the site i.e., all time inside and outside the site are included in the model for flightlines that intersect the site at some point.

Selection of target species for the collision risk model

The following 8 raptor, wader and waterbird species were recorded inside the 500 m turbine buffer boundary during the VP surveys between winter 2019/21 and winter 2021/22:

- Buzzard (*Buteo;* Green-listed);
- Common gull (*Larus canus*; Amber-listed);
- Cormorant (*Phalacrocorax carbo*; Amber-listed);
- Great black-backed gull (*Larus marinus*; Amber-listed);

- Grey Heron (*Ardea cinerea*; Green-listed);
- Greylag Goose (*Anser anser*; Amber-listed);
- Hen Harrier (*Circus cyaneus*; Annex I protected and Amber-listed)
- Herring Gull (*Larus argentatus*; Amber-listed);
- Kestrel (*Falco tinninculus*; Amber-listed);
- Lesser Black-backed Gull (*Larus graelsii*; Amber-listed);
- Mallard (*Anas platyrhynchos*; Amber-listed);
- Snipe (*Gallinago gallinago*; Red-listed)

Golden plover (*Pluvialis apricaria*; Annex I protected & Red-listed), merlin (*Falco columbarius*; Annex I protected & Amber-listed), and woodcock (*Scolopax rusticola*; Red-listed) were also recorded during VP surveys but were not recorded at rotor swept heights. Consequently, they were not included for collision risk analysis as the collision risk was predicted to be effectively zero.

Post-hoc correction of flight activity data

Flight lines that intersected the 500 m turbine buffer were included for collision risk modelling (CRM) in alignment with SNH (2017a) guidance. This is a conservative approach in relation to flightlines that pass both within and outside the 500 m turbine buffer. For flightlines of this nature, the full observation time both inside and outside the buffer has been included for modelling, rather than splitting the observation time retrospectively.

A single 6 no. turbine layout, consisting of one select model (Vestas V162) was considered, specifications of which are outlined in Table 3-2 below. The modelled turbines have a tip height of 185 m, a hub height of 104 m and a rotor diameter of 81 m. Therefore, the rotor swept height is 63.5 – 185 m. All flight duration data within the rotor swept height were therefore considered to be at potential collision risk heights (PCHs). For the earlier vertical distance bands, this corresponded to flights recorded at 50 – 150 m, and > 150 m. For the later vertical distance bands, this corresponded to flights recorded at 50 – 100 m, and 100 – 185 m.

Table 3-2: Turbine specifications considered at Tullaghmore Wind Farm.

Turbine Model	Tip Height (m)	Hub Height (m)	Rotor Diameter (m)	Rotor Swept Height (m)
Vestas V162	185	104	162	23-185

Flight times

Calculations were carried out using the flight times recorded in the ‘at-risk’ 500 m buffer zone area for a watch time of 2.5 years, as there were two summer seasons and three winter seasons in the study period. The calculation process accounted for this fact, allowing a probability of collision risk per year instead of per 2.5 years to be provided (see example calculation for buzzard). In the CRM calculations, flight times were averaged over 2.5 years watch time.

The total flight times for each species inside the 500 m buffer at rotor swept height across 2.5 years are shown in Table 3-3 below:

Table 3-3: Total Flight Times (Winters 2019/20, 2020/21 and 2021/22, and summers 2020 and 2021)

Species	Total flight times in rotor swept height band (seconds)[1]
Buzzard	688
Common gull	77
Cormorant	395
Great black-backed gull	600
Grey Heron	136
Greylag goose	30
Hen Harrier	62
Herring gull	90
Kestrel	324
Lesser Black-backed Gull	89
Mallard	160
Snipe	9

The biometrics and flight speed values used in the calculations for each of the target species is shown in Table 3-4 below. The bird body lengths and wingspans were sourced from the BTO bird facts website (https://www.bto.org/understanding-birds/birdfacts/find-a-species; last accessed 07th December 2022). The flight speeds used come from Alerstam *et al*., 2007. Birds are assumed to be active for 8 hours a day in winter and 12 hours a day in summer. Snipe was assumed to be active for 15 hours a day in summer to account for crepuscular/nocturnal display flights.

[1] Flight times shown are the raw values. For collision risk calculations, each sighing was further multiplied by the number of birds to calculate 'bird seconds'. Finally, results have been adjusted by multiplying by (100/95.46) to correct for viewshed coverage.

