APPENDIX 7-6

COLLISION RISK ASSESSMENT

Collision Risk Assessment

Cooloo Wind Farm

DOCUMENT DETAILS

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1. INTRODUCTION

This document outlines the methodology used to assess the predicted rate of collisions for birds at Cooloo Wind Farm. The collision risk assessment is based on vantage point surveys undertaken at the study area from October 2019 to March 2022 and again from August 2023 to March 2025. This represents a 50-month survey period, consisting of three breeding seasons and five winter seasons, which is in full compliance with NatureScot guidance (SNH, 2017) and exceeds the recommended two years of survey. Surveys were undertaken from three fixed vantage points.

Collision risk is calculated using a mathematical model to predict the number of birds that may be killed by collision with moving wind turbine rotor blades. The modelling method used in this collision risk calculation is known as the Band Model (Band *et al.,* 2007) and has been used in a number of studies on bird collision with wind turbines (e.g. Chamberlain *et al.,* 2006; Drewitt and Langston, 2006; Fernley *et al.,* 2006; Madders and Whitfield, 2006). Note that these are theoretical predictions, therefore results must be interpreted with a degree of caution.

Two stages are involved in the Band Model. First, the number of bird transits through the air space swept by the rotor blades of the wind turbines per year is estimated. Then the collision risk for a bird passing through the rotor blades is calculated using a mathematical formula. The product of these provides a theoretical annual collision mortality rate. Finally, a bird avoidance rate is applied to the collision mortality rate to account for birds attempting to avoid collision. This final collision mortality rate informs the assessment of impacts of the wind turbine on birds.

2. METHODOLOGY

2.1 The Band Model

The Band Model is used to predict the number of bird collisions that might be caused by a wind turbine. It uses species-specific information on bird biometrics, flight characteristics and the expected amount of flight activity, along with turbine-specific information on hub height, rotor diameter, pitch and rotational speed. Three separate turbine scenarios were assessed:

- **V162**: The turbine will be 99m at hub height, with 3 blades of a diameter of 162m, giving a maximum rotor height of 180m and a minimum rotor height of 18m;
- **SG155**: The turbine will be 102.5m at hub height, with 3 blades of a diameter of 155m, giving a maximum rotor height of 180m and a minimum rotor height of 25m;
- **V150**: The turbine will be 105m at hub height, with 3 blades of a diameter of 150m, giving a maximum rotor height of 180m and a minimum rotor height of 30m.

The model makes a number of assumptions on the turbine design and on biometrics of birds:

- Birds are assumed to be of a simple cruciform shape;
- Turbine blades are assumed to have length, depth and pitch angle, but no thickness;
- Birds fly through turbines in straight lines;
- Bird flight is not affected by the slipstream of the turbine blade;
- Because the model assumes that no action is taken by a bird to avoid collision, it is recognised that the collision risk figures derived are purely theoretical.

Two forms of collision risk modelling are outlined by Band *et al.* (2007): a **'Regular Flight Model'** and the **'Random Flight Model'**. A Regular Flight Model is generally applied to situations where flightlines form a regular pattern. This may occur, for example, when birds are using a wind farm site as a commuting corridor between roosting and feeding grounds or migratory routes, as is often observed in geese and swans. The Random Flight Model generally applied to situations where flightlines form no discernible patterns or routes. This is often observed, for example when raptors are in foraging or hunting flights.

The Regular Flight Model predicts the number of transits through a cross-sectional area of a wind farm which represents the width of the commuting corridor. A 'risk window' is identified: a 2-dimensional line the width of a wind farm to a 500m buffer of the turbines, multiplied by the rotor diameter. All commuting flights which pass through this risk window within the rotor swept height (potential collision height; PCH) are included in collision risk modelling. Any regular flights more than 500m from the turbine layout can be excluded from analysis. There are a number of key assumptions and limitations:

- The turbine rotor swept area is 2-dimensional, i.e. there is a single row of turbines in the wind farm. This represents all turbines within the commuting corridor accounted for by a single straight-line;
- Bird activity is spatially explicit;
- Birds in an observed flight only cross the turbine area once and do not pass through the cross-section a second time (or multiple times);
- Habitat and bird activity will remain the same over time and be unchanged during the operational stage of the wind farm;
- All flight activity used in the model occurred within the viewshed area calculated at the lowest swept rotor height.

The Random Flight Model predicts the number of transits through a wind farm while assuming that all flights within the vantage point viewshed are randomly occurring (i.e., any observed flight could just as easily occur within a wind farm site as outside it). All flights within PCH inside the viewshed are included in the model. There are a number of key assumptions and limitations:

- Bird activity is not spatially explicit, i.e. activity is equal throughout the viewshed area and this is equal to activity in the wind farm area;
- Habitat and bird activity will remain the same over time and be unchanged during the operational stage of the wind farm;
- All flight activity used in the model occurred within the viewshed area calculated at the lowest swept rotor height.

More detail on both the Random and Regular Flight Model calculations are available from SNH: https://www.nature.scot/wind-farm-impacts-birds-calculating-theoretical-collision-risk-assuming-no-avoiding-action. In the case of Cooloo Wind Farm, ten species recorded in flight in the study area were randomly distributed. Therefore a Random Flight Model was conducted for these species. An additional Regular Flight Model was also conducted for three of these species.

2.2 Modelling Process

The steps used in the Band Model to derive the collision mortality rate for each species observed at a wind farm site are outlined below.

- Stage 1: Estimate the number of bird transits through the air space swept by the rotor blades of the wind turbines. Transits are calculated using either the 'Regular' or 'Random' flight model (Band *et al.,* 2007), depending on flight distribution and behaviour.

- Stage 2: Calculate the collision risk for an individual bird flying through a rotating turbine blade. Collision risk is calculated using a formula which incorporates the number of bird transits (Stage 1), individual species' biometrics, individual species' flight speed and style, and the proposed turbine parameters. This formula is publicly available on the SNH website: https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision. Biometrics are available from the British Trust of Ornithology (BTO, 2021) and flight speeds are available from Alerstam *et al.* (2007). For species that can both flap and glide, the mean of the collision risk for flapping and for gliding flight is taken.

- The product of the number of birds transits per year multiplied by the collision risk provides an annual collision mortality rate. There is an assumption that birds flying towards the turbines make no attempt to avoid them.

- To account for birds attempting to avoid collision, an avoidance factor is applied to the annual collision mortality rate. This corrects for the ability of the birds to detect and manoeuvre around the turbines. Avoidance rates are available from SNH (2018). Bird avoidance rates are generally 98-99% or higher for most species, based on empirical evidence, targeted studies and literature reviews, and continue to be updated following further studies of bird behaviour and mortality rates at wind farm sites.

The final annual collision risk corrected for avoidance is a 'real-world' estimation of the number of collisions that may occur at a wind farm, based on observed bird activity during the vantage point survey period.

2.3 Turbine Specifications

The turbine specifications used in the three models are available in Table 7-5-1. Note that the SG155 specifications are based on a V150 model.

