Appendix 6.1 Collision Risk Analysis

Contents

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Appendix 6.1 Collision Risk Analysis

Introduction

Species selected for collision risk analysis

Worked collision risk analysis for nine species (greylag goose, red-throated diver, curlew, whimbrel, golden plover, great skua, Arctic skua, Arctic tern and fulmar) is contained in this Appendix.

Vantage point watches were carried out in the breeding season of 2016, the winter season of 2017/18 and the breeding season of 2018. Only breeding season flight data and observation time has been analysed since many species are not present in the winter, or do not use the airspace over the Site frequently during the winter period. For two species, great skua and whimbrel, only a single breeding season is analysed. Great skua was recorded irregularly during autumn 2017, and likely to have involved dispersing or wandering individuals that are not part of the local breeding population. Whimbrel flights were recorded infrequently during the work, and only two flights at collision risk height were recorded during the 2016 VP work. Collision modelling has been undertaken for the 2018 data; however, insufficient flight activity was recorded for whimbrel in 2016 to complete a meaningful analysis, and therefore, collision risk based on 2016 data has not been modelled.

The approach to collision risk analysis

The collision risk analysis follows the Scottish Natural Heritage (SNH) guidance note on calculating a theoretical collision risk (SNH, 2000). The calculations used in the guidance note are derived from Band *et al*., (2007). The calculations provide a collision risk based on birds undertaking no avoidance action. An avoidance factor is therefore applied to the output of the Band calculation, and this has been derived from recommended avoidance rates in SNH (2018). Each worked collision risk model in this Technical Appendix follows the calculations set out in SNH (2000).

The collision risk calculation determines the number of birds colliding per annum by multiplying the number of birds flying through the turbine rotors and the probability of a bird being hit. SNH (2000) identifies two approaches to determine the number of birds flying through the rotors; these are: the 'predictable flight' model, and the 'random flight' model.

Collision risk has been calculated using the 'predictable' flight model for greylag goose (which tends to fly in flocks and often on relatively direct flight paths) and the 'random' flight model for the other species as this is more appropriate.

For some species, a proportion of flights also fit the 'predictable' model; this is the case for breeding adult red-throated divers that consistently make direct flights between a nest and foraging area. However, the majority of such direct fights observed during survey work did not pass through the proposed turbine array, and tended to occur between lochans at the periphery of the Proposed Development footprint, away from the Site to the sea. It can be seen from Figure 6.6 that the majority of flights within the vicinity of the proposed turbine locations are typically wheeling flights, with direct flights typically occurring around Gloup Voe (in the centre-north of the Site), near Kussa Waters (beyond the north-eastern corner of the Site), near to the western coastline of Yell, and at Dalsetter (beyond the south-eastern corner of the Site).

Parameters used in the random flight model

In applying the random flight model, a "flight risk volume" has been calculated based on the area occupied by the combined effective visible area from VPs 1, 2, 3 and 6, multiplied by the height of the turbines. The combined visible area is shown on Figure 6.1. Flight data obtained from VPs 4 and 5 (as presented in the 2019 EIA Report) were excluded from the model. VP 5 did not overlook any of the proposed turbine locations in the 2020 Layout,

and VP 4 only captured proposed turbine 16 (which is also overlooked by VP 3) at the edge of its viewshed. Inclusion of VPs 4 and 5 into the model is likely to have skewed the collision risk outcome by enlarging the flight risk volume disproportionately whilst not providing information about at risk flights.

The calculated flight risk volume is presented in "Step 1" under the "Method" sections of each worked collision risk analysis. This was calculated using a maximum blade height of 200 m and the Site area calculated using ArcGIS. The Site area is illustrated in Figure 6.1.

Parameters used in the predictable flight model

For the predictable flight model (only applied to greylag goose here) a "risk window" has been calculated based on the width of the combined visible area from VPs 1, 2, 3 and 6 at the widest section perpendicular to the general flight direction. This width is measured roughly along a theoretical line through proposed turbines 5 and 25, and is presented on the first page of the greylag goose worked collision risk analysis.

Parameters used in either model

The total observation time entered into the analysis is 144 hours per season. This is based on 36 hours of observation being completed during each season for each of VPs 1, 2, 3 and 6. Collision risk analysis has been undertaken separately for each season.

For those species that do not occur frequently outside of the breeding bird season, the period of the year over which the species are likely to be present within the airspace over the Proposed Development has been entered into the model as April to August inclusive. The mean daylight hours for Shetland[1] in each month has been used to provide a total duration for which each species is active. As all of the species for which collision risk analysis has been conducted are diurnal, only 5 % of the total night time hours have been included in the analysis.

All flights recorded at > 40 m during the survey work have been defined as being at collision risk height and entered into the model. SNH (2000) guidance indicates that "*best results will be based on observational data about flight heights, such as will enable informed estimate of the proportion of flights at a level which may collide with windfarm rotors*." Whilst the flight height bands used in the field were well defined, and allowed exclusion of below collision risk (<40 m) flights from the model, the survey data did not allow exclusion of flights that occurred above the maximum tip height of the proposed turbines. This is because the maximum tip height of proposed turbines has changed during the course of survey work, and the maximum height band used in the field captured both at and above collision risk heights. To allow for this, all flights > 40 m have been entered in to the model. This has resulted in a slight overestimation of collision risk.

Estimates of bird size and flight speed for each species have been used for calculating the probability of collision. There are numerous sources of information on flight speed in birds, but few of these present figures that correspond, and birds can vary their speed according to what they are doing (e.g. soaring, gliding or pursuing prey / trying to evade capture). Precautionary (low) flight speeds are presented for each species modelled (based on data presented in Bruderer & Boldt, 2001). Slower speed makes birds less likely to avoid turning blades by chance (i.e. through flying through the rotor swept area without taking avoiding action).

The size of birds (total length and length of the wing) is also precautionary in each case, and is based on the largest given measurement for the species concerned in Baker (2016). Larger size also makes avoiding rotating blades by chance less likely. Only those flights that included time at collision risk height and that passed within 280 m (to account for the sweep of the blades (80 m) and observer error (200 m, as recommended in the relevant guidance (SNH, 2000; Band et al, 2007) were entered into the model. The flight times/ height and durations are provided for each species in the methods.

[1] Taken from www.shetland.climatetemps.com/sunlight.php

Summary of hours watched

Table 1 – VP 1 survey dates, times, and meteorological data.

Date	Start time	Stop Time	Time (Hrs)	Wind Direction	Wind speed[2]	Cloud cover[3]	Rain[4]	Snow[5]	Frost[6]
04-Apr-16	12:25	15:25	3	SSE	3	8	0	0	0
04-Apr-16	16:55	19:55	3	SE	2	7	0	0	0
22-May-16	04:40	07:40	3	W	5	7	0	0	0
22-May-16	08:10	11:10	3	W	5	5	0	0	0
06-Jun-16	16:00	19:00	3	NE	3	0	0	0	0
06-Jun-16	19:30	22:30	3	NE	2	0	0	0	0
19-Jul-16	15:35	18:35	3	W	3	8	0	0	0
19-Jul-16	19:08	22:08	3	E	3	4	0	0	0
04-Aug-16	15:05	18:05	3	N	5	8	0	0	0
04-Aug-16	18:35	21:35	3	N	4	8	0	0	0
25-Aug-16	05:40	08:40	3	S	1	3	0	0	0
25-Aug-16	09:10	12:10	3	SE	1	6	0	0	0
04-Apr-16	12:25	15:25	3	SSE	3	8	0	0	0
04-Apr-16	16:55	19:55	3	SE	2	7	0	0	0
22-May-16	04:40	07:40	3	W	5	7	0	0	0
22-May-16	08:10	11:10	3	W	5	5	0	0	0
06-Jun-16	16:00	19:00	3	NE	3	0	0	0	0
06-Jun-16	19:30	22:30	3	NE	2	0	0	0	0
19-Jul-16	15:35	18:35	3	W	3	8	0	0	0
19-Jul-16	19:08	22:08	3	E	3	4	0	0	0
04-Aug-16	15:05	18:05	3	N	5	8	0	0	0
04-Aug-16	18:35	21:35	3	N	4	8	0	0	0
25-Aug-16	05:40	08:40	3	S	1	3	0	0	0
25-Aug-16	09:10	12:10	3	SE	1	6	0	0	0
26-Sep-17	12:20	15:20	3	SSE	6	7	0	0	0
26-Sep-17	15:51	18:51	3	SSE	6	8	0	0	0
05-Oct-17	07:19	10:19	3	NW	6	8	3	0	0
05-Oct-17	10:49	13:49	3	NW	5	8	3	0	0
02-Nov-17	09:30	12:30	3	N	1	7	0	0	0
02-Nov-17	13:03	16:04	3	W	3	7	0	0	0
12-Dec-17	11:45	14:45	3	SW	3	5	0	0	2
15-Jan-18	09:40	12:40	3	S	5	6	0	0	0
21-Feb-18	07:20	10:20	3	S	5	7	0	0	1
22-Feb-18	10:55	13:55	3	S	5	6	0	0	1

[2] Beaufort scale

[3] Estimation of cloud cover given in Oktas

[4] Rain: None = 0; Occasional=1; Drizzle / mist = 2; Light shower = 3; Heavy shower = 4; Heavy rain = 5

[5] Snow: None = 0; On Site = 1; Snowing = 2

[6] Frost: None = 0; Ground = 1; All day = 2

Date	Start time	Stop Time	Time (Hrs)	Wind Direction	Wind speed[2]	Cloud cover[3]	Rain[4]	Snow[5]	Frost[6]
08-Mar-18	08:25	11:25	3	SE	4	8	0	1	0
08-Mar-18	11:55	14:55	3	SE	4	8	1	1	0
09-Apr-18	13:10	16:10	3	NE	4	8	0	0	0
09-Apr-18	17:05	20:05	3	NE	4	8	0	0	0
16-May-18	04:20	07:20	3	N	5	3	0	0	0
16-May-18	07:50	10:50	3	W	5	0	0	0	0
07-Jun-18	10:00	13:00	3	NE	3	8	0	0	0
07-Jun-18	13:30	16:30	3	NE	3	8	0	0	0
06-Jul-18	19:30	22:30	3	SW	4	6	0	0	0
06-Jul-18	16:00	19:00	3	SW	4	3	0	0	0
03-Aug-18	09:40	12:40	3	SW	3	7	0	0	0
03-Aug-18	13:10	16:10	3	SW	3	7	0	0	0
21-Aug-18	05:15	08:15	3	S	1	7	0	0	0
21-Aug-18	08:45	11:45	3	S	3	8	0	0	0
Total duration (Hrs)	Breeding 2016		36						
	Winter 2017/18		36						
	Breeding 2018		36						

Table 2 – VP 2 survey dates, times, and meteorological data.

Date	Start time	Stop Time	Time (Hrs)	Wind Direction	Wind speed	Cloud cover	Rain	Snow	Frost
05-Apr-16	13:30	16:30	3	NNW	3	8	0	0	0
05-Apr-16	17:00	20:00	3	NW	3	8	0	0	0
03-May-16	04:55	07:55	3	SSW	5	4	0	0	0
03-May-16	08:35	11:35	3	SSW	5	5	0	0	0
01-Jun-16	15:50	18:50	3	N	5	8	0	0	0
01-Jun-16	19:20	22:20	3	N	4	8	0	0	0
18-Jul-16	04:15	07:15	3	E	1	4	0	0	0
18-Jul-16	07:45	10:45	3	E	1	5	0	0	0
03-Aug-16	15:05	18:05	3	ENE	5	8	5	0	0
03-Aug-16	18:35	21:35	3	ENE	5	8	5	0	0
23-Aug-16	05:40	08:40	3	W	2	8	0	0	0
23-Aug-16	09:10	12:10	3	WNW	1	8	0	0	0
05-Apr-16	13:30	16:30	3	NNW	3	8	0	0	0
05-Apr-16	17:00	20:00	3	NW	3	8	0	0	0
03-May-16	04:55	07:55	3	SSW	5	4	0	0	0
03-May-16	08:35	11:35	3	SSW	5	5	0	0	0
01-Jun-16	15:50	18:50	3	N	5	8	0	0	0
01-Jun-16	19:20	22:20	3	N	4	8	0	0	0
18-Jul-16	04:15	07:15	3	E	1	4	0	0	0
18-Jul-16	07:45	10:45	3	E	1	5	0	0	0

Date	Start time	Stop Time	Time (Hrs)	Wind Direction	Wind speed	Cloud cover	Rain	Snow	Frost
03-Aug-16	15:05	18:05	3	ENE	5	8	5	0	0
03-Aug-16	18:35	21:35	3	ENE	5	8	5	0	0
23-Aug-16	05:40	08:40	3	W	2	8	0	0	0
23-Aug-16	09:10	12:10	3	WNW	1	8	0	0	0
21-Sep-17	16:07	19:07	3	W	1	8	2	0	0
26-Sep-17	08:30	11:30	3	SSE	6	8	0	0	0
04-Oct-17	07:19	10:19	3	W	6	7	4	0	0
04-Oct-17	10:49	13:49	3	W	5	5	0	0	0
05-Nov-17	09:26	12:26	3	NW	5	6	3	0	0
05-Nov-17	12:56	15:56	3	NW	6	5	3	0	0
15-Dec-17	09:45	12:45	3	NW	6	4	0	0	0
13-Jan-18	11:30	14:30	3	SSE	5	7	0	0	0
18-Feb-18	07:35	10:35	3	WSW	4	7	0	0	1
18-Feb-18	11:05	14:05	3	SW	3	7	0	0	0
09-Mar-18	07:25	10:25	3	SE	4	6	0	1	0
09-Mar-18	10:55	13:55	3	SE	4	5	0	1	0
04-Apr-18	13:10	16:10	3	W	2	5	0	0	0
04-Apr-18	16:50	19:50	3	W	2	1	0	0	0
02-May-18	14:10	17:10	3	SW	5	8	3	0	0
17-May-18	04:20	07:20	3	W	3	5	0	0	0
08-Jun-18	08:50	11:50	3	NE	3	8	0	0	0
08-Jun-18	12:20	15:20	3	NE	3	8	0	0	0
02-Jul-18	19:30	22:30	3	SW	4	8	0	0	0
02-Jul-18	16:00	19:00	3	SW	4	6	0	0	0
02-Aug-18	10:00	13:00	3	S	4	8	0	0	0
02-Aug-18	13:30	16:30	3	WSW	4	7	0	0	0
15-Aug-18	05:10	08:10	3	SW	3	8	2	0	0
15-Aug-18	08:40	11:40	3	S	4	8	0	0	0
Total duration (Hrs)	Breeding 2016		36						
	Winter 2017/18		36						
	Breeding 2018		36						

Table 3 – VP 3 survey dates, times, and meteorological data.

Date	Start time	Stop Time	Time (Hrs)	Wind Direction	Wind speed	Cloud cover	Rain	Snow	Frost
06-Apr-16	3	13:35	16:35	3	WSW	3	6	0	0
06-Apr-16	3	17:05	20:05	3	W	2	7	0	0
04-May-16	3	04:55	07:55	3	S	4	8	0	0
04-May-16	3	08:25	11:25	3	S	4	8	3	0
02-Jun-16	3	15:55	18:55	3	NE	6	8	0	0
02-Jun-16	3	19:25	22:25	3	NE	6	3	0	0

Date	Start time	Stop Time	Time (Hrs)	Wind Direction	Wind speed	Cloud cover	Rain	Snow	Frost
22-Jul-16	3	04:19	07:19	3	S	1	2	0	0
22-Jul-16	3	07:50	10:50	3	SE	2	2	0	0
10-Aug-16	3	14:45	17:45	3	W	3	2	0	0
10-Aug-16	3	18:15	21:15	3	WSW	2	2	0	0
31-Aug-16	3	05:35	08:35	3	SSW	5	2	0	0
31-Aug-16	3	09:25	12:25	3	SW	5	7	0	0
06-Apr-16	3	13:35	16:35	3	WSW	3	6	0	0
06-Apr-16	3	17:05	20:05	3	W	2	7	0	0
04-May-16	3	04:55	07:55	3	S	4	8	0	0
04-May-16	3	08:25	11:25	3	S	4	8	3	0
02-Jun-16	3	15:55	18:55	3	NE	6	8	0	0
02-Jun-16	3	19:25	22:25	3	NE	6	3	0	0
22-Jul-16	3	04:19	07:19	3	S	1	2	0	0
22-Jul-16	3	07:50	10:50	3	SE	2	2	0	0
10-Aug-16	3	14:45	17:45	3	W	3	2	0	0
10-Aug-16	3	18:15	21:15	3	WSW	2	2	0	0
31-Aug-16	3	05:35	08:35	3	SSW	5	2	0	0
31-Aug-16	3	09:25	12:25	3	SW	5	7	0	0
20-Sep-17	3	12:40	15:40	3	SE	3	7	0	0
20-Sep-17	3	16:10	19:10	3	SE	3	7	3	0
07-Oct-17	3	11:54	14:54	3	NE	3	8	0	0
07-Oct-17	3	15:24	18:24	3	N	3	7	0	0
06-Nov-17	3	07:40	10:40	3	S	4	8	0	0
06-Nov-17	3	11:10	14:10	3	S	5	8	0	0
11-Dec-17	3	11:50	14:50	3	WNW	4	7	1	0
11-Jan-18	3	12:15	15:15	3	NW	2	1	0	0
16-Feb-18	3	12:20	15:20	3	SW	5	5	0	0
19-Feb-18	3	07:30	10:30	3	ESE	6	5	0	0
06-Mar-18	3	09:10	12:10	3	NE	4	7	3	1
06-Mar-18	3	12:40	15:40	3	NE	3	7	3	1
03-Apr-18	3	13:00	16:00	3	E	4	8	3	0
03-Apr-18	3	16:45	19:45	3	NE	4	6	0	0
04-May-18	3	13:40	14:40	1	SW	5	8	3	0
18-May-18	3	04:10	07:10	3	SE	1	1	0	0
18-May-18	3	07:40	09:40	2	SE	2	1	0	0
07-Jun-18	3	10:00	13:00	3	NE	3	8	0	0
07-Jun-18	3	13:30	16:30	3	NE	3	8	0	0
09-Jul-18	3	19:30	22:30	3	SW	1	5	0	0
09-Jul-18	3	15:50	19:00	3	NW	3	4	0	0
31-Jul-18	3	12:15	15:15	3	S	5	5	0	0
31-Jul-18	3	15:45	18:45	3	ESE	4	1	0	0
20-Aug-18	3	05:15	08:15	3	W	2	7	0	0

Date	Start time	Stop Time	Time (Hrs)	Wind Direction	Wind speed	Cloud cover	Rain	Snow	Frost
Total duration (Hrs)	Breeding 2016		36						
	Winter 2017/18		36						
	Breeding 2018		36						

Table 4 – VP 6 survey dates, times, and meteorological data.

Date	Start time	Stop Time	Time (Hrs)	Wind Direction	Wind speed	Cloud cover	Rain	Snow	Frost
11-Apr-16	13:45	16:45	3	E	3	4	0	0	0
11-Apr-16	17:15	20:15	3	NE	3	4	0	0	0
27-May-16	05:00	08:00	3	ENE	5	8	0	0	0
27-May-16	09:00	12:00	3	ENE	4	8	4	0	0
07-Jun-16	16:00	19:00	3	N	4	8	0	0	0
07-Jun-16	19:30	22:30	3	N	3	8	0	0	0
02-Aug-16	04:50	07:50	3	NNW	3	8	0	0	0
02-Aug-16	08:20	11:20	3	NNW	3	8	0	0	0
12-Aug-16	14:40	17:40	3	WNW	3	8	0	0	0
12-Aug-16	18:10	21:10	3	W	4	8	0	0	0
24-Aug-16	13:15	16:15	3	NNW	3	8	0	0	0
24-Aug-16	16:45	19:45	3	W	2	7	0	0	0
11-Apr-16	13:45	16:45	3	E	3	4	0	0	0
11-Apr-16	17:15	20:15	3	NE	3	4	0	0	0
27-May-16	05:00	08:00	3	ENE	5	8	0	0	0
27-May-16	09:00	12:00	3	ENE	4	8	4	0	0
07-Jun-16	16:00	19:00	3	N	4	8	0	0	0
07-Jun-16	19:30	22:30	3	N	3	8	0	0	0
02-Aug-16	04:50	07:50	3	NNW	3	8	0	0	0
02-Aug-16	08:20	11:20	3	NNW	3	8	0	0	0
12-Aug-16	14:40	17:40	3	WNW	3	8	0	0	0
12-Aug-16	18:10	21:10	3	W	4	8	0	0	0
24-Aug-16	13:15	16:15	3	NNW	3	8	0	0	0
24-Aug-16	16:45	19:45	3	W	2	7	0	0	0
27-Sep-17	12:18	15:18	3	SE	6	8	0	0	0
27-Sep-17	15:48	18:48	3	SE	6	7	0	0	0
06-Oct-17	07:21	10:21	3	NW	5	8	3	0	0
06-Oct-17	10:51	13:51	3	NW	4	8	0	0	0
07-Nov-17	09:20	12:20	3	W	2	8	3	0	0
07-Nov-17	12:51	15:51	3	SW	3	8	0	0	0
14-Dec-17	10:45	13:45	3	E	3	7	1	0	1
18-Jan-18	11:00	14:00	3	W	4	5	0	0	0
21-Feb-18	07:25	10:25	3	NW	3	2	0	0	1
21-Feb-18	10:55	13:55	3	NW	2	3	0	0	1

Date	Start time	Stop Time	Time (Hrs)	Wind Direction	Wind speed	Cloud cover	Rain	Snow	Frost
31-Mar-18	11:30	14:30	3	NNW	5	4	0	0	1
31-Mar-18	15:00	18:00	3	WNW	4	3	0	0	1
10-Apr-18	13:10	16:10	3	S	2	8	0	0	0
10-Apr-18	16:50	19:50	3	S	2	7	0	0	0
15-May-18	04:20	07:20	3	SW	1	0	0	0	0
15-May-18	07:50	10:50	3	SE	4	0	0	0	0
12-Jun-18	10:00	13:00	3	W	3	6	0	0	0
12-Jun-18	13:30	16:30	3	NW	4	8	0	0	0
05-Jul-18	19:30	22:30	3	W	4	8	0	0	0
05-Jul-18	16:00	19:00	3	W	4	3	0	0	0
07-Aug-18	09:30	12:30	3	SW	3	8	1	0	0
07-Aug-18	13:00	16:00	3	S	3	8	1	0	0
24-Aug-18	05:15	08:15	3	NW	2	6	0	0	0
24-Aug-18	08:45	11:45	3	NW	4	7	2	0	0

Total duration (Hrs)		
	Breeding 2016	36
	Winter 2017/18	36
	Breeding 2018	36

*Collision **Risk** Analysis*

[Overleaf]

Site Name **Energy Isles Wind Farm**

Bird Dimensions

Species	**Greylag Goose**
length (m)	0.82
wing span (m)	1.64
speed (m/sec)	19

= data input required
= model calculates value

Sources of speed and dimension information: Bruderer & Boldt (2001); BTO Bird Facts

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781003

Note, the maximum height of turbines 5, 16, 19, 20, 24, 25, 26, 27 and 28 is lower, at 180 m

Wind Farm Dimensions

No of turbines	23
Site width (m)	5496

The width is equal to the width (perpendicular to the general flight direction of geese) across the total visible area (at a minimum 30 m above ground level) from vantage points 1, 2, 3 and 6.
The extent of the visible area is shown on Figure 6.1.

