Appendix 10.3
Collision Risk Assessment

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INTRODUCTION

As part of the assessment of the ecological impacts of the proposed Beaw Field Wind Farm, Alba Ecology Ltd. was commissioned to carry out a Collision Risk Assessment (CRA), based on a 17 turbine wind farm design layout, for the main ornithological interest species of the Site (**Figure 10.1**): red-throated diver, greylag goose, curlew, golden plover, arctic skua and great skua. This document provides an assessment of collision risk only, and does not take into account any other potential impacts on these or other bird species.

Survey Area and Survey Dates

The Study Area for the purposes of this CRA includes the 17 turbines (using the outer sweep of turbine blades) plus a buffer of 500m (Turbine Area) The total CRA survey area is 580ha. For the collision risk assessment all flightlines within this area and recorded from Vantage Points (VPs) overlooking this area were considered (SNH 2005; amended 2010 & 2014, Figure 10.3).

Survey Methods

The flight activity components follow the original SNH guidelines (Whitfield, 2002) modified in the light of Whitfield & Bullman (2004) and the SNH advisory document (SNH, 2005, updated in 2010 & 2014). As this appendix only deals with CRA, the relevant survey method which provides input to this is the VP survey method. The CRA methodological guidelines (SNH 2010) were followed. Vantage Point (VP) bird surveys commenced in October 2010 and were carried out until September 2012.

VP watches are designed to record larger birds using the Site but not necessarily breeding there; and include the collection of data on the activities and flight paths of these birds, including height from the ground, duration of sighting, and activities of the birds. Birds recorded by this method include raptors, skuas, gulls, wildfowl and waders.

Methods are outlined by Madders (unpublished; given as appendix in Whitfield, 2002, Whitfield & Bullman, 2004, and SNH, 2005, 2010, 2014), and ultimately result in an analysis of collision risk (Band *et al.*, 2005) and flightline distribution.

This method involves selecting VP locations that provide a good view of the Site, but do not make the observer too conspicuous. For the purpose of this survey, VPs were selected to cover the (potential) Turbine Area plus a 500m buffer, aiming at a maximum viewing distance of 2km. The selected VPs had a very good close coverage for much of the site with 1km viewsheds for VPs reducing distance detection effects, as per SNH recommendation (**Appendix 10.1: Bird Technical Report**). Given the landform across the Site (and 1km viewshed recommendation), some VP locations were unavoidably placed within the Turbine Area (Figure 10.3).

The number of hours spent at the selected VPs is cumulative, and a minimum of 45 survey hours per summer/breeding season and VP were conducted (as per SNH's recommendation to increase survey effort about the standard 36 hours per VP – **Appendix 10.1: Birds Technical Report**). An effort was made to vary the timing of surveys. VP surveys were conducted in daylight hours, when visibility allowed a clear view of the Site. Table 1 provides details of the survey hours.

The viewsheds were calculated using ArcView Spatial Analyst 9.3.1 software and then ground-truthed in the field. The thirteen VP locations are provided in Table 1.

Table 1. Vantage point locations of VPs overlooking the Site

Vantage Point	Grid Reference	Main viewing direction	No. of hours watched (Oct 2010 – Mar 2011)	No. of hours watched (Apr – Sept 2011)	No. of hours watched (Oct 2011 – Mar 2012)	No. of hours watched (Apr – Sept 2012)	Visible area of Site & buffer[1], ha	Visible area of Site & buffer[2], ha
1	451179/ 1183092	NNE	36.5	45	36	45	79	103
2	451050/ 1182895	SW	33	45	39	45	92	104
3	451144/ 1182801	SE	37	45	36	45	102	285
4	449968/ 1181661	NW	36	45	42	48	*	14
5	450288/ 1181570	SE	36	45	39	48	26	146
6	448500/ 1182100	ENE	37	45	39	45	*	*
7	448500/ 1182100	WSW	36	45	42	45	*	*
8	448956/ 1183635	NW	34	45	36	45	*	*
9	449488/ 1184214	ENE	36	45	36	45	15	139
10	449351/ 1184201	NW	42	45	36	45	*	*
11	449146/ 1183404	SE	42	45	36	45	12	151
12	447439/ 1183968	ESE	0	45	36	45	*	*
13	451300/ 1181970	SE	0	45	36	45	130	215

* Visible area of Site and buffer (viewing sky at 1.5 m from ground, to 20 m above ground, azimuth of max. 180 degrees extending to 2 km radius) ha. Visibility calculated using the least visible part of the airspace, the lowermost height passed through by the rotor blade tips (SNH 2005, revised 2010 & 2014).

