APPENDIX 7-5

COLLISION RISK ASSESSMENT

Planning and Environmental Consultants

Appendix 7-5 – Collision Risk Assessment

Seskin Wind Farm, Co. Carlow - EIAR

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1. INTRODUCTION

This document outlines the methodology used to assess the collision risk for birds at the Proposed Project site.

As detailed in Section 1.1.1 in Chapter 1 of the EIAR, for the purposes of this EIAR, the various project components are described and assessed using the following references: 'Proposed Project', 'Proposed Wind Farm', 'Proposed Grid Connection Route', the 'site', and 'Proposed turbines.'

The collision risk assessment is based on vantage point surveys undertaken at the Proposed Wind Farm site from April 2020 to May 2022. This represents a 24-month survey period, consisting of two breeding seasons and two winter seasons, which is in full compliance with NatureScot (previously Scottish Natural Heritage) guidance (SNH, 2017). Surveys were undertaken from 2no. fixed vantage points, one of which was used in the collision risk model (CRM). The Proposed Wind Farm site has contracted from the extent of the site covered during surveys, which encompassed an additional area approximately 3km south of the Proposed Wind Farm site. As such, the viewshed of the vantage point VP2 no longer contains Proposed turbines. This vantage point is therefore not included in the collision risk analysis.

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 Proposed 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[1] 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 Proposed turbines on birds.

[1] *When available a species-specific avoidance rate is used, where one isn't available, a generic avoidance rate is applied in line with best practice.*

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. The Proposed turbines will be between 102.5m to 105m at hub height, with a rotor diameter ranging from 149m to 155m, giving an overall ground-to-blade tip height of between 179.5 to 180m and a lowest swept height ranging from 25m to 30.5m. Three models were run to assess the full range of turbine dimensions proposed. The model makes a number of assumptions on the turbine design and on biometrics of birds:

1. *Birds are assumed to be of a simple cruciform shape.*
2. *Turbine blades are assumed to have length, depth and pitch angle, but no thickness.*
3. *Birds fly through turbines in straight lines.*
4. *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 estimates of collision. The final step in the analysis accounts for the ability of birds to avoid a collision.

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 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 windfarm. 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 windfarm.
- All flight activity used in the model occurred within the viewshed area.

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 windfarm area.
- Habitat and bird activity will remain the same over time and be unchanged during the operational stage of the windfarm.

- 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 the Proposed Project, eight species recorded in flight within the Proposed Wind Farm site were randomly distributed. Therefore, a Random Flight Model was conducted for these species. A Regular Flight Model was not conducted for any species, as no regular flight corridors were evident.

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 Proposed turbines. Transits are calculated using either the "Regular" or "Random" flight model (Band *et al.,* 2007), depending on flight distribution and behaviour – for the Proposed Project a Random Flight Model was conducted for all species.
- 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 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. Note that this is assuming theoretical precautionary conditions for collision mortality, as it assumes 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 farms.

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 dimensions of the turbines comprise a range, with an overall ground-to-blade tip height of 179.5m to 180m; a rotor blade diameter ranging from 149m to 155m; and hub height ranging from 102.5m to 105m. As such, three scenarios have been analysed via the collision risk model, representing the minimum, maximum and median of this range. In the absence of a specific turbine model, some of the turbine specifications (i.e. pitch, chord and rotational period) have been taken from existing turbine models[2] that are representative of the turbine dimensions in the scenarios modelled. The turbine specifications used in the model are available in Table 7-5-1.