Table 7 – 5 – 1 Turbine specifications

Wind Farm Component	Scenario Modelled
Turbine model	V162
Number of turbines	9
Blades per turbine rotor	3
Rotor diameter (m)	162
Rotor radius (m)	81
Hub height (m)	99
Swept height (m)	18-180
Pitch of blade (degrees)	6
Maximum chord (m) (i.e. depth of blade)	4.7
Rotational period (s)	6
*Turbine operational time	85
Turbine model	SG155
Number of turbines	9
Blades per turbine rotor	3
Rotor diameter (m)	155
Rotor radius (m)	77.5
Hub height (m)	102.5
Swept height (m)	25-180
Pitch of blade (degrees)	6
Maximum chord (m) (i.e. depth of blade)	4.2
Rotational period (s)	7.1
*Turbine operational time	85
Turbine model	V150
Number of turbines	9

Wind Farm Component	Scenario Modelled
Blades per turbine rotor	3
Rotor diameter (m)	150
Rotor radius (m)	75
Hub height (m)	105
Swept height (m)	30-180
Pitch of blade (degrees)	6
Maximum chord (m) (i.e. depth of blade)	4.2
Rotational period (s)	7.1
*Turbine operational time	85

*This operational period of 85% is referenced from a report by the British Wind Energy Association (BWEA) (2007) which identifies the standard operational period of the wind turbines in the UK to be roughly 85%.

2.4 Ornithological Receptors

The key ornithological receptors recorded in flight at PCH within the viewshed during vantage point surveys at Cooloo Wind Farm were:

- Golden Plover
- Hen Harrier
- Merlin
- Peregrine Falcon
- Whooper Swan
- Kestrel
- Lapwing
- Snipe
- Buzzard
- Long-eared Owl
- Sparrowhawk

A CRM was conducted for each of these species. It is assumed that waterbirds are active for 25% of the night along with daylight hours (as per SNH guidance) and this is accounted for in the model.

2.5 Flight Patterns

As described above, for the purposes of the collision risk analysis, flight activity should be characterised as regular (predictable) or random. Random flight patterns were observed among all species listed above. In the specific case of golden plover, lapwing and whooper swan, both random and regular flight activity was observed. For this reason, both a Random and Regular model was applied to these three species. Each is discussed separately below.

Golden Plover

A proportion of golden plover winter flight activity was associated with Horseleap Lough, which provides suitable habitat for the birds. This flight activity was predictable, consistent, and generally involved short or circling flights around and over the lough. These flights were outside the turbine area (defined as a 500m radius of the proposed turbine layout). Because of the regular flight pattern (i.e., predictable and consistent), a regular model was applied to these flights.

Regular flights associated with Horseleap Lough were extracted from the data for this model. Of the total 105 golden plover flight records collected during vantage point surveys, 12 were classified as regular. As a majority of the 12 flights were closely associated with Horseleap Lough and a considerable distance from the turbines, these birds would not be at risk of colliding with a turbine.

Lapwing

A proportion of lapwing winter flight activity was associated with Horseleap Lough and surrounds, which provides suitable foraging and roosting habitat that is favoured by the birds. This flight activity was predictable, consistent, and generally involved short or circling flights around and over the lough and fields. These flights were often outside the turbine area. Because of the regular flight pattern, a regular model was applied to these flights.

Regular flights associated with Horseleap Lough and surrounding agricultural grassland fields (i.e., the area demarked L-2 in Section 7.3.7.13 of Chapter 7 of this Environmental Impact Assessment [EIAR]) were extracted from the data for this model. Of the total 165 lapwing flight records collected during vantage point surveys, 143 were classified as regular. As a majority of the 143 flights were closely associated with Horseleap Lough and a considerable distance from the turbines, these birds would not be at risk of colliding with a turbine.

Whooper Swan

A proportion of whooper swan flight activity was associated with Horseleap Lough and surrounds, which provides suitable foraging and roosting habitat that is favoured by the birds. This flight activity was predictable, consistent, and generally involved short or circling flights around and over the lough and fields. These flights were often outside the turbine area. Because of the regular flight pattern, a regular model was applied to these flights.

Regular flights associated with Horseleap Lough and surrounding agricultural grassland fields (i.e., the area demarked WS-2 in Section 7.3.7.7 of Chapter 7 of this EIAR) were extracted from the data for this model. Of the total 183 whooper swan flight records collected during vantage point surveys, 152 were classified as regular. As a majority of the 152 flights were closely associated with Horseleap Lough and a considerable distance from the turbines, these birds would not be at risk of colliding with a turbine.

2.6 Calculation Parameters

The calculation parameters for the three vantage points are outlined in Table 7-5-2. The three different turbine scenarios are presented separately, as the minimum swept height differs for each.

Table 7- 5 - 2 Survey effort and viewshed coverage

Vantage Point	Visible Area	Risk Area	Turbines visible	Total Survey Effort
Scenario V162	Minimum Swept Height of 18m			
VP1	633.393 ha	219.764 ha	3	287 hrs
VP2	371.655 ha	86.130 ha	2	287 hrs
VP3	551.910 ha	267.290 ha	4	282 hrs
Scenario SG155	Minimum Swept Height of 25m			
VP1	634.423 ha	220.663 ha	3	287 hrs
VP2	460.670 ha	116.000 ha	2	287 hrs
VP3	571.738 ha	286.589 ha	4	282 hrs
Scenario V150	Minimum Swept Height of 30m			
VP1	635.347 ha	220.663 ha	5	287 hrs
VP2	523.741 ha	133.000 ha	2	287 hrs
VP3	592.492 ha	307.684 ha	3	282 hrs

Bird biometrics are presented in Table 7-5-3. This outlines the body length, wingspan and flight speed for each key ornithological receptor that was used in the assessment.

Table 7 – 5 – 3 Bird biometrics

Species	Body Length (m)	Wingspan (m)	Flight Speed (m/s)
Golden Plover	0.275	0.715	17.9
Hen Harrier	0.48	1.1	9.1
Merlin	0.275	0.56	10.9
Peregrine Falcon	0.445	1.05	12.1
Whooper Swan	1.5	2.2	17.3
Kestrel	0.335	0.755	10.1
Lapwing	0.295	0.845	12.8
Snipe	0.255	0.42	17.1
Buzzard	0.54	1.205	11.6
Long-eared Owl	0.36	0.895	6.7
Sparrowhawk	0.33	0.625	10

Table 7-5-4 presents the model input values. During field surveys, bird flight height was assigned to predefined height bands (0-15m, 15-25m, 25-200m and 200m+). For the assessment of the V162 turbine scenario, birds in flight within the viewshed at height bands between 15-200m above ground level have been included in the collision risk model. For the assessment of the SG155 and V150 turbine scenarios, birds in flight within the viewshed at the height band between 25-200m above ground level have been included.

For the random model, input values were bird seconds in flight at PCH observed from the vantage points during the relevant survey period. Bird seconds in flight at PCH is calculated by multiplying the number of birds observed per flight by the duration of the flight spent within PCH. For the regular model, input values were the number of birds crossing into the risk area at PCH observed from the vantage points during the relevant survey period. To apportion the 12 regular golden plover flights, 143 regular lapwing flights and 152 regular whooper swan flights into those at risk and those not at risk of a collision, the following mapping exercise was undertaken to delineate where a collision could theoretically occur. The following paragraph should be read in conjunction with Figure 7-6-1.

