DERRYADD WIND FARM: COLLISION RISK MODELLING

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1. INTRODUCTION

This report presents the results of collision risk modelling for the proposed Derryadd wind farm, Co. Longford.

Collision risk modelling (CRM) involves using flight activity data from before the construction of a wind farm to calculate the likely risk of birds colliding with turbines in the operational wind farm. There are two stages to the CRM. In stage 1, the flight activity data that was recorded is scaled up to represent the overall level of flight activity in the wind farm site across the relevant period (e.g., a full year for a resident species, or a summer or winter for a migrant species). The number of predicted transits of the rotor swept volume in the wind farm is then calculated based on the proportion of the total air spaces that is occupied by the rotor swept volume. However, most transits of the rotor swept volume will not result in a collision, because for the duration of a transit, most of the rotor swept volume is not occupied by the turbine blades. Furthermore, most birds try to avoid the turbine blades either by avoiding the wind farm area altogether, or by taking evasive action if they are likely to collide with a blade while transiting the wind farm. Therefore, stage 2 of the CRM involves converting the predicted number of transits to predicted number of collisions by multiplying by the probability of a collision per transit (assuming no avoidance behaviour) and then correcting for the avoidance rate.

The Scottish Natural Heritage guidance on wind farm assessments (Scottish Natural Heritage, 2017) requires bird survey data from two full years within the past five years. The CRM in this report used data from vantage point surveys carried out in the winters of 2014/15, 2015/16, 2016/17 and 2017/18, and the summers of 2015 and 2016. Therefore, the vantage point survey data used for this CRM complies fully with Scottish Natural Heritage guidance on wind farm assessments. Vantage point survey data is also available for the summer of 2017 but has not been included in the CRM due to data compatibility issues (see Section 3.1.8). However, this vantage point survey data for the summer of 2017 has been reviewed to assess whether it would have been likely to have significantly changes the findings of the CRM (see Section 4.1.4). The modelling was carried out using the Scottish Natural Heritage Collision Risk Model (Scottish Natural Heritage, 2000; Band et al., 2007; Band. 2012). The bird occupancy method (Scottish Natural Heritage, 2000) was used to calculate the number of bird transits through the rotors, and the single transit collision risk spreadsheet provided by Band (2012) was used to calculate collision probabilities for birds transiting through the rotors.

2. DATA SOURCES

The following data and information was provided for this assessment:

- Flight activity data recorded during the vantage point surveys (Table 1).
- Reports on the results of some of the vantage point surveys (Table 1).
- Vector mapping of the vantage point locations.
- xy coordinates of the proposed turbine locations.
- Raster mapping of the viewsheds for the VP layouts.
- Technical specifications for the proposed turbines (see Table 8); note that, as instructed by TOBIN Consulting Engineers, most of these specifications were taken from Appendix 6.7 of Cloncreen Wind Farm EIS.
- Information about the survey methodology.

Table 1. Flight activity data sources.

Season	Company	Data file(s)	Reports
Winter bird survey 2014-2015	Malachy Walsh & Partners	16380-Bord na Móna Winter 2014-15-Observations of Target Species Species.doc WBS 2014-2015 Target Species records within Final Site Bounday.docx	Winter Ornithological Survey for Lot No.1: Mountdillon, Derryarogue, Derryadd, Derraghan (Winter 2014/15) (Malachy Walsh & Partners, 16380-6001-B)
Breeding bird survey 2015	Malachy Walsh & Partners	16380-Bord na Móna Summer 2015-Observations of Target Species Species.doc BBS 2015 Target Species records within Final Site Boundary.docx	Summer Ornithological Survey Lot No.1: Mountdillon, Derryarogue, Derryadd, Derraghan (Summer 2015) (Malachy Walsh & Partners, 16380-6002-B)
Winter bird survey 2015-2016	Malachy Walsh & Partners	Winter Bird Survey 2015_16 Master Excel.xlsx	Winter 2015/2016 Ornithological Surveys: Lot No.1 (Mountdillon/Derrycashel, Derryarogue, Derryadd/Lough Bannow, Derraghan/Derryshanoge/Derrycolumb Bog Complexes) (Malachy Walsh & Partners, 16380-6003-B)
Breeding bird survey 2016	TOBIN Consulting Engineers	8057_ Derryadd Bird Data Base_AB_09.11.16.xlsx	-
Winter bird survey 2016-2017	TOBIN Consulting Engineers	BNM Winter Bird Survey 2016_17 Master Excel.xlsx	-
Breeding bird survey 2017	McCarthy Keville O'Sullivan	Derryadd Masterbird - breeding 2017.xlsx	170217 – Breeding Birds Survey 2017 Derryadd Survey Report (McCarthy Keville O'Sullivan, 170217-BBS-2017.12.22-F)
Winter bird survey 2017-2018	TOBIN Consulting Engineers	10364 Derryadd Winter Data 2017_20171130.xlsx	-

All the data and information used in this assessment about the vantage point surveys and the proposed wind farm development was provided by TOBIN Consulting Engineers. All statements made in this report about the vantage point survey methodology are based on information provided by TOBIN Consulting Engineers, and/or review of data supplied by TOBIN Consulting Engineers.

This report uses the data and information about the vantage point as supplied and does not discuss the vantage point survey methodology, except in so far as is required for the CRM analyses.

3. REVIEW AND ANALYSIS OF THE VANTAGE POINT SURVEY COVERAGE AND RESULTS

3.1.1. Vantage point locations

Three sets of vantage points were used in the surveys. The winter bird survey 2014-2015, breeding bird survey 2015 and winter bird survey 2015-2016 used 7 no. vantage points (referred to in this report as VP layout 1; Figure 1). The breeding bird survey 2016 and breeding bird survey 2017 surveys used 11 no. vantage points, of which six were in the same, or very similar, locations as VP layout 1, and four of which were in new locations (referred to in this report as VP layout 2; Figure 1). However, the viewshed mapping indicates that the aspects of the viewsheds used for some of the VPs differed significantly between the two sets of surveys and there may also have been minor differences in the exact locations of the VPs. The winter bird survey 2016-2017 and winter bird survey 2017-2018 used 12 no. vantage points, of which 11 were in the same, or similar, locations as the breeding bird survey 2016 vantage points, and one was in a new location (referred to in this report as VP layout 3; Figure 1).

The numbering sequence of the vantage points was different in VP layout 1 from that used in VP layouts 2 and 3. The vantage point numbering used in VP layout 3 has been used in this report, and the correspondence between the vantage points from the three VP layouts to this numbering is shown in Table 2.

Table 2. Correspondence between vantage point locations used in the various seasons surveyed.

VP number used in this report	VP layout 1	VP layout 2	VP layout 3
VP1	not surveyed	VP1	VP1
VP2*	not surveyed	VP2	VP2
VP3**	VP4	VP3	VP3
VP4	VP5	VP4	VP4
VP5	VP6	VP5	VP5
VP6	not surveyed	VP6	VP6
VP7***	VP7	VP7	VP7
VP8	VP8	VP8	VP8
VP9	VP12	VP9	VP9
VP10	VP15	VP10	VP10
VP11	not surveyed	VP11	VP11
VP12	not surveyed	not surveyed	VP12

* Vantage point positions in summer 2016 and winter 2016/17 approximately 100 m apart.

** Vantage point positions in winter 2015/16 and winter 2016/17 approximately 800 m apart, with the vantage point position in summer 2016 in between.

*** Vantage point positions in winter 2014/15-summer 2016 and winter 2016/17 approximately 650 m apart.

3.1.2. Vantage point viewsheds

Malachy Walsh & Partners and TOBIN Consulting Engineers

Vantage point viewshed maps for the surveys have been provided by TOBIN Consulting Engineers. The mapped viewsheds indicate 100% coverage of a semi-circle of radius 2 km from each vantage point. According to information provided by TOBIN Consulting Engineers, this unusually high level of viewshed coverage reflects the flat topography and the height of the turbine blades.

Two of the vantage points (VPs 1 and 2) are located along the River Shannon to the north-west of the wind farm site, and the viewsheds from these vantage points do not overlap any of the turbine locations. The flight activity recorded at these vantage points does not appear to be representative of the wind farm site, due to high levels of flight activity of some species associated with the River Shannon that occurred at much lower levels at the other vantage points (Mallard, Cormorant and Little Egret), or were absent from the other vantage points (Common Tern). Therefore, these vantage points have been excluded from the CRM analysis, although the data from these vantage points has been used for analysis of seasonal patterns of flight activity.