Table 3-4: Avian Biometric Data and Avoidance Rates

Species	Length (m)	Wingspan (m)	Average speed (m/s)	Avoidance rates[2] (%)
Buzzard	0.52	1.20	13.3	98
Common gull	0.43	1.10	13.4	98
Cormorant	0.86	1.40	15.2	98
Great black-backed gull	0.64	1.59	13.7	98
Grey Heron	0.94	1.85	11.2	98
Greylag goose	0.82	1.64	11.2	99.8
Hen Harrier	0.6	1.44	12.8	99
Herring gull	0.58	1.42	11.9	98
Kestrel	0.34	0.76	10.1	95
Lesser Black-backed Gull	0.58	1.42	11.9	98
Mallard	0.58	0.9	18.5	98
Snipe	0.26	0.46	17.1	98

[2] Avoidance rates refer to the frequency at which birds may avoid a wind farm. SNH (2018) guidance states that this may be due to displacement from the area, avoidance of turbines or evasive action to prevent a collision. Avoidance rates may be different for different bird species and SNH (2018) guidance provides a list of recommended avoidance rates that should be applied to raw collision risk probabilities.

4. MODEL DETAILS

Collision risk calculations have been performed using a random flight model as detailed by Band *et al.,* (2007).

The planned turbine model for the 6 no. turbines of the proposed development is the Vestas V162. Details of the turbine parameters are show in Table 4-1 (below). Data on blade chord length and rotational speed were provided by EMPower.

Table 4-1: Wind Farm and Wind Turbine Parameters

Parameter	Value	Comments
Hub height (m)	104	Information provided by client
Blade diameter (m)	162	Information provided by client
Blade radius (m)	81	Calculated
Maximum swept height (m)	185	Information provided by client
Minimum swept height (m)	23	Calculated
Number of blades	3	Information provided by client
Maximum blade chord length (m)	4.3	Information provided by client
Fastest rotational speed (r.p.m)	9.53	Information provided by client
Fastest rotation period (s)	6.296	Calculated
Blade pitch (degrees)	6	Typical value
No. of turbines with these dimensions proposed	6	Information provided by client
Wind farm operation (%)	85	Typical value

5. EXAMPLE CALCULATION OF THE COLLISON RISK FOR BUZZARD (*BUTEO BUTEO*)

An example of a collision risk calculation used for buzzard (based on the Vesta V162 turbine model) is provided below.

Buzzard is a resident species in the area around the proposed wind farm site. A total of 688 bird-seconds (i.e., each flight duration was multiplied by the number of birds flying) of buzzard flight time within the rotor swept height was observed from the VP watches in the winters of 2019/20, 2020/21 and 2021/22 and summers of 2020 and 2021. A correction factor was applied to all raw flight times (i.e., all flight times were multiplied by (100/95.46) to account for viewshed coverage. All flight times across the 2.5 years of surveys were averaged to calculate a mean annual flight time.

The total watch time across two summers and three winters was a total of 619.75 hours or 2,231,100 seconds. As flight times were averaged to mean annual flight times, the watch time was also assumed to be for a single summer and single winter i.e., a total of 72 hours or 259,200 seconds.

(i) To calculate the probability of a bird flying through the rotor swept area:

Note, the time at rotor swept height, proportion of observation time at rotor swept height and flight activity per visible hectare was calculated individually for each VP viewshed. Flight activity per visible hectares was averaged across all VPs. This accounts for the overlap in the areas that were viewed from different VPs. For the sake of brevity, only calculations for VP1 are shown below.

Flight time (corrected and averaged over 2.5 years) at which buzzards were recorded at potential collision height (PCH; heights between 63.5 m and 185 m) at VP viewshed 1: 222.908 bird-seconds.

Proportion of total observation time during which buzzards were recorded in flight at PCH:

(1) $t = 222.908 / 260{,}280 = 0.000856$ (proportion)

The proportion of flight activity per hectare of visible area, F = t/Area of VP1 viewshed.

(2) $F = 0.000856 / 267.27 = 3.204 \times 10^{-6}$ (proportion per hectare) for VP1.

This process was then repeated for all other viewsheds. The mean value of F across all VP viewsheds = 0.0000285.

The Flight Risk Area of the proposed wind farm (calculated in QGIS as the area of a minimum convex polygon based on the locations of all proposed turbines, surrounded by an additional buffer corresponding to the 81 m rotor radius) = 1,803,200 m^2.