Turbine Specifications

K: [1D or [3D] (0 or 1)	1
NoBlades	3
MaxChord	4 *
Pitch (degrees)	20 *
Rotation period	3 *

Flight Characteristics

Flapping (0) or gliding (+1)	0

Night adjustment

What percentage of the night is the target species active? 5 **%**

Survey Data

Total survey time (hours)	144

Period when Greylag Goose likely to be on site.

Type in the number of days in each month where the target species is present within the site

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
31	28	31	30	31	30	31	31	30	31	30	31

Total number of months when Greylag Goose **likely to be present:** 12

Enter the date of each record, the time the bird(s) was recorded in the collision risk area and the number of birds on a separate
Bird occupancy is automatically calculated.

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume	
03/05/2016	105	3	315	(the time in seconds is
03/05/2016	30	1	30	aggregated time for each
03/05/2016	15	2	30	species modelled)
03/05/2016	70	2	140	
22/05/2016	135	8	1080	
22/05/2016	120	1	120	
22/05/2016	60	2	120	
22/05/2016	150	3	450	
22/05/2016	15	1	15	
22/05/2016	30	2	60	
22/05/2016	135	2	270	
22/05/2016	45	1	45	
27/05/2016	110	4	440	
27/05/2016	55	2	110	
27/05/2016	30	2	60	
01/06/2016	30	3	90	
01/06/2016	45	4	180	
06/06/2016	60	1	60	
06/06/2016	75	2	150	
06/06/2016	70	8	560	
06/06/2016	120	3	360	
06/06/2016	120	1	120	
10/08/2016	185	1	185	
23/08/2016	10	2	20	
Total	**1820**	**61**	**5010**	

Method 2 - Regular flights through windfarm (to be used for birds that fly across the site using the same flight path)

= data input required
= model calculates value

Step 1 **Go to Data Input**

Input data about the species that is being assessed - body length, wing span and flight speed
Input data on turbine dimensions
Input data on wind farm area
Input data on turbine dimensions and specification
Input all vantage point data for the species that is being assessed - number of birds and flight time within the study area
Input the number of days for each month where the species is likely to be present within the site
Input days for those months where the species is likely to be present within the site
Input the appropriate night time correction factor for the species being assessed, e.g. a 25% nocturnal flight time correction was proposed by Band et al for geese. This correction cannot be applied to all species, for example raptors.

Step 2 **Go to Collision Risk**

Final collision risk estimates are highlighted
Only use the collision risk estimate for the method that has been used

Scottish Natural Heritage: Calculating a theoretical collision risk assuming no avoiding action

Site Name: Energy Isles Wind Farm

= data input required
= model calculates value

Stage 1: Number of birds flying through rotors

Input Parameters

Bird Dimensions

Species	Greylag Goose
length (m)	0.82
wing span (m)	1.64
speed (m/sec)	19

Bird Flight Data

No of birds	61
Time spent in V_w (sec)	164584.92

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781

Wind Farm Dimensions

No of turbines	23
Site width (m)	5496

Method 2 - Regular flights through windfarm

(to be used for birds that fly across the site using the same flight path)

1 Risk window (site width x height of turbine)

width of site 5496 m
height of turbine 200 m
cross-sectional area = 1099200 sq m

2 Number of birds flying through risk window per annum

hours of observation 144
number of birds observed 61
birds/hr 0.423611

number of hrs birds active 4730.585 hrs per year

number of birds in risk window (birds per hr x number of hrs birds active per yr) 2003.928

3 area of rotors N x 3.1412 x r^2

N = 23 N = no of turbines
r = 77 r = rotor radius
area = 428356.02 sq m

4 rotor area as proportion of risk window (rotor area / cross-sectional area) 0.39

5 number of birds passing through rotor 780.93

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Input parameters regarding the turbine specification will need to be obtained from the design engineers or manufacturers.

W Band 03/03/2020

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4	m
Pitch (degrees)	20	
BirdLength	0.82	m
Wingspan	1.64	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	19	m/sec
RotorDiam	154	m
RotationPeriod	3.00	sec
Bird aspect ratioo: β	0.50	

Calculation of alpha and p(collision) as a function of radius

				Upwind:			Downwind:		
r/R	c/C	α	collide		contribution	collide		contribution
radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
0.025	0.575	4.71	18.70	0.98	0.00123	17.13	0.90	0.00113
0.075	0.575	1.57	6.76	0.36	0.00267	5.18	0.27	0.00205
0.125	0.702	0.94	4.99	0.26	0.00328	3.07	0.16	0.00202
0.175	0.860	0.67	4.46	0.23	0.00411	2.10	0.11	0.00194
0.225	0.994	0.52	4.18	0.22	0.00495	1.46	0.08	0.00172
0.275	0.947	0.43	3.64	0.19	0.00527	1.05	0.06	0.00152
0.325	0.899	0.36	3.27	0.17	0.00560	0.82	0.04	0.00141
0.375	0.851	0.31	2.99	0.16	0.00590	0.98	0.05	0.00193
0.425	0.804	0.28	2.76	0.15	0.00617	1.08	0.06	0.00242
0.475	0.756	0.25	2.56	0.13	0.00640	1.15	0.06	0.00287
0.525	0.708	0.22	2.39	0.13	0.00659	1.19	0.06	0.00329
0.575	0.660	0.20	2.23	0.12	0.00676	1.21	0.06	0.00368
0.625	0.613	0.19	2.09	0.11	0.00688	1.22	0.06	0.00403
0.675	0.565	0.17	1.96	0.10	0.00698	1.22	0.06	0.00434
0.725	0.517	0.16	1.84	0.10	0.00704	1.21	0.06	0.00462
0.775	0.470	0.15	1.73	0.09	0.00706	1.19	0.06	0.00487
0.825	0.422	0.14	1.62	0.09	0.00705	1.17	0.06	0.00508
0.875	0.374	0.13	1.52	0.08	0.00701	1.14	0.06	0.00526
0.925	0.327	0.13	1.42	0.07	0.00693	1.11	0.06	0.00541
0.975	0.279	0.12	1.33	0.07	0.00682	1.07	0.06	0.00552

Overall p(collision) = Upwind 11.5% Downwind 6.5%

Average 9.0%

Bird survey data

Date	Time observed (seconds)		Number of geese	Bird Occupancy in flight risk volume
TOTAL	1820		61	5010
TOTAL SURVEY TIME	144	hours or	518400	seconds

Period when Greylag Goose likely to be on site (see below) =

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
31	28	31	30	31	30	31	31	30	31	30	31

Total days = 365 Total hours (corrected - see below) = 4730.585

Period when Greylag Goose likely to be on site = 17030104 seconds (in each year)

Assumptions (write in any assumptions that have been included in the model)

Assumption 1: The flying period extends from dawn to dusk and includes 5% of night.

Assumption 2:

Assumption 3:

Assumption 4:

Proportion of time during which a collision may occur = 17030104 (in each year)

Greylag Goose flight time = 5010 seconds in 518400 seconds survey time

Therefore in 12 months = 164584.92 seconds

Note: This table is only relevant when calculating collision risk for goose species. It provides an adjustment for nocturnal flight behaviour for these species.

Number of hours geese are potentially active during winter (from Band et al, in press)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nox	Dec	
Mean Daylight hours**	6.8	9.08	11.78	14.62	17.23	18.77	18.05	15.68	12.88	10.05	7.45	5.98	
Mean Nocturnal hrs* 5	0.86	0.746	0.611	0.469	0.3385	0.2615	0.2975	0.416	0.556	0.6975	0.8275	0.901	
Combined Daily Mean	7.66	9.826	12.391	15.089	17.5685	19.0315	18.3475	16.096	13.436	10.7475	8.2775	6.881	
No of days birds present	31	28	31	30	31	30	31	31	30	31	30	31	
Total hours each month	**237.46**	**275.128**	**384.121**	**452.67**	**544.6235**	**570.945**	**568.7725**	**498.976**	**403.08**	**333.1725**	**248.325**	**213.311**	**4730.585**
Total hours per year	**4730.5845**												

**Mean daylight hours taken from www.shetland.climatetemps.com/sunlight.php

Method 2 - Regular flights through windfarm (to be used for birds that fly across the site using the same flight path)

Number of bird transits through the rotors per annum = 780.93

Average collision risk for bird passing through rotor = 9.0%

Number of birds potentially killed by rotors per annum = 70.20

NB: The above calculation assumes no avoidance

Correcting for 95% collision risk:

Number of birds potentially killed by rotors per annum = **3.509909**

1 bird killed every 0.284908 years

Correcting for 98% avoidance rate:

Number of birds potentially killed by rotors per annum = **1.403964**

1 bird killed every 0.712269 years

Correcting for 99% avoidance rate:

Number of birds potentially killed by rotors per annum = **0.701982**

1 bird killed every 1.424538 years

Correcting for 99.8% avoidance rate:

Number of birds potentially killed by rotors per annum = **0.14**

1 bird killed every 7.122692 years

Site Name **Energy Isles Wind Farm**

Bird Dimensions

Species	**Greylag Goose**
length (m)	0.82
wing span (m)	1.64
speed (m/sec)	19

= data input required
= model calculates value

Sources of speed and dimension information: Bruderer & Boldt (2001); BTO Bird Facts

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781003

Note, the maximum height of turbines 5, 16, 19, 20, 24, 25, 26, 27 and 28 is lower, at 180 m

Wind Farm Dimensions

No of turbines	23
Site width (m)	5496

The width is equal to the width (perpendicular to the general flight direction of geese) across the total visible area (at a minimum 30 m above ground level) from vantage points 1, 2, 3 and 6.
The extent of the visible area is shown on Figure 6.1.

Turbine Specifications

K: [1D or [3D] (0 or 1)	1
NoBlades	3
MaxChord	4 *
Pitch (degrees)	20 *
Rotation period	3 *

Flight Characteristics

Flapping (0) or gliding (+1)	0

Night adjustment

What percentage of the night is the target species active? 5 **%**

Survey Data

Total survey time (hours)	288

Period when Greylag Goose likely to be on site.

Type in the number of days in each month where the target species is present within the site

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
31	28	31	30	31	30	31	31	30	31	30	31

Total number of months when Greylag Goose **likely to be present:** 12

Enter the date of each record, the time the bird(s) was recorded in the collision risk area and the number of birds on a separate
Bird occupancy is automatically calculated.

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume	
21/09/2017	35	1	35	(the time in seconds is
21/09/2017	60	16	960	aggregated time for each
21/09/2017	97	4	388	species modelled)
26/09/2017	60	4	240	
26/09/2017	80	4	320	
04/10/2017	15	13	195	
04/10/2017	30	9	270	
02/11/2017	30	2	60	
02/11/2017	45	7	315	
02/11/2017	120	10	1200	
05/11/2017	30	5	150	
06/11/2017	65	1	65	
06/11/2017	25	5	125	
06/11/2017	30	2	60	
14/12/2017	65	1	65	
19/02/2018	72	1	72	
19/02/2018	45	1	45	
19/02/2018	15	3	45	
22/02/2018	56	2	112	
18/02/2018	62	9	558	
21/02/2018	4	2	8	
08/03/2018	80	2	160	
09/03/2018	70	2	140	
31/03/2018	60	2	120	
10/04/2018	90	2	180	
15/05/2018	15	2	30	
07/06/2018	15	2	30	
07/06/2018	130	1	130	
07/06/2018	90	7	630	
07/06/2018	75	1	75	
08/06/2018	45	1	45	
21/08/2018	15	4	60	
Total	**1726**	**128**	**6888**	

Method 2 - Regular flights through windfarm (to be used for birds that fly across the site using the same flight path)

= data input required
= model calculates value

Step 1 **Go to Data Input**

Input data about the species that is being assessed - body length, wing span and flight speed
Input data on turbine dimensions
Input data on wind farm area
Input data on turbine dimensions and specification
Input all vantage point data for the species that is being assessed - number of birds and flight time within the study area
Input the number of days for each month where the species is likely to be present within the site
Input days for those months where the species is likely to be present within the site
Input the appropriate night time correction factor for the species being assessed, e.g. a 25% nocturnal flight time correction was proposed by Band et al for geese. This correction cannot be applied to all species, for example raptors.

Step 2 **Go to Collision Risk**

Final collision risk estimates are highlighted
Only use the collision risk estimate for the method that has been used

Scottish Natural Heritage: Calculating a theoretical collision risk assuming no avoiding action

Site Name: Energy Isles Wind Farm

= data input required
= model calculates value

Stage 1: Number of birds flying through rotors

Input Parameters

Bird Dimensions

Species	Greylag Goose
length (m)	0.82
wing span (m)	1.64
speed (m/sec)	19

Bird Flight Data

No of birds	128
Time spent in V_w (sec)	113139.81

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781

Wind Farm Dimensions

No of turbines	23
Site width (m)	5496

Method 2 - Regular flights through windfarm

(to be used for birds that fly across the site using the same flight path)

1 Risk window (site width x height of turbine)

width of site	5496	m
height of turbine	200	m
cross-sectional area =	1099200	sq m

2 Number of birds flying through risk window per annum

hours of observation	288
number of birds observed	128
birds/hr	0.444444

			number of hrs birds active	4730.585	hrs per year
	number of birds in risk window	(birds per hr x number of hrs birds active per yr)		2102.482	
3	area of rotors	N x 3.1412 x r^2	N =	23	N = no of turbines
			r =	77	r = rotor radius
			area =	428356.02 sq m	
4	rotor area as proportion of risk window	(rotor area / cross-sectional area)		0.39	
5	number of birds passing through rotor			819.33	

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Input parameters regarding the turbine specification will need to be obtained from the design engineers or manufacturers.

W Band 03/03/2020

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4	m
Pitch (degrees)	20	
BirdLength	0.82	m
Wingspan	1.64	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	19	m/sec
RotorDiam	154	m
RotationPeriod	3.00	sec
Bird aspect ratioo: β	0.50	

Calculation of alpha and p(collision) as a function of radius

				Upwind:			Downwind:		
r/R	c/C	α	collide		contribution	collide		contribution
radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
0.025	0.575	4.71	18.70	0.98	0.00123	17.13	0.90	0.00113
0.075	0.575	1.57	6.76	0.36	0.00267	5.18	0.27	0.00205
0.125	0.702	0.94	4.99	0.26	0.00328	3.07	0.16	0.00202
0.175	0.860	0.67	4.46	0.23	0.00411	2.10	0.11	0.00194
0.225	0.994	0.52	4.18	0.22	0.00495	1.46	0.08	0.00172
0.275	0.947	0.43	3.64	0.19	0.00527	1.05	0.06	0.00152
0.325	0.899	0.36	3.27	0.17	0.00560	0.82	0.04	0.00141
0.375	0.851	0.31	2.99	0.16	0.00590	0.98	0.05	0.00193
0.425	0.804	0.28	2.76	0.15	0.00617	1.08	0.06	0.00242
0.475	0.756	0.25	2.56	0.13	0.00640	1.15	0.06	0.00287
0.525	0.708	0.22	2.39	0.13	0.00659	1.19	0.06	0.00329
0.575	0.660	0.20	2.23	0.12	0.00676	1.21	0.06	0.00368
0.625	0.613	0.19	2.09	0.11	0.00688	1.22	0.06	0.00403
0.675	0.565	0.17	1.96	0.10	0.00698	1.22	0.06	0.00434
0.725	0.517	0.16	1.84	0.10	0.00704	1.21	0.06	0.00462
0.775	0.470	0.15	1.73	0.09	0.00706	1.19	0.06	0.00487
0.825	0.422	0.14	1.62	0.09	0.00705	1.17	0.06	0.00508
0.875	0.374	0.13	1.52	0.08	0.00701	1.14	0.06	0.00526
0.925	0.327	0.13	1.42	0.07	0.00693	1.11	0.06	0.00541
0.975	0.279	0.12	1.33	0.07	0.00682	1.07	0.06	0.00552

Overall p(collision) = Upwind 11.5% Downwind 6.5%

Average 9.0%

Bird survey data

Date	Time observed (seconds)		Number of geese	Bird Occupancy in flight risk volume
TOTAL	1726		128	6888
TOTAL SURVEY TIME	288	hours or	1036800	seconds

Period when Greylag Goose likely to be on site (see below) =

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
31	28	31	30	31	30	31	31	30	31	30	31

Total days = 365 Total hours (corrected - see below) = 4730.585

Period when Greylag Goose likely to be on site = 17030104 seconds (in each year)

Assumptions (write in any assumptions that have been included in the model)

Assumption 1: The flying period extends from dawn to dusk and includes 5% of night.
Assumption 2:
Assumption 3:
Assumption 4:

Proportion of time during which a collision may occur = 17030104 (in each year)

Greylag Goose flight time = 6888 seconds in 1036800 seconds survey time

Therefore in 12 months = 113139.81 seconds

Note: This table is only relevant when calculating collision risk for goose species. It provides an adjustment for nocturnal flight behaviour for these species.

Number of hours geese are potentially active during winter (from Band et al, in press)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nox	Dec	
Mean Daylight hours**	6.8	9.08	11.78	14.62	17.23	18.77	18.05	15.68	12.88	10.05	7.45	5.98	
Mean Nocturnal hrs* 5	0.86	0.746	0.611	0.469	0.3385	0.2615	0.2975	0.416	0.556	0.6975	0.8275	0.901	
Combined Daily Mean	7.66	9.826	12.391	15.089	17.5685	19.0315	18.3475	16.096	13.436	10.7475	8.2775	6.881	
No of days birds present	31	28	31	30	31	30	31	31	30	31	30	31	
Total hours each month	**237.46**	**275.128**	**384.121**	**452.67**	**544.6235**	**570.945**	**568.7725**	**498.976**	**403.08**	**333.1725**	**248.325**	**213.311**	**4730.585**
Total hours per year	**4730.5845**												

**Mean daylight hours taken from www.shetland.climatetemps.com/sunlight.php

Method 2 - Regular flights through windfarm (to be used for birds that fly across the site using the same flight path)

Number of bird transits through the rotors per annum = 819.33

Average collision risk for bird passing through rotor = 9.0%

Number of birds potentially killed by rotors per annum = 73.65

NB: The above calculation assumes no avoidance

Correcting for 95% collision risk:

Number of birds potentially killed by rotors per annum = **3.682527**

1 bird killed every 0.271553 years

Correcting for 98% avoidance rate:

Number of birds potentially killed by rotors per annum = **1.473011**

1 bird killed every 0.678882 years

Correcting for 99% avoidance rate:

Number of birds potentially killed by rotors per annum = **0.736505**

1 bird killed every 1.357763 years

Correcting for 99.8% avoidance rate:

Number of birds potentially killed by rotors per annum = **0.15**

1 bird killed every 6.788816 years

Site Name **Energy Isles Wind Farm**

Bird Dimensions

Species	**Red-throated diver**
length (m)	0.61
wing span (m)	1.11
speed (m/sec)	21.1

= data input required
= model calculates value

Sources of speed and dimension information: Bruderer & Boldt (2001); BTO Bird Facts

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781003

Note, the maximum height of turbines 5, 16, 19, 20, 24, 25, 26, 27 and 28 is lower, at 180 m

Wind Farm Dimensions

No of turbines	23
Site area (m^2)	19680000

The area is equal to the total visible area (at a minimum 30 m above ground level) from vantage points 1, 2, 3 and 6. The extent of this area is shown on Figure 6.1.

Turbine Specifications

K: [1D or [3D] (0 or 1)	1
NoBlades	3
MaxChord	4 *
Pitch (degrees)	20 *
Rotation period	3 *

Flight Characteristics

Flapping (0) or gliding (+1)	0

Night adjustment

What percentage of the night is the target species active? 5 **%**

Survey Data

Total survey time (hours)	144

Period when Red-throated diver likely to be on site. **Type in the number of days in each month where the target species is present within the site**

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total number of months when Red-throated diver **likely to be present:** 5

Enter the date of each record, the time the bird(s) was recorded in the collision risk area and the number of birds on a separate
Bird occupancy is automatically calculated.