Weather permitting, VP watches usually lasted for a three-hour period. From the pre-selected VPs (ES Volume 2: Figure 10.3), the visible area within an 180^o arc was scanned for target species over a three hour period. Flights of target species seen from VPs were recorded within three height bands: below turbine height; approx. turbine height (so called 'at risk height'); and above turbine height. While these heights may not match the dimensions of turbines exactly, there is a certain amount of error on the part of the fieldworker in estimating heights of birds from a distance, and fieldworkers are practised in estimating heights, and this is regularly reinforced by using a hand-held clinometer on objects of known height. In practice, birds vary their flight height all the time, but it is usually easy to place bird heights within three bands: high flights were invariably well above turbine height

These height bands were divided into three, which at the time of survey corresponded with turbine models available then and likely to be used:

- Below turbine height (<20m);
- Turbine (danger) height (20-120m); and
- Above turbine height (>120m).

Surveyors were instructed to always put all birds close to 'turbine/danger height' into that height band. Consequently all birds at or just above the 120m height, which was defined as within 25m of it, i.e. up to 145m were included in the 'turbine height' band. Only where the flight height was judged to be well above the 'turbine height' band were flights recorded on sheets as 'above turbine height'. Thus, flights recorded as above turbine height were above the danger height i.e. >145m. Turbine models used in the wind farm industry have varied in size and even at the time of writing (January 2016) the actual model and size of turbines available in the future at the time of construction is unknown. For the purpose of the ES, the turbines used in this Proposed Development are described in **Chapter 3: Project Description** as '*17 turbines with a maximum tip height of up to 145m with a generating capacity greater than 50MW*'. Thus, the turbine height bands used to record bird flightlines broadly matches the maximum height of the turbines to be used.

For all species, flightlines were plotted on ArcView 9.3.1, and divided into sections where birds exhibited different behaviours or travelled at different speeds, and distances of these within the survey area measured.

COLLISION RISK ASSESSMENTS

A method of assessing collision risk of birds with turbine blades has been developed by Band and co-workers (2005). Collision risk is given as the product of:

(a) The number of birds flying through the rotor(s) (stage 1);

(b) The probability of a bird flying through a rotor being hit (stage 2).

Survey effort at the VPs is given in Table 1 and VP viewsheds are given in Figure 10.3 and show the site coverage of the viewsheds.

The "flight risk area" of the wind farm (outer turbines plus rotor radius, plus a buffer of 500m) was 580ha.

The probability of a bird colliding with a turbine blade when making a transit through a rotor depends on many factors, and several of these are unknown, though as more wind farm work progresses in the UK, statistics become more reliable with increasing data. Not least, the avoidance factor whereby birds are able to take evasive action when approaching turbines, which for each of the relevant species is given thereinafter. The following calculation therefore gives a value for probability which assumes birds would take no evasive action; unlikely to happen in practice, but gives a baseline estimation to work from. A number of simplifications have to be made, adding to the potential for error, and Band *et al.* (2005) suggest an interpretation of the results within a wide margin, e.g. ±10%. Simplifications include:

- Birds are assumed to be a simple cruciform shape;
- Turbine blades are assumed to have width and pitch angle but no thickness;
- The effects of slipstream will have no effect on the bird flight; and
- Birds fly through turbines in straight lines.

The probability of bird collision, for given bird and blade dimensions and speeds, is the probability, where the bird placed anywhere at random on the line of flight, of it overlapping with a blade swathe. Where the angle of approach is shallow, it is the length of the bird, compared to the separation distance of successive swathes, which is the controlling factor. Where the angle of approach is high, it is the wingspan of the bird compared to the physical distance between blades, which is the controlling factor.

The calculation derives a probability $p(r, \phi)$ of collision for a bird at a radius r from the hub, and at a position along a radial line which is an angle ϕ from the vertical. It is then necessary to integrate this probability over the entire rotor disc, assuming that the bird transit may be anywhere at random within the area of the rotor disc.

The calculation is further based on the following technical parameters (Table 2) provided by the Applicant.