McCarthy Keville O'Sullivan

The survey report for the summer 2017 surveys carried out by McCarthy Keville O'Sullivan includes a map showing the combined viewsheds across all the vantage points. While this map can be difficult to interpret for some of the vantage points, it indicates a much reduced level of viewshed coverage compared to the viewshed maps for the Malachy Walsh & Partners and

TOBIN Consulting Engineers surveys. This is partly due to the fact that the McCarthy Keville O'Sullivan viewshed analysis uses a much lower height of 25 m, compared to the 55 m height used in the TOBIN Consulting Engineers viewshed analyses. It also appears that some of the McCarthy Keville O'Sullivan viewsheds do not include a full 180° view from the VP, which presumably reflects the lower height used for the viewshed analysis.

3.1.3. Vantage point survey effort

The overall vantage point survey effort in each dataset ranged from 30-42 hours per vantage point per season (Table 3). In the winter 2014/15, summer 2015, and winter 2015/16 datasets, there was a constant effort of 6 hours/VP/month, and the variation in overall effort was due to the different numbers of months covered in each of these datasets (Table 3). In the summer 2016 dataset, the overall survey effort per vantage point varied from 33-39 hours (Table 3). The distribution of survey effort across the months covered also varied between the vantage points in this dataset (Table 4). However, the overall level of coverage in summer 2016 was adequate for the purposes of this CRM.

Table 3. Vantage point survey effort.

Dataset	Months	Effort/month	Total hours per VP	Source
2014/15 winter	Oct-Mar	6 hours/VP/month	36	1
2015 summer	Apr-Aug	6 hours/VP/month	30	1
2015/16 winter	Sep-Mar	6 hours/VP/month	42	1
2016 summer	Apr-Sep	variable	33-39 (mean 37)	2
2016/17 winter	Oct-Mar	not known	36	3
2017 summer	Apr-Sep	6 hours/VP/month*	36*	4
2017/18 winter	Oct-Mar	6 hours/VP/month	36	5

* 12 hours survey carried out at VP8 in August, with a total of 42 hours survey at this VP across the survey period.

Sources: 1 = Malachy Walsh & Partners reports (see Table 1); 2 = analysis of data in 8057_ Derryadd Bird Data Base_AB_09.11.16.xlsx; 3 = information on number of hours provided by TOBIN Consulting Engineers, while months covered are based on analysis of data in BNM Winter Bird Survey 2016_17 Master Excel.xlsx; 4 = analysis of data in Derryadd Masterbird - breeding 2017.xlsx; 5 = analysis of data in 10364 Derryadd Winter Data 2017_20171130.xlsx.

Table 4. Vantage point survey effort (hours) per month in the summer 2016 dataset.

VP	Apr	May	Jun	July	Aug	Sep	Total/VP
VP1	0	6	12	9	6	6	39
VP2	0	6	12.5	6	6	6	36.5
VP3	6	6	6	6	6	6	36
VP4	6	6	6	9	6	6	39
VP5	6	3	6	12	9	0	36
VP6	0	6	6	15	9	3	39
VP7	6	0	12	6	0	12	36
VP8	6	6	6	6	3	9	36
VP9	7	6	6	8	6	6	39
VP10	6	3	6	9	6	6	36
VP11	0	0	12	9	6	6	33
Total/month	**43**	**48**	**90.5**	**95**	**63**	**66**	**405.5**

Source: analysis of data in 8057_ Derryadd Bird Data Base_AB_09.11.16.xlsx.

3.1.4. Flight heights

General

The first version of this CRM was developed at a time when the collision risk height zone for the proposed turbines was taken to be 40-170 m. The proposed turbines now will have a collision risk height zone of 55-185 m. However, due to the complexity of the analyses already carried out, and the lack of specific data recorded using a 55-185 m height band, the analyses of flight activity data previously carried out using the 40-170 m height band has been retained, while the new data added to this version of the CRM uses a 35-175 m height band as the collision risk height zone (see below). Assuming accurate recording of flight heights, this will tend to produce conservative analyses (i.e., overestimation of collision risk), as there will be much more flight activity in the 35-55 m, or 40-55 m height bands included in the CRM, than in the 170-185 m, or 175-185 m height bands excluded from the CRM.

2014/15-2016/17 surveys

Flight heights were recorded using a variety of scales: in some cases the heights were estimated to the nearest 10 m (or even more precisely), while in other cases the heights were recorded within height bands, with a range of such bands used. In order to provide consistent classification of flight heights across all the datasets, the following procedure was adopted. Flight heights were classified from all individual records of the species included in the CRM analyses using the following categories: 1 = 0-10 m, 2 = 10-40 m, 3 = 10-100 m, 4= 40-100 m, 5 = 100-170 m, 6 = > 100 m, 7 = > 170 m. Where individual flights were given a specific distance band spanning categories 1 and 2, 2 and 4, or 4 and 5, the flight was split between the two categories, with the duration divided equally between the categories. This procedure was not adopted to split flights in category 3 between categories 2 and 4, as, for several species, it was likely that the majority of such flights would have been in the 10-40 m height band. Instead, for most species, I the total duration of all recorded flights in categories 2 and 4 was used to split the durations of flights in category 3 between categories 2 and 4. For the following three species, this procedure was not appropriate, and other procedures were used that made conservative assumptions (i.e., assumptions that are likely to have overestimate flight activity in category 4). For, Hen Harrier and Peregrine, due to the very low level of recorded flight activity, the duration of flights in category 3 were split equally between categories 2 and 4. For Curlew, there was a low level of flight activity in category 4, but a high level in category 5, and the combined level of flight activity in categories 4 and 5, compared to category 2, was used to split flights in category 3 between categories 2 and 4.

There were a small number of flights for which the number of birds, or duration of flight, were not recorded. Where the number of birds was not recorded, I assumed that the flight referred to a single bird. Where the duration was not recorded, I used the mean flight duration for that species (in the relevant season, if there was sufficient data, or across the entire dataset).

Summer 2017 and winter 2017/18 surveys

The summer 2017 survey recorded flight heights in four bands: 0-10 m; 10-25 m; 25-175 m; and > 175 m. This data was not included in the CRM.

The winter 2017/18 surveys recorded flight heights in four bands: 0-10 m; 10-35 m; 35-175 m; and > 175 m. The 35-175 m height band has been taken to represent the flight activity within the collision risk height zone.

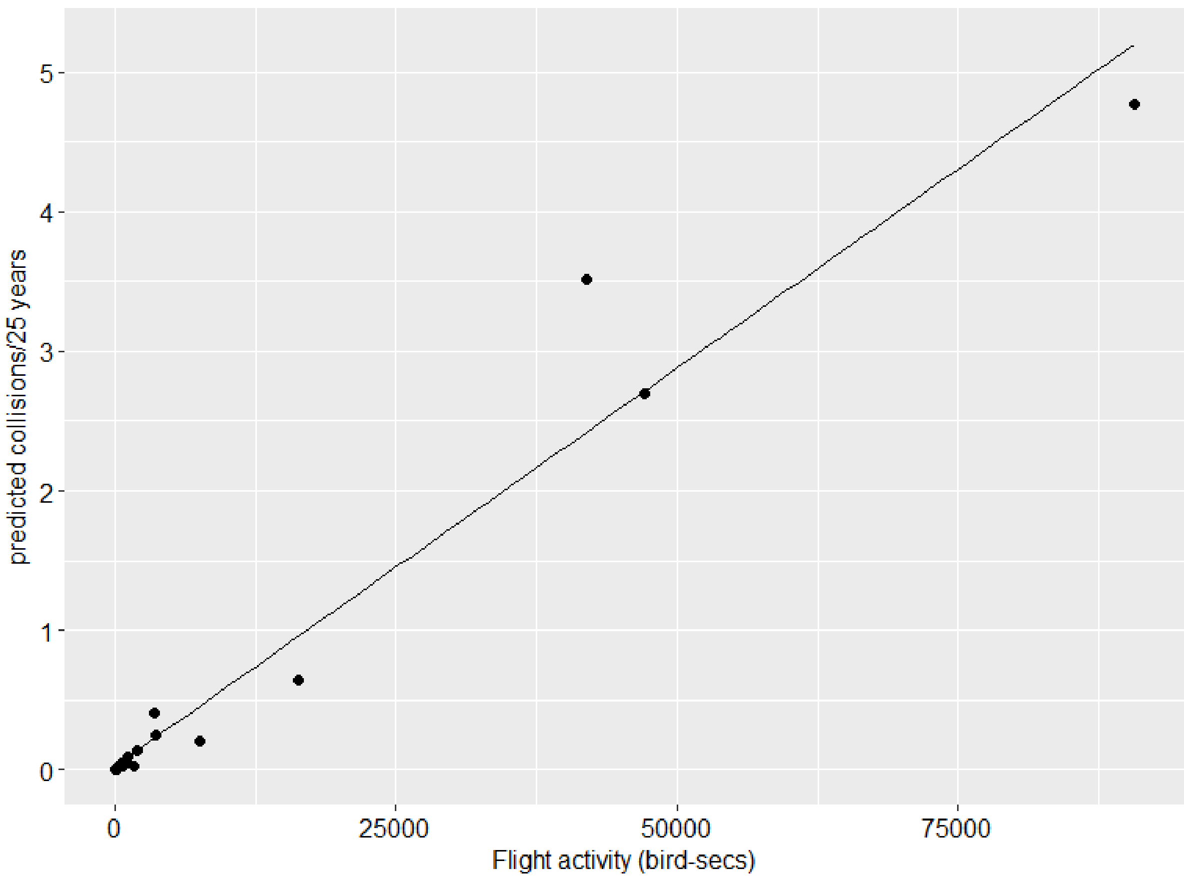
3.1.5. Selection of target species for the collision risk model