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume
05/04/2016	140	2	280
03/05/2016	60	1	60
03/05/2016	5	1	5
04/05/2016	120	1	120
22/05/2016	45	1	45
22/05/2016	60	2	120
06/06/2016	40	2	80
07/06/2016	90	2	180
07/06/2016	45	1	45
07/06/2016	10	1	10
07/06/2016	310	1	310
07/06/2016	135	1	135
07/06/2016	30	1	30
07/06/2016	220	2	440
07/06/2016	25	2	50
18/07/2016	304	2	608
18/07/2016	105	1	105
18/07/2016	20	5	100
18/07/2016	72	2	144
18/07/2016	186	1	186
18/07/2016	131	1	131
18/07/2016	198	2	396
18/07/2016	363	2	726
19/07/2016	41	2	82
19/07/2016	78	2	156
19/07/2016	113	2	226
22/07/2016	39	2	78
22/07/2016	223	2	446
02/08/2016	90	1	90
02/08/2016	210	1	210
02/08/2016	240	2	480
02/08/2016	240	3	720
02/08/2016	225	2	450
02/08/2016	45	2	90
02/08/2016	15	2	30

02/08/2016	255	2	510
02/08/2016	135	2	270
02/08/2016	60	2	120
04/08/2016	150	2	300
04/08/2016	60	1	60
10/08/2016	390	1	390
12/08/2016	75	1	75
12/08/2016	55	2	110
12/08/2016	30	1	30
12/08/2016	45	4	180
23/08/2016	225	2	450
23/08/2016	75	1	75
23/08/2016	40	1	40
23/08/2016	10	1	10
24/08/2016	5	1	5
24/08/2016	495	2	990
24/08/2016	240	1	240
24/08/2016	135	1	135
24/08/2016	160	1	160
24/08/2016	85	1	85
24/08/2016	340	2	680
24/08/2016	100	2	200
Total	**7438**	**94**	**12479**

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

= data input required
= model calculates value

Step 1 **Go to Data Input**

Input data about the species that is being assessed - body length, wing span and flight speed
Input data on turbine dimensions
Input data on wind farm area
Input data on turbine dimensions and specification
Input all vantage point data for the species that is being assessed - number of birds and flight time within the study area
Input the number of days for each month where the species is likely to be present within the site
Input days for those months where the species is likely to be present within the site
Input the appropriate night time correction factor for the species being assessed, e.g. a 25% nocturnal flight time correction was proposed by Band et al for geese. This correction cannot be applied to all species, for example raptors.

Step 2 **Go to Collision Risk**

Final collision risk estimates are highlighted
Only use the collision risk estimate for the method that has been used

Scottish Natural Heritage: Calculating a theoretical collision risk assuming no avoiding action

Site Name: Energy Isles Wind Farm

= data input required
= model calculates value

Stage 1: Number of birds flying through rotors

Input Parameters

Bird Dimensions

Species	Red-throated diver
length (m)	0.61
wing span (m)	1.11
speed (m/sec)	21.1

Bird Flight Data

No of birds	94
Time spent in V_w (sec)	228433.90

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781

Wind Farm Dimensions

No of turbines	23
Site Area (m^2)	19680000

Method 1 - Birds using the windfarm airspace

(to be used for birds that fly across the site using a variety of different flight paths)

Step No	Description of Calculation		Calculation	Comments
1	Identify 'flight risk volume' V_w' which is the area of the wind farm multiplied by the height of the turbines	V_w =	3936000000 m^3	Area is equivalent to the total area visible from VPs 1, 2, 3 and 6
2	Calculate the combined volume swept out by the rotors $V_r = N \times \pi R^2 \times (d + l)$ where N is the number of turbines, d is the depth of the	V_r =	1825559.55 m^3	

	rotor front to back, and l is the bird length				
3	Estimate bird occupancy n within V_w This is the number of birds multiplied by the time spent within V_w (per season/year)	n =	228433.90	secs per yr	Bird occupancy is based on observations of birds flying through rotor-swept area
4	Bird occupancy of V_r n x (V_r / V_w) bird-seconds	occupancy =	105.95	bird-seconds	
5	Time taken for a bird to make transit through and completely clear the rotors t = (d + l) / v where v is bird speed (m/sec)	t =	0.20	seconds	Speed should be assessed in the field but published values are available
6	Calculate number of bird transits through the rotors = n x (V_r / V_w) / t	transits =	524.56	bird transits per annum	

Number of bird transits through the rotors per annum = 524.56

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Input parameters regarding the turbine specification will need to be obtained from the design engineers or manufacturers.

W Band 03/03/2020

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4	m
Pitch (degrees)	20	
BirdLength	0.61	m
Wingspan	1.11	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	21.1	m/sec
RotorDiam	154	m
RotationPeriod	3.00	sec
Bird aspect ratioo: β	0.55	

Calculation of alpha and p(collision) as a function of radius

				Upwind:			Downwind:		
r/R	c/C	α	collide		contribution	collide		contribution
radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
0.025	0.575	5.23	17.91	0.85	0.00106	16.33	0.77	0.00097
0.075	0.575	1.74	6.49	0.31	0.00231	4.92	0.23	0.00175
0.125	0.702	1.05	4.88	0.23	0.00289	2.96	0.14	0.00175
0.175	0.860	0.75	4.42	0.21	0.00367	2.07	0.10	0.00172
0.225	0.994	0.58	4.18	0.20	0.00446	1.46	0.07	0.00156
0.275	0.947	0.48	3.60	0.17	0.00469	1.01	0.05	0.00131
0.325	0.899	0.40	3.20	0.15	0.00493	0.74	0.04	0.00114
0.375	0.851	0.35	2.89	0.14	0.00514	0.66	0.03	0.00117
0.425	0.804	0.31	2.64	0.13	0.00532	0.78	0.04	0.00157
0.475	0.756	0.28	2.43	0.12	0.00546	0.86	0.04	0.00194
0.525	0.708	0.25	2.24	0.11	0.00558	0.92	0.04	0.00228
0.575	0.660	0.23	2.08	0.10	0.00566	0.95	0.04	0.00259
0.625	0.613	0.21	1.93	0.09	0.00572	0.97	0.05	0.00286
0.675	0.565	0.19	1.79	0.09	0.00574	0.97	0.05	0.00311
0.725	0.517	0.18	1.67	0.08	0.00573	0.97	0.05	0.00332
0.775	0.470	0.17	1.55	0.07	0.00570	0.95	0.05	0.00351
0.825	0.422	0.16	1.44	0.07	0.00563	0.94	0.04	0.00366
0.875	0.374	0.15	1.33	0.06	0.00553	0.91	0.04	0.00378
0.925	0.327	0.14	1.23	0.06	0.00539	0.88	0.04	0.00387
0.975	0.279	0.13	1.13	0.05	0.00523	0.85	0.04	0.00393

Overall p(collision) = Upwind 9.6% Downwind 4.8%

Average 7.2%

Bird survey data

Date	Time observed (seconds)			Number of birds	Bird Occupancy in flight risk volume
TOTAL	7438			94	12479

TOTAL SURVEY TIME 144 hours or 518400 seconds

Period when Red-throated likely to be on site (see below) =

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total days = 153 Total hours (corrected - see below) = 2635.987

Period when Red-throated likely to be on site = 9489553 seconds (in each year)

Assumptions (write in any assumptions that have been included in the model)

Assumption 1: The flying period extends from dawn to dusk and includes 25% of night.

Assumption 2:

Assumption 3:

Assumption 4:

Proportion of time during which a collision may occur = 9489553 (in each year)

Red-throated d flight time = 12479 seconds in 518400 seconds survey time

Therefore in 5 months = 228433.90 seconds

Note: This table is only relevant when calculating collision risk for goose species. It provides an adjustment for nocturnal flight behaviour for these species.

Number of hours geese are potentially active during winter (from Band et al, in press)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nox	Dec	
Mean Daylight hours**		6.8	9.08	11.78	14.62	17.23	18.77	18.05	15.68	12.88	10.05	7.45	5.98	
Mean Nocturnal hrs*	5	0.86	0.746	0.611	0.469	0.3385	0.2615	0.2975	0.416	0.556	0.6975	0.8275	0.901	
Combined Daily Mean		7.66	9.826	12.391	15.089	17.5685	19.0315	18.3475	16.096	13.436	10.7475	8.2775	6.881	
No of days birds present		0	0	0	30	31	30	31	31	0	0	0	0	
Total hours each month		**0**	**0**	**0**	**452.67**	**544.6235**	**570.945**	**568.7725**	**498.976**	**0**	**0**	**0**	**0**	**2635.987**
Total hours per year		**2635.987**												

**Mean daylight hours taken from www.shetland.climatetemps.com/sunlight.php

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

Number of bird transits through the rotors per annum =	524.56
Average collision risk for bird passing through rotor =	7.2%
Number of birds potentially killed by rotors per annum =	37.67

NB: The above calculation assumes no avoidance

Correcting for 95% avoidance rate:

Number of birds potentially killed by rotors per annum =	1.883262
1 bird killed every	0.530994 years

Correcting for 98% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.753305
1 bird killed every	1.327484 years

Correcting for 99% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.37665
1 bird killed every	2.654968 years

Correcting for 99.5% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.18833
1 bird killed every	5.309937 years

Site Name **Energy Isles Wind Farm**

Bird Dimensions

Species	**Red-throated diver**
length (m)	0.61
wing span (m)	1.11
speed (m/sec)	21.1

= data input required
= model calculates value

Sources of speed and dimension information: Bruderer & Boldt (2001); BTO Bird Facts

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781003

Note, the maximum height of turbines 5, 16, 19, 20, 24, 25, 26, 27 and 28 is lower, at 180 m

Wind Farm Dimensions

No of turbines	23
Site area (m2)	19680000

The area is equal to the total visible area (at a minimum 30 m above ground level) from vantage points 1, 2, 3 and 6. The extent of this area is shown on Figure 6.1.

Turbine Specifications

K: [1D or [3D] (0 or 1)	1
NoBlades	3
MaxChord	4 *
Pitch (degrees)	20 *
Rotation period	3 *

Flight Characteristics

Flapping (0) or gliding (+1)	0

Night adjustment

What percentage of the night is the target species active? 5 **%**

Survey Data

Total survey time (hours)	144

36 hours at each of 4 VP locations.

Period when Red-throated diver likely to be on site. **Type in the number of days in each month where the target species is present within the site**

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total number of months when Red-throated diver **likely to be present:** 5

Enter the date of each record, the time the bird(s) was recorded in the collision risk area and the number of birds on a separate
Bird occupancy is automatically calculated.

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume
17/05/2018	70	1	70
17/05/2018	100	1	100
17/05/2018	45	1	45
17/05/2018	15	2	30
17/05/2018	30	1	30
18/05/2018	145	1	145
15/05/2018	33	2	66
15/05/2018	67	1	67
15/05/2018	15	1	15
15/05/2018	224	2	448
15/05/2018	60	1	60
15/05/2018	30	1	30
15/05/2018	75	1	75
15/05/2018	15	2	30
16/05/2018	30	2	60
16/05/2018	20	3	60
07/06/2018	39	1	39
07/06/2018	160	1	160
07/06/2018	165	2	330
07/06/2018	85	3	255
07/06/2018	117	1	117
07/06/2018	10	1	10
07/06/2018	133	2	266
07/06/2018	69	1	69
07/06/2018	133	1	133
07/06/2018	149	1	149
08/06/2018	90	3	270
08/06/2018	130	1	130
12/06/2018	25	1	25
12/06/2018	166	2	332
12/06/2018	30	1	30
12/06/2018	216	1	216
05/07/2018	650	3	1950
05/07/2018	90	1	90
05/07/2018	108	1	108

05/07/2018	109	1	109
05/07/2018	30	2	60
05/07/2018	105	1	105
05/07/2018	35	1	35
05/07/2018	40	1	40
02/07/2018	30	2	60
02/07/2018	122	2	244
02/07/2018	14	1	14
02/07/2018	85	2	170
06/07/2018	127	1	127
06/07/2018	150	2	300
06/07/2018	45	1	45
06/07/2018	30	1	30
02/08/2018	36	2	72
02/08/2018	54	2	108
02/08/2018	199	3	597
02/08/2018	144	1	144
02/08/2018	30	1	30
03/08/2018	48	2	96
03/08/2018	175	2	350
07/08/2018	15	2	30
15/08/2018	115	1	115
15/08/2018	45	2	90
15/08/2018	45	3	135
15/08/2018	31	1	31
15/08/2018	38	1	38
15/08/2018	150	1	150
20/08/2018	67	2	134
20/08/2018	85	2	170
20/08/2018	60	2	120
21/08/2018	75	2	150
21/08/2018	45	1	45
21/08/2018	240	2	480
21/08/2018	345	2	690
21/08/2018	110	3	330
21/08/2018	435	2	870
21/08/2018	35	1	35
21/08/2018	250	2	500
21/08/2018	100	2	200
21/08/2018	285	3	855

21/08/2018	53	1	53
21/08/2018	120	2	240
24/08/2018	90	2	180
24/08/2018	60	2	120
24/08/2018	180	1	180
Total	**8221**	**127**	**14687**

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

= data input required
= model calculates value

Step 1 **Go to Data Input**

Input data about the species that is being assessed - body length, wing span and flight speed
Input data on turbine dimensions
Input data on wind farm area
Input data on turbine dimensions and specification
Input all vantage point data for the species that is being assessed - number of birds and flight time within the study area
Input the number of days for each month where the species is likely to be present within the site
Input days for those months where the species is likely to be present within the site
Input the appropriate night time correction factor for the species being assessed, e.g. a 25% nocturnal flight time correction was proposed by Band et al for geese. This correction cannot be applied to all species, for example raptors.

Step 2 **Go to Collision Risk**

Final collision risk estimates are highlighted
Only use the collision risk estimate for the method that has been used

Scottish Natural Heritage: Calculating a theoretical collision risk assuming no avoiding action

Site Name: Energy Isles Wind Farm

= data input required
= model calculates value

Stage 1: Number of birds flying through rotors

Input Parameters

Bird Dimensions

Species	Red-throated diver
length (m)	0.61
wing span (m)	1.11
speed (m/sec)	21.1

Bird Flight Data

No of birds	127
Time spent in V_w (sec)	268852.37

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781

Wind Farm Dimensions

No of turbines	23
Site Area (m2)	19680000

Method 1 - Birds using the windfarm airspace

(to be used for birds that fly across the site using a variety of different flight paths)

Step No	Description of Calculation		Calculation	Comments
1	Identify 'flight risk volume' V_w' which is the area of the wind farm multiplied by the height of the turbines	V_w =	3936000000 m^3	Area is equivalent to the total area visible from VPs 1, 2, 3 and 6
2	Calculate the combined volume swept out by the rotors $V_r = N \times \pi R^2 \times (d + l)$ where N is the number of turbines, d is the depth of the	V_r =	1825559.55 m^3	

	rotor front to back, and l is the bird length				
3	Estimate bird occupancy n within V_w This is the number of birds multiplied by the time spent within V_w (per season/year)	n =	268852.37	secs per yr	Bird occupancy is based on observations of birds flying through rotor-swept area
4	Bird occupancy of V_r n x (V_r / V_w) bird-seconds	occupancy =	124.70	bird-seconds	
5	Time taken for a bird to make transit through and completely clear the rotors t = (d + l) / v where v is bird speed (m/sec)	t =	0.20	seconds	Speed should be assessed in the field but published values are available
6	Calculate number of bird transits through the rotors = n x (V_r / V_w) / t	transits =	617.37	bird transits per annum	

Number of bird transits through the rotors per annum = 617.37

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Input parameters regarding the turbine specification will need to be obtained from the design engineers or manufacturers.

W Band 03/03/2020

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4	m
Pitch (degrees)	20	
BirdLength	0.61	m
Wingspan	1.11	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	21.1	m/sec
RotorDiam	154	m
RotationPeriod	3.00	sec
Bird aspect ratioo: β	0.55	

Calculation of alpha and p(collision) as a function of radius

				Upwind:			Downwind:		
r/R	c/C	α	collide		contribution	collide		contribution
radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
0.025	0.575	5.23	17.91	0.85	0.00106	16.33	0.77	0.00097
0.075	0.575	1.74	6.49	0.31	0.00231	4.92	0.23	0.00175
0.125	0.702	1.05	4.88	0.23	0.00289	2.96	0.14	0.00175
0.175	0.860	0.75	4.42	0.21	0.00367	2.07	0.10	0.00172
0.225	0.994	0.58	4.18	0.20	0.00446	1.46	0.07	0.00156
0.275	0.947	0.48	3.60	0.17	0.00469	1.01	0.05	0.00131
0.325	0.899	0.40	3.20	0.15	0.00493	0.74	0.04	0.00114
0.375	0.851	0.35	2.89	0.14	0.00514	0.66	0.03	0.00117
0.425	0.804	0.31	2.64	0.13	0.00532	0.78	0.04	0.00157
0.475	0.756	0.28	2.43	0.12	0.00546	0.86	0.04	0.00194
0.525	0.708	0.25	2.24	0.11	0.00558	0.92	0.04	0.00228
0.575	0.660	0.23	2.08	0.10	0.00566	0.95	0.04	0.00259
0.625	0.613	0.21	1.93	0.09	0.00572	0.97	0.05	0.00286
0.675	0.565	0.19	1.79	0.09	0.00574	0.97	0.05	0.00311
0.725	0.517	0.18	1.67	0.08	0.00573	0.97	0.05	0.00332
0.775	0.470	0.17	1.55	0.07	0.00570	0.95	0.05	0.00351
0.825	0.422	0.16	1.44	0.07	0.00563	0.94	0.04	0.00366
0.875	0.374	0.15	1.33	0.06	0.00553	0.91	0.04	0.00378
0.925	0.327	0.14	1.23	0.06	0.00539	0.88	0.04	0.00387
0.975	0.279	0.13	1.13	0.05	0.00523	0.85	0.04	0.00393

Overall p(collision) = Upwind 9.6% Downwind 4.8%

Average 7.2%

Bird survey data

Date	Time observed (seconds)			Number of birds	Bird Occupancy in flight risk volume
TOTAL	8221			127	14687
TOTAL SURVEY TIME	144	hours	or	518400	seconds

Period when Red-throated likely to be on site (see below) =

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total days = 153 Total hours (corrected - see below) = 2635.987

Period when Red-throated likely to be on site = 9489553 seconds (in each year)

Assumptions (write in any assumptions that have been included in the model)

Assumption 1: The flying period extends from dawn to dusk and includes 25% of night.

Assumption 2:

Assumption 3:

Assumption 4:

Proportion of time during which a collision may occur = 9489553 (in each year)

Red-throated d flight time = 14687 seconds in 518400 seconds survey time

Therefore in 5 months = 268852.37 seconds

Note: This table is only relevant when calculating collision risk for goose species. It provides an adjustment for nocturnal flight behaviour for these species.

Number of hours geese are potentially active during winter (from Band et al, in press)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nox	Dec	
Mean Daylight hours**		6.8	9.08	11.78	14.62	17.23	18.77	18.05	15.68	12.88	10.05	7.45	5.98	
Mean Nocturnal hrs*	5	0.86	0.746	0.611	0.469	0.3385	0.2615	0.2975	0.416	0.556	0.6975	0.8275	0.901	
Combined Daily Mean		7.66	9.826	12.391	15.089	17.5685	19.0315	18.3475	16.096	13.436	10.7475	8.2775	6.881	
No of days birds present		0	0	0	30	31	30	31	31	0	0	0	0	
Total hours each month		**0**	**0**	**0**	**452.67**	**544.6235**	**570.945**	**568.7725**	**498.976**	**0**	**0**	**0**	**0**	**2635.987**
Total hours per year		**2635.987**												

**Mean daylight hours taken from www.shetland.climatetemps.com/sunlight.php

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

Number of bird transits through the rotors per annum =	617.37
Average collision risk for bird passing through rotor =	7.2%
Number of birds potentially killed by rotors per annum =	44.33

NB: The above calculation assumes no avoidance

Correcting for 95% avoidance rate:

Number of birds potentially killed by rotors per annum =	2.216481
1 bird killed every	0.451166 years

Correcting for 98% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.886592
1 bird killed every	1.127914 years

Correcting for 99% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.44330
1 bird killed every	2.255828 years

Correcting for 99.5% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.22165
1 bird killed every	4.511656 years

Site Name **Energy Isles Wind Farm**

Bird Dimensions

Species	**Great Skua**
length (m)	0.56
wing span (m)	1.36
speed (m/sec)	16

= data input required
= model calculates value

Sources of speed and dimension information: Bruderer & Boldt (2001); BTO Bird Facts

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781003

Note, the maximum height of turbines 5, 16, 19, 20, 24, 25, 26, 27 and 28 is lower, at 180 m

Wind Farm Dimensions

No of turbines	23
Site area (m2)	19680000

The area is equal to the total visible area (at a minimum 30 m above ground level) from vantage points 1, 2, 3 and 6. The extent of this area is shown on Figure 6.1.

Turbine Specifications

K: [1D or [3D] (0 or 1)	1
NoBlades	3
MaxChord	4 *
Pitch (degrees)	20 *
Rotation period	3 *

Flight Characteristics

Flapping (0) or gliding (+1) 0

Night adjustment

What percentage of the night is the target species active? 5 **%**

Survey Data

Total survey time (hours) 144

Period when Great Skua likely to be on site.

Type in the number of days in each month where the target species is present within the site

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total number of months when Great Skua **likely to be present:** 5

Enter the date of each record, the time the bird(s) was recorded in the collision risk area and the number of birds on a separate
Bird occupancy is automatically calculated.