On a map of the turbine area, a line was drawn connecting the centroid of the turbine area to the centroid of Horseleap Lough (as delineated on the Ordnance Survey map). Two additional parallel lines were drawn - one marking the maximum extent of the turbine area in one direction, and the other in the other direction. A fourth line was drawn perpendicular to the first line marking the closest extent of the turbine area to Horseleap Lough. The length of this fourth line was the distance between the two parallel lines (i.e., the maximum extent of the turbine area; 2,562m). This fourth line represents the area in space at which flying birds associated with Horseleap Lough and the surrounding agricultural grassland fields could enter the turbine area, in which there is potential for a collision to occur.

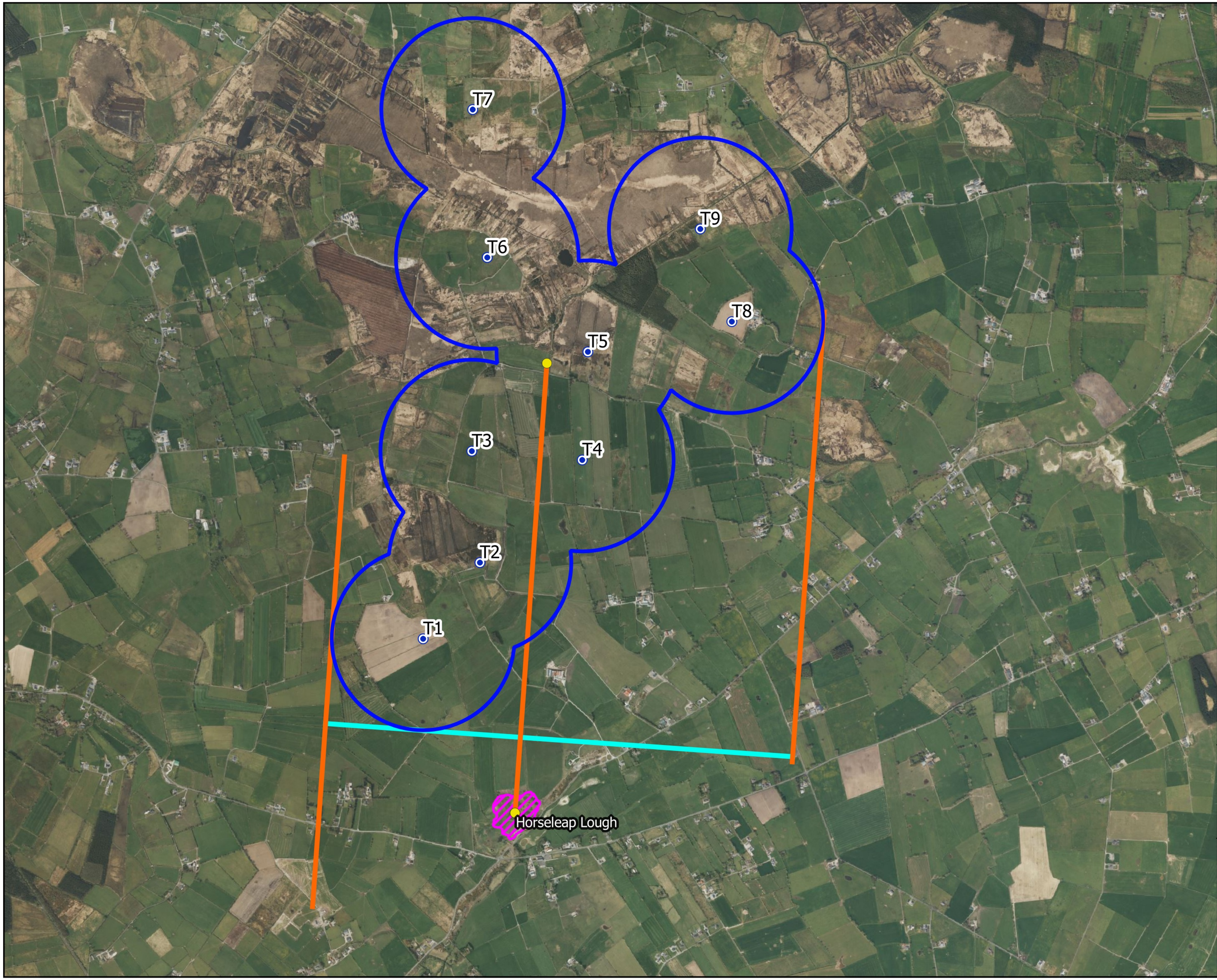
Golden plover flights at PCH that intersect the fourth line were included in the model. These represent golden plover crossing between Horseleap Lough and the turbine area, where there is potential for a collision to occur. A total of eight flights intersected this line. Similarly, lapwing flights at PCH that intersect the fourth line were included in the model. These represent lapwing crossing between L-2 and the turbine area, where there is potential for a collision to occur. A total of 54 flights intersected this line. Finally, whooper swan flights at PCH that intersect the fourth line were included in the model. These represent whooper swan crossing between WS-2 and the turbine area, where there is potential for a collision to occur. A total of 93 flights intersected this line.

Table 7 – 5 – 4 Model input values

Species	Model	Period	Input values		
Scenario V163					
Random Model			**VP1**	**VP2**	**VP3**
Golden Plover	random	October to April	2184577s	7018291s	1960800s
Hen Harrier	random	September to March	86s	0s	202s
Merlin	random	All	50s	0s	26s
Peregrine Falcon	random	All	635s	62s	208s
Whooper Swan	random	October to April	7658s	4628s	2567s
Kestrel	random	All	4376s	1118s	6384s
Lapwing	random	Winter	153200s	9645s	14000s
Snipe	random	All	2131s	17161s	16750s
Buzzard	random	All	17269s	6588s	14172s
Long-eared Owl	random	Breeding	47s	0s	0s
Sparrowhawk	random	All	250s	304s	171s
Regular Model			**Number of birds**		
Lapwing	regular	Winter	4248		
Golden Plover	regular	October to April	1407		
Whooper Swan	regular	Winter	607		
Scenario SG155					
Random Model			**VP1**	**VP2**	**VP3**
Golden Plover	random	October to April	2127339s	6610051s	1958400s
Hen Harrier	random	September to March	0s	0s	71s
Merlin	random	All	20s	0s	26s
Peregrine Falcon	random	All	320s	42s	158s
Whooper Swan	random	October to April	2118s	3028s	1721s
Kestrel	random	All	1949s	708s	3370s
Lapwing	random	Winter	153200s	8775s	10800s
Snipe	random	All	1899s	12821s	7918s
Buzzard	random	All	13688s	4799s	10686s
Sparrowhawk	random	All	100s	235s	0s
Regular Model			**Number of birds**		
Lapwing	regular	Winter	3615		
Golden Plover	regular	October to April	997		
Whooper Swan	regular	Winter	140		
Scenario V150					
Random Model			**VP1**	**VP2**	**VP3**
Golden Plover	random	October to April	2127339s	6610051s	1958400s
Hen Harrier	random	September to March	0s	0s	71s
Merlin	random	All	20s	0s	26s
Peregrine Falcon	random	All	320s	42s	158s
Whooper Swan	random	October to April	2118s	3028s	1721s
Kestrel	random	All	1949s	708s	3370s
Lapwing	random	Winter	153200s	8775s	10800s
Snipe	random	All	1899s	12821s	7918s
Buzzard	random	All	13688s	4799s	10686s

Species	Model	Period	Input values		
Sparrowhawk	random	All	100s	235s	0s
Regular Model			**Number of birds**		
Lapwing	regular	Winter	3615		
Golden Plover	regular	October to April	997		
Whooper Swan	regular	Winter	140		

The avoidance rates applied to the collision risk were: 0.996 for golden plover (Gittings, 2022), 0.995 for whooper swan, 0.99 for hen harrier, 0.98 for merlin, peregrine falcon, lapwing, snipe, buzzard and sparrowhawk, and 0.95 for kestrel (SNH, 2018).