The following raptor and waterbird species were recorded in the vantage point surveys: Mute Swan, Whooper Swan, Greenland White-fronted Goose, Greylag Goose, Canada Goose, Wigeon, Teal, Mallard, Tufted Duck, Cormorant, Little Egret, Grey Heron, Little Grebe, Great Crested Grebe, White-tailed Eagle, Hen Harrier, Sparrowhawk, Buzzard, Water Rail, Moorhen, Coot, Golden Plover, Lapwing, Ringed Plover, Curlew, Woodcock, Snipe, Common Tern, Black-headed Gull, Common Gull, Lesser Black-backed Gull, Herring Gull, Great Black-backed Gull, Short-eared Owl, Kingfisher, Kestrel, Merlin and Peregrine.

The species selected for analysis are: Whooper Swan, Mallard, Cormorant, Hen Harrier, Sparrowhawk, Golden Plover, Lapwing, Curlew, Black-headed Gull, Common Gull, Lesser Black-backed Gull, Herring Gull, Great Black-backed Gull, Kestrel, and Peregrine. These species have been selected because they are of conservation concern: i.e., they are red or amber-listed in *Birds of Conservation Concern Ireland 2014-2019* (Colhoun and Cummins, 2013), and/or are listed on Annex I of the Birds Directive (79/409/EEC), and/or are Special Conservation Interests of SPAs close to the wind farm site (i.e., Lough Ree SPA or the Ballykenny-Fisherstown Bog SPA, as listed in the Malachy Walsh survey reports).

Other species of conservation concern recorded in the vantage point surveys have been excluded for the following reasons:

- Greenland White-fronted Goose, Greylag Goose, Tufted Duck, Little Grebe, Great Crested Grebe, White-tailed Eagle, Water Rail, Coot, Ringed Plover, Short-eared Owl and Kingfisher were not recorded flying within the collision risk height band. For these species, the collision risk can be assumed to be effectively zero: i.e, D_{bird} = 0 (see Table 10), so $N_{transits}$ = 0 (see Table 13).
- Wigeon, Teal and Common Tern were only recorded flying within the collision risk height band from VPs 1 and 2, apart from one record of Common Tern from VP4. VPs 1 and 2 have been excluded from the analysis, as the data from these vantage points include large amounts of flight activity along the River Shannon, which is not representative of the wind farm site, and the viewsheds do not include any of the turbine locations. Similarly, the viewshed for VP4 includes a section of the River Shannon, and the Common Tern record from this vantage point is assumed to refer to a bird flying along/close to the River Shannon.
- Mute Swan, Teal, Little Egret and Merlin were excluded on the basis of the above criteria in an analysis of the 2014/15-2016/17 VP data. In the summer 2017 and/or winter 2017/18 VP surveys, these species were recorded within the collision risk height band in VPs 3-12. However, the total number of bird-secs recorded for each species was < 1,300. The results of the analysis of the 2014/15-2016/17 VP data show that over 20,000 bird-secs of flight activity in the collision risk zone are required to cause one collision every 25 years (Text Figure 1). Therefore, these species have been excluded from the analyses due to the low level of flight activity recorded.
- Whimbrel and Redshank were only recorded in the summer 2017 and/or winter 2017/18 VP surveys. These species were also excluded on the basis of the low level of flight activity recorded within the collision risk height band (1,030 bird-secs for Whimbrel and 25 bird-secs for Redshank, compared to the 20,000 bird-secs of flight activity in the collision risk zone that would be required to cause one collision every 25 years; Text Figure 1).
- Woodcock and Snipe were recorded flying within the collision risk height band. However, vantage point surveys are not an effective method of recording flight activity of these species, so collision risk modelling would not provide meaningful predictions of likely collision risks.



Text Figure 1. Relationship between total flight activity recorded (across all datasets) and calculated collision risk for the 18 species/populations (including separate breeding and non-breeding populations of three species) included in the CRM, based on the analysis of the 2014/15-2016/17 datasets.

3.1.6. Definition of seasonal periods for the collision risk model

It is necessary to consider seasonal patterns of flight activity in CRM analyses to define the duration of the season that will be used in the CRM analysis. The definition of the duration of the season will affect the results of the CRM analysis due to variation in daylength, as well as the effects of any seasonal variation in survey effort. It is also necessary to consider whether there are separate populations occurring at different times of the year (e.g., a breeding population and a separate wintering population). This is an important consideration because the potential population impact of the predicted collision risk will depend upon the overall size of the population and the background mortality rate, both of which may differ between separate seasonal populations of the same species. Also, the flight activity behaviour may vary between separate seasonal populations of the same species.

Seasonal periods of occurrence were defined for each species (Table 5), based on the seasonal pattern of flight activity recorded by the vantage point surveys (Table 6). However, in doing so, over-interpretation of the monthly flight activity patterns was avoided, and experience and knowledge about species typical occurrence patterns was used to inform the definitions of the seasonal periods. The nature of vantage point surveys is that there will be random fluctuations of flight activity between months, particularly for species where there were only a small number of observations. Based on this analysis, separate seasonal populations were defined for Mallard, Black-headed Gull and Lesser Black-backed Gull.

For Mallard, a breeding/post-breeding population (which covers the breeding season and the post-breeding moulting period) and a separate wintering population were defined. The flight activity data shows much higher levels of flight activity in breeding/post-breeding season, compared to the winter season, which probably reflects, in part, the habit of this species to disperse away from major waterbodies to find nest sites in the breeding season.

For Black-headed Gull, separate breeding and non-breeding populations were defined, reflecting the fact that large breeding colonies of this species occur on Lough Ree. The high levels of flight activity in May and June may represent birds from these colonies travelling to forage for food to provision fledglings.

For Lesser Black-backed Gull, separate breeding and migrant populations were defined, again reflecting the fact that large breeding colonies of this species occur on Lough Ree. The high levels of flight activity in June and July may represent birds from these colonies travelling to forage for food to provision fledglings (Lesser Black-backed Gull breeds slightly later than Black-headed Gull). The definition of a separate migrant population reflects the fact that this species shows significant migration through Ireland, particularly in the spring.

For Cormorant, Golden Plover, Lapwing, Curlew, Common Gull, Herring Gull and Great Black-backed Gull, the data in Table 6 shows some flight activity outside the seasonal periods defined in Table 5. However, the levels of flight activity at collision risk height for these species outside the relevant seasonal periods were zero or very low (maximum of 240 bird-secs for Curlew). As the birds recorded at these times are likely to belong to different populations from those recorded during the seasonal periods defined in Table 5, and as these levels of flight activity are too low to generate any collision risk (see Section 3.1.5), the data from these times has not been included in the collision risk analyses.

For the other species listed in Table 5, no flight activity outside the seasonal periods defined in Table 5 was recorded.

Table 5. Seasonal periods used in the collision risk model.

Species	Season	Months
Whooper Swan	non-breeding	October-March
Mallard	non-breeding breeding/post-breeding	October-February March-September
Cormorant	pre-breeding/breeding	January-August
Hen Harrier	non-breeding	August-March
Sparrowhawk	all year	January-December
Golden Plover	non-breeding	October-April
Lapwing	non-breeding	October-February
Curlew	migration	April-August
Black-headed Gull	non-breeding breeding	September-March April-August
Common Gull	breeding	April-August
Lesser Black-backed Gull	migration breeding	February-March, September April-August
Herring Gull	summering	April-August
Great Black-backed Gull	summering	April-August
Kestrel	all year	January-December
Peregrine	all year	January-December

3.1.7. Definition of viewsheds for the target species

In the context of collision risk modelling, the purpose of vantage point surveys is to generate data on bird flight activity density: e.g., the number of bird-seconds[1] of flight activity per unit area within

[1] Bird-seconds, or bird-secs, measures flight activity as the product of the number of birds flying and the duration of their flight activity.

the study area over the course of a season. Each vantage point survey represents a sample of this flight activity density. The combined data from all the surveys, across all the relevant vantage points, during the appropriate seasonal period, are used to generate the final estimate of flight activity density by dividing the total duration of flight activity observed by the total area covered by the vantage points, and scaling up to represent the total duration of the season. Where more than one vantage point is used, and the viewsheds for some of the vantage points overlap, the total survey area that should be used for the above calculation is the sum of the viewsheds across all the vantage points, not the combined area covered by the vantage points. This means that areas overlapped by viewsheds of two vantage points are counted twice in deriving the total area covered. Where there is significant overlap between viewsheds, failure to take this into account will result in a significant overestimation of flight activity density, and, therefore, a significant overestimation of the potential collision risk. Therefore, the total area covered by the vantage point watches in each dataset (A_{vis}) is the sum of the viewsheds for each vantage point, with the area of each individual viewshed being a semi-circle of radius 2 km (see Section 3.1.2).