Therefore, the proportion of flight time spent in flight at PCH in the wind farm area is:

(3) $t2 = F * (\text{Flight Risk Area} / 10{,}000) = 0.0000285 * (1{,}803{,}200 / 10{,}000) = 0.000514$ (proportion)

In order to account for buzzard occupancy over the summer survey period, birds have been assumed to be present between April to September inclusive (183 days). An assumption is made that the birds are active for 12 hours per day during summer. For winter, birds have been assumed to be present between October to March inclusive (182 days) and have been assumed to be active for 8 hours per day.

(4) Occupancy, n of risk area per year = 3,652 * 0.000514 = 1.88 hours per year.

The flight risk volume, Vw = flight risk area * diameter of rotors

(5) Vw = 1,803,200m^2 * 81 metres = 292,118,400 m^3

Volume swept by the rotors, Vr = number of turbines * πr^2 * (d+l), where d is the average depth of the rotors, l is the average length of the birds and r is the radius of the rotors (81 m). Average chord length is assumed to be the same as average rotor depth.

(6) Vr = 6 * π*(81)^2 * (4.3 + 0.52) = 596,098.7335 m^3.

The bird occupancy of swept volume, b = n * (Vr/Vw) * 3,600, where n is the bird occupancy for the year, from (4) above.

(7) b = 1.88 * (596,098/ 292,118,400) * 3,600 = 13.8 seconds per year.

Time taken for a bird to fly through rotors of one turbine, t3 = (d+l)/v, where v is the average velocity of the birds.

(8) t3 = (4.3 + 0.52) / 13.3 = 0.362406015 seconds.

Therefore, number of bird transits through the rotors is:

(9) b / t3 = 4.19 / 0.362406015 = 38.08 bird transits per year.

(ii) To calculate the probability of the birds colliding with the turbine rotors:

The probability of a bird actually colliding with the turbine blades when making a transit through a rotor depends on a number of factors that are imperfectly known and at present have to be estimated. Not least of these is the avoidance factor that is used to approximate the ability of birds to take evasive action when coming close to wind turbine blades. The method of Band *et al.,* (2007) makes a number of assumptions: birds are assumed to be of a simple cruciform shape, turbine blades are assumed to have width and pitch angle, but no thickness, birds fly through turbines in straight lines and their flight is not affected by the slipstream of the turbine blade etc. In the calculations the length of a buzzard is taken to be 0.52 metres and the wingspan 1.2 metres (these figures are the means of published ranges taken from the BTO website on 07/12/2022). The flight velocity of buzzard is assumed to be 13.3 metres per second. The maximum chord of the blades is taken to be 4.3 metres, pitch is assumed to be 6 degrees and the rotation cycle at maximum operating speed (9.53 rpm) is taken to be 6.296 seconds per rotation.

A probability, ρ (r, ϕ), of collision for a bird at radius r from the hub and at a position along a radial line that is at angle ϕ from the vertical is calculated. This probability is then integrated over the entire rotor disc, assuming that the bird transit may be anywhere at random within the area of the disc.

Scottish Natural Heritage have made available a spreadsheet to aid the calculation of these probabilities (http://www.snh.gov.uk/planning-and-development/renewable-energy/onshore-wind/bird-collisionrisks-guidance/). For a full explanation of the calculation methods see Band *et al.,* (2007).

Assuming the worst-case scenario (i.e., shortest rotation time and bird flapping rather than gliding), the average of the upwind and downwind probabilities of collision is 5.3%.

Estimated maximum operation of the wind farm is assumed to be 85%.

So, the product of the number of bird transits per year and the probability of collision (assuming 85% operation) is:

(11) 38.08 X 0.053 x 0.85 = 1.707 collisions per year, without any avoidance of the turbine blades by the birds.

The SNH (SNH, 2018) recommended avoidance rate for buzzard is 98%.

Therefore, the predicted number of buzzard collisions per year with 98% avoidance is:

(12) 1.71 X 0.02 = **0.03 collisions per year**.

This is equivalent to 1.02 collisions approximately every 30 years using the flight data between 63.5 and 185 metres.

The calculations detailed for buzzard above were also carried out for each of the other target species.

6. RESULTS

The results of the collision risk calculations for all target species are shown in Tables 6-1, 6-2, and 6-3, below. The avoidance rate factors used are as recommended by Scottish Natural Heritage (SNH, 2010; SNH 2018).

For all target species, the probabilities of collision with turbines were all well below one per year, ranging from 0 (common gull and herring gull) to 0.02 (buzzard, great black-backed gull, and kestrel).