[2] *Scenario 1 = Siemens SG155; Scenario 2 = Nordex N149; Scenario 3 = Vestas V150.*

Table 7-5- 1 Turbine specifications

Wind Farm Component	Value
Scenario 1 (25m – 180m)	
Number of turbines	7
Blades per turbine rotor	3
Pitch of blade (degrees)	6
Maximum chord (m) (i.e. depth of blade)	4.2
Rotational period (s)	7.1
Turbine operational time (%)	85[3]
Rotor diameter (m)	155
Rotor radius (m)	77.5
Hub height (m)	102.5
Swept height (m)	25 – 180
Scenario 2 (30.5m – 179.5)	
Number of turbines	7
Blades per turbine rotor	3
Pitch of blade (degrees)	6
Maximum chord (m) (i.e. depth of blade)	4.5
Rotational period (s)	6.417
Turbine operational time (%)	85
Rotor diameter (m)	149
Rotor radius (m)	74.5
Hub height (m)	105
Swept height (m)	30.5 – 179.5
Scenario 3 (30m – 180m)	
Number of turbines	7
Blades per turbine rotor	3
Pitch of blade (degrees)	6
Maximum chord (m) (i.e. depth of blade)	4.2
Rotational period (s)	7.1
Turbine operational time (%)	85
Rotor diameter (m)	150
Rotor radius (m)	75
Hub height (m)	105
Swept height (m)	30 – 180

As only bird flights that overlap with the rotor-swept height are at risk of collision, only the vantage point survey flight activity height band of 25-200m above ground level has been included in the CRM with respect to the three scenarios, i.e. rotor-swept heights of 25-180m, 30.5-179.5m and 30-180m.

[3] *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 species of conservation concern recorded at the potential collision height during vantage point surveys at the Proposed Wind Farm site were:

- Golden Plover
- Kestrel
- Lapwing
- Snipe
- Woodcock
- Buzzard
- Sparrowhawk

A CRM was conducted for each of these species. To account for the nocturnal flight activity of some waterbirds it is assumed that these species are active for 25% of the night along with daylight hours (as per SNH guidance).

2.5 Calculation Parameters

The calculation parameters for the vantage points are outlined in Table 7-5-2. Bird biometrics are presented in Table 7-5-3. Table 7-5-4 presents the model input values for the random model: 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 (PCH = height band of 25-200m).

Table 7-5- 2 Survey effort and viewshed coverage

Vantage Point	Visible Area (ha)	Risk Area (ha)	Turbines visible	Total Survey Effort (hrs)
Scenario 1 – Viewshed at 25m				
VP1	581ha	299ha	6	144
Scenario 2 – Viewshed 30.5m				
VP1	630ha	322ha	7	144
Scenario 3 – Viewshed at 30m				
VP1	627ha	321ha	7	144

Table 7-5- 3 Bird biometrics

Species	Body Length(m)	Wingspan(m)	Flight Speed(m/s)
Golden Plover	0.275	0.715	17.9
Kestrel	0.335	0.755	10.1
Lapwing	0.295	0.845	12.8
Woodcock	0.255	0.42	17.1
Snipe	0.34	0.6	17.1
Buzzard	0.54	1.205	11.6
Sparrowhawk	0.33	0.625	10

Table 7-5- 4 Model input values.

Species	Model	Period	Bird seconds at PCH (Scenario 1)
Golden Plover	random	October - April	[4]3,029,237
Kestrel	random	All	7,443
Lapwing	random	Breeding	2,132
Snipe	random	September - April	1,438
Woodcock	random	All	217
Buzzard	random	All	14,503
Sparrowhawk	random	All	3,958

The avoidance rates applied to the collision risk were: 99.8-99.6% for golden plover[5], 95% for kestrel and 98% for the remaining species.

[4] *Note: Golden plover flights GP055, GP057, GP058, GP059, GP062 & GP063 were omitted from the CRM as they were predictably associated with birds landing in agricultural fields on one day over 2km from the nearest Proposed turbine, and therefore not random in nature.*
[5] *See Appendix 1 of this report for further details.*

3. RESULTS

The predicted number of transits per year and the collision risk for the three scenarios modelled 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 Results of CRM