In a large wind farm site, there may be variation in flight activity levels between different areas of the site. This variation may affect the collision risk, depending upon how the flight activity is concentrated relative to the proposed locations of the turbines. However, as with assessing seasonal patterns of activity, it is necessary to avoid over-interpretation of the distribution of flight activity patterns, as the nature of vantage point surveys is that there will be random fluctuations of flight activity between vantage points, particularly for species where there were only a small number of observations.

The overall distribution of flight activity between the vantage points is shown in Table 7. It should be noted, that, while the data has been standardised to allow for variable survey effort between the vantage points, the recorded flight activity levels in vantage points that were covered for fewer seasons (VPs 1, 2, 6, 11 and 12) are more likely to be biased by random variation. This table shows the concentration of flight activity for certain species in vantage points 1 and 2 and, as discussed above, these vantage points have been excluded from the CRM analysis. Excluding these vantage points, the other apparently significant variation in flight activity involved Cormorant, Curlew, Black-headed Gull, and Lesser Black-backed Gull.

All the recorded Cormorant flight activity was observed from two clusters of VPs: VPs 1-5 and 12; and VPs 9-11. The concentration of flight activity in the first cluster is likely to be associated its proximity to the River Shannon. The second cluster had much lower levels of flight activity and only had one record (27 bird-secs) at collision risk height during the seasonal period defined for Cormorant. Therefore, the overall viewshed (A_{vis}) for Cormorant has been defined as the viewsheds for VPs 3-5 and 12.

All Curlew records occurred from VPs 4, 9 and 10. However, most Curlew records occurred in just three months (July and August 2016 and August 2017), and there do not appear to be any specific habitat factors that would explain the concentration of records in these areas. Therefore, the overall viewshed (A_{vis}) for Curlew has been retained as the overall area covered by all the vantage points.

Flight activity for Black-headed Gull and Lesser Black-backed Gull was recorded from all vantage points except VP12, but showed a strong concentration in the viewshed for VP6. The birds recorded from this vantage point were mainly flying east-west across the site and were presumably commuting to/from Lough Ree. However, because of the overlapping viewsheds and the lack of flight mapping information, it is difficult to factor this variation into the CRM analysis. The viewshed for VP6 includes a relatively low number of proposed turbines (4 no. turbines, compared to a mean of 6.3 across all the vantage points). This means that using the overall area covered by all the vantage points for the CRM analysis without accounting for the concentration of activity in the viewshed for VP6 will tend to overestimate the potential collision risk.

Table 6. Monthly distribution of flight activity recorded for the target species during the vantage point watches.

Species	Standardised	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whooper Swan	records	18	32	12	0	0	0	0	0	0	31	27	29
	bird-secs	3813	14495	8450	0	0	0	0	0	0	5092	6941	9290
Mallard	records	7	19	38	75	43	19	15	21	39	7	12	8
	bird-secs	1074	1828	3325	4251	2276	612	692	1982	1673	2192	22532	213
Cormorant	records	5	39	38	58	141	59	44	21	1	3	0	4
	bird-secs	322	1867	4516	3349	10934	6183	3175	2603	103	70	0	95
Hen Harrier	records	6	1	2	0	0	0	0	1	3	5	2	2
	bird-secs	887	23	114	0	0	0	0	20	37	191	141	95
Sparrowhawk	records	11	12	8	8	10	11	15	14	9	12	11	16
	bird-secs	450	365	295	828	551	824	1436	434	801	457	254	1416
Golden Plover	records	15	6	13	31	3	0	0	0	0	27	11	4
	bird-secs	91318	12335	354202	380645	3284	0	0	0	0	509993	8633	4616
Lapwing	records	10	5	1	0	0	1	1	2	1	5	23	6
	bird-secs	27777	10979	0	0	0	154	2554	3264	75177	11478	97536	24105
Curlew	records	0	0	0	3	0	0	10	11	0	1	0	1
	bird-secs	0	0	0	182	0	0	16923	1378	0	27	0	191
Black-headed Gull	records	11	13	25	21	117	118	15	3	2	2	11	11
	bird-secs	1913	10030	17866	5581	18099	13294	1151	932	261	172	9487	2106
Common Gull	records	0	0	7	4	0	3	1	0	0	0	0	0
	bird-secs	0	0	2331	1147	0	327	18	0	0	0	0	0
Lesser Black-backed Gull	records	5	5	88	237	468	599	440	221	18	0	4	0
	bird-secs	230	1214	82345	33832	73972	122758	109788	135490	47905	0	159	0
Herring Gull	records	0	0	1	1	0	0	3	0	0	0	0	0
	bird-secs	0	0	55	312	0	0	44	0	0	0	0	0
Great Black-backed Gull	records	2	0	1	17	4	7	9	0	0	0	0	0
	bird-secs	100	0	436	833	239	363	476	0	0	0	0	0

Species	Standardised	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kestrel	records	27	15	19	17	5	17	28	32	61	49	35	34
	bird-secs	6584	901	1311	2128	684	1553	1477	3350	9009	9808	6828	6389
Peregrine	records	1	0	0	1	0	3	0	0	2	1	3	1
	bird-secs	164	0	0	120	0	148	0	0	407	23	668	55

Based on analysis of all flight activity data, including data from VPs 1 and 2, and observations of flights below and above the collision risk height band. The records and bird-sec values have been standardised to represent equal survey effort per month, using the following formula: standardised $value_i$ = raw $value_i$/total VP $effort_i$*mean VP effort, where i is the month and VP $effort_i$ is the total duration of vantage point watches in month I, and mean VP effort is the mean VP effort per month.

Table 7. Distribution between vantage points of the flight activity recorded for the target species during the vantage point watches.

Species	Standardised	VP1*	VP2*	VP3	VP4	VP5	VP6*	VP7	VP8	VP9	VP10	VP11*	VP12**
Whooper Swan	records	104	20	11	14	12	2	7	3	3	7	0	23
	bird-secs	19523	2319	1768	6775	11783	816	2732	846	893	2761	0	6273
Mallard	records	111	74	4	33	15	15	6	11	6	27	4	14
	bird-secs	39033	3890	451	2688	871	625	275	790	1823	2396	307	1402
Cormorant	records	111	246	39	47	7	0	0	1	1	2	3	3
	bird-secs	12060	16524	2703	4132	1001	0	0	47	48	132	172	14
Hen Harrier	records	10	2	0	1	3	2	1	2	2	1	5	0
	bird-secs	362	24	0	47	208	163	345	47	192	47	294	0
Sparrowhawk	records	10	27	13	6	4	11	5	12	17	10	19	22
	bird-secs	733	1159	958	989	246	151	318	767	1021	494	561	483
Golden Plover	records	23	2	13	9	5	8	9	11	18	3	8	0
	bird-secs	692459	457	109425	31688	28631	394637	22668	206957	140970	9311	11334	0
Lapwing	records	38	21	1	3	4	0	1	2	0	1	0	16
	bird-secs	87725	999	901	18643	94090	0	47	2867	0	7990	0	78594
Curlew	records	1	1	0	2	0	0	0	0	2	15	0	0
	bird-secs	115	110	0	194	0	0	0	0	90	15442	0	0
Black-headed Gull	records	116	185	5	13	16	47	8	9	4	4	3	3
	bird-secs	36604	34853	226	4055	5331	14074	1658	2673	66	404	201	492

Species	Standardised	VP1*	VP2*	VP3	VP4	VP5	VP6*	VP7	VP8	VP9	VP10	VP11*	VP12**
Common Gull	records	7	5	1	0	2	0	0	1	0	1	0	0
	bird-secs	2341	895	50	0	534	0	0	188	0	16	0	0
Lesser Black-backed Gull	records	279	260	182	149	202	468	170	95	55	50	112	11
	bird-secs	105814	28899	41862	20978	112202	119142	79762	21274	10245	6992	40252	2416
Herring Gull	records	1	0	2	0	0	0	0	1	0	0	0	0
	bird-secs	68	0	37	0	0	0	0	188	0	0	0	0
Great Black-backed Gull	records	5	0	1	2	7	7	3	4	2	0	0	0
	bird-secs	703	0	25	30	229	171	286	532	115	0	0	0
Kestrel	records	17	7	34	19	39	30	18	33	17	43	27	87
	bird-secs	1115	718	8517	3417	2691	2232	2187	6974	898	4822	4683	22668
Peregrine	records	0	0	5	1	0	1	1	1	0	2	0	0
	bird-secs	0	0	178	143	0	165	530	47	0	290	0	0

Based on analysis of all flight activity data, including data from VPs 1 and 2, and observations of flights below and above the collision risk height band. The records and bird-sec values have been standardised to represent equal survey effort per vantage point, using the following formula: standardised $value_i$ = raw $value_i$/total VP $effort_i$*mean VP effort, where i is the vantage point and VP $effort_i$ is the total duration of vantage point watches at that vantage point, and mean VP effort is the mean VP effort per vantage point.