Map Legend

- Turbine Location
- 500m Turbine Radius
- Horseleap Lough
- Centroids
- Parallel Lines
- Perpendicular Line (fourth line)

Drawing Title	Regular flight apportioning
Project Title	Cooloo Wind Farm, Co. Galway
Drawn By: SD	Checked By: PC
Project No.: 190723-m	Drawing No.: Fig 7-6-1
Scale: 1:27,000	Date: 2025.09.15

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3. RESULTS AND DISCUSSION

A Random and Regular collision risk model has been conducted for birds observed during vantage points surveys at Cooloo Wind Farm using the Band Model, following best practice guidance from NatureScot. Collision risk models provide theoretical predictions of the probability of bird collision with wind turbine rotor blades. The results are affected by sources of uncertainty including the representativeness of the survey data, natural variability in bird populations, model assumptions and estimates on bird attraction and avoidance rates. As such, the results are considered to be a best estimate of collision risk, rather than a precise figure. The predicted number of transits per year and the estimated collision risk is presented in Table 7-5-5, along with the final predicted number of collisions per year. Note that for birds that both flap and glide, the average collision risk percentage between flapping and gliding is taken.

Table 7 – 5 – 5 Collision rate predictions. For each species, the survey period and model type are specified, along with the predicted number of transits through the risk area and the collision risk (for flapping flight, gliding flight and the average of both). Two values for collision rate are presented: the initial collision rate without avoidance and a final estimated collision rate (with an avoidance factor). Finally, the estimated number of collisions over the lifetime of the turbines in presented, along with the corresponding estimated number of years of operation for one collision to occur.

Species	Survey Period	Model	Transits	Collision Risk			Collision Rate			Estimated Collisions Over Lifetime of Wind Farm	One Bird Collision
				flapping	gliding	overall	without avoidance	avoidance factor	with avoidance		
Scenario V162											
Golden Plover	October to April	random	1101585	4.45%	no gliding flight	4.45%	49050	99.6%	196.200	6867 birds	<1 year
Hen Harrier	September to March	random	8.7	6.24%	6.13%	6.19%	0.54	99%	0.005	0.19 birds	186 years
Merlin	All	random	3	4.81%	4.75%	4.78%	0.14	98%	0.003	0.1 birds	348 years
Peregrine Falcon	All	random	40.8	5.49%	5.34%	5.42%	2.21	98%	0.044	1.55 birds	23 years
Whooper Swan	October to April	random	1202	8.11%	no gliding flight	8.11%	97.52	99.5%	0.488	17.07 birds	2 years
Kestrel	All	random	475.7	5.23%	5.16%	5.19%	24.7	95%	1.235	43.23 birds	1 year

Species	Survey Period	Model	Transits	Collision Risk			Collision Rate			Estimated Collisions Over Lifetime of Wind Farm	One Bird Collision
				flapping	gliding	overall	without avoidance	avoidance factor	with avoidance		
Lapwing	Winter	random	8769.5	4.82%	no gliding flight	4.82%	422.4	98%	8.448	295.68 birds	<1 year
Snipe	All	random	3574	4.29%	no gliding flight	4.29%	153.31	98%	3.066	107.32 birds	<1 year
Buzzard	All	random	1790.9	5.98%	5.84%	5.91%	105.88	98%	2.118	74.12 birds	<1 year
Long-eared Owl	Breeding	random	1.4	6.31%	6.25%	6.28%	0.09	98%	0.002	0.06 birds	581 years
Sparrowhawk	All	random	33.1	5.19%	5.14%	5.16%	1.71	98%	0.034	1.2 birds	29 years
Lapwing	Winter	regular	24305.8	4.82%	no gliding flight	4.82%	1170.74	98%	23.415	819.52 birds	<1 year
Golden Plover	October to April	regular	9037.7	4.45%	no gliding flight	4.45%	402.42	99.6%	1.610	56.34 birds	1 year
Whooper Swan	Winter	regular	3473.1	8.11%	no gliding flight	8.11%	281.79	99.5%	1.409	49.31 birds	1 year
Scenario SG155											
Golden Plover	October to April	random	860296.6	4.17%	no gliding flight	4.17%	35880.3	99.6%	143.521	5023.24 birds	<1 year
Hen Harrier	September to March	random	2.1	5.65%	5.51%	5.58%	0.12	99%	0.001	0.04 birds	867 years
Merlin	All	random	1.8	4.4%	4.34%	4.37%	0.08	98%	0.002	0.05 birds	649 years

Species	Survey Period	Model	Transits	Collision Risk			Collision Rate			Estimated Collisions Over Lifetime of Wind Farm	One Bird Collision
				flapping	gliding	overall	without avoidance	avoidance factor	with avoidance		
Peregrine Falcon	All	random	22	5.04%	4.86%	4.95%	1.09	98%	0.022	0.76 birds	46 years
Whooper Swan	October to April	random	508.7	7.32%	no gliding flight	7.32%	37.26	99.5%	0.186	6.52 birds	5 years
Kestrel	All	random	222.6	4.78%	4.67%	4.72%	10.51	95%	0.526	18.39 birds	2 years
Lapwing	Winter	random	7997.9	4.47%	no gliding flight	4.47%	357.57	98%	7.151	250.3 birds	<1 year
Snipe	All	random	1909.7	3.97%	no gliding flight	3.97%	75.78	98%	1.516	53.05 birds	1 year
Buzzard	All	random	1229.2	5.45%	5.25%	5.35%	65.8	98%	1.316	46.06 birds	1 year
Sparrowhawk	All	random	13.9	4.73%	4.65%	4.69%	0.65	98%	0.013	0.45 birds	77 years
Lapwing	Winter	regular	19790.2	4.47%	no gliding flight	4.47%	884.78	98%	17.696	619.35 birds	<1 year
Golden Plover	October to April	regular	6127.4	4.17%	no gliding flight	4.17%	255.56	99.6%	1.022	35.78 birds	1 year
Whooper Swan	Winter	regular	766.4	7.32%	no gliding flight	7.32%	56.13	99.5%	0.281	9.82 birds	4 years

Species	Survey Period	Model	Transits	Collision Risk			Collision Rate			Estimated Collisions Over Lifetime of Wind Farm	One Bird Collision
				flapping	gliding	overall	without avoidance	avoidance factor	with avoidance		
Scenario V150											
Golden Plover	October to April	random	759567.9	4.3%	no gliding flight	4.3%	32651.37	99.6%	130.605	4571.19 birds	<1 year
Hen Harrier	September to March	random	1.9	5.77%	5.63%	5.7%	0.11	99%	0.001	0.04 birds	909 years
Merlin	All	random	1.7	4.52%	4.44%	4.48%	0.07	98%	0.001	0.05 birds	669 years
Peregrine Falcon	All	random	20.8	5.16%	4.95%	5.06%	1.05	98%	0.021	0.74 birds	48 years
Whooper Swan	October to April	random	457.9	7.46%	no gliding flight	7.46%	34.16	99.5%	0.171	5.98 birds	6 years
Kestrel	All	random	207.3	4.9%	4.78%	4.84%	10.03	95%	0.501	17.55 birds	2 years
Lapwing	Winter	random	7648.7	4.6%	no gliding flight	4.6%	351.62	98%	7.032	246.14 birds	<1 year
Snipe	All	random	1689.8	4.08%	no gliding flight	4.08%	68.99	98%	1.38	48.29 birds	1 year
Buzzard	All	random	1144.1	5.58%	5.37%	5.48%	62.65	98%	1.253	43.86 birds	1 year
Sparrowhawk	All	random	12.2	4.84%	4.76%	4.8%	0.58	98%	0.012	0.41 birds	86 years