Table 2. Technical parameters (Turbine model Senvion 3xM)

Number of blades	3
Pitch (average, degrees)	45
Rotation period (maximum, s)	6
Rotation period (minimum, s)	3
Rotor diameter (m)	108
Number of turbines	17
Operation time average, estimated (%)	85
Turbine height to hub (m)	91

As described before, the calculation proceeds in two stages (SNH 2000):

Stage 1: The number of birds flying through the rotor(s);

Stage 2: The probability of a bird flying through a rotor being hit.

For stage 1 there are two standard approaches depending on the species and flight behaviour.

1) Regular flights through a wind farm – where birds make regular flights through the wind farm possibly in a reasonably defined direction within habitually-used flight corridors such as over-wintering geese and divers.

2) Birds using the wind farm airspace – most appropriate for birds that occupy a recognised territory such as raptors and waders.

1) Birds making regular flights through the wind farm

Red-throated diver

As red-throated diver flightlines generally follow a straight-line rather than the more random flightlines of the raptors and waders, the approach for regular flights through the wind farm, possibly in reasonable defined direction was used (Band *et al*., 2005).

Two six months summer periods are included in the CRA (summer 2011 and summer 2012; **Appendix 10.2: Confidential Information**). In summer 2015 (April to September 2015) another set of dedicated diver nest surveys were carried out which are not part of the CRA.

During the **summer season 2011**, a total of 160 flightlines involving 242 red-throated diver were recorded from VPs overlooking the site, of which 70 flightlines involving a total of 108 birds entered the proposed turbine sweep + 500m at risk height. Records involved between one and four birds.

During **summer season 2012**, a total of 75 flightlines involving 106 red-throated diver were recorded from VPs overlooking the site, of which 41 flightlines involving a total of 55 birds entered the proposed turbine sweep + 500m at risk height. Records involved between one and six birds.

The CRA is based on the biological parameters in Table 3 below.

Table 3. Biological parameters used - red-throated diver

Bird length (m)[1]	1.11
Wingspan (m)[1]	0.61
assumed Bird speed (m/s)	21.1
Hours per day present (summer)	15.5
Days per season present (summer)	183
Avoidance rate (%, Furness 2015**)**	99
Avoidance rate (%, Furness 2015**)**	99.5

Probability of a bird flying through the rotor swept area

The “risk window” of the wind farm (W) is its width perpendicular to the lines of flight multiplied by the maximum height of the highest turbine, i.e. 3,950m x 145m:

$$W = 572{,}750m^2$$

[1] http://app.bto.org/birdfacts/results/bob4850.htm, accessed 29/12/2015

The total number of divers flying through the risk window per hour of observation time (D) is:

D = (number of birds x frequency of flight) / observation time (hours)

Table 4. Total number of red-throated divers flying through the risk window per hour of observation time (D)

Season	Number of divers flying through risk window per observation time D (diver/hour)
Summer 2011	0.3
Summer 2012	0.15

Assuming that red-throated divers during summer are active (on average) in flight 15.5 hours per day, and present only in the summer season (183 days per year):

- ➔ the occupancy results in (n) = days present x hours present x D:

Table 5. Occupancy (n) of red-throated divers within the Study Area

Season	Occupancy (n)
Summer 2011	850.95
Summer 2012	426.25

The area (A) presented by the wind farm rotors $N \times \pi R^2$, where N is the number of rotors and R is the rotor radius is given as:

$A = 17 \times \pi \times (54m)^2 = 155{,}735m^2$.

Note that it is assumed the rotors are aligned in the plane of the risk window.

The proportion of the risk window occupied by the rotors is A / W:

$155{,}735m^2 / 572{,}750m^2 = 0.272$

Therefore the number of red-throated divers assumed to pass through the rotors each year is :

n x A / W

Table 6. Number of red-throated divers assumed to pass through the rotors each year

Season	Number of red-throated divers pass through risk window per season
Summer 2011	231.4
Summer 2012	115.9

This figure does not take into account the possibility of red-throated divers avoiding the area for other reasons or after construction of the wind farm.

Probability of birds colliding with rotors

The second stage of the calculation is the same principal as that for regular flights through a wind farm as described by SNH (2000). Results of calculations are presented below. Note that the flight of this species does not vary in the way that raptor flight does; flight speed is much more constant and birds only use flight as a means to get from a to b rather than for hunting or display. The flight can be described as flapping rather than gliding at all times.