* = not covered before summer 2016.

** = only covered in winter 2016/17 and winter 2017/18.

3.1.8. Summer 2017 data

The review and analysis of the vantage point survey coverage and results presented above shows that the summer 2017 VP surveys are something of an outlier. There appear to be significant differences in the VP coverage, due to use of different aspects for some of the VPs, the viewshed mapping indicates reduced viewshed coverage (even allowing for the differences in the heights used for the viewshed analyses), and the VP data uses a significantly lower height band for the collision risk height zone. As detailed maps of the viewshed coverage, at the relevant height level, for the summer 2017 surveys are not available, it has not been possible to include the data from the summer 2017 surveys in the CRM. However, Section 4.1.4 presents a qualitative assessment of the broad degree of the likely changes in the predicted collision risk in data from the summer 2017 VP survey was included has been included.

4. COLLISION RISK MODELLING

4.1.1. Parameters

The wind turbine parameters used for the calculations are shown in Table 8. The bird dimension and behaviour parameters used for calculations are shown in Table 9. The parameters derived from the vantage point observations are shown in Table 10, Table 11 and Table 12.

Table 8. Wind turbine parameters used in the collision risk calculations.

Parameter	Value	Units	Details
N_{turb}	9 (Cormorant)* 24 (all other species)	-	Number of turbines
183	183 (Cormorant)* 1,008 (all other species)	ha	Flight risk area, defined as the area enclosed by the outer turbines, plus a buffer equal to the rotor radius around this area.
H_{rotor}	130	m	Rotor diameter
L_{rotor}	1.13	m	Rotor depth
V_w	0.238 (Cormorant)* 1.310 (all other species)	km^3	Flight risk volume, defined as A_{risk}* H_{rotor}
V_r	species-specific values	m^3	Volume swept by the rotors, defined as N_{turb}* π* $(H_{rotor}/2)^2$*$(L_{rotor}+L_{bird})$
b	3		Number of blades in rotor
c_{max}	3.13	m	Maximum chord of rotor blade
γ	30°		Average pitch angle of blade
Rotation speed	10.35	rpm	Calculated from the mid-point of the operational range of rotor speeds (7.5-13.2 rpm)

* See Section 3.1.7 for the rationale for using a reduced viewshed for Cormorant, which results in including lower values of N_{turb}, A_{risk} and V_w in the analysis. As discussed there, this provides a more accurate assessment of the likely collision risk than would result from using the full viewshed for the analysis.

Sources: N_{turb} and H_{rotor} supplied by TOBIN Consulting Engineers; A_{risk} derived from 201711_DerryaddWF_24WT_coordinates_INGTM65_withWTlabels.xlsx; L_{rotor}, c_{max}, γ and rotation speed taken from Appendix 6.7 of Cloncreen Wind Farm EIS.

Note: In the calculations of bird transits, L_{rotor} cancels out, so the value of this parameter is not important. However, it is useful to include the parameter for visualisation of the calculation steps.

Table 9. General bird parameters used in the collision risk calculations.

Parameter	Species	Value	Units	Details
	Whooper Swan	1.52		
	Mallard	0.58		
	Cormorant	0.9		
	Hen Harrier	0.48		
	Sparrowhawk	0.33		
	Golden Plover	0.28		
	Lapwing	0.3		
L_{bird}	Curlew	0.55	m	Bird length
	Black-headed Gull	0.36		
	Common Gull	0.41		
	Lesser Black-backed Gull	0.58		
	Herring Gull	0.6		
	Great Black-backed Gull	0.71		
	Kestrel	0.34		
	Peregrine	0.42		
	Whooper Swan	2.3		
	Mallard	0.9		
	Cormorant	1.45		
	Hen Harrier	1.1		
	Sparrowhawk	0.62		
	Golden Plover	0.72		
	Lapwing	0.84		
W_{bird}	Curlew	0.9	m	Bird wingspan
	Black-headed Gull	1.05		
	Common Gull	1.2		
	Lesser Black-backed Gull	1.42		
	Herring Gull	1.44		
	Great Black-backed Gull	1.58		
	Kestrel	0.76		
	Peregrine	1.02		
	Whooper Swan	17.3		
	Mallard	18.5		
	Cormorant	15.2		
	Hen Harrier	9.1		
	Sparrowhawk	11.3		
	Golden Plover	17.9		
	Lapwing	12.8		
v_{bird}	Curlew	16.3	m/sec	Mean velocity of a flying bird
	Black-headed Gull	11.9		
	Common Gull	13.4		
	Lesser Black-backed Gull	13.1		
	Herring Gull	12.8		
	Great Black-backed Gull	13.7		
	Kestrel	10.1		
	Peregrine	12.1		

Parameter	Species	Value	Units	Details
T_{bird}	Whooper Swan	0.153	secs	Time taken for a bird to fly through rotors of one turbine, calculated as $(L_{rotor}+L_{bird})/v_{bird}$
	Mallard	0.092		
	Cormorant	0.134		
	Hen Harrier	0.177		
	Sparrowhawk	0.129		
	Golden Plover	0.0788		
	Lapwing	0.112		
	Curlew	0.103		
	Black-headed Gull	0.125		
	Common Gull	0.115		
	Lesser Black-backed Gull	0.131		
	Herring Gull	0.135		
	Great Black-backed Gull	0.134		
	Kestrel	0.146		
	Peregrine	0.128		
D_{season}	Whooper Swan	1704	hours	Total duration of flight period across the season, defined as the product of the number of days in the season and the mean day length
	Mallard (breeding)	3148		
	Mallard (non-breeding)	1339		
	Cormorant	3281		
	Hen Harrier	2086		
	Sparrowhawk	4480		
	Golden Plover	2127		
	Lapwing	1339		
	Curlew	2400		
	Black-headed Gull (breeding)	2400		
	Black-headed Gull (non-breeding)	2086		
	Common Gull	2400		
	Lesser Black-backed Gull (breeding)	2400		
	Lesser Black-backed Gull (non-breeding)	1017		
	Herring Gull	2400		
	Great Black-backed Gull	2400		
	Kestrel	4480		
	Peregrine	4480		
Avoidance rates	Whooper Swan	0.995		See Section 4.1.3 for details
	Mallard	0.98		
	Cormorant	0.98		
	Hen Harrier	0.99		
	Sparrowhawk	0.98		
	Golden Plover	0.98		
	Lapwing	0.98		
	Curlew	0.98		
	Black-headed Gull	0.98		
	Common Gull	0.98		
	Lesser Black-backed Gull	0.98		
	Herring Gull	0.98		
	Great Black-backed Gull	0.98		
	Kestrel	0.95		
	Peregrine	0.98		

L_{bird} and W_{bird} values taken from www.bto.org/about-birds/birdfacts (accessed 08/06/2017). v_{bird} values taken from Alerstam et al. (2007); for Golden Plover, which is not included in that source, the flight speed for Grey Plover has been used (which is of similar size and build). Avoidance rates taken from Scottish Natural Heritage (2016). Note, where relevant, values are presented rounded to three significant figures but unrounded figures were used for the calculations.

Table 10. Vantage point observation parameters used in the collision risk calculations.