Species	Survey Period	Model	Transits	Collision Risk			Collision Rate			Estimated Collisions Over Lifetime of Wind Farm	One Bird Collision
				flapping	gliding	overall	without avoidance	avoidance factor	with avoidance		
Lapwing	Winter	regular	19151.8	4.6%	no gliding flight	4.6%	880.45	98%	17.609	616.31 birds	<1 year
Golden Plover	October to April	regular	5929.8	4.3%	no gliding flight	4.3%	254.9	99.6%	1.02	35.69 birds	1 year
Whooper Swan	Winter	regular	741.7	7.46%	no gliding flight	7.46%	55.33	99.5%	0.277	9.68 birds	4 years

Taking into account the uncertainties associated with the model, the predicted collision risk is negligible for the species hen harrier, merlin and long-eared owl. At least one collision over the lifetime of the wind farm is predicted for the species peregrine falcon, whooper swan, kestrel, lapwing, snipe, buzzard and sparrowhawk. Further assessment of these species is conducted in Chapter 7 of the associated EIAR.

The highest number of collisions was predicted for golden plover during the winter and passage season. As the magnitude of the predicted collision risk is assessed to be medium (see Section 7.5.2.1 of Chapter 7 of the EIAR), a Bird Mitigation Plan with the objective of reducing golden plover flight activity in the turbine area has been prepared. This is described in Section 7.6 and Appendix 7-7. Following successful implementation of the mitigation plan, no significant effects of collision risk are anticipated.

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APPENDIX 7-6-1

GOLDEN PLOVER AVOIDANCE RATES

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CONTENTS

SUMMARY

This report assesses the evidence for developing a species-specific avoidance rate for wintering Golden Plover populations, and makes recommendations for specifying this rate.

Collision risk modelling for onshore wind farms in Ireland generally follows the latest Scottish Natural Heritage / Natural Scotland avoidance rate guidance. This guidance includes two types of avoidance rates: species-specific avoidance rates; and a default avoidance rate that should be applied to all other species. Based on the latest version of the guidance, the default avoidance rate of 98% applies to wintering Golden Plover populations. However, review of the development of the SNH avoidance rate guidance shows that the default avoidance rate of 98% is not based on any published empirical evidence, the trend is for avoidance rates to increase as more data becomes available, and the guidance does not always reflect the latest evidence on species-specific avoidance rates. Therefore, the lack of a species-specific avoidance rate for Golden Plover in the SNH avoidance rate guidance does not necessarily mean that there is not any robust data available that could be used to develop a species-specific avoidance rate for Golden Plover.

There are reports for four UK wind farms that provide data that can be used to estimate avoidance rates, or which provide their own estimates of avoidance rates, for wintering Golden Plover populations. For three of these wind farms, the collision monitoring methodologies are robust and generally comply with best practice guidance, so the collision fatality estimates can be regarded as reliable. The avoidance rates calculated for the wintering Golden Plover populations at these wind farms range from 99.87-99.98%. For the fourth wind farm, the available information on the collision monitoring methodology was limited, but there may have been some issues with the methodology and results. The avoidance rate for the wintering Golden Plover population given in the relevant reports for this wind farm was 99.6%.

The highest avoidance rate currently recommended by Scottish Natural Heritage / Natural Scotland is 99.8% for geese. The narrow range of the avoidance rate values for wintering Golden Plover populations at the three wind farms with reliable collision fatality estimates would suggest that 99.8% is a suitable avoidance rate for wintering Golden Plover populations. The 99.6% avoidance rate at the other wind farm is lower than this value, although there may be some issues with this avoidance rate. Therefore, I recommend that collision risk modelling for wintering Golden Plover populations use two avoidance rate values: 99.6% and 99.8%. In practice, this will mean two predicted collision rates, with the one calculated with the 99.6% avoidance rate being twice the value of the other calculated with the 99.8% avoidance rate. These predicted collisions will be five times, and ten times, respectively, lower than predicted collisions calculated with the default 98% avoidance rate.

1. INTRODUCTION

This report was commissioned by MKO.

The objective of the report was to assess the evidence for developing a species-specific avoidance rate for wintering Golden Plover populations, and, if appropriate, make recommendations for specifying this rate.

Collision risk modelling for onshore wind farms in Ireland generally follows the latest Scottish Natural Heritage / Natural Scotland avoidance rate guidance (referred to hereafter as the SNH avoidance rate guidance). The latest version of this guidance (SNH, 2018) does not include a species-specific avoidance rate for wintering Golden Plover populations. Therefore, following the SNH avoidance rate guidance would mean that the default 98% avoidance rate should be applied to wintering Golden Plover populations. However, there is apparently robust data available from post-construction monitoring that indicates that a much higher avoidance rate should be applied to wintering Golden Plover populations.

In this report, I first review the development of the SNH avoidance rate guidance and consider whether the history of its development affects the interpretation of the fact that it does not include a species-specific avoidance rate for wintering Golden Plover populations. I then review the methods and results of four post-construction monitoring studies, and use the data from these studies to derive empirical avoidance rates for the wintering Golden Plover population in each study. I then assess the overall weight of evidence for applying a species-specific avoidance rate to wintering Golden Plover populations and make recommendations for avoidance rate values that should be used in collision risk modelling for such populations.

2. THE SNH AVOIDANCE RATE GUIDANCE

2.1. TYPES OF AVOIDANCE RATES

The SNH avoidance rate guidance includes two types of avoidance rates: specific avoidance rates for individual species, or groups of closely-related species (e.g., swans or geese); and a default avoidance rate that should be applied to all other species.

2.2. THE EVOLUTION OF THE SNH AVOIDANCE RATES

The latest version of the SNH avoidance rate guidance (SNH, 2018) includes a default 98% avoidance rate for species not listed in their guidance. However, this default avoidance rate does not appear to have any empirical basis.

In 2000, the first guidance from Scottish Natural Heritage on avoidance rates recommended a precautionary avoidance rate of 95%, which was "based solely on expert opinion and has little or no empirical basis, as no sound, relevant data were available at the time" (SNH, 2010). In 2010, Scottish Natural Heritage updated their guidance on avoidance rates to included species-specific avoidance rates where relevant data was available (SNH, 2010). They also updated the default avoidance rate for other species to 98% because "in the majority of cases where avoidance rates have been derived from empirical data, the avoidance rates are higher than 95%" (SNH, 2010). Further revisions of the SNH avoidance rate guidance were published in 2016 and 2018 (SNH, 2016; 2018). Comparison of the first species-specific avoidance rates published by Scottish Natural Heritage with the latest species-specific avoidance rates (Table 2.1) shows that as the knowledge base has developed there has been an increase in the recommended avoidance rates. Most species-specific avoidance rates are 99% or higher. The only species with species-specific avoidance rates of less than 99% are White-tailed Eagle and Kestrel.