Table 7. Red-throated diver collision probabilities

	Rotation Period	%p, upwind	%p, downwind	%p, mean
Maximum risk	3s	13.4%	7.8%	10.6%
Minimum risk	6s	8.7%	3.8%	6.3%

Assuming an avoidance factor of 99% / 99.5%, by which red-throated divers may be able to take evasive action to avoid colliding with a turbine blade, gives the following numbers of collisions:

Table 8. Red-throated diver collisions

Season	Avoidance factor, assuming no preference away from wind farm site	Collisions at 3s rotation	Collisions at 6s rotation
Summer 2011	No avoidance	20.847	12.292
	99%	**0.209**	0.123
	99.5%	**0.104**	0.062
Summer 2012	No avoidance	10.442	6.157
	99%	0.104	**0.062**
	99.5%	0.052	**0.031**

With red-throated divers being mainly present on the Study Area in the summer season, considering the birds mainly flap and rarely glide, taking the recently advised highly conservative avoidance rate of 99% (Furness, 2015), the collision risk per year results in between 0.208 collisions per year and summer season in worst-case (one bird every 4.8 years and summer seasons) and 0.062 collisions per year and summer season in best-case (one bird every 16.2 years and summer seasons).

Furness (2015) reported that the highly precautionary 99% avoidance rate should be used until generality of the results can be established, but that it would be consistent with evidence from Orkney and overseas to also adopt a 99.5% avoidance rate. Using the 99.5% avoidance rate results in CRA predictions of between 0.104 collisions per year and summer season in worst-case (i.e. one bird every 9.6 years) and 0.031 collisions per year and summer season in best-case (i.e. one bird every 32.5 years).

Greylag Goose

As greylag geese flightlines generally follow a pattern rather than the more random flightlines of raptors and waders, the approach for regular flights through the wind farm, possibly in reasonably defined direction was used (Band *et al.,* 2005). The birds were seen to cross the proposed site in 2012 predominantly in NNE to SSW direction and vice versa.

Two six months summer seasons (summer 2011 and summer 2012) and two six months winter seasons are included in the CRA (winter 2010/11 and winter 2011/12).

During the **winter season 2010/11**, a total of 12 flightlines involving 105 greylag geese were recorded from VPs overlooking the site, of which 4 flightlines involving a total of 26 birds entered the proposed turbine sweep + 500m at risk height. Records involved between 2 and 24 birds.

During the **summer season 2011**, a total of 93 flightlines involving 366 greylag geese were recorded from VPs overlooking the site, of which 26 flightlines involving a total of 179 birds entered the proposed turbine sweep + 500m at risk height. Records involved between 1 and 30 birds.

During the **winter season 2011/12**, a total of 42 flightlines involving 223 greylag geese were recorded from VPs overlooking the site, of which 15 flightlines involving a total of 95 birds entered the proposed turbine sweep + 500m at risk height. Records involved between 1 and 19 birds.

During the **summer season 2012**, a total of 63 flightlines involving 126 greylag geese were recorded from VPs overlooking the site, of which 19 flightlines involving a total of 57 birds entered the proposed turbine sweep + 500m at risk height. Records involved between 1 and 23 birds.

The CRA is based on the biological parameters in Table 9 below.

Table 9. Biological parameters used -greylag goose

Bird length (m)[2]	0.82
Wingspan (m)[2]	1.64
Assumed Bird speed (m/s)[3]	15/19
Hours per day present (summer)	15.5
Days per season present (summer)	183
Hours per day present (winter)	9
Days per season present (winter)	182
Avoidance rate (%, SNH**)**	99.8

Probability of a bird flying through the rotor swept area

The "risk window" of the wind farm (W) is its width perpendicular to the lines of flight multiplied by the maximum height of the highest turbine, i.e. 3,950m x 145m:

$$W = 572{,}750m^2$$

[2] http://app.bto.org/birdfacts/results/bob4850.htm, accessed 29/12/2015

[3] Pennycuick CJ, Akesson S, Hedenstrom A. 2013 Air speeds of migrating birds observed by ornithodolite and compared with predictions from flight theory. J R Soc Interface 10: 20130419. http://dx.doi.org/10.1098/rsif.2013.0419

The total number of greylag geese flying through the risk window per hour of observation time (D) is:

D = (number of birds x frequency of flight) / observation time (hours)

Table 10. Total number of greylag geese flying through the risk window per hour of observation time (D)