Parameter	Species/season	Values	Units	Details
VP_{eff}	Species-specific values for each dataset, calculated as the total survey effort in the months covered by the dataset that overlap the seasonal period of occurrence for the species/population	see Table 11	hours	Total duration of vantage point watches in the relevant survey period
A_{vis} (Cormorant)	winter 2014/15-winter 2015/16 summer 2016 winter 2016/17 and winter 2017/18	1885 1885 2513	ha	Overall viewshed (A_{vis})
A_{vis} (all other species)	winter 2014/15-winter 2015/16 summer 2016 winter 2016/17 and winter 2017/18	4398 5655 6285	ha	Overall viewshed (A_{vis})
D_{bird}	Species-specific values for each dataset	see Table 12	bird-secs	Total observed flight activity (bird-secs) at rotor height, summed across all vantage point watches in the relevant survey period

Table 11. Species-specific vantage point effort in hours for each dataset included in the CRM.

Species/season	2014/15 winter	2015 summer	2015/16 winter	2016 summer	2016/17 winter	2017/18 winter
Whooper Swan	252	0	252	0	360	360
Mallard (breeding)	42	210	84	406	60	60
Mallard (non-breeding)	210	0	210	0	300	300
Cormorant	54	90	54	113	72	72
Hen Harrier	252	210	294	406	360	360
Sparrowhawk	252	210	294	406	360	360
Golden Plover	252	42	252	43	360	360
Lapwing	210	0	210	0	300	300
Curlew	0	210	0	340	0	0
Black-headed Gull (breeding)	0	210	0	340	0	0
Black-headed Gull (non-breeding)	252	0	294	66	360	360
Common Gull	0	210	0	340	0	0
Lesser Black-backed Gull (breeding)	0	210	0	340	0	0
Lesser Black-backed Gull (migration)	84	0	126	66	120	120
Herring Gull	0	210	0	340	0	0
Great Black-backed Gull	0	210	0	340	0	0
Kestrel	252	210	294	406	360	360
Peregrine	252	210	294	406	360	360

Table 12. Species-specific flight-activity data in bird-secs for each dataset included in the CRM.

Species/season	2014/15 winter	2015 summer	2015/16 winter	2016 summer	2016/17 winter	2017/18 winter
Whooper Swan	890	0	123	0	684	11,909
Mallard (breeding)	12	0	210	384	0	755
Mallard (non-breeding)	75	0	0	0	8	545
Cormorant	14	0	0	1,023	0	250
Hen Harrier	30	0	0	0	0	85
Sparrowhawk	441	0	52	75	150	285
Golden Plover	75,191	0	2,100	660	12,697	379,884
Lapwing	0	0	10,200	0	6,150	64,330
Curlew	0	1	0	1,911	0	0
Black-headed Gull (breeding)	0	312	0	3,361	0	0
Black-headed Gull (non-breeding)	317	0	24	0	7,200	4,245
Common Gull	0	0	0	639	0	0
Lesser Black-backed Gull (breeding)	0	5,157	0	36,755	0	0
Lesser Black-backed Gull (migration)	0	0	13,470	600	33,045	10,191
Herring Gull	0	0	0	252	0	0
Great Black-backed Gull	30	8	0	1,049	0	0
Kestrel	267	159	288	1,840	979	10,771
Peregrine	0	0	0	120	0	0

4.1.2. Stage 1 calculations

The stage 1 calculations use the vantage point survey data to calculate the predicted number of bird transits across the rotor swept volume. There are two methods described by Scottish Natural Heritage (2000) for carrying out stage 1 calculations: the “risk window” approach for when birds make regular flights through the flight risk area (e.g., geese commuting between roost sites and feeding areas); and the “bird occupancy” approach for when birds show variable patterns of flight activity within flight risk area. Review of flightline mapping is normally used to determine the appropriate method, but complete flightline mapping was not available for this assessment. However, the “bird occupancy” approach is generally the appropriate method for species that show variable patterns of flight activity and, given the nature of the Derryadd wind farm site and its landscape position, is likely to be the appropriate method for most/all of the species included in this assessment.

The sequential calculation steps used for this stage are shown in Table 13. Because there was variable survey effort (number of vantage points and duration of vantage point watches) between the different datasets included in the CRM analysis, separate calculations were carried out for each dataset. The overall predicted number of transits per year for each species was then calculated by the following formula:

$$\text{predicted number of transits per year} = \text{sum}_{(i=1\text{ to }5)}(N_{transits(i)})/\text{sum}_{(i=1\text{ to }5)}(m_i/M)$$

where i is the dataset number (1 = winter 2014/15, 2 = summer 2015, 3 = winter 2015/16, 4 = summer 2016, 5 = winter 2016/17), m_i is the number of months from that dataset included in the season for that species/population, and M is the total number of months included in the season for that species/population.

The predicted number of transits per year is shown in Table 15.

Table 13. Sequential steps in the calculations of predicted number of bird transects across the rotor swept volume.

Step	Parameter	Calculation	Units	Details
1	t_1	D_{bird}/VP_{eff}	birds	Instantaneous mean number of birds flying at rotor height across the total observation time
2	F	t_1/A_{vis}	birds/ha	Instantaneous mean number of birds flying at rotor height across the total observation time per hectare of visible area
3	t_2	$F*A_{risk}$	birds	Predicted instantaneous mean number of birds flying at rotor height in the flight risk area across the total observation time
4	n	$t_2*D_{season}*3600$	bird-secs	Predicted total flight activity at rotor height in the flight risk area across the entire season
5	b	$n*(V_r/V_w)$	bird-secs	Bird occupancy of the swept volume across the entire season
6	$N_{transits}$	b/T_{bird}	bird transits	Predicted number of transits across the swept volume across the entire season

Note: step 3 is not strictly necessary for the calculation (as it cancels out in step 5, because $V_w = A_{risk} * H_{rotor}$). However, this step is included as it is useful to visualise the total amount of flight activity in the wind farm area.

4.1.3. Stage 2 calculations

The probability of a bird actually colliding with the turbine blades when making a transit through a rotor depends on a number of factors. These include: the size and flight speed of the bird, the position of the bird relative to the turbine hub, the angle of approach of the bird, the chord width and pitch angle of the turbine blades, and the rotation speed of the turbine. The Scottish Natural Heritage collision risk model (Scottish Natural Heritage, 2000; Band et al., 2007; Band, 2012) calculates the probability, p (r, φ), of collision for a bird at radius r from the hub and at a position along a radial line that is at angle φ from the vertical. This probability is then integrated over the entire rotor disc, assuming that the bird transit may be anywhere at random within the area of the disc. Separate calculations are made for flapping and gliding birds and for upwind and downwind transits. This method makes the following assumptions: birds are assumed to be of a simple cruciform shape, to fly through turbines in straight lines with a perpendicular approach to the plane of the rotor, and their flight is not affected by the slipstream of the turbine blade; and turbine blades are assumed to have width and pitch angle, but no thickness.

The calculated collision probability values are shown in Table 17. These were calculated using the single transit collision risk spreadsheet provided by Band (2012). This spreadsheet was used, instead of the original spreadsheet from Scottish Natural Heritage (2000), because the taper profile included is more likely to be representative of modern turbine blades.

The predicted collision rate (collisions/year) is calculated as the product of the predicted number of bird transits/year (calculated in stage 1) and the probability of a collision occurring per transit (as in Table 14). However, a further factor that reduces the collision rate is avoidance and it is likely that most potential collisions are avoided due to birds taking evasive action (Scottish Natural Heritage, 2010). This avoidance rate includes both behavioural avoidance (micro-avoidance) and behavioural displacement (macro-avoidance). Behavioural avoidance is “action taken by a bird, when close to an operational wind farm, which prevents a collision”. Behavioural displacement refers to the process by which a “bird may (possibly over time) change its home range, territory, or flight routes between roosting areas and feeding areas, so that its range use (or flight paths) no longer bring the bird into the vicinity of an operational wind farm”. Scottish Natural Heritage provides guidance on avoidance rates to use in collision risk assessments (Scottish Natural Heritage, 2010, 2016). For some species, including Whooper Swan, Hen Harrier and Kestrel, there is some evidence available that has been used to specify species-specific avoidance rates. However, for most species a default avoidance rate of 98% has been specified in the absence of any evidence. The avoidance rates used in the present assessment are listed in Table 9.

The predicted collision rates obtained from the collision risk modelling carried out in this assessment are shown in Table 15.

Table 14. Collision probability calculations.