Table 2.1. Species-specific avoidance rates defined in SNH guidance

Species	SNH Guidance	
	2010	2018
Divers	98%	99.5%
Swans	98%	99.5%
Geese	99%	99.8%
Red Kite	98%	99%
Hen Harrier	99%	99%
Golden Eagle	99%	99%
White-tailed Eagle	95%	95%
Kestrel	95%	95%
Skuas	98%	99.5%

Sources: SNH (2010, 2018). Divers: the 2010 guidance gives a species-specific avoidance rate for Red-throated Diver and a default avoidance rate for Black-throated Diver. Swans: the 2010 guidance gives a species-specific avoidance rate for Whooper Swan, and does not provide avoidance rates for other swan species, while the 2018 guidance gives a species-specific avoidance rate for all swan species. Geese: the 2010 guidance gives separate (but identical) species-specific avoidance rates for Greylag, Pink-footed, Greenland White-fronted and Barnacle Geese, while the 2018 guidance gives a single species-specific avoidance rate for all geese species. Skuas: the 2010 guidance gives a single default avoidance rate for all skua species, while the 2018 guidance gives separate (but identical) species-specific avoidance rates for Great Skua and Arctic Skua.

2.3. EXAMPLES OF SPECIES-SPECIFIC AVOIDANCE RATES IN THE SNH AVOIDANCE RATE GUIDANCE

The 95% avoidance rate for White-tailed Eagle is described as being based on: "sufficient evidence from flight behaviour and collision monitoring studies in Norway for vulnerability to collisions; see May *at al.* (2011)" (SNH, 2018). However, this appears to include a citation error as May *at al.* (2011) provides an estimate for a year-round avoidance rate of 98%, with a confidence interval of 95-99%, based on satellite telemetry data. Presumably, the intended citation was May *at al.* (2010), which included an estimated avoidance rate of 95.8%, based on VP survey data, corrected for the observed wind speed distribution at the study site. This latter reference also included avoidance rates of 97.8% and 97.9% for fixed rotation speeds, and an avoidance rate of 92.5% when the collision risk was modelled using uncertainty levels. The SNH avoidance rate guidance on avoidance rates does not discuss these differing estimates of White-tailed Eagle avoidance rates, and the recommended 95% avoidance rate has remained unchanged since 2010 without any caveats added to reflect the various avoidance rates indicated by the May *at al.* (2010 and 2011) studies.

The 95% avoidance rate for Kestrel is described as being based on: *"*sufficient evidence from flight behaviour (including hovering) and collision monitoring studies for vulnerability to collisions*"* (SNH, 2018). The cited source (Whitfield and Madders, 2006) is, in fact, a review of avoidance rates for Red Kite. The information on Kestrel is derived from an analysis which finds a significant correlation between the *"*numbers of individuals seen*"* against numbers of carcasses found for 16 raptor species at a single wind farm in Spain. Kestrel is a large outlier above the regression line, and this appears to be the only empirical evidence that has been used by SNH to support the 95% avoidance rate for Kestrel. However, even taken at face value, all this analysis does is indicate that Kestrel has a lower avoidance rate than other raptor species, but it does not provide any quantitative data that can be used to estimate the avoidance rate. More seriously, this analysis does not account for behavioural and ecological differences between species that may affect the relationship between recorded bird activity and collisions. It is also subject to the perennial problem with analyses of collision rates: the small absolute numbers of collisions which means that random sampling error may have significant effects.

These two examples show that the species-specific avoidance rates in the SNH avoidance rate guidance do not necessarily reflect all the available evidence (White-tailed Eagle) and can be based on rather sketchy evidence (Kestrel).

2.4. UPDATING THE SNH AVOIDANCE RATE GUIDANCE

The SNH avoidance rate guidance states that *"*it is updated when robust new information becomes available*"* (SNH, 2018). However, while this may be an aspiration, it may not necessarily happen quickly. For example, the SNH avoidance rate guidance currently does not give species-specific avoidance rates for gulls, so the default avoidance rate of 98% applies to all gull species. This guidance refers specifically to onshore wind farms, while separate guidance has been developed for offshore wind farms (JNCC *at al.*, 2014). The latter guidance recommends an avoidance rate of 99.5% for large gulls, based on a review by Cook *at al.* (2014). The discrepancy between the recommended avoidance rates for large gulls between offshore and onshore wind farms, was not addressed until a review by Furness (2019), which was commissioned by SNH. This review recommended that the 99.5% avoidance rate for large gulls at offshore wind farms should also be adopted for onshore wind farms. The review also recommended an avoidance rate of 99.2% for small gulls, which was also based on the data in Cook *at al.* (2014). However, as of June 2022, Scottish Natural Heritage / NatureScot have not updated their guidance on avoidance rates for onshore wind farms to reflect the robust evidence that has been available about species-specific avoidance rates for gulls since at least 2014.

2.5. CONCLUSIONS

The above analysis of the development of the SNH avoidance rate guidance and its treatment of avoidance rates for White-tailed Eagle, Kestrel and gulls, shows that the default avoidance rate of 98% is not based on any published empirical evidence, the trend is for avoidance rates to increase as more data becomes available, and the guidance does not always reflect the latest evidence on species-specific avoidance rates. Therefore, the lack of a species-specific avoidance rate for Golden Plover in the SNH avoidance rate guidance does not necessarily mean that there is not any robust data available that could be used to develop a species-specific avoidance rate for Golden Plover.

3. REVIEW OF GOLDEN PLOVER AVOIDANCE RATES

3.1. SOURCES

I found post-construction monitoring reports for three UK wind farms that provide robust data on Golden Plover collision fatality rates, and, for which, there was appropriate data available that could be used to estimate avoidance rates. These reports were for the Blood Hill Wind Farm (Percival *at al.*, 2008), the Goole Fields I Wind Farm (Percival *at al.*, 2018a) and the Goole Fields II Wind Farm (Percival *at al.*, 2018b, 2019). In addition, information on Golden Plover collision fatality rates and avoidance rates is included in the Habitats Regulations Assessment reports for another UK wind farm site (Haverigg II and III[1]; Percival, 2020a, 2020b), although the reports do not contain sufficient detail to allow full review of the collision monitoring methods and results. Unless otherwise stated, all information and data used in this report for each wind farm was taken from the relevant references cited above.

The characteristics of these wind farms are summarised in Table 3.1.

Table 3.1. Characteristics of the wind farms.

Wind farm	Location	Commissioned	Number of turbines	Hub height (m)	Turbine dimeter (m)
Blood Hill Wind Farm	Norfolk	1992	10	30	27
Goole Fields I	Yorkshire	2014	16	80	92
Goole Fields II	Yorkshire	2016	17	80	92
Haverigg II	Cumbria	1998	4	62.5	42
Haverigg III	Cumbria	2005	4	76	52

Sources: Percival (2020a, 2020 b); Percival *at al.* (2008, 2018a, 2018b, 2019).