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume
11/04/2016	45	1	45
11/04/2016	60	1	60
11/04/2016	30	1	30
11/04/2016	30	1	30
03/05/2016	80	1	80
03/05/2016	150	1	150
04/05/2016	45	1	45
04/05/2016	20	1	20
04/05/2016	40	1	40
04/05/2016	40	1	40
04/05/2016	100	1	100
04/05/2016	40	1	40
04/05/2016	6	1	6
22/05/2016	15	2	30
22/05/2016	210	3	630
22/05/2016	30	3	90
22/05/2016	105	1	105
22/05/2016	60	1	60
27/05/2016	195	1	195
27/05/2016	80	1	80
27/05/2016	65	1	65
27/05/2016	345	4	1380
27/05/2016	65	1	65
27/05/2016	90	1	90
27/05/2016	45	1	45
27/05/2016	90	1	90
27/05/2016	285	2	570
27/05/2016	120	1	120
27/05/2016	720	6	4320
27/05/2016	145	1	145
27/05/2016	420	4	1680
27/05/2016	180	4	720
27/05/2016	60	4	240
02/06/2016	30	1	30
02/06/2016	70	2	140

02/06/2016	15	1	15
02/06/2016	25	1	25
02/06/2016	75	1	75
06/06/2016	75	1	75
06/06/2016	240	1	240
06/06/2016	45	1	45
06/06/2016	30	1	30
06/06/2016	60	1	60
06/06/2016	15	1	15
06/06/2016	30	1	30
06/06/2016	35	1	35
06/06/2016	195	1	195
06/06/2016	55	1	55
06/06/2016	90	1	90
06/06/2016	105	1	105
06/06/2016	90	1	90
07/06/2016	240	1	240
07/06/2016	60	1	60
07/06/2016	135	1	135
07/06/2016	75	1	75
07/06/2016	90	1	90
07/06/2016	20	1	20
07/06/2016	135	1	135
18/07/2016	184	1	184
18/07/2016	75	1	75
18/07/2016	103	1	103
18/07/2016	30	1	30
18/07/2016	35	3	105
18/07/2016	75	1	75
18/07/2016	90	3	270
18/07/2016	109	1	109
18/07/2016	73	1	73
18/07/2016	45	2	90
18/07/2016	90	1	90
18/07/2016	142	1	142
18/07/2016	75	1	75
18/07/2016	468	1	468
18/07/2016	106	1	106
18/07/2016	165	1	165
18/07/2016	135	1	135

18/07/2016	115	1	115
18/07/2016	128	1	128
19/07/2016	60	2	120
19/07/2016	76	1	76
19/07/2016	34	1	34
19/07/2016	30	3	90
19/07/2016	77	1	77
19/07/2016	62	2	124
19/07/2016	173	2	346
19/07/2016	71	2	142
19/07/2016	82	1	82
19/07/2016	59	1	59
19/07/2016	117	1	117
19/07/2016	98	1	98
19/07/2016	21	1	21
19/07/2016	211	1	211
19/07/2016	77	1	77
19/07/2016	25	1	25
19/07/2016	117	1	117
19/07/2016	30	1	30
19/07/2016	94	1	94
19/07/2016	75	1	75
19/07/2016	75	1	75
22/07/2016	75	1	75
22/07/2016	60	1	60
22/07/2016	23	1	23
22/07/2016	137	1	137
22/07/2016	104	1	104
22/07/2016	159	1	159
22/07/2016	87	1	87
22/07/2016	45	1	45
22/07/2016	2	1	2
22/07/2016	150	2	300
02/08/2016	90	1	90
02/08/2016	30	1	30
02/08/2016	30	1	30
02/08/2016	15	2	30
02/08/2016	75	1	75
02/08/2016	15	1	15
02/08/2016	210	1	210

03/08/2016	15	1	15
03/08/2016	135	2	270
03/08/2016	5	1	5
04/08/2016	100	2	200
04/08/2016	15	1	15
04/08/2016	30	1	30
04/08/2016	15	1	15
04/08/2016	45	1	45
04/08/2016	30	1	30
04/08/2016	15	1	15
04/08/2016	48	1	48
04/08/2016	45	1	45
04/08/2016	35	1	35
04/08/2016	75	1	75
04/08/2016	145	1	145
10/08/2016	160	1	160
10/08/2016	180	1	180
10/08/2016	60	1	60
10/08/2016	105	1	105
10/08/2016	45	1	45
10/08/2016	90	1	90
10/08/2016	85	1	85
10/08/2016	60	1	60
12/08/2016	60	1	60
12/08/2016	15	1	15
12/08/2016	30	1	30
12/08/2016	105	1	105
23/08/2016	15	1	15
23/08/2016	120	1	120
23/08/2016	20	1	20
23/08/2016	15	2	30
23/08/2016	95	1	95
23/08/2016	20	1	20
23/08/2016	95	1	95
23/08/2016	20	1	20
23/08/2016	60	1	60
24/08/2016	60	1	60
24/08/2016	95	1	95
24/08/2016	165	1	165
24/08/2016	70	1	70

24/08/2016	185	1	185
24/08/2016	230	1	230
24/08/2016	190	1	190
25/08/2016	180	1	180
25/08/2016	50	1	50
25/08/2016	135	1	135
25/08/2016	265	1	265
25/08/2016	270	1	270
25/08/2016	100	1	100
25/08/2016	25	1	25
25/08/2016	155	1	155
25/08/2016	140	1	140
25/08/2016	105	1	105
25/08/2016	170	1	170
25/08/2016	900	2	1800
25/08/2016	90	1	90
25/08/2016	810	1	810
25/08/2016	135	1	135
25/08/2016	15	2	30
25/08/2016	450	1	450
31/08/2016	60	1	60
31/08/2016	5	1	5
31/08/2016	75	1	75
31/08/2016	15	1	15
31/08/2016	105	1	105
31/08/2016	60	1	60
31/08/2016	140	1	140
31/08/2016	90	1	90
31/08/2016	10	1	10
Total	**19018**	**226**	**28534**

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

= data input required
= model calculates value

Step 1 **Go to Data Input**

Input data about the species that is being assessed - body length, wing span and flight speed
Input data on turbine dimensions
Input data on wind farm area
Input data on turbine dimensions and specification
Input all vantage point data for the species that is being assessed - number of birds and flight time within the study area
Input the number of days for each month where the species is likely to be present within the site
Input days for those months where the species is likely to be present within the site
Input the appropriate night time correction factor for the species being assessed, e.g. a 25% nocturnal flight time correction was proposed by Band et al for geese. This correction cannot be applied to all species, for example raptors.

Step 2 **Go to Collision Risk**

Final collision risk estimates are highlighted
Only use the collision risk estimate for the method that has been used

Scottish Natural Heritage: Calculating a theoretical collision risk assuming no avoiding action

Site Name: Energy Isles Wind Farm

= data input required
= model calculates value

Stage 1: Number of birds flying through rotors

Input Parameters

Bird Dimensions

Species	Great Skua
length (m)	0.56
wing span (m)	1.36
speed (m/sec)	16

Bird Flight Data

No of birds	226
Time spent in V_w (sec)	522328.15

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781

Wind Farm Dimensions

No of turbines	23
Site Area (m2)	19680000

Method 1 - Birds using the windfarm airspace

(to be used for birds that fly across the site using a variety of different flight paths)

Step No	Description of Calculation		Calculation	Comments
1	Identify 'flight risk volume' V_w' which is the area of the wind farm multiplied by the height of the turbines	V_w =	3936000000 m^3	Area is equivalent to the total area visible from VPs 1, 2, 3 and 6
2	Calculate the combined volume swept out by the rotors $V_r = N \times \pi R^2 \times (d + l)$ where N is the number of turbines, d is the depth of the	V_r =	1804141.75 m^3	

	rotor front to back, and l is the bird length				
3	Estimate bird occupancy n within V_w This is the number of birds multiplied by the time spent within V_w (per season/year)	n =	522328.15	secs per yr	Bird occupancy is based on observations of birds flying through rotor-swept area
4	Bird occupancy of V_r n x (V_r / V_w) bird-seconds	occupancy =	239.42	bird-seconds	
5	Time taken for a bird to make transit through and completely clear the rotors t = (d + l) / v where v is bird speed (m/sec)	t =	0.26	seconds	Speed should be assessed in the field but published values are available
6	Calculate number of bird transits through the rotors = n x (V_r / V_w) / t	transits =	909.52	bird transits per annum	

Number of bird transits through the rotors per annum = 909.52

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Input parameters regarding the turbine specification will need to be obtained from the design engineers or manufacturers.

W Band 03/03/2020

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4	m
Pitch (degrees)	20	
BirdLength	0.56	m
Wingspan	1.36	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	16	m/sec
RotorDiam	154	m
RotationPeriod	3.00	sec
Bird aspect ratioo: β	0.41	

Calculation of alpha and p(collision) as a function of radius

				Upwind:			Downwind:		
r/R	c/C	α	collide		contribution	collide		contribution
radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
0.025	0.575	3.97	14.76	0.92	0.00115	13.19	0.82	0.00103
0.075	0.575	1.32	5.44	0.34	0.00255	3.87	0.24	0.00181
0.125	0.702	0.79	4.13	0.26	0.00323	2.21	0.14	0.00173
0.175	0.860	0.57	3.78	0.24	0.00413	1.43	0.09	0.00156
0.225	0.994	0.44	3.61	0.23	0.00507	0.89	0.06	0.00125
0.275	0.947	0.36	3.14	0.20	0.00539	0.57	0.04	0.00098
0.325	0.899	0.31	2.82	0.18	0.00573	0.76	0.05	0.00154
0.375	0.851	0.26	2.57	0.16	0.00603	0.88	0.05	0.00206
0.425	0.804	0.23	2.36	0.15	0.00628	0.95	0.06	0.00253
0.475	0.756	0.21	2.19	0.14	0.00649	1.00	0.06	0.00297
0.525	0.708	0.19	2.03	0.13	0.00667	1.03	0.06	0.00337
0.575	0.660	0.17	1.89	0.12	0.00680	1.04	0.06	0.00372
0.625	0.613	0.16	1.76	0.11	0.00689	1.03	0.06	0.00403
0.675	0.565	0.15	1.65	0.10	0.00694	1.02	0.06	0.00431
0.725	0.517	0.14	1.53	0.10	0.00695	1.00	0.06	0.00454
0.775	0.470	0.13	1.43	0.09	0.00692	0.98	0.06	0.00473
0.825	0.422	0.12	1.33	0.08	0.00685	0.95	0.06	0.00488
0.875	0.374	0.11	1.23	0.08	0.00673	0.91	0.06	0.00499
0.925	0.327	0.11	1.14	0.07	0.00658	0.88	0.05	0.00506
0.975	0.279	0.10	1.05	0.07	0.00639	0.83	0.05	0.00509

Overall p(collision) = Upwind 11.4% Downwind 6.2%

Average 8.8%

Bird survey data

Date	Time observed (seconds)			Number of birds	Bird Occupancy in flight risk volume
TOTAL	19018			226	28534
TOTAL SURVEY TIME	144	hours	or	518400	seconds

Period when Great Skua likely to be on site (see below) =

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total days = 153 Total hours (corrected - see below) = 2635.987

Period when Great Skua likely to be on site = 9489553 seconds (in each year)

Assumptions (write in any assumptions that have been included in the model)
Assumption 1: The flying period extends from dawn to dusk and includes 25% of night.
Assumption 2:
Assumption 3:
Assumption 4:

Proportion of time during which a collision may occur = 9489553 (in each year)

Great Skua flight time = 28534 seconds in 518400 seconds survey time

Therefore in 5 months = 522328.15 seconds

Note: This table is only relevant when calculating collision risk for goose species. It provides an adjustment for nocturnal flight behaviour for these species.

Number of hours birds are potentially active during winter (from Band et al, in press)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nox	Dec	
Mean Daylight hours**		6.8	9.08	11.78	14.62	17.23	18.77	18.05	15.68	12.88	10.05	7.45	5.98	
Mean Nocturnal hrs*	5	0.86	0.746	0.611	0.469	0.3385	0.2615	0.2975	0.416	0.556	0.6975	0.8275	0.901	
Combined Daily Mean		7.66	9.826	12.391	15.089	17.5685	19.0315	18.3475	16.096	13.436	10.7475	8.2775	6.881	
No of days birds present		0	0	0	30	31	30	31	31	0	0	0	0	
Total hours each month		**0**	**0**	**0**	**452.67**	**544.6235**	**570.945**	**568.7725**	**498.976**	**0**	**0**	**0**	**0**	**2635.987**
Total hours per year		**2635.987**												

**Mean daylight hours taken from www.shetland.climatetemps.com/sunlight.php

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

Number of bird transits through the rotors per annum = 909.52

Average collision risk for bird passing through rotor = 8.8%

Number of birds potentially killed by rotors per annum = 80.02

NB: The above calculation assumes no avoidance

Correcting for 95% avoidance rate:

Number of birds potentially killed by rotors per annum = **4.001150**

1 bird killed every 0.25 years

Correcting for 98% avoidance rate:

Number of birds potentially killed by rotors per annum = **1.600460**

1 bird killed every 0.62 years

Correcting for 99% avoidance rate:

Number of birds potentially killed by rotors per annum = **0.80023**

1 bird killed every 1.25 years

Correcting for 99.5% avoidance rate:

Number of birds potentially killed by rotors per annum = **0.40012**

1 bird killed every 2.50 years

Site Name **Energy Isles Wind Farm**

Bird Dimensions

Species	**Arctic Skua**
length (m)	0.44
wing span (m)	1.18
speed (m/sec)	12

= data input required
= model calculates value

Sources of speed and dimension information: Bruderer & Boldt (2001); BTO Bird Facts

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781003

Note, the maximum height of turbines 5, 16, 19, 20, 24, 25, 26, 27 and 28 is lower, at 180 m

Wind Farm Dimensions

No of turbines	23
Site area (m^2)	19680000

The area is equal to the total visible area (at a minimum 30 m above ground level) from vantage points 1, 2, 3 and 6. The extent of this area is shown on Figure 6.1.

Turbine Specifications

K: [1D or [3D] (0 or 1)	1
NoBlades	3
MaxChord	4 *
Pitch (degrees)	20 *
Rotation period	3 *

Flight Characteristics

Flapping (0) or gliding (+1)	0

Night adjustment

What percentage of the night is the target species active? 5 **%**

Survey Data

Total survey time (hours)	144

Period when Arctic Skua likely to be on site. **Type in the number of days in each month where the target species is present within the site**

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total number of months when Arctic Skua **likely to be present:** 5

Enter the date of each record, the time the bird(s) was recorded in the collision risk area and the number of birds on a separate
Bird occupancy is automatically calculated.

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume
22/05/2016	60	1	60
18/07/2016	31	1	31
22/07/2016	144	1	144
23/08/2016	105	1	105
Total	**340**	**4**	**340**

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

= data input required
= model calculates value

Step 1 **Go to Data Input**

Input data about the species that is being assessed - body length, wing span and flight speed
Input data on turbine dimensions
Input data on wind farm area
Input data on turbine dimensions and specification
Input all vantage point data for the species that is being assessed - number of birds and flight time within the study area
Input the number of days for each month where the species is likely to be present within the site
Input days for those months where the species is likely to be present within the site
Input the appropriate night time correction factor for the species being assessed, e.g. a 25% nocturnal flight time correction was proposed by Band et al for geese. This correction cannot be applied to all species, for example raptors.

Step 2 **Go to Collision Risk**

Final collision risk estimates are highlighted
Only use the collision risk estimate for the method that has been used

Scottish Natural Heritage: Calculating a theoretical collision risk assuming no avoiding action

Site Name: Energy Isles Wind Farm

= data input required
= model calculates value

Stage 1: Number of birds flying through rotors

Input Parameters

Bird Dimensions

Species	Arctic Skua
length (m)	0.44
wing span (m)	1.18
speed (m/sec)	12

Bird Flight Data

No of birds	4
Time spent in V_w (sec)	6223.86

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781

Wind Farm Dimensions

No of turbines	23
Site Area (m2)	19680000

Method 1 - Birds using the windfarm airspace

(to be used for birds that fly across the site using a variety of different flight paths)

Step No	Description of Calculation		Calculation	Comments
1	Identify 'flight risk volume' V_w' which is the area of the wind farm multiplied by the height of the turbines	V_w =	3936000000 m^3	Area is equivalent to the total area visible from VPs 1, 2, 3 and 6
2	Calculate the combined volume swept out by the rotors $V_r = N \times \pi R^2 \times (d + l)$ where N is the number of turbines, d is the depth of the	V_r =	1752739.03 m^3	

	rotor front to back, and l is the bird length				
3	Estimate bird occupancy n within V_w This is the number of birds multiplied by the time spent within V_w (per season/year)	n =	6223.86	secs per yr	Bird occupancy is based on observations of birds flying through rotor-swept area
4	Bird occupancy of V_r n x (V_r / V_w) bird-seconds	occupancy =	2.77	bird-seconds	
5	Time taken for a bird to make transit through and completely clear the rotors t = (d + l) / v where v is bird speed (m/sec)	t =	0.34	seconds	Speed should be assessed in the field but published values are available
6	Calculate number of bird transits through the rotors = n x (V_r / V_w) / t	transits =	8.13	bird transits per annum	

Number of bird transits through the rotors per annum = 8.13

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Input parameters regarding the turbine specification will need to be obtained from the design engineers or manufacturers.

W Band 03/03/2020

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4	m
Pitch (degrees)	20	
BirdLength	0.44	m
Wingspan	1.18	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	12	m/sec
RotorDiam	154	m
RotationPeriod	3.00	sec
Bird aspect ratioo: β	0.37	

Calculation of alpha and p(collision) as a function of radius

				Upwind:			Downwind:		
r/R	c/C	α	collide		contribution	collide		contribution
radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
0.025	0.575	2.98	10.73	0.89	0.00112	9.16	0.76	0.00095
0.075	0.575	0.99	4.10	0.34	0.00256	2.53	0.21	0.00158
0.125	0.702	0.60	3.23	0.27	0.00337	1.31	0.11	0.00137
0.175	0.860	0.43	3.05	0.25	0.00445	0.70	0.06	0.00102
0.225	0.994	0.33	3.04	0.25	0.00569	0.56	0.05	0.00106
0.275	0.947	0.27	2.70	0.22	0.00618	0.77	0.06	0.00177
0.325	0.899	0.23	2.44	0.20	0.00662	0.90	0.07	0.00243
0.375	0.851	0.20	2.24	0.19	0.00700	0.97	0.08	0.00303
0.425	0.804	0.18	2.07	0.17	0.00732	1.01	0.08	0.00358
0.475	0.756	0.16	1.92	0.16	0.00760	1.03	0.09	0.00407
0.525	0.708	0.14	1.79	0.15	0.00781	1.03	0.09	0.00451
0.575	0.660	0.13	1.66	0.14	0.00798	1.02	0.09	0.00490
0.625	0.613	0.12	1.55	0.13	0.00809	1.00	0.08	0.00523
0.675	0.565	0.11	1.45	0.12	0.00814	0.98	0.08	0.00551
0.725	0.517	0.10	1.35	0.11	0.00814	0.95	0.08	0.00573
0.775	0.470	0.10	1.25	0.10	0.00809	0.91	0.08	0.00590
0.825	0.422	0.09	1.16	0.10	0.00798	0.87	0.07	0.00601
0.875	0.374	0.09	1.07	0.09	0.00781	0.83	0.07	0.00607
0.925	0.327	0.08	0.99	0.08	0.00760	0.79	0.07	0.00607
0.975	0.279	0.08	0.90	0.08	0.00732	0.74	0.06	0.00602

Overall p(collision) = Upwind 13.1% Downwind 7.7%

Average 10.4%

Bird survey data

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume
TOTAL	340	4	340

TOTAL SURVEY TIME 144 hours or 518400 seconds

Period when Arctic Skua likely to be on site (see below) =

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total days = 153 Total hours (corrected - see below) = 2635.987

Period when Arctic Skua likely to be on site = 9489553 seconds (in each year)

Assumptions (write in any assumptions that have been included in the model)

Assumption 1: The flying period extends from dawn to dusk and includes 25% of night.

Assumption 2:

Assumption 3:

Assumption 4:

Proportion of time during which a collision may occur = 9489553 (in each year)

Arctic Skua flight time = 340 seconds in 518400 seconds survey time

Therefore in 5 months = 6223.86 seconds

Note: This table is only relevant when calculating collision risk for goose species. It provides an adjustment for nocturnal flight behaviour for these species.

Number of hours birds are potentially active during winter (from Band et al, in press)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nox	Dec	
Mean Daylight hours**		6.8	9.08	11.78	14.62	17.23	18.77	18.05	15.68	12.88	10.05	7.45	5.98	
Mean Nocturnal hrs*	5	0.86	0.746	0.611	0.469	0.3385	0.2615	0.2975	0.416	0.556	0.6975	0.8275	0.901	
Combined Daily Mean		7.66	9.826	12.391	15.089	17.5685	19.0315	18.3475	16.096	13.436	10.7475	8.2775	6.881	
No of days birds present		0	0	0	30	31	30	31	31	0	0	0	0	
Total hours each month		**0**	**0**	**0**	**452.67**	**544.6235**	**570.945**	**568.7725**	**498.976**	**0**	**0**	**0**	**0**	**2635.987**
Total hours per year		**2635.987**												

**Mean daylight hours taken from www.shetland.climatetemps.com/sunlight.php

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

Number of bird transits through the rotors per annum =	8.13
Average collision risk for bird passing through rotor =	10.4%
Number of birds potentially killed by rotors per annum =	0.84

NB: The above calculation assumes no avoidance

Correcting for 95% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.042201
1 bird killed every	23.696037 years

Correcting for 98% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.016880
1 bird killed every	59.240092 years

Correcting for 99% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.00844
1 bird killed every	118.480184 years

Correcting for 99.5% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.00422
1 bird killed every	236.960369 years

Site Name **Energy Isles Wind Farm**

Bird Dimensions

Species	**Arctic Skua**
length (m)	0.44
wing span (m)	1.18
speed (m/sec)	12

= data input required
= model calculates value

Sources of speed and dimension information: Bruderer & Boldt (2001); BTO Bird Facts

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781003

Note, the maximum height of turbines 5, 16, 19, 20, 24, 25, 26, 27 and 28 is lower, at 180 m

Wind Farm Dimensions

No of turbines	23
Site area (m^2)	19680000

The area is equal to the total visible area (at a minimum 30 m above ground level) from vantage points 1, 2, 3 and 6. The extent of this area is shown on Figure 6.1.

Turbine Specifications

K: [1D or [3D] (0 or 1)	1
NoBlades	3
MaxChord	4 *
Pitch (degrees)	20 *
Rotation period	3 *

Flight Characteristics

Flapping (0) or gliding (+1)	0

Night adjustment

What percentage of the night is the target species active? 5 **%**

Survey Data

Total survey time (hours)	144

Period when Arctic Skua likely to be on site. **Type in the number of days in each month where the target species is present within the site**

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total number of months when Arctic Skua **likely to be present:** 5

Enter the date of each record, the time the bird(s) was recorded in the collision risk area and the number of birds on a separate
Bird occupancy is automatically calculated.