Season	Number of geese flying through risk window per observation time D (geese/hour)
Winter 2010/11	0.101
Summer 2011	0.497
Winter 2011/12	0.317
Summer 2012	0.156

Assuming that greylag geese during summer (183 days) are active in flight 15.5 hours per day, and during winter season (182 days) are active in flight 9 hours per day:

➔ the occupancy results in (n) = days present x hours present x D:

Table 11. Occupancy (n) of greylag geese on within the Study Area

Season	Occupancy (n)
Winter 2010/11	166.0
Summer 2011	1410.4
Winter 2011/12	518.7
Summer 2012	441.8

The area (A) presented by the wind farm rotors $N \times \pi R^2$, where N is the number of rotors and R is the rotor radius is given as:

$$A = 17 \times \pi \times (54\text{m})^2 = 155{,}735\text{m}^2.$$

Note that it is assumed the rotors are aligned in the plane of the risk window. The proportion of the risk window occupied by the rotors is A / W:

$$155{,}735\text{m}^2 / 572{,}750\text{m}^2 = 0.272$$

Therefore the number of greylag geese assumed to pass through the rotors each year is per season

n x A / W:

Table 12. Number of greylag geese assumed to pass through the rotors each year

Season	Number of greylag geese pass through risk window per season
Winter 2010/11	45.15
Summer 2011	383.49
Winter 2011/12	141.04
Summer 2012	120.12

This figure does not take into account the possibility of greylag geese avoiding the Study Area for other reasons or after construction of the wind farm.

Probability of birds colliding with rotors

The second stage of the calculation is the same principal as that for regular flights through a wind farm as described by SNH (2000). Results of calculations are presented below. Note that the flight of this species does not vary in the way that raptor flight does; flight speed is much more constant and birds only use flight as a means to get from a to b rather than for hunting or display. The flight can be described as flapping rather than gliding at all times.

Table 13. Greylag goose collision probabilities

	Rotation Period	%p, upwind	%p, downwind	%p, mean
Maximum risk	3s	15.8	10.1	12.9
Minimum risk	6s	8.6	5.7	7.2

Assuming an avoidance factor of 99.8%, by which greylag geese may be able to take evasive action to avoid colliding with a turbine blade, gives the following numbers of collisions:

Table 14. Greylag geese collisions

Season	Avoidance factor, assuming no preference away from Site	Collisions at 3s rotation	Collisions at 6s rotation
Winter 2010/11	No avoidance	4.952	2.750
	99.8%	0.010	0.006
Summer 2011	No avoidance	42.063	23.356
	99.8%	**0.084**	0.047
Winter 2011/12	No avoidance	15.470	8.590
	99.8%	**0.031**	**0.017**
Summer 2012	No avoidance	13.175	7.315
	99.8%	0.026	**0.015**

This results in the following year-round collision risks:

- Max risk winter 2010-summer 2011: 0.010 + 0.084 = 0.094, i.e. one bird every 10.6 years.
- Min risk winter 2010-summer 2011: 0.006 + 0.047 = 0.053, i.e. one bird every 18.9 years.
- Max risk winter 2011-summer 2012: 0.031 + 0.026 = 0.057, i.e. one bird every 17.5 years.
- Min risk winter 2011-summer 2012: 0.017 + 0.015 = 0.032, i.e. one bird every 31.3 years.

With greylag geese in the Turbine Area throughout the year (but mainly summer), considering the birds flap, taking the precautionary 99.8% avoidance factor and assuming no evasive behaviour, the collision risk per year results in between 0.094 collisions per year in worst-case (one bird every 10.6 years) and 0.032 collisions per year best-case (one bird every 31.3 years).

2) Birds using the wind farm airspace

For birds using the wind farm airspace irregularly such as waders, the calculation was made of the time (seconds) spent at different heights within the Turbine Area and also within the polygon viewshed from the VP at which the bird was seen, as a proportion of the total flight time in sections where birds were assumed to be moving at a uniform speed, using the equation: time in flightline section = (total time/total length) x length of flightline section. Each flight time was subsequently multiplied by the number of birds recorded during that flight and then added to give a total flight time within the collision risk zone.

Curlew

Curlews are present all year round in the Turbine Area and are diurnal. They are considered to mainly flap and rarely glide. As curlew flightlines are generally more randomly distributed than flightlines of e.g. divers and geese which tend to follow a more regular pattern, the approach for birds using the wind farm airspace was used (Band *et al.,* 2005).