3.2. COLLISION MONITORING

3.2.1. Methods

The post-construction monitoring for the Blood Hill and Goole Fields I and II wind farms were carried out by the same consultancy and used the similar methodology for collision monitoring. These included weekly searches for carcasses, and searcher efficiency trials and carcass removal trials (Table 3.2). The weekly carcass searches included detailed searches of radii of 100 m (Blood Hill and Goole Fields I), or 130 m (Goole Fields II) around each turbine, with an additional 250 m scanned for large carcasses (Goole Fields I and Goole Fields II). The carcasses found were left in situ to provide data on searcher efficiency and removal rates. In addition, dedicated searcher efficiency, and carcass removal, trials were carried out at all three wind farms. These involved putting out a number of carcasses. A separate observer then tried to locate these carcasses the same day, while the carcasses were also monitored by trail cameras to investigate removal rates.

Table 3.2. Collision monitoring methods.

Wind farm	Seasons	Search frequency	Search radius	Searcher efficiency / carcass removal trials
Blood Hill	2006/07-2007/08	weekly	100 m	67 carcasses
Goole Fields I	2015/16-2018/19	weekly	100 m detailed search 250 m large carcass search	18 carcasses
Goole Fields II	2017/18-2018/19	weekly	130 m detailed search 250 m large carcass search	48 carcasses

Sources: Percival *at al.* (2008, 2018a, 2018b, 2019).

[1] Haverigg I and II are separate, but adjacent, wind farms. However, the reports combine the data for the two wind farms to calculate a single avoidance rate.

The post-construction monitoring for the Haverigg II and III wind farms was carried out between September 2018 and February 2019, with approximately monthly visits. Detailed information about the methodology of this monitoring was not available to me for this review. However, it included searcher efficiency and carcass removal trials.

3.2.2. Results

No Golden Plover fatalities were recorded at the Blood Hill Wind Farm, single fatalities were recorded at the Goole Fields I and Goole Fields II Wind Farms, and one probable Golden Plover fatality and another probable wader fatality were recorded at the Haverigg II and III Wind Farms (Table 3.3). At Blood Hill, searcher efficiency was very high, and the report notes that conditions were good for searching with winter cereals or bare ploughed ground under the turbines. At Goole Fields I and Goole Fields II, crop growth prevented full coverage of the search area on each visit, with overall coverage levels of 60-88% across the five winters covered at these two wind farms. Searcher efficiency was lower than at Blood Hill but still relatively high.

Table 3.3. Collision monitoring results.

Wind farm	Seasons	Golden Plover / wader fatalities recorded	Coverage	Searcher efficiency	% of carcasses missed due to scavengers
Blood Hill	2006/07 2007/08	0 0	100% 100%	> 99%	38%
Goole Fields I	2015/16 2016/17 2018/19	1 0 0	60% 81% 79%	82%	14%
Goole Fields II	2017/18 2018/19	1 0	81% 88%	91%	17%
Haverigg II and III	2018/19	2	no data	93%	33%

All data taken from the relevant reports cited in Section 3.1. The fatalities at Goole Fields I and Goole Fields II were confirmed Golden Plover fatalities. The fatalities at Haverigg II and III were one probable Golden Plover and one probable wader.

3.3. DERIVATION OF AVOIDANCE RATES

3.3.1. Avoidance rate calculations

Table 3.4 shows the predicted number of collisions using the SNH default 98% avoidance rate, the estimated number of collision fatalities, and the empirical avoidance rates for each site. The estimated number of collision fatalities are the actual number of collision fatalities recorded adjusted for coverage, searcher efficiency and carcass removal. Note that the data for Haverigg II and III is a combined estimate for Golden Plover and Curlew. At Blood Hill, Goole Fields I and Goole Fields II, the estimated numbers of collision fatalities were 30-90 times lower than the predicted collisions. The difference was lower at Haverigg II and III, but the estimated numbers of collision fatalities number of collision fatalities was still around six times lower than the predicted collisions. The empirical avoidance rates vary from 99.6% to 99.98%.

For the Blood Hill Wind Farm, there does not appear to be any pre-construction collision risk estimates available. Instead, collision risk estimates were obtained from post-construction vantage point surveys. The reports for the Haverigg II and III Wind Farms were for lifetime extension applications, so the collision risk estimates were also obtained from post-construction vantage point surveys. As noted in the reports, comparison of these estimates with the collision monitoring results may underestimate the avoidance rate, as birds avoiding the wind farm (macro-avoidance) will not be included in the collision risk predictions. However, the monitoring data does not indicate any significant displacement impacts to Golden Plover, so macro-avoidance may not be a significant factor for this species. For the Goole Fields I and Goole Fields II Wind Farms, the post-construction monitoring reports include the pre-construction collision risk predictions from the Environmental Statements for the projects.

No Golden Plover fatalities were recorded in the post-construction monitoring at Blood Hill. However, it would be incorrect to assume a 100% avoidance rate as, where collision rates are low, zero fatalities will be expected in some years ("false negatives"; SNH, 2009). The study by Fijn et al. (2012), which was used by Whitfield and Urquhart (2015) to derive an avoidance rate for Whooper Swan, also did not record any fatalities. To derive an avoidance rate, they assumed that one swan had been killed, and Whitfield and Urquhart (2015) followed that assumption. Therefore, to obtain an avoidance rate estimate for Blood Hill, I used a nominal value of 0.7 Golden Plover fatalities at Blood Hill (equal to one Golden Plover carcass found over two years, corrected for the expected percentage of carcasses missed due to scavenger removal).

Table 3.4. Comparison of collision risk predictions with collision monitoring results.

Wind farm	Predicted collisions (98% avoidance rate) per year	Golden Plover / wader fatalities per year	Avoidance rate
Blood Hill	62	0.7	99.98%
Goole Fields I	56	0.6	99.98%
Goole Fields II	53	1.7	99.94%
Haverigg II and III	28	5.0	99.6%

The data in this table for Haverigg II and III are combined calculations for Golden Plover and Curlew.

The predicted collisions were obtained from the data reported in the post-construction monitoring reports (see Section 3.1). In those reports, the predicted collisions were calculated from post-construction vantage point survey data for Blood Hill and Haverigg II and III, and from pre-construction vantage point survey data for Goole Fields I and Goole Fields II. For Blood Hill, the post-construction monitoring report includes the predicted collisions with an avoidance rate of 0% and the predicted collisions with a 98% avoidance rate were calculated from this figure. For Goole Fields I and Goole Fields II, the post-construction monitoring reports include the predicted collisions with a 99% avoidance rate, and the predicted collisions with a 98% avoidance rate were calculated from these figures.

The Golden Plover / wader fatalities (excluding Blood Hill) were obtained from the data reported in the post-construction monitoring reports (see Section 3.1). In those reports, the Golden Plover / wader fatalities are estimated figures that were calculated from the recorded collisions, adjusted for coverage, searcher efficiency and carcass removal. For Blood Hill, as no Golden Plover fatalities were recorded, a nominal value of 0.7 Golden Plover fatalities is used here to calculate the avoidance rate (see text). For Haverigg II and III, the recorded collisions used for the calculations comprised one probable Golden Plover and one probable wader.

The avoidance rates for Blood Hill, Goole Fields I and Goole Fields II were calculated from the predicted collisions and Golden Plover fatality data provided in the relevant post-construction monitoring reports (see Section 3.1). The avoidance rate for Haverigg II and III is the avoidance rate figure provided in the relevant reports (see Section 3.1).