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume
05/07/2018	35	6	210
05/07/2018	100	4	400
09/07/2018	150	1	150
06/07/2018	15	2	30
07/08/2018	75	1	75
07/08/2018	73	1	73
21/08/2018	21	3	63
Total	**469**	**18**	**1001**

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

= data input required
= model calculates value

Step 1 **Go to Data Input**

Input data about the species that is being assessed - body length, wing span and flight speed
Input data on turbine dimensions
Input data on wind farm area
Input data on turbine dimensions and specification
Input all vantage point data for the species that is being assessed - number of birds and flight time within the study area
Input the number of days for each month where the species is likely to be present within the site
Input days for those months where the species is likely to be present within the site
Input the appropriate night time correction factor for the species being assessed, e.g. a 25% nocturnal flight time correction was proposed by Band et al for geese. This correction cannot be applied to all species, for example raptors.

Step 2 **Go to Collision Risk**

Final collision risk estimates are highlighted
Only use the collision risk estimate for the method that has been used

Scottish Natural Heritage: Calculating a theoretical collision risk assuming no avoiding action

Site Name: Energy Isles Wind Farm

= data input required
= model calculates value

Stage 1: Number of birds flying through rotors

Input Parameters

Bird Dimensions

Species	Arctic Skua
length (m)	0.44
wing span (m)	1.18
speed (m/sec)	12

Bird Flight Data

No of birds	18
Time spent in V_w (sec)	18323.77

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781

Wind Farm Dimensions

No of turbines	23
Site Area (m^2)	19680000

Method 1 - Birds using the windfarm airspace

(to be used for birds that fly across the site using a variety of different flight paths)

Step No	Description of Calculation		Calculation	Comments
1	Identify 'flight risk volume' V_w' which is the area of the wind farm multiplied by the height of the turbines	V_w =	3936000000 m^3	Area is equivalent to the total area visible from VPs 1, 2, 3 and 6
2	Calculate the combined volume swept out by the rotors $V_r = N \times \pi R^2 \times (d + l)$ where N is the number of turbines, d is the depth of the	V_r =	1752739.03 m^3	

	rotor front to back, and l is the bird length				
3	Estimate bird occupancy n within V_w This is the number of birds multiplied by the time spent within V_w (per season/year)	n =	18323.77	secs per yr	Bird occupancy is based on observations of birds flying through rotor-swept area
4	Bird occupancy of V_r n x (V_r / V_w) bird-seconds	occupancy =	8.16	bird-seconds	
5	Time taken for a bird to make transit through and completely clear the rotors t = (d + l) / v where v is bird speed (m/sec)	t =	0.34	seconds	Speed should be assessed in the field but published values are available
6	Calculate number of bird transits through the rotors = n x (V_r / V_w) / t	transits =	23.93	bird transits per annum	

Number of bird transits through the rotors per annum = 23.93

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Input parameters regarding the turbine specification will need to be obtained from the design engineers or manufacturers.

W Band 03/03/2020

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4	m
Pitch (degrees)	20	
BirdLength	0.44	m
Wingspan	1.18	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	12	m/sec
RotorDiam	154	m
RotationPeriod	3.00	sec
Bird aspect ratioo: β	0.37	

Calculation of alpha and p(collision) as a function of radius

				Upwind:			Downwind:		
r/R	c/C	α	collide		contribution	collide		contribution
radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
0.025	0.575	2.98	10.73	0.89	0.00112	9.16	0.76	0.00095
0.075	0.575	0.99	4.10	0.34	0.00256	2.53	0.21	0.00158
0.125	0.702	0.60	3.23	0.27	0.00337	1.31	0.11	0.00137
0.175	0.860	0.43	3.05	0.25	0.00445	0.70	0.06	0.00102
0.225	0.994	0.33	3.04	0.25	0.00569	0.56	0.05	0.00106
0.275	0.947	0.27	2.70	0.22	0.00618	0.77	0.06	0.00177
0.325	0.899	0.23	2.44	0.20	0.00662	0.90	0.07	0.00243
0.375	0.851	0.20	2.24	0.19	0.00700	0.97	0.08	0.00303
0.425	0.804	0.18	2.07	0.17	0.00732	1.01	0.08	0.00358
0.475	0.756	0.16	1.92	0.16	0.00760	1.03	0.09	0.00407
0.525	0.708	0.14	1.79	0.15	0.00781	1.03	0.09	0.00451
0.575	0.660	0.13	1.66	0.14	0.00798	1.02	0.09	0.00490
0.625	0.613	0.12	1.55	0.13	0.00809	1.00	0.08	0.00523
0.675	0.565	0.11	1.45	0.12	0.00814	0.98	0.08	0.00551
0.725	0.517	0.10	1.35	0.11	0.00814	0.95	0.08	0.00573
0.775	0.470	0.10	1.25	0.10	0.00809	0.91	0.08	0.00590
0.825	0.422	0.09	1.16	0.10	0.00798	0.87	0.07	0.00601
0.875	0.374	0.09	1.07	0.09	0.00781	0.83	0.07	0.00607
0.925	0.327	0.08	0.99	0.08	0.00760	0.79	0.07	0.00607
0.975	0.279	0.08	0.90	0.08	0.00732	0.74	0.06	0.00602

Overall p(collision) = Upwind 13.1% Downwind 7.7%

Average 10.4%

Bird survey data

Date	Time observed (seconds)			Number of birds	Bird Occupancy in flight risk volume
TOTAL	469			18	1001
TOTAL SURVEY TIME	144	hours	or	518400	seconds

Period when Arctic Skua likely to be on site (see below) =

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total days = 153 Total hours (corrected - see below) = 2635.987

Period when Arctic Skua likely to be on site = 9489553 seconds (in each year)

Assumptions (write in any assumptions that have been included in the model)

Assumption 1: The flying period extends from dawn to dusk and includes 25% of night.

Assumption 2:

Assumption 3:

Assumption 4:

Proportion of time during which a collision may occur = 9489553 (in each year)

Arctic Skua flight time = 1001 seconds in 518400 seconds survey time

Therefore in 5 months = 18323.77 seconds

Note: This table is only relevant when calculating collision risk for goose species. It provides an adjustment for nocturnal flight behaviour for these species.

Number of hours birds are potentially active during winter (from Band et al, in press)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nox	Dec	
Mean Daylight hours**		6.8	9.08	11.78	14.62	17.23	18.77	18.05	15.68	12.88	10.05	7.45	5.98	
Mean Nocturnal hrs*	5	0.86	0.746	0.611	0.469	0.3385	0.2615	0.2975	0.416	0.556	0.6975	0.8275	0.901	
Combined Daily Mean		7.66	9.826	12.391	15.089	17.5685	19.0315	18.3475	16.096	13.436	10.7475	8.2775	6.881	
No of days birds present		0	0	0	30	31	30	31	31	0	0	0	0	
Total hours each month		**0**	**0**	**0**	**452.67**	**544.6235**	**570.945**	**568.7725**	**498.976**	**0**	**0**	**0**	**0**	**2635.987**
Total hours per year		**2635.987**												

**Mean daylight hours taken from www.shetland.climatetemps.com/sunlight.php

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

Number of bird transits through the rotors per annum =	23.93
Average collision risk for bird passing through rotor =	10.4%
Number of birds potentially killed by rotors per annum =	2.48

NB: The above calculation assumes no avoidance

Correcting for 95% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.124245
1 bird killed every	8.048604 years

Correcting for 98% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.049698
1 bird killed every	20.121510 years

Correcting for 99% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.02485
1 bird killed every	40.243020 years

Correcting for 99.5% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.01242
1 bird killed every	80.486039 years

Site Name **Energy Isles Wind Farm**

Bird Dimensions

Species	**Arctic Tern**
length (m)	0.34
wing span (m)	0.8
speed (m/sec)	10

= data input required
= model calculates value

Sources of speed and dimension information: Bruderer & Boldt (2001); BTO Bird Facts

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781003

Note, the maximum height of turbines 5, 16, 19, 20, 24, 25, 26, 27 and 28 is lower, at 180 m

Wind Farm Dimensions

No of turbines	23
Site area (m2)	19680000

The area is equal to the total visible area (at a minimum 30 m above ground level) from vantage points 1, 2, 3 and 6. The extent of this area is shown on Figure 6.1.

Turbine Specifications

K: [1D or [3D] (0 or 1)	1
NoBlades	3
MaxChord	4 *
Pitch (degrees)	20 *
Rotation period	3 *

Flight Characteristics

Flapping (0) or gliding (+1)	0

Night adjustment

What percentage of the night is the target species active? 5 **%**

Survey Data

Total survey time (hours)	144

Period when Arctic Tern likely to be on site.

Type in the number of days in each month where the target species is present within the site

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total number of months when Arctic Tern **likely to be present:** 5

Enter the date of each record, the time the bird(s) was recorded in the collision risk area and the number of birds on a separate
Bird occupancy is automatically calculated.

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume
22/05/2016	125	2	250
27/05/2016	210	4	840
27/05/2016	25	1	25
01/06/2016	35	2	70
01/06/2016	15	2	30
06/06/2016	70	1	70
18/07/2016	34	2	68
18/07/2016	96	2	192
19/07/2016	45	1	45
22/07/2016	107	4	428
22/07/2016	171	1	171
Total	**933**	**22**	**2189**

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

= data input required
= model calculates value

Step 1 **Go to Data Input**

Input data about the species that is being assessed - body length, wing span and flight speed
Input data on turbine dimensions
Input data on wind farm area
Input data on turbine dimensions and specification
Input all vantage point data for the species that is being assessed - number of birds and flight time within the study area
Input the number of days for each month where the species is likely to be present within the site
Input days for those months where the species is likely to be present within the site
Input the appropriate night time correction factor for the species being assessed, e.g. a 25% nocturnal flight time correction was proposed by Band et al for geese. This correction cannot be applied to all species, for example raptors.

Step 2 **Go to Collision Risk**

Final collision risk estimates are highlighted
Only use the collision risk estimate for the method that has been used

Scottish Natural Heritage: Calculating a theoretical collision risk assuming no avoiding action

Site Name: Energy Isles Wind Farm

= data input required
= model calculates value

Stage 1: Number of birds flying through rotors

Input Parameters

Bird Dimensions

Species	Arctic Tern
length (m)	0.34
wing span (m)	0.8
speed (m/sec)	10

Bird Flight Data

No of birds	22
Time spent in V_w (sec)	40070.66

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781

Wind Farm Dimensions

No of turbines	23
Site Area (m2)	19680000

Method 1 - Birds using the windfarm airspace

(to be used for birds that fly across the site using a variety of different flight paths)

Step No	Description of Calculation		Calculation	Comments
1	Identify 'flight risk volume' V_w' which is the area of the wind farm multiplied by the height of the turbines	V_w =	3936000000 m^3	Area is equivalent to the total area visible from VPs 1, 2, 3 and 6
2	Calculate the combined volume swept out by the rotors $V_r = N \times \pi R^2 \times (d + l)$ where N is the number of turbines, d is the depth of the	V_r =	1709903.42 m^3	

	rotor front to back, and l is the bird length				
3	Estimate bird occupancy n within V_w This is the number of birds multiplied by the time spent within V_w (per season/year)	n =	40070.66	secs per yr	Bird occupancy is based on observations of birds flying through rotor-swept area
4	Bird occupancy of V_r n x (V_r / V_w) bird-seconds	occupancy =	17.41	bird-seconds	
5	Time taken for a bird to make transit through and completely clear the rotors t = (d + l) / v where v is bird speed (m/sec)	t =	0.40	seconds	Speed should be assessed in the field but published values are available
6	Calculate number of bird transits through the rotors = n x (V_r / V_w) / t	transits =	43.61	bird transits per annum	

Number of bird transits through the rotors per annum = 43.61

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Input parameters regarding the turbine specification will need to be obtained from the design engineers or manufacturers.

W Band 03/03/2020

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4	m
Pitch (degrees)	20	
BirdLength	0.34	m
Wingspan	0.8	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	10	m/sec
RotorDiam	154	m
RotationPeriod	3.00	sec
Bird aspect ratioo: β	0.43	

Calculation of alpha and p(collision) as a function of radius

				Upwind:			Downwind:		
r/R	c/C	α	collide		contribution	collide		contribution
radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
0.025	0.575	2.48	8.13	0.81	0.00102	6.56	0.66	0.00082
0.075	0.575	0.83	3.23	0.32	0.00243	1.66	0.17	0.00125
0.125	0.702	0.50	2.66	0.27	0.00333	0.75	0.07	0.00093
0.175	0.860	0.35	2.66	0.27	0.00466	0.37	0.04	0.00065
0.225	0.994	0.28	2.73	0.27	0.00614	0.67	0.07	0.00151
0.275	0.947	0.23	2.44	0.24	0.00670	0.83	0.08	0.00229
0.325	0.899	0.19	2.21	0.22	0.00720	0.93	0.09	0.00301
0.375	0.851	0.17	2.03	0.20	0.00763	0.98	0.10	0.00366
0.425	0.804	0.15	1.88	0.19	0.00799	1.00	0.10	0.00424
0.475	0.756	0.13	1.74	0.17	0.00829	1.00	0.10	0.00477
0.525	0.708	0.12	1.62	0.16	0.00852	0.99	0.10	0.00522
0.575	0.660	0.11	1.51	0.15	0.00869	0.98	0.10	0.00561
0.625	0.613	0.10	1.41	0.14	0.00879	0.95	0.09	0.00594
0.675	0.565	0.09	1.31	0.13	0.00883	0.92	0.09	0.00620
0.725	0.517	0.09	1.21	0.12	0.00880	0.88	0.09	0.00639
0.775	0.470	0.08	1.12	0.11	0.00871	0.84	0.08	0.00652
0.825	0.422	0.08	1.04	0.10	0.00855	0.80	0.08	0.00658
0.875	0.374	0.07	0.95	0.10	0.00833	0.75	0.08	0.00658
0.925	0.327	0.07	0.87	0.09	0.00804	0.70	0.07	0.00652
0.975	0.279	0.06	0.79	0.08	0.00768	0.65	0.07	0.00638

Overall p(collision) = Upwind 14.0% Downwind 8.5%

Average 11.3%

Bird survey data

Date	Time observed (seconds)		Number of birds	Bird Occupancy in flight risk volume
TOTAL	933		22	2189

TOTAL SURVEY TIME 144 hours or 518400 seconds

Period when Arctic Tern likely to be on site (see below) =

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total days = 153 Total hours (corrected - see below) = 2635.987

Period when Arctic Tern likely to be on site = 9489553 seconds (in each year)

Assumptions (write in any assumptions that have been included in the model)

Assumption 1: The flying period extends from dawn to dusk and includes 25% of night.

Assumption 2:

Assumption 3:

Assumption 4:

Proportion of time during which a collision may occur = 9489553 (in each year)

Arctic Tern flight time = 2189 seconds in 518400 seconds survey time

Therefore in 5 months = 40070.66 seconds

Note: This table is only relevant when calculating collision risk for goose species. It provides an adjustment for nocturnal flight behaviour for these species.

Number of hours birds are potentially active during winter (from Band et al, in press)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nox	Dec	
Mean Daylight hours**		6.8	9.08	11.78	14.62	17.23	18.77	18.05	15.68	12.88	10.05	7.45	5.98	
Mean Nocturnal hrs*	5	0.86	0.746	0.611	0.469	0.3385	0.2615	0.2975	0.416	0.556	0.6975	0.8275	0.901	
Combined Daily Mean		7.66	9.826	12.391	15.089	17.5685	19.0315	18.3475	16.096	13.436	10.7475	8.2775	6.881	
No of days birds present		0	0	0	30	31	30	31	31	0	0	0	0	
Total hours each month		**0**	**0**	**0**	**452.67**	**544.6235**	**570.945**	**568.7725**	**498.976**	**0**	**0**	**0**	**0**	**2635.987**
Total hours per year		**2635.987**												

**Mean daylight hours taken from www.shetland.climatetemps.com/sunlight.php

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

Number of bird transits through the rotors per annum =	43.61
Average collision risk for bird passing through rotor =	11.3%
Number of birds potentially killed by rotors per annum =	4.91

NB: The above calculation assumes no avoidance

Correcting for 95% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.245724
1 bird killed every	4.069602 years

Correcting for 98% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.098290
1 bird killed every	10.174006 years

Correcting for 99% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.04914
1 bird killed every	20.348012 years

Site Name **Energy Isles Wind Farm**

Bird Dimensions

Species	**Arctic Tern**
length (m)	0.34
wing span (m)	0.8
speed (m/sec)	10

= data input required
= model calculates value

Sources of speed and dimension information: Bruderer & Boldt (2001); BTO Bird Facts

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781003

Note, the maximum height of turbines 5, 16, 19, 20, 24, 25, 26, 27 and 28 is lower, at 180 m

Wind Farm Dimensions

No of turbines	23
Site area (m2)	19680000

The area is equal to the total visible area (at a minimum 30 m above ground level) from vantage points 1, 2, 3 and 6. The extent of this area is shown on Figure 6.1.

Turbine Specifications

K: [1D or [3D] (0 or 1)	1
NoBlades	3
MaxChord	4 *
Pitch (degrees)	20 *
Rotation period	3 *

Flight Characteristics

Flapping (0) or gliding (+1)	0

Night adjustment

What percentage of the night is the target species active? 5 **%**

Survey Data

Total survey time (hours)	144

Period when Arctic Tern likely to be on site.

Type in the number of days in each month where the target species is present within the site

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total number of months when Arctic Tern **likely to be present:** 5

Enter the date of each record, the time the bird(s) was recorded in the collision risk area and the number of birds on a separate
Bird occupancy is automatically calculated.

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume
18/05/2018	31	2	62
08/06/2018	15	1	15
05/07/2018	30	3	90
09/07/2018	90	2	180
Total	**166**	**8**	**347**

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

= data input required
= model calculates value

Step 1 **Go to Data Input**

Input data about the species that is being assessed - body length, wing span and flight speed
Input data on turbine dimensions
Input data on wind farm area
Input data on turbine dimensions and specification
Input all vantage point data for the species that is being assessed - number of birds and flight time within the study area
Input the number of days for each month where the species is likely to be present within the site
Input days for those months where the species is likely to be present within the site
Input the appropriate night time correction factor for the species being assessed, e.g. a 25% nocturnal flight time correction was proposed by Band et al for geese. This correction cannot be applied to all species, for example raptors.

Step 2 **Go to Collision Risk**

Final collision risk estimates are highlighted
Only use the collision risk estimate for the method that has been used

Scottish Natural Heritage: Calculating a theoretical collision risk assuming no avoiding action

Site Name: Energy Isles Wind Farm

= data input required
= model calculates value

Stage 1: Number of birds flying through rotors

Input Parameters

Bird Dimensions

Species	Arctic Tern
length (m)	0.34
wing span (m)	0.8
speed (m/sec)	10

Bird Flight Data

No of birds	8
Time spent in V_w (sec)	6352.00

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781

Wind Farm Dimensions

No of turbines	23
Site Area (m2)	19680000

Method 1 - Birds using the windfarm airspace

(to be used for birds that fly across the site using a variety of different flight paths)

Step No	Description of Calculation		Calculation	Comments
1	Identify 'flight risk volume' V_w' which is the area of the wind farm multiplied by the height of the turbines	V_w =	3936000000 m^3	Area is equivalent to the total area visible from VPs 1, 2, 3 and 6
2	Calculate the combined volume swept out by the rotors $V_r = N \times \pi R^2 \times (d + l)$ where N is the number of turbines, d is the depth of the	V_r =	1709903.42 m^3	

	rotor front to back, and l is the bird length				
3	Estimate bird occupancy n within V_w This is the number of birds multiplied by the time spent within V_w (per season/year)	n =	6352.00	secs per yr	Bird occupancy is based on observations of birds flying through rotor-swept area
4	Bird occupancy of V_r n x (V_r / V_w) bird-seconds	occupancy =	2.76	bird-seconds	
5	Time taken for a bird to make transit through and completely clear the rotors t = (d + l) / v where v is bird speed (m/sec)	t =	0.40	seconds	Speed should be assessed in the field but published values are available
6	Calculate number of bird transits through the rotors = n x (V_r / V_w) / t	transits =	6.91	bird transits per annum	

Number of bird transits through the rotors per annum = 6.91

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Input parameters regarding the turbine specification will need to be obtained from the design engineers or manufacturers.

W Band 03/03/2020

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4	m
Pitch (degrees)	20	
BirdLength	0.34	m
Wingspan	0.8	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	10	m/sec
RotorDiam	154	m
RotationPeriod	3.00	sec
Bird aspect ratioo: β	0.43	

Calculation of alpha and p(collision) as a function of radius

				Upwind:			Downwind:		
r/R	c/C	α	collide		contribution	collide		contribution
radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
0.025	0.575	2.48	8.13	0.81	0.00102	6.56	0.66	0.00082
0.075	0.575	0.83	3.23	0.32	0.00243	1.66	0.17	0.00125
0.125	0.702	0.50	2.66	0.27	0.00333	0.75	0.07	0.00093
0.175	0.860	0.35	2.66	0.27	0.00466	0.37	0.04	0.00065
0.225	0.994	0.28	2.73	0.27	0.00614	0.67	0.07	0.00151
0.275	0.947	0.23	2.44	0.24	0.00670	0.83	0.08	0.00229
0.325	0.899	0.19	2.21	0.22	0.00720	0.93	0.09	0.00301
0.375	0.851	0.17	2.03	0.20	0.00763	0.98	0.10	0.00366
0.425	0.804	0.15	1.88	0.19	0.00799	1.00	0.10	0.00424
0.475	0.756	0.13	1.74	0.17	0.00829	1.00	0.10	0.00477
0.525	0.708	0.12	1.62	0.16	0.00852	0.99	0.10	0.00522
0.575	0.660	0.11	1.51	0.15	0.00869	0.98	0.10	0.00561
0.625	0.613	0.10	1.41	0.14	0.00879	0.95	0.09	0.00594
0.675	0.565	0.09	1.31	0.13	0.00883	0.92	0.09	0.00620
0.725	0.517	0.09	1.21	0.12	0.00880	0.88	0.09	0.00639
0.775	0.470	0.08	1.12	0.11	0.00871	0.84	0.08	0.00652
0.825	0.422	0.08	1.04	0.10	0.00855	0.80	0.08	0.00658
0.875	0.374	0.07	0.95	0.10	0.00833	0.75	0.08	0.00658
0.925	0.327	0.07	0.87	0.09	0.00804	0.70	0.07	0.00652
0.975	0.279	0.06	0.79	0.08	0.00768	0.65	0.07	0.00638

Overall p(collision) = Upwind 14.0% Downwind 8.5%

Average 11.3%

Bird survey data

Date	Time observed (seconds)			Number of birds	Bird Occupancy in flight risk volume
TOTAL	166			8	347

TOTAL SURVEY TIME 144 hours or 518400 seconds

Period when Arctic Tern likely to be on site (see below) =

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total days = 153 Total hours (corrected - see below) = 2635.987

Period when Arctic Tern likely to be on site = 9489553 seconds (in each year)

Assumptions (write in any assumptions that have been included in the model)

Assumption 1: The flying period extends from dawn to dusk and includes 25% of night.