During the **winter season 2010/11**, a total of 13 flightlines involving 60 curlew (4,721s) were recorded from VPs overlooking the Turbine Area, of which three flightlines involving a total of 17 birds (377s) entered the proposed turbine sweep + 500m at risk height. Records involved between 1 and 14 birds. Only birds recorded from VPs overlooking the site and seen within the 2km viewshed of the associated VP were included in the calculation. For the winter season 2010 this applied to three flights involving 17 birds.

During the **summer season 2011**, a total of 62 flightlines involving 73 curlew (2,295s) were recorded from VPs overlooking the site, of which 14 flightlines involving a total of 16 birds (370s) entered the proposed turbine sweep + 500m at risk height. Records involved between 1 and 2 birds. Of these 11 flights involving a total of 13 birds were seen within the 2km viewsheds of associated VPs.

During the **winter season 2011/12**, a total of 12 flightlines involving 26 curlew (1,150s) were recorded from VPs overlooking the site, of which one flightline involving a total of 5 birds (259s) entered the proposed turbine sweep + 500m at risk height. Records involved between 1 and 5 birds. Of these flightlines one flight involving a total of five birds were seen within the 2km viewsheds of associated VPs.

During the **summer season 2012**, a total of 73 flightlines involving 113 curlew (4,990s) were recorded from VPs overlooking the site, of which 19 flightlines involving a total of 33 birds (1,572s) entered the proposed turbine sweep + 500m at risk height. Records involved between 1 and 4 birds. Of these 5 flights involving a total of 9 birds were seen within the 2km viewsheds of associated VPs.

Table 15. Summary of curlew flightlines recorded

	Season	Total	Risk height
Flight time within collision risk window (s)	Winter 2010/11	1,554	370
	Summer 2011	704	244
	Winter 2011/12	255	230
	Summer 2012	1,796	1,378
Flying time per area watched (hr/hahr)	Winter 2010/11	0.0000433275	0.0000097466
	Summer 2011	0.0000307749	0.0000099938
	Winter 2011/12	0.0000089753	0.0000082544
	Summer 2012	0.0000600511	0.0000446630
Proportional flying time per area watched (hr/hahr)	Winter 2010/11	0.000012	0.000003
	Summer 2011	0.000004	0.000001
	Winter 2011/12	0.000002	0.000002
	Summer 2012	0.000009	0.000007
Proportional time in wind farm	Winter 2010/11	0.007179	0.001709
	Summer 2011	0.002177	0.000754
	Winter 2011/12	0.000966	0.000871
	Summer 2012	0.005505	0.004222

Furthermore, the CRA is based on the biological parameters in Table 16 below.

Table 16. Biological parameters used - curlew

Bird length (m)[4]	0.55
Wingspan (m)[3]	0.9
Bird speed (m/s)[5]	15.6
Hours per day present (summer)	15.5
Days per season present (summer)	183
Hours per day present (winter)	9
Days per season present (winter)	182
Avoidance rate (%, SNH**)**	98

Golden Plover

Golden plover are present all year round on Beaw and are diurnal. They are considered to mainly flap and rarely glide. As golden plover flightlines are generally more randomly distributed than flightlines of e.g. divers and geese which follow a pattern, the approach for birds using the wind farm airspace was used (Band *et al*., 2005).

[4] http://app.bto.org/birdfacts/results/bob4850.htm, accessed 29/12/2015

[5] Cooke, M.T. (1933). Speed of Bird Flight. (Flight speed for Long-billed Curlew, considered to be a comparable species in terms of size and flight speed, has been used as no value of flight speed for Eurasian Curlew have been available) as recommended by Scottish Natural Heritage, 2014 (2))

During the **winter season 2010/11**, a total of 13 flightlines involving 175 golden plover (7,390s) were recorded from VPs overlooking the site, of which three flightlines involving a total of 41 birds (603s) entered the proposed turbine sweep + 500m at risk height. Records involved between 2 and 37 birds. Only birds recorded from VPs overlooking the site and seen within the 2km viewshed of the associated VP were included in the calculation. For the winter season 2010 this applied to three flights involving 41 birds.

During the **summer season 2011**, a total of 60 flightlines involving 97 golden plover (3,700s) were recorded from VPs overlooking the site, of which 19 flightlines involving a total of 35 birds (1,169s) entered the proposed turbine sweep + 500m at risk height. Records involved between 1 and 11 birds. Of these 16 flights involving a total of 85 birds were seen within the 2km viewsheds of associated VPs.