Species	Flapping bird, %p		Gliding bird, %p		mean %p
	upwind	downwind	upwind	downwind	
Whooper Swan	10.2%	6.3%	9.7%	5.9%	8.0%
Mallard	6.8%	3.0%	6.6%	2.9%	4.8%
Cormorant	8.8%	4.8%	8.6%	4.6%	6.7%
Hen Harrier	10.3%	5.7%	10.1%	5.6%	7.9%
Sparrowhawk	8.1%	3.7%	8.0%	3.6%	5.8%
Golden Plover	6.1%	2.3%	5.9%	2.1%	4.1%
Lapwing	7.5%	3.2%	7.2%	3.0%	5.2%
Curlew	7.2%	3.3%	7.0%	3.1%	5.2%
Black-headed Gull	8.1%	3.8%	7.9%	3.6%	5.8%
Common Gull	7.9%	3.7%	7.5%	3.3%	5.6%
Lesser Black-backed Gull	8.6%	4.4%	8.3%	4.0%	6.3%
Herring Gull	8.8%	4.6%	8.5%	4.2%	6.5%
Great Black-backed Gull	8.9%	4.7%	8.5%	4.4%	6.6%
Kestrel	8.8%	4.3%	8.7%	4.2%	6.5%
Peregrine	8.2%	3.9%	8.0%	3.7%	6.0%

Table 15. Predicted collision rate.

Species	Season	mean p	Transits/ year	collisions/ year	collisions/ 30 years	years/ collisions
Whooper Swan	non-breeding	8.0%	11.7	0.0047	0.1412	212
Mallard	breeding/post-breeding	4.8%	10.4	0.0100	0.3000	100
	non-breeding		0.7	0.0006	0.0190	1,575
Cormorant	pre-breeding/breeding	6.7%	5.6	0.0075	0.2258	133
Hen Harrier	non-breeding	7.9%	0.1	0.00006	0.0017	17,978
Sparrowhawk	all year	5.8%	1.1	0.0013	0.0380	790
Golden Plover	non-breeding	4.1%	491.0	0.4037	12.1098	2
Lapwing	non-breeding	5.2%	58.9	0.0616	1.8490	16
Curlew	migration	5.2%	4.8	0.0049	0.1477	203
Black-headed Gull	breeding	5.8%	7.3	0.0085	0.2563	117
	non-breeding		7.2	0.0084	0.2519	119
Common Gull	breeding	5.6%	1.3	0.0015	0.0439	684
Lesser Black-backed Gull	breeding	6.3%	95.3	0.1205	3.6162	8
	migration		76.8	0.0972	2.9170	10
Herring Gull	summering	6.5%	0.5	0.0006	0.0194	1,550
Great Black-backed Gull	summering	6.6%	2.2	0.0030	0.0888	338
Kestrel	all year	6.5%	10.2	0.0330	0.9901	30
Peregrine	all year	6.0%	0.1	0.0002	0.0052	5,824

4.1.4. Summer 2017

It has not been possible to include the summer 2017 VP data in the collision risk modelling, for the reasons discussed in Section 3.1.8 However, it is possible to make some inferences about how this data would have affected the output of the CRM by comparing the overall level of flight activity recorded in the three summer VP survey datasets (Table 16), taking account of the fact that the survey effort in summer 2015 was only around half the level of the survey efforts in summer 2016 and summer 2017.

The most striking difference in flight activity in summer 2017, compared to the previous summers, was the high level of Lapwing flight activity as this species was not recorded in the previous summers. However, this flight activity resulted from just two records, with most of the bird-secs being contributed by one flock of 80 birds recorded in flight for a period of nearly 14 minutes. There was also a very large increase in Golden Plover flight activity, with most of this flight activity being recorded in the April VP watches.

Inclusion of the summer 2017 data would increase the overall estimates of summer flight activity for eight of the species by 88-360%, and decrease the overall estimates of summer flight activity for six of the target species by 6-33% (Table 16). For summer/breeding populations, the estimates of collision risk can be adjusted by these percentage changes to give an approximate indication of the change in collision risk that would be caused by including the summer 2017 data. For resident (all year) populations, the estimates of collision risk can be adjusted by half the level of these percentage changes to give an approximate indication of the change in collision risk that would be caused by including the summer 2017 data. For populations that partially overlap the summer and winter periods, the change will be more complex.

Note that using the percentage changes in Table 16 to indicate the change in collision risk that would be caused by including the summer 2017 data assumes that the variations in the level of flight activity at collision risk height are correlated with variations in the overall level of flight activity. This assumption is likely to be correct for species with high levels of flight activity that typically occur as individuals or in small groups. However, for species with low levels of flight activity, or which can occur in large flocks, a single record can cause big differences in recorded levels of flight activity, so the assumption may not be correct.

Bird flight activity data as recorded by vantage point surveys is inherently variable. This can often reflect real variation in bird flight activity: e.g., a migratory flock of Lapwings may settle in the area for a few days in one year but not in another year. There will also be sampling effects: e.g., migratory flock of Lapwings may pass through the area each year but are only present for a few days, and the vantage point surveys may happen to coincide with their occurrence in one year but not in another year. This means that repeated vantage point surveys in the same area each year will record different levels of flight activity and CRMs derived from these surveys will produce different estimates of collision risk. Therefore, while the CRM produces figures that appear to be very precise, given this inherent variability, it is probably safest to interpret the results of CRM analyses as only indicating the order of magnitude of the predicted collision risk. None of the percentage change figures in Table 16 would result in an order of magnitude increase in the predicted collision risk. Therefore, the analysis in Table 16 indicates that inclusion of the summer 2017 data would not significantly change the overall findings of the collision risk assessment for the Derryadd Wind Farm.

Table 16. Comparison of the flight activity of the target species recorded in the summer datasets.

Species	Total flight activity (bird-secs) in recorded:			% change
	Summer 2015	Summer 2016	Summer 2017	
Mallard	0	2,073	3,794	+89%
Cormorant	0	1,503	8,080	+325%
Hen Harrier	0	15	0	-33%
Sparrowhawk	658	338	2,322	+60%
Golden Plover	15,090	660	181,839	+360%
Lapwing	0	0	69,565	-
Curlew	52	17,938	698	-31%
Black-headed Gull	317	7,703	3,364	-6%
Common Gull	0	961	0	-33%
Lesser Black-backed Gull	8,110	126,525	258,751	+88%
Herring Gull	0	285	0	-33%
Great Black-backed Gull	8	1,540	0	-33%
Kestrel	320	3,343	11,824	+165%
Peregrine	0	150	453	+168%

Based on analysis of all flight activity data, excluding data from VPs 1 and 2, and observations of flights below and above the collision risk height band.

% change = (mean flight activity across all three summers)/(mean flight activity in summer 2015 and summer 2016)*100; with the summer 2015 flight activity multiplied by a factor of two to account for the lower survey effort.

Survey efforts: 210 hours (April-August) in summer 2016; 405.5 hours (April-September) in summer 2016; and 402 hours (April-September) in summer 2017.

4.1.5. Assessment of significance

The population-level consequences of predicted collision risks can be assessed by considering the additional mortality that would be caused (assuming that the collision risk is non-additive) relative to background mortality rates in the population, with a threshold level of a 1% increase in annual mortality used to determine whether the impact will be significant (Percival, 2003). Estimates of the potential increase in annual mortality rates for the four species (Golden Plover, Lapwing and Lesser Black-backed Gull) with measurable collision risks (i.e., at least one collision in 30 years) are shown in Table 17. These estimates are broadly indicative only, as there is limited data available on the relevant population sizes. However, the estimates make conservative assumptions. For all four species, the additional mortality due to collision risk is below the 1% threshold.

For both Golden Plover and Lesser Black-backed Gull, inclusion of the summer 2017 data would be likely to increase the overall collision risk (see Section 4.1.4) and, therefore, cause a higher level of potential increase in annual mortality rates. In the case of Golden Plover, the summer 2017 survey period (April-September) only overlaps with one of the seven months included in the Golden Plover seasonal period (October-April). Therefore, the percentage change in Table 16 should be multiplied by a factor of 1/7 to give an approximate indication of the change in collision risk that would be caused by including the summer 2017 data. This suggests that inclusion of the summer 2017 data would increase the calculated collision risk by around 50%, but the additional mortality due to collision risk would remain well below the 1% threshold. In the case of Lesser Black-backed Gull, the summer 2017 survey period (April-September) includes the entire Lesser Black-backed Gull breeding season (April-August) and includes one-third of the Lesser Black-backed Gull migration season. This suggests that inclusion of the summer 2017 data would cause a near doubling of the calculated collision risk for the Lesser Black-backed Gull breeding population, and an increase in the calculated collision risk for the Lesser Black-backed Gull migratory population of around one-third. This would push the level of additional mortality due to collision risk to close to the 1% threshold.

Table 17. Calculations of potential increases in annual mortality rates due to the predicted collision mortality rates for Golden Plover and Lesser Black-backed Gull.