Assumption 2:

Assumption 3:

Assumption 4:

Proportion of time during which a collision may occur = 9489553 (in each year)

Arctic Tern flight time = 347 seconds in 518400 seconds survey time

Therefore in 5 months = 6352.00 seconds

Note: This table is only relevant when calculating collision risk for goose species. It provides an adjustment for nocturnal flight behaviour for these species.

Number of hours birds are potentially active during winter (from Band et al, in press)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nox	Dec	
Mean Daylight hours**		6.8	9.08	11.78	14.62	17.23	18.77	18.05	15.68	12.88	10.05	7.45	5.98	
Mean Nocturnal hrs*	5	0.86	0.746	0.611	0.469	0.3385	0.2615	0.2975	0.416	0.556	0.6975	0.8275	0.901	
Combined Daily Mean		7.66	9.826	12.391	15.089	17.5685	19.0315	18.3475	16.096	13.436	10.7475	8.2775	6.881	
No of days birds present		0	0	0	30	31	30	31	31	0	0	0	0	
Total hours each month		**0**	**0**	**0**	**452.67**	**544.6235**	**570.945**	**568.7725**	**498.976**	**0**	**0**	**0**	**0**	**2635.987**
Total hours per year		**2635.987**												

**Mean daylight hours taken from www.shetland.climatetemps.com/sunlight.php

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

Number of bird transits through the rotors per annum =	6.91
Average collision risk for bird passing through rotor =	11.3%
Number of birds potentially killed by rotors per annum =	0.78

NB: The above calculation assumes no avoidance

Correcting for 95% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.038952
1 bird killed every	25.672507 years

Correcting for 98% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.015581
1 bird killed every	64.181267 years

Correcting for 99% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.00779
1 bird killed every	128.362533 years

Site Name **Energy Isles Wind Farm**

Bird Dimensions

Species	**Fulmar**
length (m)	0.48
wing span (m)	1.07
speed (m/sec)	13

= data input required
= model calculates value

Sources of speed and dimension information: Bruderer & Boldt (2001); BTO Bird Facts

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781003

Note, the maximum height of turbines 5, 16, 19, 20, 24, 25, 26, 27 and 28 is lower, at 180 m

Wind Farm Dimensions

No of turbines	23
Site area (m2)	19680000

The area is equal to the total visible area (at a minimum 30 m above ground level) from vantage points 1, 2, 3 and 6. The extent of this area is shown on Figure 6.1.

Turbine Specifications

K: [1D or [3D] (0 or 1)	1
NoBlades	3
MaxChord	4 *
Pitch (degrees)	20 *
Rotation period	3 *

Flight Characteristics

Flapping (0) or gliding (+1)	0

Night adjustment

What percentage of the night is the target species active? 5 **%**

Survey Data

Total survey time (hours)	144

Period when Fulmar likely to be on site. **Type in the number of days in each month where the target species is present within the site**

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total number of months when Fulmar **likely to be present:** 5

Enter the date of each record, the time the bird(s) was recorded in the collision risk area and the number of birds on a separate
Bird occupancy is automatically calculated.

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume
05/04/2016	15	1	15
18/07/2016	106	2	212
19/07/2016	66	2	132
19/07/2016	129	1	129
10/08/2016	225	1	225
12/08/2016	375	1	375
12/08/2016	60	1	60
12/08/2016	10	1	10
12/08/2016	130	1	130
24/08/2016	60	1	60
24/08/2016	130	1	130
24/08/2016	150	1	150
24/08/2016	45	1	45
24/08/2016	175	5	875
31/08/2016	220	8	1760
31/08/2016	60	1	60
31/08/2016	100	2	200
31/08/2016	135	4	540
31/08/2016	100	2	200
Total	**2291**	**37**	**5308**

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

= data input required
= model calculates value

Step 1 **Go to Data Input**

Input data about the species that is being assessed - body length, wing span and flight speed
Input data on turbine dimensions
Input data on wind farm area
Input data on turbine dimensions and specification
Input all vantage point data for the species that is being assessed - number of birds and flight time within the study area
Input the number of days for each month where the species is likely to be present within the site
Input days for those months where the species is likely to be present within the site
Input the appropriate night time correction factor for the species being assessed, e.g. a 25% nocturnal flight time correction was proposed by Band et al for geese. This correction cannot be applied to all species, for example raptors.

Step 2 **Go to Collision Risk**

Final collision risk estimates are highlighted
Only use the collision risk estimate for the method that has been used

Scottish Natural Heritage: Calculating a theoretical collision risk assuming no avoiding action

Site Name: Energy Isles Wind Farm

= data input required
= model calculates value

Stage 1: Number of birds flying through rotors

Input Parameters

Bird Dimensions

Species	Fulmar
length (m)	0.48
wing span (m)	1.07
speed (m/sec)	13

Bird Flight Data

No of birds	37
Time spent in V_w (sec)	97165.41

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781

Wind Farm Dimensions

No of turbines	23
Site Area (m2)	19680000

Method 1 - Birds using the windfarm airspace

(to be used for birds that fly across the site using a variety of different flight paths)

Step No	Description of Calculation		Calculation	Comments
1	Identify 'flight risk volume' V_w' which is the area of the wind farm multiplied by the height of the turbines	V_w =	3936000000 m^3	Area is equivalent to the total area visible from VPs 1, 2, 3 and 6
2	Calculate the combined volume swept out by the rotors $V_r = N \times \pi R^2 \times (d + l)$ where N is the number of turbines, d is the depth of the	V_r =	1769873.27 m^3	

	rotor front to back, and l is the bird length				
3	Estimate bird occupancy n within V_w This is the number of birds multiplied by the time spent within V_w (per season/year)	n =	97165.41	secs per yr	Bird occupancy is based on observations of birds flying through rotor-swept area
4	Bird occupancy of V_r n x (V_r / V_w) bird-seconds	occupancy =	43.69	bird-seconds	
5	Time taken for a bird to make transit through and completely clear the rotors t = (d + l) / v where v is bird speed (m/sec)	t =	0.32	seconds	Speed should be assessed in the field but published values are available
6	Calculate number of bird transits through the rotors = n x (V_r / V_w) / t	transits =	137.47	bird transits per annum	

Number of bird transits through the rotors per annum = 137.47

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Input parameters regarding the turbine specification will need to be obtained from the design engineers or manufacturers.

W Band 03/03/2020

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4	m
Pitch (degrees)	20	
BirdLength	0.48	m
Wingspan	1.07	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	13	m/sec
RotorDiam	154	m
RotationPeriod	3.00	sec
Bird aspect ratioo: β	0.45	

Calculation of alpha and p(collision) as a function of radius

				Upwind:			Downwind:		
r/R	c/C	α	collide		contribution	collide		contribution
radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
0.025	0.575	3.22	11.21	0.86	0.00108	9.63	0.74	0.00093
0.075	0.575	1.07	4.26	0.33	0.00246	2.69	0.21	0.00155
0.125	0.702	0.64	3.35	0.26	0.00322	1.43	0.11	0.00138
0.175	0.860	0.46	3.16	0.24	0.00425	0.81	0.06	0.00108
0.225	0.994	0.36	3.18	0.24	0.00550	0.50	0.04	0.00087
0.275	0.947	0.29	2.82	0.22	0.00596	0.73	0.06	0.00155
0.325	0.899	0.25	2.55	0.20	0.00637	0.87	0.07	0.00218
0.375	0.851	0.21	2.33	0.18	0.00673	0.96	0.07	0.00276
0.425	0.804	0.19	2.15	0.17	0.00704	1.01	0.08	0.00329
0.475	0.756	0.17	2.00	0.15	0.00729	1.03	0.08	0.00377
0.525	0.708	0.15	1.86	0.14	0.00750	1.04	0.08	0.00420
0.575	0.660	0.14	1.73	0.13	0.00766	1.04	0.08	0.00458
0.625	0.613	0.13	1.62	0.12	0.00777	1.02	0.08	0.00491
0.675	0.565	0.12	1.51	0.12	0.00782	1.00	0.08	0.00519
0.725	0.517	0.11	1.40	0.11	0.00783	0.97	0.07	0.00542
0.775	0.470	0.10	1.31	0.10	0.00779	0.94	0.07	0.00560
0.825	0.422	0.10	1.21	0.09	0.00769	0.90	0.07	0.00573
0.875	0.374	0.09	1.12	0.09	0.00755	0.86	0.07	0.00580
0.925	0.327	0.09	1.03	0.08	0.00736	0.82	0.06	0.00583
0.975	0.279	0.08	0.95	0.07	0.00711	0.77	0.06	0.00581

Overall p(collision) = Upwind 12.6% Downwind 7.2%

Average 9.9%

Bird survey data

Date	Time observed (seconds)		Number of birds	Bird Occupancy in flight risk volume
TOTAL	2291		37	5308

TOTAL SURVEY TIME 144 hours or 518400 seconds

Period when Fulmar likely to be on site (see below) =

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total days = 153 Total hours (corrected - see below) = 2635.987

Period when Fulmar likely to be on site = 9489553 seconds (in each year)

Assumptions (write in any assumptions that have been included in the model)

Assumption 1: The flying period extends from dawn to dusk and includes 25% of night.

Assumption 2:

Assumption 3:

Assumption 4:

Proportion of time during which a collision may occur = 9489553 (in each year)

Fulmar flight time = 5308 seconds in 518400 seconds survey time

Therefore in 5 months = 97165.41 seconds

Note: This table is only relevant when calculating collision risk for goose species. It provides an adjustment for nocturnal flight behaviour for these species.

Number of hours birds are potentially active during winter (from Band et al, in press)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nox	Dec	
Mean Daylight hours**		6.8	9.08	11.78	14.62	17.23	18.77	18.05	15.68	12.88	10.05	7.45	5.98	
Mean Nocturnal hrs*	5	0.86	0.746	0.611	0.469	0.3385	0.2615	0.2975	0.416	0.556	0.6975	0.8275	0.901	
Combined Daily Mean		7.66	9.826	12.391	15.089	17.5685	19.0315	18.3475	16.096	13.436	10.7475	8.2775	6.881	
No of days birds present		0	0	0	30	31	30	31	31	0	0	0	0	
Total hours each month		**0**	**0**	**0**	**452.67**	**544.6235**	**570.945**	**568.7725**	**498.976**	**0**	**0**	**0**	**0**	**2635.987**
Total hours per year		**2635.987**												

**Mean daylight hours taken from www.shetland.climatetemps.com/sunlight.php

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

Number of bird transits through the rotors per annum =	137.47
Average collision risk for bird passing through rotor =	9.9%
Number of birds potentially killed by rotors per annum =	13.64

NB: The above calculation assumes no avoidance

Correcting for 95% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.681838
1 bird killed every	1.466624 years

Correcting for 98% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.272735
1 bird killed every	3.666560 years

Correcting for 99% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.13637
1 bird killed every	7.333121 years

Correcting for 99.5% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.06818
1 bird killed every	14.666241 years

Site Name **Energy Isles Wind Farm**

Bird Dimensions

Species	**Fulmar**
length (m)	0.48
wing span (m)	1.07
speed (m/sec)	13

= data input required
= model calculates value

Sources of speed and dimension information: Bruderer & Boldt (2001); BTO Bird Facts

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781003

Note, the maximum height of turbines 5, 16, 19, 20, 24, 25, 26, 27 and 28 is lower, at 180 m

Wind Farm Dimensions

No of turbines	23
Site area (m2)	19680000

The area is equal to the total visible area (at a minimum 30 m above ground level) from vantage points 1, 2, 3 and 6. The extent of this area is shown on Figure 6.1.

Turbine Specifications

K: [1D or [3D] (0 or 1)	1
NoBlades	3
MaxChord	4 *
Pitch (degrees)	20 *
Rotation period	3 *

Flight Characteristics

Flapping (0) or gliding (+1)	0

Night adjustment

What percentage of the night is the target species active? 5 **%**

Survey Data

Total survey time (hours)	144

Period when Fulmar likely to be on site. **Type in the number of days in each month where the target species is present within the site**

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total number of months when Fulmar **likely to be present:** 5

Enter the date of each record, the time the bird(s) was recorded in the collision risk area and the number of birds on a separate
Bird occupancy is automatically calculated.

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume
18/05/2018	110	1	110
05/07/2018	100	1	100
05/07/2018	60	1	60
05/07/2018	15	1	15
07/08/2018	30	4	120
07/08/2018	55	1	55
07/08/2018	150	2	300
07/08/2018	15	1	15
24/08/2018	85	3	255
24/08/2018	15	1	15
24/08/2018	15	1	15
Total	**650**	**17**	**1060**

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

= data input required
= model calculates value

Step 1 **Go to Data Input**

Input data about the species that is being assessed - body length, wing span and flight speed
Input data on turbine dimensions
Input data on wind farm area
Input data on turbine dimensions and specification
Input all vantage point data for the species that is being assessed - number of birds and flight time within the study area
Input the number of days for each month where the species is likely to be present within the site
Input days for those months where the species is likely to be present within the site
Input the appropriate night time correction factor for the species being assessed, e.g. a 25% nocturnal flight time correction was proposed by Band et al for geese. This correction cannot be applied to all species, for example raptors.

Step 2 **Go to Collision Risk**

Final collision risk estimates are highlighted
Only use the collision risk estimate for the method that has been used

Scottish Natural Heritage: Calculating a theoretical collision risk assuming no avoiding action

Site Name: Energy Isles Wind Farm

= data input required
= model calculates value

Stage 1: Number of birds flying through rotors

Input Parameters

Bird Dimensions

Species	Fulmar
length (m)	0.48
wing span (m)	1.07
speed (m/sec)	13

Bird Flight Data

No of birds	17
Time spent in V_w (sec)	19403.79

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781

Wind Farm Dimensions

No of turbines	23
Site Area (m2)	19680000

Method 1 - Birds using the windfarm airspace

(to be used for birds that fly across the site using a variety of different flight paths)

Step No	Description of Calculation		Calculation	Comments
1	Identify 'flight risk volume' V_w' which is the area of the wind farm multiplied by the height of the turbines	V_w =	3936000000 m^3	Area is equivalent to the total area visible from VPs 1, 2, 3 and 6
2	Calculate the combined volume swept out by the rotors $V_r = N \times \pi R^2 \times (d + l)$ where N is the number of turbines, d is the depth of the	V_r =	1769873.27 m^3	

	rotor front to back, and l is the bird length				
3	Estimate bird occupancy n within V_w This is the number of birds multiplied by the time spent within V_w (per season/year)	n =	19403.79	secs per yr	Bird occupancy is based on observations of birds flying through rotor-swept area
4	Bird occupancy of V_r n x (V_r / V_w) bird-seconds	occupancy =	8.73	bird-seconds	
5	Time taken for a bird to make transit through and completely clear the rotors t = (d + l) / v where v is bird speed (m/sec)	t =	0.32	seconds	Speed should be assessed in the field but published values are available
6	Calculate number of bird transits through the rotors = n x (V_r / V_w) / t	transits =	27.45	bird transits per annum	

Number of bird transits through the rotors per annum = 27.45

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Input parameters regarding the turbine specification will need to be obtained from the design engineers or manufacturers.

W Band 03/03/2020

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4	m
Pitch (degrees)	20	
BirdLength	0.48	m
Wingspan	1.07	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	13	m/sec
RotorDiam	154	m
RotationPeriod	3.00	sec
Bird aspect ratioo: β	0.45	

Calculation of alpha and p(collision) as a function of radius

				Upwind:			Downwind:		
r/R	c/C	α	collide		contribution	collide		contribution
radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
0.025	0.575	3.22	11.21	0.86	0.00108	9.63	0.74	0.00093
0.075	0.575	1.07	4.26	0.33	0.00246	2.69	0.21	0.00155
0.125	0.702	0.64	3.35	0.26	0.00322	1.43	0.11	0.00138
0.175	0.860	0.46	3.16	0.24	0.00425	0.81	0.06	0.00108
0.225	0.994	0.36	3.18	0.24	0.00550	0.50	0.04	0.00087
0.275	0.947	0.29	2.82	0.22	0.00596	0.73	0.06	0.00155
0.325	0.899	0.25	2.55	0.20	0.00637	0.87	0.07	0.00218
0.375	0.851	0.21	2.33	0.18	0.00673	0.96	0.07	0.00276
0.425	0.804	0.19	2.15	0.17	0.00704	1.01	0.08	0.00329
0.475	0.756	0.17	2.00	0.15	0.00729	1.03	0.08	0.00377
0.525	0.708	0.15	1.86	0.14	0.00750	1.04	0.08	0.00420
0.575	0.660	0.14	1.73	0.13	0.00766	1.04	0.08	0.00458
0.625	0.613	0.13	1.62	0.12	0.00777	1.02	0.08	0.00491
0.675	0.565	0.12	1.51	0.12	0.00782	1.00	0.08	0.00519
0.725	0.517	0.11	1.40	0.11	0.00783	0.97	0.07	0.00542
0.775	0.470	0.10	1.31	0.10	0.00779	0.94	0.07	0.00560
0.825	0.422	0.10	1.21	0.09	0.00769	0.90	0.07	0.00573
0.875	0.374	0.09	1.12	0.09	0.00755	0.86	0.07	0.00580
0.925	0.327	0.09	1.03	0.08	0.00736	0.82	0.06	0.00583
0.975	0.279	0.08	0.95	0.07	0.00711	0.77	0.06	0.00581

Overall p(collision) = Upwind 12.6% Downwind 7.2%

Average 9.9%

Bird survey data

Date	Time observed (seconds)			Number of birds	Bird Occupancy in flight risk volume
TOTAL	650			17	1060

TOTAL SURVEY TIME 144 hours or 518400 seconds

Period when Fulmar likely to be on site (see below) =

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total days = 153 Total hours (corrected - see below) = 2635.987

Period when Fulmar likely to be on site = 9489553 seconds (in each year)

Assumptions (write in any assumptions that have been included in the model)

Assumption 1: The flying period extends from dawn to dusk and includes 25% of night.

Assumption 2:

Assumption 3:

Assumption 4:

Proportion of time during which a collision may occur = 9489553 (in each year)

Fulmar flight time = 1060 seconds in 518400 seconds survey time

Therefore in 5 months = 19403.79 seconds

Note: This table is only relevant when calculating collision risk for goose species. It provides an adjustment for nocturnal flight behaviour for these species.

Number of hours birds are potentially active during winter (from Band et al, in press)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nox	Dec	
Mean Daylight hours**		6.8	9.08	11.78	14.62	17.23	18.77	18.05	15.68	12.88	10.05	7.45	5.98	
Mean Nocturnal hrs*	5	0.86	0.746	0.611	0.469	0.3385	0.2615	0.2975	0.416	0.556	0.6975	0.8275	0.901	
Combined Daily Mean		7.66	9.826	12.391	15.089	17.5685	19.0315	18.3475	16.096	13.436	10.7475	8.2775	6.881	
No of days birds present		0	0	0	30	31	30	31	31	0	0	0	0	
Total hours each month		**0**	**0**	**0**	**452.67**	**544.6235**	**570.945**	**568.7725**	**498.976**	**0**	**0**	**0**	**0**	**2635.987**
Total hours per year		**2635.987**												

**Mean daylight hours taken from www.shetland.climatetemps.com/sunlight.php

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

Number of bird transits through the rotors per annum =	27.45
Average collision risk for bird passing through rotor =	9.9%
Number of birds potentially killed by rotors per annum =	2.72

NB: The above calculation assumes no avoidance

Correcting for 95% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.136162
1 bird killed every	7.344189 years

Correcting for 98% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.054465
1 bird killed every	18.360474 years

Correcting for 99% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.02723
1 bird killed every	36.720947 years

Site Name **Energy Isles Wind Farm**

Bird Dimensions

Species	**Curlew**
length (m)	0.55
wing span (m)	0.9
speed (m/sec)	14

= data input required
= model calculates value

Sources of speed and dimension information: Bruderer & Boldt (2001); BTO Bird Facts

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781003

Note, the maximum height of turbines 5, 16, 19, 20, 24, 25, 26, 27 and 28 is lower, at 180 m

Wind Farm Dimensions

No of turbines	23
Site area (m2)	19680000

The area is equal to the total visible area (at a minimum 30 m above ground level) from vantage points 1, 2, 3 and 6. The extent of this area is shown on Figure 6.1.

Turbine Specifications

K: [1D or [3D] (0 or 1)	1
NoBlades	3
MaxChord	4 *
Pitch (degrees)	20 *
Rotation period	3 *

Flight Characteristics

Flapping (0) or gliding (+1)	0

Night adjustment

What percentage of the night is the target species active? 5 **%**

Survey Data

Total survey time (hours)	144

Period when Curlew likely to be on site. **Type in the number of days in each month where the target species is present within the site**

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total number of months when Curlew **likely to be present:** 5

Enter the date of each record, the time the bird(s) was recorded in the collision risk area and the number of birds on a separate
Bird occupancy is automatically calculated.