3.3.2. Correction factors

There are some complicating factors that need to be taken into account in assessing the reliability of the avoidance rate estimates in Table 3.4.

The maps of Golden Plover flightlines in the Blood Hill post-construction monitoring report show a concentration of flightlines in the western section of the 500 m buffer used for the collision risk model, with relatively few flightlines actually crossing the central part of the buffer where the turbines are located. This pattern suggests that the assuming random distribution of flight activity within the 500 m buffer will overestimate the actual collision risk.

For the Goole Fields I and Goole Fields II Wind Farms, the use of pre-construction vantage point survey data for the collision risk predictions means that the accuracy of the avoidance rate estimates is dependent on the pre-construction Golden Plover flight activity being representative of the post-construction Golden Plover flight activity (allowing for any macro-avoidance effects). At Goole Fields II, the mean Golden Plover bird-days/km^2 were around 2.1 times higher in the pre-construction surveys, compared to the post-construction surveys (Figure 15 in Percival *at al.*, 2019), while the mean Golden Plover count within the 600 m buffer zone was around 2.2 times higher during the pre-construction surveys, compared to the post-construction surveys (Table 22 in Percival *at al.*, 2019). These differences seem unlikely to be due to macro-avoidance effects as any displacement impacts to wintering Golden Plover would be likely to be contained within the 600 m buffer zone (and the mean Golden Plover bird-days/km^2 included counts outside the 600 m buffer zone).

The collision risk predictions used for the avoidance rate calculation for the Haverigg II and III Wind Farms used post-construction vantage point survey data. However, this was from a different winter (2014/15) than the winter used for the collision monitoring (2018/19). Therefore, the accuracy of the avoidance rate estimates is dependent on the Golden Plover flight activity patterns being similar in the two winters.

To allow for the above issues, I have used correction factors of 2.0 for the Blood Hill non-avoidance rate estimate, and 2.15 for the Goole Fields II non-avoidance rate estimate. The correction factor of 2.0 for the Blood Hill non-avoidance rate estimate is based on a visual estimate of differences in flightline densities in the western section of the buffer, compared to the central and eastern sections. The correction factor of 2.15 for the Goole Fields II non-avoidance rate estimate is the mean of the pre-construction / post-construction ratio of Golden Plover bird-days/km^2 and the pre-construction / post-construction ratio of Golden Plover counts within the 600 m buffer zone.

Applying correction factors of 2.0 to the Blood Hill non-avoidance rate estimate, and 2.15 to the Goole Fields II non-avoidance rate estimate, gives corrected avoidance rate estimates of 99.87-99.98%, while sufficient information is not available to assess whether a correction factor should be applied to the 99.6% avoidance rate for Haverigg II and III (Table 3.5).

Table 3.5. Corrected avoidance rate estimates.

Wind farm	Avoidance rate		Correction factor	Reason
	original	corrected		
Blood Hill	99.98%	99.96%	2.0	Uneven distribution of flight activity relative to turbine locations
Goole Fields I	99.98%	99.98%	1.0	-
Goole Fields II	99.94%	99.87%	2.15	Reduction in Golden Plover numbers
Haverigg II and III	99.6%	-	-	No data available to assess whether correction factor is needed (see text)

Note that the correction factor is applied to the non-avoidance rate. See text for further details of the reasons for the avoidance rate correction factors.

4. CONCLUSIONS

The collision monitoring methodologies used in the Blood Hill, Goole Fields I and Goole Fields II post-construction monitoring studies are robust and generally comply with best practice guidance (SNH, 2009). Therefore, I consider that the Golden Plover collision fatality estimates for the Goole Fields I and Goole Fields II Wind Farms from these studies are reliable. The reported zero collision fatality estimate for the Blood Hill Wind Farm does not include any correction for “false negatives” (cf., SNH, 2009), but I have allowed for this by using a nominal estimate in my calculations of avoidance rates.

The avoidance rates derived from these studies are very high, and even when I corrected two of them by doubling the non-avoidance rate to reflect uneven distribution of flight activity (Blood Hill) and apparent reductions in Golden Plover numbers (Goole Fields II), they remain around, or higher than, 99.9%. However, a degree of caution is necessary in applying these figures. Due to the low collision rate, very few collision fatalities are found. This means that random variation in the number of collision fatalities found will can cause significant changes in the avoidance rate estimate. For example, if a second fatality had been found at Goole Fields II, then the corrected avoidance rate estimate would decrease from 99.87%-99.74%. While this change may seem small, it would cause a doubling in the predicted collision risk.

Detailed information about the collision monitoring methodology used for the Haverigg II and III Wind Farms post-construction monitoring study was not available to me for this review. However, I note that there was a lower frequency of monitoring (approximately monthly) compared to the other studies (weekly). This will have made the collision fatality estimate less reliable. The avoidance rate calculation for this wind farm used combined data for Golden Plover and Curlew, while the two collision fatalities were a probable Golden Plover and a probable wader. Also, the avoidance rate calculations used flight activity and collision fatality data from different winters, and, unlike with Goole Fields I and Goole Fields II it was not possible for me to assess whether differences in Golden Plover flight activity patterns between the winters could have affected the calculations[2]. Therefore, it is possible that the significantly lower avoidance rate calculated for this wind farm, compared to the avoidance rates for Blood Hill, Goole Fields I and Goole Fields II, reflects methodological issues.

These avoidance rates are only derived from four studies, with two of these studies carried out at adjoining wind farms. However, these still represent a much stronger evidence base for a species-specific avoidance rate than the evidence used for Kestrel in the SHN avoidance rate guidance (see Section 2.3). Also, other species-specific avoidance rates in the SHN avoidance rate guidance are based on data from limited numbers of sites: e.g., both the White-tailed Eagle avoidance rate (see Section 2.3) and the Whooper Swan avoidance rate (Whitfield and Urquhart, 2015) are based on data from single sites. Therefore, the evidence base for a species-specific avoidance rate is relatively strong for Golden Plover compared to some of the species for which the SNH avoidance rate guidance does include species-specific avoidance rates. The lack of a species-specific avoidance rate for Golden Plover in the SNH avoidance rate guidance may reflect the fact that the conservation concern about Golden Plover and wind farms in Scotland is focussed on breeding populations. Data from wintering populations (such as in the studies reviewed here) may not be applicable to breeding populations due to the differences in their behaviour and ecology.

The highest avoidance rate currently recommended by SNH (2018) is 99.8% for geese. The narrow range of the corrected avoidance rates for Blood Hill, Goole Fields I and Goole Fields II (99.87-99.98%) would suggest that 99.8% is a suitable avoidance rate for wintering Golden Plover populations. The 99.6% avoidance rate at Haverigg II and III is lower than this value, although

[2] Note that, while my assessment of this issue for the Goole Fields II Wind Farm resulted in an increase in the corrected avoidance rate, compared to the original value, it is equally plausible that differences in flight activity between winters could cause a decrease in the corrected avoidance rate, compared to the original value.

there may be some issues with this avoidance rate. Therefore, I recommend that collision risk modelling for wintering Golden Plover populations use two avoidance rate values: 99.6% and 99.8%. In practice, this will mean two predicted collision rates, with the one calculated with the 99.6% avoidance rate being twice the value of the other calculated with the 99.8% avoidance rate. These predicted collisions will be five times, and ten times, respectively, lower than predicted collisions calculated with the default 98% avoidance rate.

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