Parameter	Description	Source/ calculation	Golden Plover (local wintering population)	Lapwing (local wintering population)	Lesser Black-backed Gull (Lough Ree breeding population)	Kestrel (local population in hectad centred on wind farm site)
pop	population size	Source 1	1300	500	500	50
surv	annual survival rate	Source 2	0.73	0.705	0.913	0.505
mort(back)	annual background mortality	pop*(1-surv)	351	147.5	43.5	15.5
mort(coll)	predicted annual collision mortality	Source 3	0.40	0.06	0.22	0.03
∆mort	increase in annual mortality rate due to collisions	mort(coll))/ mort(back)	0.12%	0.04%	0.50%	0.21%

Source 1: mean annual peak count for Fortwilliam Turlough, 2004/05-2008/09 (Boland and Crowe, 2012) for Golden Plover; 50% of the maximum count for Fortwilliam Turlough, 2004/05-2008/09 (Boland and Crowe, 2012) for Lapwing; based on 250 apparently occupied territories recorded in 2012 (Hunt et al., 2013) for Lesser Black-backed Gull; based on low density population density estimate in Clements (2008) of 20 pairs/hectad with an additional ten birds added to represent juveniles post-fledging for Kestrel.

Source 2: adult survival rates from www.bto.org/about-birds/birdfacts, accessed 12/06/2017; note that the Golden Plover, Lapwing and Kestrel populations will include first year birds with lower annual survival rates.

Source 3: predicted collision rates from Table 15; note that the collision rate used for Lesser Black-backed Gull is the combined collision rate for the migrant and breeding populations to account for potential overlap between these populations (i.e., some of the birds recorded during the migration season are likely to be part of the Lough Ree breeding population).

5. CONCLUSIONS

There are a number of potential sources of error/uncertainty that apply to all CRM analyses. The main potential sources of error in CRM analyses are the representativeness of the flight activity data (which will affect the accuracy of the predicted transit rate), the simplifications involved in the calculation of collision probabilities, and the lack of knowledge about avoidance rates for most species. For some species, another source of uncertainty is that the flight activity data is necessarily restricted to daylight hours, while these species may also be active at night. In the present assessment, the only species that are likely to have significant levels of flight activity at night are Mallard, Golden Plover and Lapwing, while Whooper Swan commuting flights to/from roosts may extend a short time before sunrise/after sunset, and Curlew can show significant levels of nocturnal activity in some circumstances[2]. For species that are active at night, the predicted collision rate should be increased by a factor representing the proportion of activity that occurs at night. Therefore, while the CRM produces figures that appear to be very precise, given these uncertainties, it is probably safest to interpret the results of CRM analyses as only indicating the order of magnitude of the predicted collision risk. However, in the present assessment, the predicted collision risks are very low for all the target species, with only Golden Plover, Lapwing and Lesser Black-backed Gull being predicted to have any collisions within the nominal 30 year

[2] Curlew wintering in intertidal habitats are active at night, but wintering populations of Curlew feeding in fields show strictly diurnal activity patterns.

operational period of the wind farm. Therefore, even allowing for the uncertainties associated with CRM analyses, it can be concluded that the collision risk for most of the target species is negligible, without carrying out assessment of population level consequences.

Measurable collision risks (i.e., at least one collision in 30 years) are predicted for four of the target species: Golden Plover, Lapwing, Lesser Black-backed Gull and Kestrel. For Golden Plover and Lapwing, the population level consequences of the predicted collision risk, even allowing for the various uncertainties associated with CRM analyses, and the increased collision risk that would result from inclusion of the summer 2017 data are not likely to be significant. For Lesser Black-backed Gull, the predicted collision mortality rate is calculated to cause an increase in the annual mortality rate of 0.5%. Given the uncertainties associated with CRM analyses, and the fact that inclusion of the summer 2017 data could have resulted in a significant increase in the calculated collision risk, this is close enough to the 1% threshold to require further assessment.

6. REFERENCES

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Appendix 1 Scientific Names

English name	Species name	English name	Species name
Black-headed Gull	*Chroicocephalus ridibundus*	Little Egret	*Egretta garzetta*
Buzzard	*Buteo buteo*	Little Grebe	*Tachybaptus ruficollis*
Canada Goose	*Branta canadensis*	Mallard	*Anas platyrhynchos*
Common Gull	*Larus canus*	Merlin	*Falco columbarius*
Common Tern	*Sterna hirundo*	Moorhen	*Gallinula chloropus*
Coot	*Fulica atra*	Mute Swan	*Cygnus olor*
Cormorant	*Phalacrocorax carbo*	Peregrine	*Falco peregrinus*
Curlew	*Numenius arquata*	Redshank	*Tringa totanus*
Golden Plover	*Pluvialis apricaria*	Ringed Plover	*Charadrius hiaticula*
Great Black-backed Gull	*Larus marinus*	Short-eared Owl	*Asio flammeus*
Great Crested Grebe	*Podiceps cristatus*	Snipe	*Gallinago gallinago*
Greenland White-fronted Goose	*Anser albifrons flavirostris*	Sparrowhawk	*Accipiter nisus*
Grey Heron	*Ardea cinerea*	Teal	*Anas crecca*
Greylag Goose	*Anser anser*	Tufted Duck	*Aythya fuligula*
Hen Harrier	*Circus cyaneus*	Water Rail	*Rallus aquaticus*
Herring Gull	*Larus argentatus*	Whimbrel	*Numenius phaeopus*
Kestrel	*Falco tinnunculus*	White-tailed Eagle	*Haliaeetus albicilla*
Kingfisher	*Alcedo atthis*	Whooper Swan	*Cygnus cygnus*
Lapwing	*Vanellus vanellus*	Wigeon	*Anas penelope*
Lesser Black-backed Gull	*Larus fuscus*	Woodcock	*Scolopax rusticola*

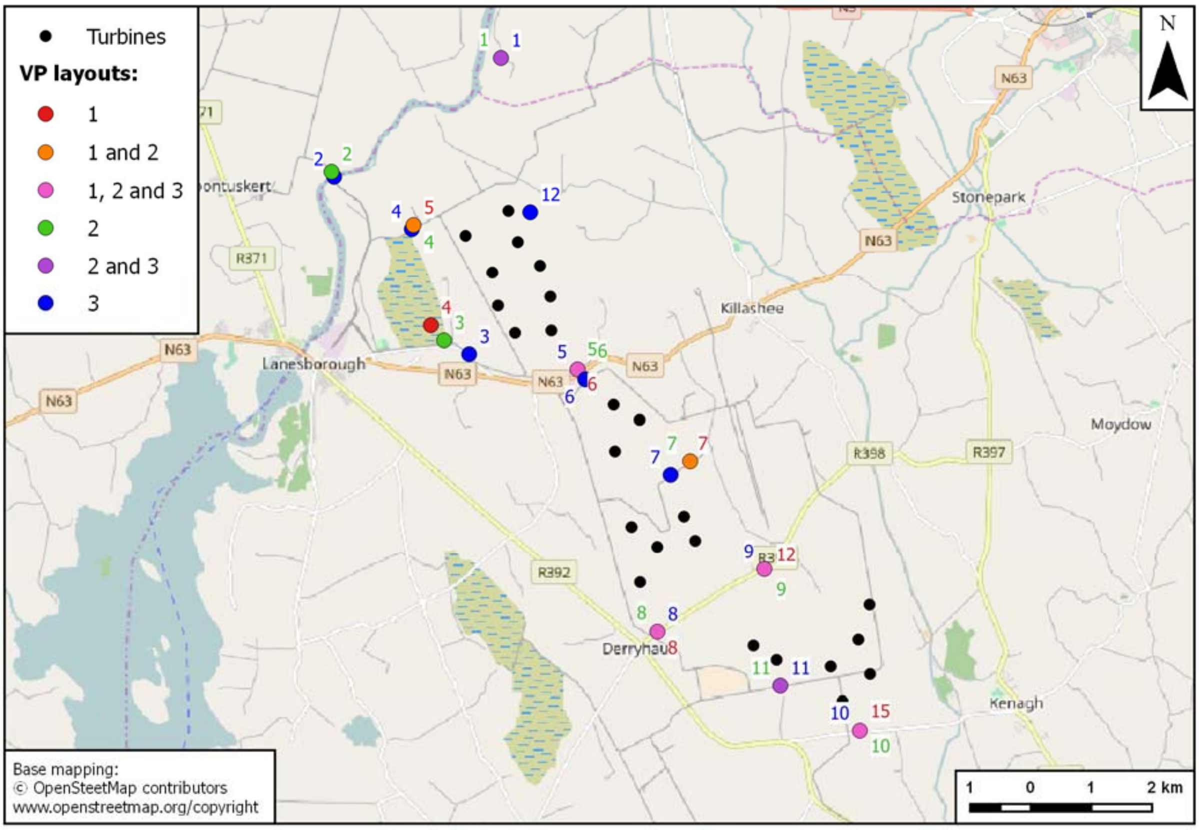

Figure 1. Vantage point layouts.