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume
11/04/2016	80	1	80
22/05/2016	120	1	120
22/05/2016	45	1	45
22/05/2016	75	1	75
02/06/2016	30	1	30
06/06/2016	190	1	190
06/06/2016	95	1	95
07/06/2016	90	1	90
Total	**725**	**8**	**725**

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

= data input required
= model calculates value

Step 1 **Go to Data Input**

Input data about the species that is being assessed - body length, wing span and flight speed
Input data on turbine dimensions
Input data on wind farm area
Input data on turbine dimensions and specification
Input all vantage point data for the species that is being assessed - number of birds and flight time within the study area
Input the number of days for each month where the species is likely to be present within the site
Input days for those months where the species is likely to be present within the site
Input the appropriate night time correction factor for the species being assessed, e.g. a 25% nocturnal flight time correction was proposed by Band et al for geese. This correction cannot be applied to all species, for example raptors.

Step 2 **Go to Collision Risk**

Final collision risk estimates are highlighted
Only use the collision risk estimate for the method that has been used

Scottish Natural Heritage: Calculating a theoretical collision risk assuming no avoiding action

Site Name: Energy Isles Wind Farm

= data input required
= model calculates value

Stage 1: Number of birds flying through rotors

Input Parameters

Bird Dimensions

Species	Curlew
length (m)	0.55
wing span (m)	0.9
speed (m/sec)	14

Bird Flight Data

No of birds	8
Time spent in V_w (sec)	13271.46

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781

Wind Farm Dimensions

No of turbines	23
Site Area (m^2)	19680000

Method 1 - Birds using the windfarm airspace

(to be used for birds that fly across the site using a variety of different flight paths)

Step No	Description of Calculation		Calculation	Comments
1	Identify 'flight risk volume' V_w' which is the area of the wind farm multiplied by the height of the turbines	V_w =	3936000000 m^3	Area is equivalent to the total area visible from VPs 1, 2, 3 and 6
2	Calculate the combined volume swept out by the rotors $V_r = N \times \pi R^2 \times (d + l)$ where N is the number of turbines, d is the depth of the	V_r =	1799858.19 m^3	

	rotor front to back, and l is the bird length				
3	Estimate bird occupancy n within V_w This is the number of birds multiplied by the time spent within V_w (per season/year)	n =	13271.46	secs per yr	Bird occupancy is based on observations of birds flying through rotor-swept area
4	Bird occupancy of V_r n x (V_r / V_w) bird-seconds	occupancy =	6.07	bird-seconds	
5	Time taken for a bird to make transit through and completely clear the rotors t = (d + l) / v where v is bird speed (m/sec)	t =	0.30	seconds	Speed should be assessed in the field but published values are available
6	Calculate number of bird transits through the rotors = n x (V_r / V_w) / t	transits =	20.22	bird transits per annum	

Number of bird transits through the rotors per annum = 20.22

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Input parameters regarding the turbine specification will need to be obtained from the design engineers or manufacturers.

W Band 03/03/2020

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4	m
Pitch (degrees)	20	
BirdLength	0.55	m
Wingspan	0.9	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	14	m/sec
RotorDiam	154	m
RotationPeriod	3.00	sec
Bird aspect ratioo: β	0.61	

Calculation of alpha and p(collision) as a function of radius

				Upwind:			Downwind:		
r/R	c/C	α	collide		contribution	collide		contribution
radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
0.025	0.575	3.47	11.42	0.82	0.00102	9.84	0.70	0.00088
0.075	0.575	1.16	4.33	0.31	0.00232	2.76	0.20	0.00148
0.125	0.702	0.69	3.42	0.24	0.00305	1.50	0.11	0.00134
0.175	0.860	0.50	3.33	0.24	0.00416	0.98	0.07	0.00122
0.225	0.994	0.39	3.35	0.24	0.00539	0.63	0.05	0.00102
0.275	0.947	0.32	2.97	0.21	0.00583	0.72	0.05	0.00142
0.325	0.899	0.27	2.68	0.19	0.00623	0.88	0.06	0.00204
0.375	0.851	0.23	2.46	0.18	0.00658	0.97	0.07	0.00261
0.425	0.804	0.20	2.27	0.16	0.00688	1.03	0.07	0.00313
0.475	0.756	0.18	2.10	0.15	0.00714	1.06	0.08	0.00361
0.525	0.708	0.17	1.96	0.14	0.00735	1.08	0.08	0.00404
0.575	0.660	0.15	1.83	0.13	0.00751	1.08	0.08	0.00443
0.625	0.613	0.14	1.71	0.12	0.00763	1.07	0.08	0.00477
0.675	0.565	0.13	1.60	0.11	0.00770	1.05	0.07	0.00506
0.725	0.517	0.12	1.49	0.11	0.00772	1.02	0.07	0.00531
0.775	0.470	0.11	1.39	0.10	0.00770	0.99	0.07	0.00551
0.825	0.422	0.11	1.29	0.09	0.00763	0.96	0.07	0.00566
0.875	0.374	0.10	1.20	0.09	0.00751	0.92	0.07	0.00577
0.925	0.327	0.09	1.11	0.08	0.00735	0.88	0.06	0.00582
0.975	0.279	0.09	1.02	0.07	0.00714	0.84	0.06	0.00584

Overall p(collision) = Upwind 12.4% Downwind 7.1%

Average 9.7%

Bird survey data

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume
TOTAL	725	8	725

TOTAL SURVEY TIME 144 hours or 518400 seconds

Period when Curlew likely to be on site (see below) =

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total days = 153 Total hours (corrected - see below) = 2635.987

Period when Curlew likely to be on site = 9489553 seconds (in each year)

Assumptions (write in any assumptions that have been included in the model)

Assumption 1: The flying period extends from dawn to dusk and includes 25% of night.

Assumption 2:

Assumption 3:

Assumption 4:

Proportion of time during which a collision may occur = 9489553 (in each year)

Curlew flight time = 725 seconds in 518400 seconds survey time

Therefore in 5 months = 13271.46 seconds

Note: This table is only relevant when calculating collision risk for goose species. It provides an adjustment for nocturnal flight behaviour for these species.

Number of hours birds are potentially active during winter (from Band et al, in press)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nox	Dec	
Mean Daylight hours**		6.8	9.08	11.78	14.62	17.23	18.77	18.05	15.68	12.88	10.05	7.45	5.98	
Mean Nocturnal hrs*	5	0.86	0.746	0.611	0.469	0.3385	0.2615	0.2975	0.416	0.556	0.6975	0.8275	0.901	
Combined Daily Mean		7.66	9.826	12.391	15.089	17.5685	19.0315	18.3475	16.096	13.436	10.7475	8.2775	6.881	
No of days birds present		0	0	0	30	31	30	31	31	0	0	0	0	
Total hours each month		**0**	**0**	**0**	**452.67**	**544.6235**	**570.945**	**568.7725**	**498.976**	**0**	**0**	**0**	**0**	**2635.987**
Total hours per year		**2635.987**												

**Mean daylight hours taken from www.shetland.climatetemps.com/sunlight.php

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

Number of bird transits through the rotors per annum = 20.22

Average collision risk for bird passing through rotor = 9.7%

Number of birds potentially killed by rotors per annum = 1.97

NB: The above calculation assumes no avoidance

Correcting for 95% avoidance rate:

Number of birds potentially killed by rotors per annum = **0.098449**

1 bird killed every 10.157543 years

Correcting for 98% avoidance rate:

Number of birds potentially killed by rotors per annum = **0.039380**

1 bird killed every 25.393859 years

Correcting for 99% avoidance rate:

Number of birds potentially killed by rotors per annum = **0.01969**

1 bird killed every 50.787717 years

Site Name **Energy Isles Wind Farm**

Bird Dimensions

Species	**Curlew**
length (m)	0.55
wing span (m)	0.9
speed (m/sec)	14

= data input required
= model calculates value

Sources of speed and dimension information: Bruderer & Boldt (2001); BTO Bird Facts

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781003

Note, the maximum height of turbines 5, 16, 19, 20, 24, 25, 26, 27 and 28 is lower, at 180 m

Wind Farm Dimensions

No of turbines	23
Site area (m2)	19680000

The area is equal to the total visible area (at a minimum 30 m above ground level) from vantage points 1, 2, 3 and 6. The extent of this area is shown on Figure 6.1.

Turbine Specifications

K: [1D or [3D] (0 or 1)	1
NoBlades	3
MaxChord	4 *
Pitch (degrees)	20 *
Rotation period	3 *

Flight Characteristics

Flapping (0) or gliding (+1)	0

Night adjustment

What percentage of the night is the target species active? 5 **%**

Survey Data

Total survey time (hours)	144

Period when Curlew likely to be on site. **Type in the number of days in each month where the target species is present within the site**

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total number of months when Curlew **likely to be present:** 5

Enter the date of each record, the time the bird(s) was recorded in the collision risk area and the number of birds on a separate
Bird occupancy is automatically calculated.

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume
09/03/2018	15	3	10
10/04/2018	10	1	134
06/07/2018	134	3	50
02/08/2018	68	1	50
15/08/2018	35	4	50
Total	**262**	**12**	**294**

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

= data input required
= model calculates value

Step 1 **Go to Data Input**

Input data about the species that is being assessed - body length, wing span and flight speed
Input data on turbine dimensions
Input data on wind farm area
Input data on turbine dimensions and specification
Input all vantage point data for the species that is being assessed - number of birds and flight time within the study area
Input the number of days for each month where the species is likely to be present within the site
Input days for those months where the species is likely to be present within the site
Input the appropriate night time correction factor for the species being assessed, e.g. a 25% nocturnal flight time correction was proposed by Band et al for geese. This correction cannot be applied to all species, for example raptors.

Step 2 **Go to Collision Risk**

Final collision risk estimates are highlighted
Only use the collision risk estimate for the method that has been used

Scottish Natural Heritage: Calculating a theoretical collision risk assuming no avoiding action

Site Name: Energy Isles Wind Farm

= data input required
= model calculates value

Stage 1: Number of birds flying through rotors

Input Parameters

Bird Dimensions

Species	Curlew
length (m)	0.55
wing span (m)	0.9
speed (m/sec)	14

Bird Flight Data

No of birds	12
Time spent in V_w (sec)	5381.81

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781

Wind Farm Dimensions

No of turbines	23
Site Area (m^2)	19680000

Method 1 - Birds using the windfarm airspace

(to be used for birds that fly across the site using a variety of different flight paths)

Step No	Description of Calculation		Calculation	Comments
1	Identify 'flight risk volume' V_w' which is the area of the wind farm multiplied by the height of the turbines	V_w =	3936000000 m^3	Area is equivalent to the total area visible from VPs 1, 2, 3 and 6
2	Calculate the combined volume swept out by the rotors $V_r = N \times \pi R^2 \times (d + l)$ where N is the number of turbines, d is the depth of the	V_r =	1799858.19 m^3	

	rotor front to back, and l is the bird length				
3	Estimate bird occupancy n within V_w This is the number of birds multiplied by the time spent within V_w (per season/year)	n =	5381.81	secs per yr	Bird occupancy is based on observations of birds flying through rotor-swept area
4	Bird occupancy of V_r n x (V_r / V_w) bird-seconds	occupancy =	2.46	bird-seconds	
5	Time taken for a bird to make transit through and completely clear the rotors t = (d + l) / v where v is bird speed (m/sec)	t =	0.30	seconds	Speed should be assessed in the field but published values are available
6	Calculate number of bird transits through the rotors = n x (V_r / V_w) / t	transits =	8.20	bird transits per annum	

Number of bird transits through the rotors per annum = 8.20

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Input parameters regarding the turbine specification will need to be obtained from the design engineers or manufacturers.

W Band 03/03/2020

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4	m
Pitch (degrees)	20	
BirdLength	0.55	m
Wingspan	0.9	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	14	m/sec
RotorDiam	154	m
RotationPeriod	3.00	sec
Bird aspect ratioo: β	0.61	

Calculation of alpha and p(collision) as a function of radius

				Upwind:			Downwind:		
r/R	c/C	α	collide		contribution	collide		contribution
radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
0.025	0.575	3.47	11.42	0.82	0.00102	9.84	0.70	0.00088
0.075	0.575	1.16	4.33	0.31	0.00232	2.76	0.20	0.00148
0.125	0.702	0.69	3.42	0.24	0.00305	1.50	0.11	0.00134
0.175	0.860	0.50	3.33	0.24	0.00416	0.98	0.07	0.00122
0.225	0.994	0.39	3.35	0.24	0.00539	0.63	0.05	0.00102
0.275	0.947	0.32	2.97	0.21	0.00583	0.72	0.05	0.00142
0.325	0.899	0.27	2.68	0.19	0.00623	0.88	0.06	0.00204
0.375	0.851	0.23	2.46	0.18	0.00658	0.97	0.07	0.00261
0.425	0.804	0.20	2.27	0.16	0.00688	1.03	0.07	0.00313
0.475	0.756	0.18	2.10	0.15	0.00714	1.06	0.08	0.00361
0.525	0.708	0.17	1.96	0.14	0.00735	1.08	0.08	0.00404
0.575	0.660	0.15	1.83	0.13	0.00751	1.08	0.08	0.00443
0.625	0.613	0.14	1.71	0.12	0.00763	1.07	0.08	0.00477
0.675	0.565	0.13	1.60	0.11	0.00770	1.05	0.07	0.00506
0.725	0.517	0.12	1.49	0.11	0.00772	1.02	0.07	0.00531
0.775	0.470	0.11	1.39	0.10	0.00770	0.99	0.07	0.00551
0.825	0.422	0.11	1.29	0.09	0.00763	0.96	0.07	0.00566
0.875	0.374	0.10	1.20	0.09	0.00751	0.92	0.07	0.00577
0.925	0.327	0.09	1.11	0.08	0.00735	0.88	0.06	0.00582
0.975	0.279	0.09	1.02	0.07	0.00714	0.84	0.06	0.00584

Overall p(collision) = Upwind 12.4% Downwind 7.1%

Average 9.7%

Bird survey data

Date	Time observed (seconds)			Number of birds	Bird Occupancy in flight risk volume
TOTAL	262			12	294

TOTAL SURVEY TIME 144 hours or 518400 seconds

Period when Curlew likely to be on site (see below) =

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total days = 153 Total hours (corrected - see below) = 2635.987

Period when Curlew likely to be on site = 9489553 seconds (in each year)

Assumptions (write in any assumptions that have been included in the model)
Assumption 1: The flying period extends from dawn to dusk and includes 25% of night.
Assumption 2:
Assumption 3:
Assumption 4:

Proportion of time during which a collision may occur = 9489553 (in each year)

Curlew flight time = 294 seconds in 518400 seconds survey time

Therefore in 5 months = 5381.81 seconds

Note: This table is only relevant when calculating collision risk for goose species. It provides an adjustment for nocturnal flight behaviour for these species.

Number of hours birds are potentially active during winter (from Band et al, in press)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nox	Dec	
Mean Daylight hours**		6.8	9.08	11.78	14.62	17.23	18.77	18.05	15.68	12.88	10.05	7.45	5.98	
Mean Nocturnal hrs*	5	0.86	0.746	0.611	0.469	0.3385	0.2615	0.2975	0.416	0.556	0.6975	0.8275	0.901	
Combined Daily Mean		7.66	9.826	12.391	15.089	17.5685	19.0315	18.3475	16.096	13.436	10.7475	8.2775	6.881	
No of days birds present		0	0	0	30	31	30	31	31	0	0	0	0	
Total hours each month		**0**	**0**	**0**	**452.67**	**544.6235**	**570.945**	**568.7725**	**498.976**	**0**	**0**	**0**	**0**	**2635.987**
Total hours per year		**2635.987**												

**Mean daylight hours taken from www.shetland.climatetemps.com/sunlight.php

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

Number of bird transits through the rotors per annum =	8.20
Average collision risk for bird passing through rotor =	9.7%
Number of birds potentially killed by rotors per annum =	0.80

NB: The above calculation assumes no avoidance

Correcting for 95% avoidance rate:

Number of birds potentially killed by rotors per annum =	**0.039923**
1 bird killed every	**25.048364 years**

Correcting for 98% avoidance rate:

Number of birds potentially killed by rotors per annum =	**0.015969**
1 bird killed every	**62.620910 years**

Correcting for 99% avoidance rate:

Number of birds potentially killed by rotors per annum =	**0.00798**
1 bird killed every	**125.241820 years**

Site Name	**Energy Isles Wind Farm**

Bird Dimensions

Species	**Whimbrel**
length (m)	0.41
wing span (m)	0.82
speed (m/sec)	14

= data input required
= model calculates value

Sources of speed and dimension information: Bruderer & Boldt (2001); BTO Bird Facts

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781003

Note, the maximum height of turbines 5, 16, 19, 20, 24, 25, 26, 27 and 28 is lower, at 180 m

Wind Farm Dimensions

No of turbines	23
Site area (m2)	19680000

The area is equal to the total visible area (at a minimum 30 m above ground level) from vantage points 1, 2, 3 and 6. The extent of this area is shown on Figure 6.1.

Turbine Specifications

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4	*
Pitch (degrees)	20	*
Rotation period	3	*

Flight Characteristics

Flapping (0) or gliding (+1)	0

Night adjustment

What percentage of the night is the target species active? 5 **%**

Survey Data

Total survey time (hours)	144

Period when Whimbrel likely to be on site. **Type in the number of days in each month where the target species is present within the site**

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	30	30	31	31	0	0	0	0

Total number of months when Whimbrel **likely to be present:** 5

Enter the date of each record, the time the bird(s) was recorded in the collision risk area and the number of birds on a separate
Bird occupancy is automatically calculated.

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume
01/08/2018	62	8	496
03/08/2018	50	4	200
03/08/2018	30	5	150
Total	**142**	**17**	**846**

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

= data input required
= model calculates value

Step 1 **Go to Data Input**

Input data about the species that is being assessed - body length, wing span and flight speed
Input data on turbine dimensions
Input data on wind farm area
Input data on turbine dimensions and specification
Input all vantage point data for the species that is being assessed - number of birds and flight time within the study area
Input the number of days for each month where the species is likely to be present within the site
Input days for those months where the species is likely to be present within the site
Input the appropriate night time correction factor for the species being assessed, e.g. a 25% nocturnal flight time correction was proposed by Band et al for geese. This correction cannot be applied to all species, for example raptors.

Step 2 **Go to Collision Risk**

Final collision risk estimates are highlighted
Only use the collision risk estimate for the method that has been used

Scottish Natural Heritage: Calculating a theoretical collision risk assuming no avoiding action

Site Name: Energy Isles Wind Farm

= data input required
= model calculates value

Stage 1: Number of birds flying through rotors

Input Parameters

Bird Dimensions

Species	Whimbrel
length (m)	0.41
wing span (m)	0.82
speed (m/sec)	14

Bird Flight Data

No of birds	17
Time spent in V_w (sec)	15383.21

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781

Wind Farm Dimensions

No of turbines	23
Site Area (m2)	19680000

Method 1 - Birds using the windfarm airspace

(to be used for birds that fly across the site using a variety of different flight paths)

Step No	Description of Calculation		Calculation	Comments
1	Identify 'flight risk volume' V_w' which is the area of the wind farm multiplied by the height of the turbines	V_w =	3936000000 m^3	Area is equivalent to the total area visible from VPs 1, 2, 3 and 6
2	Calculate the combined volume swept out by the rotors $V_r = N \times \pi R^2 \times (d + l)$ where N is the number of turbines, d is the depth of the	V_r =	1739888.35 m^3	

	rotor front to back, and l is the bird length				
3	Estimate bird occupancy n within V_w This is the number of birds multiplied by the time spent within V_w (per season/year)	n =	15383.21	secs per yr	Bird occupancy is based on observations of birds flying through rotor-swept area
4	Bird occupancy of V_r n x (V_r / V_w) bird-seconds	occupancy =	6.80	bird-seconds	
5	Time taken for a bird to make transit through and completely clear the rotors t = (d + l) / v where v is bird speed (m/sec)	t =	0.29	seconds	Speed should be assessed in the field but published values are available
6	Calculate number of bird transits through the rotors = n x (V_r / V_w) / t	transits =	23.44	bird transits per annum	

Number of bird transits through the rotors per annum = 23.44

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Input parameters regarding the turbine specification will need to be obtained from the design engineers or manufacturers.

W Band 03/03/2020

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4	m
Pitch (degrees)	20	
BirdLength	0.41	m
Wingspan	0.82	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	14	m/sec
RotorDiam	154	m
RotationPeriod	3.00	sec
Bird aspect ratioo: β	0.50	

Calculation of alpha and p(collision) as a function of radius

				Upwind:			Downwind:		
r/R	c/C	α	collide		contribution	collide		contribution
radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
0.025	0.575	3.47	11.14	0.80	0.00099	9.57	0.68	0.00085
0.075	0.575	1.16	4.24	0.30	0.00227	2.66	0.19	0.00143
0.125	0.702	0.69	3.36	0.24	0.00300	1.44	0.10	0.00129
0.175	0.860	0.50	3.19	0.23	0.00399	0.84	0.06	0.00105
0.225	0.994	0.39	3.21	0.23	0.00516	0.49	0.04	0.00079
0.275	0.947	0.32	2.83	0.20	0.00556	0.58	0.04	0.00114
0.325	0.899	0.27	2.54	0.18	0.00590	0.74	0.05	0.00171
0.375	0.851	0.23	2.32	0.17	0.00620	0.83	0.06	0.00223
0.425	0.804	0.20	2.13	0.15	0.00645	0.89	0.06	0.00271
0.475	0.756	0.18	1.96	0.14	0.00666	0.92	0.07	0.00314
0.525	0.708	0.17	1.82	0.13	0.00682	0.94	0.07	0.00352
0.575	0.660	0.15	1.69	0.12	0.00693	0.94	0.07	0.00386
0.625	0.613	0.14	1.57	0.11	0.00700	0.93	0.07	0.00414
0.675	0.565	0.13	1.46	0.10	0.00702	0.91	0.06	0.00439
0.725	0.517	0.12	1.35	0.10	0.00699	0.88	0.06	0.00458
0.775	0.470	0.11	1.25	0.09	0.00692	0.85	0.06	0.00473
0.825	0.422	0.11	1.15	0.08	0.00680	0.82	0.06	0.00483
0.875	0.374	0.10	1.06	0.08	0.00663	0.78	0.06	0.00489
0.925	0.327	0.09	0.97	0.07	0.00642	0.74	0.05	0.00490
0.975	0.279	0.09	0.88	0.06	0.00616	0.70	0.05	0.00486

Overall p(collision) = Upwind 11.4% Downwind 6.1%

Average 8.7%

Bird survey data

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume
TOTAL	142	17	846

TOTAL SURVEY TIME 144 hours or 518400 seconds

Period when Whimbrel likely to be on site (see below) =

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	30	30	31	31	0	0	0	0

Total days = 152 Total hours (corrected - see below) = 2618.419

Period when Whimbrel likely to be on site = 9426307 seconds (in each year)

Assumptions (write in any assumptions that have been included in the model)
Assumption 1: The flying period extends from dawn to dusk and includes 25% of night.
Assumption 2:
Assumption 3:
Assumption 4:

Proportion of time during which a collision may occur = 9426307 (in each year)

Whimbrel flight time = 846 seconds in 518400 seconds survey time

Therefore in 5 months = 15383.21 seconds

Note: This table is only relevant when calculating collision risk for goose species. It provides an adjustment for nocturnal flight behaviour for these species.