Table 6-1: No. of predicted collisions per year (assuming avoidance)[3]

Species	Number of predicted collisions per year
Buzzard	0.03
Common gull	0.01
Cormorant	0.02
Great black-backed gull	0.02
Grey Heron	0.20
Greylag goose	0.00
Hen Harrier	0.08
Herring gull	0.00
Kestrel	0.03
Lesser Black-backed Gull	0.10
Mallard	0.01
Snipe	0.02

Table 6-2: No. of years between predicted collisions (assuming avoidance)[3]

Species	Number of years between predicted collisions
Buzzard	29.29
Common gull	197.15
Cormorant	49.84
Great black-backed gull	46.58
Grey Heron	5.01
Greylag goose	963.21

[3] With correction factors applied for the following: avoidance rates, operating time, and the fact that 95.46% and not 100% of the study area was visible during surveys. Where the number of predicted collisions is shown as 0.00, it means the number of predicted collisions are <0.01 per year.

Species	Number of years between predicted collisions
Hen Harrier	12.93
Herring gull	404.19
Kestrel	34.17
Lesser Black-backed Gull	9.90
Mallard	70.36
Snipe	43.93

Table 6-3: No. of predicted collisions in 30-year nominal lifespan of wind farm (assuming avoidance)

Species	Number of predicted collisions in 30-year nominal lifespan of wind farm
Buzzard	1.02
Common gull	0.15
Cormorant	0.60
Great black-backed gull	0.64
Grey Heron	5.98
Greylag goose	0.03
Hen Harrier	2.32
Herring gull	0.07
Kestrel	0.88
Lesser Black-backed Gull	3.03
Mallard	0.43
Snipe	0.68

7. DISCUSSION

From the collision risk probabilities calculated, it can be concluded that the proposed Tullaghmore wind farm will have a negligible effect on collision risk for the populations of 15 target bird species. No collisions (<1 predicted collision) are predicted for all targets (buzzard, common gull, cormorant, golden plover, great black-backed gull, grey heron, greylag goose, hen harrier, herring gull, kestrel, lesser black-backed gull, mallard, merlin, snipe, and woodcock) in the 30-year nominal lifespan of the wind farm.

The Band CRM model involves making a number of assumptions. The amount of time that a species may be active within the site is also required for the model and must be estimated with respect to the bird species' known behaviour and observations of its occurrence at the study area.

The model assumes that no action is taken by a bird to avoid collision, so that the unadjusted collision risk figures derived are purely theoretical and represent worst case estimates. In reality, birds are able to perceive potential obstacles while in flight and actively take avoiding action. Given the general absence of empirically derived avoidance estimates for individual species, additional assumptions about likely levels of active avoidance on the part of birds are generally made in order to draw conclusions. Available evidence to date (SNH, 2010; SNH, 2017; Fernley *et al*., 2006; Whitfield & Madders, 2006; Whitfield, 2009; Whitfield & Urquhart, 2015) suggests that avoidance rates are well in excess of 95%. Accordingly, outputs from collision risk analysis where precautionary avoidance rates are used must be interpreted with care.

The Band model favoured by SNH has been the subject of academic study regarding its relevance and usefulness (Chamberlain *et al*., 2005; Chamberlain *et al*., 2006) and the conclusions have been that the model can be considered to be mathematically robust. However, the main influence on the final result of collision risk analysis is the avoidance rate that is applied to the model; and without accurate avoidance rates, the usefulness of the model as a predictor of impact can be badly impaired. The avoidance rate factors used are those that are currently recommended by SNH (SNH, 2010; SNH, 2018). These avoidance rates are widely considered to be highly precautionary in nature. It should be remembered that the difference between an avoidance factor of 98% and 99% will have the effect of doubling the calculated annual collision rate. In many cases where collision mortality has been monitored for operating wind farms, observed mortality has been below that which was predicted by modelling pre-construction bird survey data.

In the case of the calculations for the proposed Tullaghmore wind farm site, a conservative approach was taken in the choice of which bird flights to include in the collision risk calculations. In addition, a worst-case scenario i.e., shortest rotation time (top turbine rotating speed) and birds flapping, rather than gliding has been used. Other studies use the mean of the worst-case scenario and best-case scenario (longest rotation period and bird gliding rather than flapping) probabilities. Finally, the calculations have used the conservative downtime estimate (15%, or turbines rotating 85% of the time), but in reality, this level of downtime may be greater. A conservative correction factor was also applied to the recorded flight durations based on the assumption that 95.46% of the 500 m turbine buffer area was visible during surveys. Therefore, the likely empirical collision mortality figures should be lower than those presented here.

In conclusion, the results show that the proposed Tullaghmore wind farm will likely have negligible effects on populations of the 15 target bird species present with predicted annual collisions of <1 for all target species.

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