Species	Survey Period	Model	Transits	Collision Risk			Collision Rate			One Bird Collision
				flapping	gliding	overall	without avoidance	avoidance factor	with avoidance	
Scenario 1 (25m – 180m)										
Golden Plover	October – April	random	515238.7	4.17%	no gliding flight	4.17%	21489.01	99.8%	42.978	<1 year
								99.6%	85.956	<1 year
Kestrel	All	random	678.7	4.78%	4.67%	4.72%	32.05	95%	1.603	1 year
Lapwing	Breeding	random	325.1	4.47%	no gliding flight	4.47%	14.53	98%	0.291	3 years
Snipe	September – April	random	237.1	3.97%	no gliding flight	3.97%	9.41	98%	0.188	5 years
Woodcock	All	random	39.2	4.23%	no gliding flight	4.23%	1.66	98%	0.033	30 years
Buzzard	All	random	1519	5.45%	5.25%	5.35%	81.31	98%	1.626	1 year
Sparrowhawk	All	random	357.4	4.73%	4.65%	4.69%	16.75	98%	0.335	3 years
Scenario 2 (30.5m – 179.5)										
Golden Plover	October – April	random	456569.9	4.6%	no gliding flight	4.6%	21021.92	99.8%	42.044	<1 year
								99.6%	84.088	<1 year
Kestrel	All	random	601.5	5.29%	5.2%	5.25%	31.55	95%	1.578	1 year
Lapwing	Breeding	random	288	4.94%	no gliding flight	4.94%	14.23	98%	0.285	4 years
Snipe	September – April	random	210.1	4.4%	no gliding flight	4.4%	9.25	98%	0.185	5 years

Species	Survey Period	Model	Transits	Collision Risk			Collision Rate			One Bird Collision
				flapping	gliding	overall	without avoidance	avoidance factor	with avoidance	
Woodcock	All	random	34.7	4.69%	no gliding flight	4.69%	1.63	98%	0.033	31 years
Buzzard	All	random	1346	6.03%	5.85%	5.94%	79.92	98%	1.598	1 year
Sparrowhawk	All	random	316.7	5.24%	5.18%	5.21%	16.5	98%	0.33	3 years
Scenario 3 (30m – 180)										
Golden Plover	October – April	random	461833.3	4.3%	no gliding flight	4.3%	19852.72	99.8%	39.705	<1 year
								99.6%	79.41	<1 year
Kestrel	All	random	608.4	4.9%	4.78%	4.84%	29.44	95%	1.472	1 year
Lapwing	Breeding	random	291.4	4.6%	no gliding flight	4.6%	13.39	98%	0.268	4 years
Snipe	September – April	random	212.5	4.08%	no gliding flight	4.08%	8.68	98%	0.174	6 years
Woodcock	All	random	35.1	4.35%	no gliding flight	4.35%	1.53	98%	0.031	33 years
Buzzard	All	random	1361.5	5.58%	5.37%	5.48%	74.56	98%	1.491	1 year
Sparrowhawk	All	random	320.3	4.84%	4.76%	4.8%	15.38	98%	0.308	3 years

Table 7-5- 6 Results Comparison: The highest rates of predicted collisions have been written in bold text.

Species	Survey Period	Collision Risk (with avoidance)			One Bird Collision		
		Scenario 1 (25-180m)	Scenario 2 (30.5-179.5m)	Scenario 3 (30-180m)	Scenario 1 (22-185m)	Scenario 2 (36-185m)	Scenario 3 (30-185m)
Golden Plover	October - April	**42.978 – 85.956**	42.044 – 84.088	39.705 – 79.41	**<1 year**	<1 year	<1 year
Kestrel	All	**1.603**	1.578	1.472	**1 year**	1 year	1 year
Lapwing	Breeding	**0.291**	0.285	0.268	**3 years**	4 years	4 years
Snipe	September - April	**0.188**	0.185	0.174	**5 years**	5 years	6 years
Woodcock	All	**0.033**	0.033	0.031	**30 years**	31 years	33 years
Buzzard	All	**1.626**	1.598	1.491	**1 year**	1 year	1 year
Sparrowhawk	All	**0.335**	0.33	0.308	**3 years**	3 years	3 years

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APPENDIX 1

GOLDEN PLOVER AVOIDANCE RATES

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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	0	100%	> 99%	38%
	2007/08	0	100%		
Goole Fields I	2015/16	1	60%	82%	14%
	2016/17	0	81%		
	2018/19	0	79%		
Goole Fields II	2017/18	1	81%	91%	17%
	2018/19	0	88%		
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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