Number of hours birds are potentially active during winter (from Band et al, in press)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nox	Dec	
Mean Daylight hours**		6.8	9.08	11.78	14.62	17.23	18.77	18.05	15.68	12.88	10.05	7.45	5.98	
Mean Nocturnal hrs*	5	0.86	0.746	0.611	0.469	0.3385	0.2615	0.2975	0.416	0.556	0.6975	0.8275	0.901	
Combined Daily Mean		7.66	9.826	12.391	15.089	17.5685	19.0315	18.3475	16.096	13.436	10.7475	8.2775	6.881	
No of days birds present		0	0	0	30	30	30	31	31	0	0	0	0	
Total hours each month		**0**	**0**	**0**	**452.67**	**527.055**	**570.945**	**568.7725**	**498.976**	**0**	**0**	**0**	**0**	**2618.419**
Total hours per year		**2618.4185**												

**Mean daylight hours taken from www.shetland.climatetemps.com/sunlight.php

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

Number of bird transits through the rotors per annum =	23.44
Average collision risk for bird passing through rotor =	8.7%
Number of birds potentially killed by rotors per annum =	2.05

NB: The above calculation assumes no avoidance

Correcting for 95% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.102513
1 bird killed every	9.754825 years

Correcting for 98% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.041005
1 bird killed every	24.387063 years

Correcting for 99% avoidance rate:

Number of birds potentially killed by rotors per annum =	0.02050
1 bird killed every	48.774126 years

Site Name **Energy Isles Wind Farm**

Bird Dimensions

Species	**Golden Plover**
length (m)	0.28
wing span (m)	0.72
speed (m/sec)	17.9

= data input required
= model calculates value

Sources of speed and dimension information: Bruderer & Boldt (2001); BTO Bird Facts

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781003

Note, the maximum height of turbines 5, 16, 19, 20, 24, 25, 26, 27 and 28 is lower, at 180 m

Wind Farm Dimensions

No of turbines	23
Site area (m2)	19680000

The area is equal to the total visible area (at a minimum 30 m above ground level) from vantage points 1, 2, 3 and 6. The extent of this area is shown on Figure 6.1.

Turbine Specifications

K: [1D or [3D] (0 or 1)	1
NoBlades	3
MaxChord	4 *
Pitch (degrees)	20 *
Rotation period	3 *

Flight Characteristics

Flapping (0) or gliding (+1)	0

Night adjustment

What percentage of the night is the target species active? 5 **%**

Survey Data

Total survey time (hours)	144

Period when Golden Plover likely to be on site.

Type in the number of days in each month where the target species is present within the site

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total number of months when Golden Plover **likely to be present:** 5

Enter the date of each record, the time the bird(s) was recorded in the collision risk area and the number of birds on a separate
Bird occupancy is automatically calculated.

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume
18/07/2016	3	1	3
19/07/2016	30	1	30
22/07/2016	45	1	45
22/07/2016	30	1	30
Total	**108**	**4**	**108**

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

= data input required
= model calculates value

Step 1 **Go to Data Input**

Input data about the species that is being assessed - body length, wing span and flight speed
Input data on turbine dimensions
Input data on wind farm area
Input data on turbine dimensions and specification
Input all vantage point data for the species that is being assessed - number of birds and flight time within the study area
Input the number of days for each month where the species is likely to be present within the site
Input days for those months where the species is likely to be present within the site
Input the appropriate night time correction factor for the species being assessed, e.g. a 25% nocturnal flight time correction was proposed by Band et al for geese. This correction cannot be applied to all species, for example raptors.

Step 2 **Go to Collision Risk**

Final collision risk estimates are highlighted
Only use the collision risk estimate for the method that has been used

Scottish Natural Heritage: Calculating a theoretical collision risk assuming no avoiding action

Site Name: Energy Isles Wind Farm

= data input required
= model calculates value

Stage 1: Number of birds flying through rotors

Input Parameters

Bird Dimensions

Species	Golden Plover
length (m)	0.28
wing span (m)	0.72
speed (m/sec)	17.9

Bird Flight Data

No of birds	4
Time spent in V_w (sec)	1976.99

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781

Wind Farm Dimensions

No of turbines	23
Site Area (m2)	19680000

Method 1 - Birds using the windfarm airspace

(to be used for birds that fly across the site using a variety of different flight paths)

Step No	Description of Calculation		Calculation	Comments
1	Identify 'flight risk volume' V_w' which is the area of the wind farm multiplied by the height of the turbines	V_w =	3936000000 m^3	Area is equivalent to the total area visible from VPs 1, 2, 3 and 6
2	Calculate the combined volume swept out by the rotors $V_r = N \times \pi R^2 \times (d + l)$ where N is the number of turbines, d is the depth of the	V_r =	1684202.06 m^3	

	rotor front to back, and l is the bird length				
3	Estimate bird occupancy n within V_w This is the number of birds multiplied by the time spent within V_w (per season/year)	n =	1976.99	secs per yr	Bird occupancy is based on observations of birds flying through rotor-swept area
4	Bird occupancy of V_r n x (V_r / V_w) bird-seconds	occupancy =	0.85	bird-seconds	
5	Time taken for a bird to make transit through and completely clear the rotors t = (d + l) / v where v is bird speed (m/sec)	t =	0.22	seconds	Speed should be assessed in the field but published values are available
6	Calculate number of bird transits through the rotors = n x (V_r / V_w) / t	transits =	3.85	bird transits per annum	

Number of bird transits through the rotors per annum = 3.85

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Input parameters regarding the turbine specification will need to be obtained from the design engineers or manufacturers.

W Band 03/03/2020

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4	m
Pitch (degrees)	20	
BirdLength	0.28	m
Wingspan	0.72	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	17.9	m/sec
RotorDiam	154	m
RotationPeriod	3.00	sec
Bird aspect ratioo: β	0.39	

Calculation of alpha and p(collision) as a function of radius

				Upwind:			Downwind:		
r/R	c/C	α	collide		contribution	collide		contribution
radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
0.025	0.575	4.44	13.58	0.76	0.00095	12.01	0.67	0.00084
0.075	0.575	1.48	5.05	0.28	0.00212	3.48	0.19	0.00146
0.125	0.702	0.89	3.94	0.22	0.00275	2.02	0.11	0.00141
0.175	0.860	0.63	3.68	0.21	0.00360	1.33	0.07	0.00130
0.225	0.994	0.49	3.56	0.20	0.00447	0.84	0.05	0.00105
0.275	0.947	0.40	3.02	0.17	0.00464	0.43	0.02	0.00066
0.325	0.899	0.34	2.66	0.15	0.00484	0.36	0.02	0.00065
0.375	0.851	0.30	2.39	0.13	0.00501	0.50	0.03	0.00104
0.425	0.804	0.26	2.17	0.12	0.00515	0.59	0.03	0.00140
0.475	0.756	0.23	1.98	0.11	0.00525	0.65	0.04	0.00173
0.525	0.708	0.21	1.81	0.10	0.00531	0.69	0.04	0.00201
0.575	0.660	0.19	1.66	0.09	0.00534	0.70	0.04	0.00226
0.625	0.613	0.18	1.53	0.09	0.00533	0.71	0.04	0.00248
0.675	0.565	0.16	1.40	0.08	0.00529	0.70	0.04	0.00265
0.725	0.517	0.15	1.29	0.07	0.00521	0.69	0.04	0.00279
0.775	0.470	0.14	1.18	0.07	0.00509	0.67	0.04	0.00290
0.825	0.422	0.13	1.07	0.06	0.00493	0.64	0.04	0.00297
0.875	0.374	0.13	0.97	0.05	0.00474	0.61	0.03	0.00300
0.925	0.327	0.12	0.87	0.05	0.00452	0.58	0.03	0.00299
0.975	0.279	0.11	0.78	0.04	0.00425	0.54	0.03	0.00295

Overall p(collision) = Upwind 8.9% Downwind 3.9%

Average 6.4%

Bird survey data

Date	Time observed (seconds)		Number of birds	Bird Occupancy in flight risk volume
TOTAL	108		4	108

TOTAL SURVEY TIME 144 hours or 518400 seconds

Period when Golden Plove likely to be on site (see below) =

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total days = 153 Total hours (corrected - see below) = 2635.987

Period when Golden Plove likely to be on site = 9489553 seconds (in each year)

Assumptions (write in any assumptions that have been included in the model)

Assumption 1: The flying period extends from dawn to dusk and includes 25% of night.

Assumption 2:

Assumption 3:

Assumption 4:

Proportion of time during which a collision may occur = 9489553 (in each year)

Golden Plover flight time = 108 seconds in 518400 seconds survey time

Therefore in 5 months = 1976.99 seconds

Note: This table is only relevant when calculating collision risk for goose species. It provides an adjustment for nocturnal flight behaviour for these species.

Number of hours birds are potentially active during winter (from Band et al, in press)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nox	Dec	
Mean Daylight hours**		6.8	9.08	11.78	14.62	17.23	18.77	18.05	15.68	12.88	10.05	7.45	5.98	
Mean Nocturnal hrs*	5	0.86	0.746	0.611	0.469	0.3385	0.2615	0.2975	0.416	0.556	0.6975	0.8275	0.901	
Combined Daily Mean		7.66	9.826	12.391	15.089	17.5685	19.0315	18.3475	16.096	13.436	10.7475	8.2775	6.881	
No of days birds present		0	0	0	30	31	30	31	31	0	0	0	0	
Total hours each month		**0**	**0**	**0**	**452.67**	**544.6235**	**570.945**	**568.7725**	**498.976**	**0**	**0**	**0**	**0**	**2635.987**
Total hours per year		**2635.987**												

**Mean daylight hours taken from www.shetland.climatetemps.com/sunlight.php

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

Number of bird transits through the rotors per annum =	3.85
Average collision risk for bird passing through rotor =	6.4%
Number of birds potentially killed by rotors per annum =	0.25

NB: The above calculation assumes no avoidance

Correcting for 95% avoidance rate:

Number of birds potentially killed by rotors per annum =	**0.012262**
1 bird killed every	**81.554984 years**

Correcting for 98% avoidance rate:

Number of birds potentially killed by rotors per annum =	**0.004905**
1 bird killed every	**203.887461 years**

Correcting for 99% avoidance rate:

Number of birds potentially killed by rotors per annum =	**0.00245**
1 bird killed every	**407.774922 years**

Site Name **Energy Isles Wind Farm**

Bird Dimensions

Species	**Golden Plover**
length (m)	0.28
wing span (m)	0.72
speed (m/sec)	17.9

= data input required
= model calculates value

Sources of speed and dimension information: Bruderer & Boldt (2001); BTO Bird Facts

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781003

Note, the maximum height of turbines 5, 16, 19, 20, 24, 25, 26, 27 and 28 is lower, at 180 m

Wind Farm Dimensions

No of turbines	23
Site area (m2)	19680000

The area is equal to the total visible area (at a minimum 30 m above ground level) from vantage points 1, 2, 3 and 6. The extent of this area is shown on Figure 6.1.

Turbine Specifications

K: [1D or [3D] (0 or 1)	1
NoBlades	3
MaxChord	4 *
Pitch (degrees)	20 *
Rotation period	3 *

Flight Characteristics

Flapping (0) or gliding (+1)	0

Night adjustment

What percentage of the night is the target species active? 5 **%**

Survey Data

Total survey time (hours)	144

Period when Golden Plover likely to be on site.

Type in the number of days in each month where the target species is present within the site

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total number of months when Golden Plover **likely to be present:** 5

Enter the date of each record, the time the bird(s) was recorded in the collision risk area and the number of birds on a separate
Bird occupancy is automatically calculated.

Date	Time observed (seconds)	Number of birds	Bird Occupancy in flight risk volume
04/04/2018	48	1	48
04/04/2018	95	1	95
10/04/2018	140	1	140
10/04/2018	49	1	49
10/04/2018	332	1	332
10/04/2018	105	2	210
15/05/2018	35	1	35
15/05/2018	45	1	45
16/05/2018	25	2	50
16/05/2018	206	1	206
16/05/2018	130	1	130
16/05/2018	105	1	105
16/05/2018	15	1	15
07/06/2018	104	1	104
07/06/2018	117	1	117
08/06/2018	58	1	58
06/07/2018	165	2	330
06/07/2018	145	1	145
02/08/2018	135	41	5535
Total	**2054**	**62**	**7749**

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

= data input required
= model calculates value

Step 1 **Go to Data Input**

Input data about the species that is being assessed - body length, wing span and flight speed
Input data on turbine dimensions
Input data on wind farm area
Input data on turbine dimensions and specification
Input all vantage point data for the species that is being assessed - number of birds and flight time within the study area
Input the number of days for each month where the species is likely to be present within the site
Input days for those months where the species is likely to be present within the site
Input the appropriate night time correction factor for the species being assessed, e.g. a 25% nocturnal flight time correction was proposed by Band et al for geese. This correction cannot be applied to all species, for example raptors.

Step 2 **Go to Collision Risk**

Final collision risk estimates are highlighted
Only use the collision risk estimate for the method that has been used

Scottish Natural Heritage: Calculating a theoretical collision risk assuming no avoiding action

Site Name: Energy Isles Wind Farm

= data input required
= model calculates value

Stage 1: Number of birds flying through rotors

Input Parameters

Bird Dimensions

Species	Golden Plover
length (m)	0.28
wing span (m)	0.72
speed (m/sec)	17.9

Bird Flight Data

No of birds	62
Time spent in V_w (sec)	141849.05

Turbine Dimensions

Height of tower (m)	123
Blade length (m)	77
Max blade height (m)	200
Min blade height (m)	46
Depth of rotor (m)	3.651781

Wind Farm Dimensions

No of turbines	23
Site Area (m2)	19680000

Method 1 - Birds using the windfarm airspace

(to be used for birds that fly across the site using a variety of different flight paths)

Step No	Description of Calculation		Calculation	Comments
1	Identify 'flight risk volume' V_w' which is the area of the wind farm multiplied by the height of the turbines	V_w =	3936000000 m^3	Area is equivalent to the total area visible from VPs 1, 2, 3 and 6
2	Calculate the combined volume swept out by the rotors $V_r = N \times \pi R^2 \times (d + l)$ where N is the number of turbines, d is the depth of the	V_r =	1684202.06 m^3	

	rotor front to back, and l is the bird length				
3	Estimate bird occupancy n within V_w This is the number of birds multiplied by the time spent within V_w (per season/year)	n =	141849.05	secs per yr	Bird occupancy is based on observations of birds flying through rotor-swept area
4	Bird occupancy of V_r n x (V_r / V_w) bird-seconds	occupancy =	60.70	bird-seconds	
5	Time taken for a bird to make transit through and completely clear the rotors t = (d + l) / v where v is bird speed (m/sec)	t =	0.22	seconds	Speed should be assessed in the field but published values are available
6	Calculate number of bird transits through the rotors = n x (V_r / V_w) / t	transits =	276.33	bird transits per annum	

Number of bird transits through the rotors per annum = 276.33

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Input parameters regarding the turbine specification will need to be obtained from the design engineers or manufacturers.

W Band 03/03/2020

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4	m
Pitch (degrees)	20	
BirdLength	0.28	m
Wingspan	0.72	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	17.9	m/sec
RotorDiam	154	m
RotationPeriod	3.00	sec
Bird aspect ratioo: β	0.39	

Calculation of alpha and p(collision) as a function of radius

				Upwind:			Downwind:		
r/R	c/C	α	collide		contribution	collide		contribution
radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
0.025	0.575	4.44	13.58	0.76	0.00095	12.01	0.67	0.00084
0.075	0.575	1.48	5.05	0.28	0.00212	3.48	0.19	0.00146
0.125	0.702	0.89	3.94	0.22	0.00275	2.02	0.11	0.00141
0.175	0.860	0.63	3.68	0.21	0.00360	1.33	0.07	0.00130
0.225	0.994	0.49	3.56	0.20	0.00447	0.84	0.05	0.00105
0.275	0.947	0.40	3.02	0.17	0.00464	0.43	0.02	0.00066
0.325	0.899	0.34	2.66	0.15	0.00484	0.36	0.02	0.00065
0.375	0.851	0.30	2.39	0.13	0.00501	0.50	0.03	0.00104
0.425	0.804	0.26	2.17	0.12	0.00515	0.59	0.03	0.00140
0.475	0.756	0.23	1.98	0.11	0.00525	0.65	0.04	0.00173
0.525	0.708	0.21	1.81	0.10	0.00531	0.69	0.04	0.00201
0.575	0.660	0.19	1.66	0.09	0.00534	0.70	0.04	0.00226
0.625	0.613	0.18	1.53	0.09	0.00533	0.71	0.04	0.00248
0.675	0.565	0.16	1.40	0.08	0.00529	0.70	0.04	0.00265
0.725	0.517	0.15	1.29	0.07	0.00521	0.69	0.04	0.00279
0.775	0.470	0.14	1.18	0.07	0.00509	0.67	0.04	0.00290
0.825	0.422	0.13	1.07	0.06	0.00493	0.64	0.04	0.00297
0.875	0.374	0.13	0.97	0.05	0.00474	0.61	0.03	0.00300
0.925	0.327	0.12	0.87	0.05	0.00452	0.58	0.03	0.00299
0.975	0.279	0.11	0.78	0.04	0.00425	0.54	0.03	0.00295

Overall p(collision) = Upwind 8.9% Downwind 3.9%

Average 6.4%

Bird survey data

Date	Time observed (seconds)		Number of birds	Bird Occupancy in flight risk volume
TOTAL	2054		62	7749

TOTAL SURVEY TIME 144 hours or 518400 seconds

Period when Golden Plove likely to be on site (see below) =

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	30	31	30	31	31	0	0	0	0

Total days = 153 Total hours (corrected - see below) = 2635.987

Period when Golden Plove likely to be on site = 9489553 seconds (in each year)

Assumptions (write in any assumptions that have been included in the model)

Assumption 1: The flying period extends from dawn to dusk and includes 25% of night.

Assumption 2:

Assumption 3:

Assumption 4:

Proportion of time during which a collision may occur = 9489553 (in each year)

Golden Plover flight time = 7749 seconds in 518400 seconds survey time

Therefore in 5 months = 141849.05 seconds

Note: This table is only relevant when calculating collision risk for goose species. It provides an adjustment for nocturnal flight behaviour for these species.

Number of hours birds are potentially active during winter (from Band et al, in press)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nox	Dec	
Mean Daylight hours**		6.8	9.08	11.78	14.62	17.23	18.77	18.05	15.68	12.88	10.05	7.45	5.98	
Mean Nocturnal hrs*	5	0.86	0.746	0.611	0.469	0.3385	0.2615	0.2975	0.416	0.556	0.6975	0.8275	0.901	
Combined Daily Mean		7.66	9.826	12.391	15.089	17.5685	19.0315	18.3475	16.096	13.436	10.7475	8.2775	6.881	
No of days birds present		0	0	0	30	31	30	31	31	0	0	0	0	
Total hours each month		**0**	**0**	**0**	**452.67**	**544.6235**	**570.945**	**568.7725**	**498.976**	**0**	**0**	**0**	**0**	**2635.987**
Total hours per year		**2635.987**												

**Mean daylight hours taken from www.shetland.climatetemps.com/sunlight.php

Method 1 - Birds using the windfarm airspace (to be used for birds that fly across the site using a variety of different flight paths)

Number of bird transits through the rotors per annum = 276.33

Average collision risk for bird passing through rotor = 6.4%

Number of birds potentially killed by rotors per annum = 17.60

NB: The above calculation assumes no avoidance

Correcting for 95% avoidance rate:

Number of birds potentially killed by rotors per annum = **0.879775**

1 bird killed every 1.136655 years

Correcting for 98% avoidance rate:

Number of birds potentially killed by rotors per annum = **0.351910**

1 bird killed every 2.841637 years

Correcting for 99% avoidance rate:

Number of birds potentially killed by rotors per annum = **0.17595**

1 bird killed every 5.683274 years

References

Band, W, Madders, M, & Whitfield, D.P. (2007) *Developing field and analytical methods to assess avian collision risk at wind farms.* In: Janss, G, de Lucas, M & Ferrer, M (eds.) Birds and Wind Farms. Quercus, Madrid. 259-275

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Bruderer, B. & Boldt, A. (2001) *Flight characteristics of birds: I. radar measurements of speeds*. Ibis.143. Pp. 178-204

Scottish Natural Heritage (2000) Windfarms and Birds - Calculating a theoretical collision risk assuming no avoiding action. SNH Guidance Note.

Scottish Natural Heritage (2018) Avoidance Rates for the onshore SNH Wind Farm Collision Risk Model. SNH Guidance Note.