During the **winter season 2011/12**, a total of 44 flightlines involving 165 golden plover (23,230s) were recorded from VPs overlooking the site, of which 21 flightlines involving a total of 42 birds (5,961s) entered the proposed turbine sweep + 500m at risk height. Records involved between 2 and 60 birds. Of these flightlines 18 flights involving a total of 38 birds were seen within the 2km viewsheds of associated VPs.

During the **summer season 2012**, a total of 121 flightlines involving 206 golden plover (10,426s) were recorded from VPs overlooking the site, of which 38 flightlines involving a total of 53 birds (2,265s) entered the proposed turbine sweep + 500m at risk height. Records involved between 1 and 6 birds. Of these 27 flights involving a total of 40 birds were seen within the 2km viewsheds of associated VPs.

Table 17. Summary of golden plover flightlines recorded

	Season	Total	Risk height
Flight time within collision risk window (s)	Winter 2010/11	649	603
	Summer 2011	1556	944
	Winter 2011/12	1673	1501
	Summer 2012	1777	1226
Flying time per area watched (hr/hahr)	Winter 2010/11	0.0000361937	0.0000327949
	Summer 2011	0.0000750576	0.0000499652
	Winter 2011/12	0.0001023918	0.0000914344
	Summer 2012	0.0000819015	0.0000567912
Proportional flying time per area watched (hr/hahr)	Winter 2010/11	0.000005	0.000005
	Summer 2011	0.000008	0.000005
	Winter 2011/12	0.000011	0.000010
	Summer 2012	0.000009	0.000006
Proportional time in wind farm	Winter 2010/11	0.002998	0.002786
	Summer 2011	0.004811	0.002919
	Winter 2011/12	0.006338	0.005687

	Summer 2012	0.005444	0.003756

Furthermore, the CRA is based on the biological parameters in Table 18 below.

Table 18. Biological parameters used - golden plover

Bird length (m)[6]	0.275
Wingspan (m)[5]	0.715
Bird speed (m/s)[7]	17.9
Hours per day present (summer)	15.5
Days per season present (summer)	183
Hours per day present (winter)	9
Days per season present (winter)	182
Avoidance rate (%, SNH**)**	98

SNH (2014, (2)) recommend to use a surrogate species where data for any particular species are not available. Species with similar taxonomy and morphology have similar flight speeds due to similar wing loadings (Alerstam *et al*. 2007). SNH (2014(2)) suggest for golden plover (*Pluvialis apricaria*) to use the flight speed of the closely related grey plover (*Pluvialis squatarola*) which is 17.9m/s.

Great Skua

Great skua are present April to October on Beaw and are diurnal. As great skua flightlines are generally more randomly distributed than flightlines of e.g. divers and geese which follow a pattern, the approach for birds using the wind farm airspace was used (Band *et al.*, 2005).

During the **summer season 2011**, a total of 819 flightlines involving 1,036 great skua (30,159s) were recorded from VPs overlooking the site, of which 239 flightlines involving a total of 303 birds (12,517s) entered the proposed turbine sweep + 500m at risk height. Records involved between one and five birds. Only birds recorded from VPs overlooking the site and seen within the 2km viewshed of the associated VP were included in the calculation. For the summer season 2011 this applied to 189 flights involving 237 birds.

During the **summer season 2012**, a total of 739 flightlines involving 851 great skua (32,032s) were recorded from VPs overlooking the site, of which 190 flightlines involving a total of 209 birds (6,907s) entered the proposed turbine sweep + 500m at risk height. Records involved between one and five birds. Only birds recorded from VPs overlooking the site and seen within the 2km viewshed of the associated VP were included in the calculation. For the summer season 2012 this applied to 176 flights involving 193 birds.

[6] http://app.bto.org/birdfacts/results/bob4850.htm, accessed 29/12/2015
[7] Flight speed for grey plover (*Pluvialis squatarola*), considered to be a comparable species in terms of size, weight and therefore and flight speed, has been used as no value of flight speed for golden plover (*Pluvialis apricaria*) have been available, as recommended by Scottish Natural Heritage, 2014 (2))

Table 19. Summary of great skua flightlines recorded

	Season	Total	Risk height
Flight time within collision risk window (s)	Summer 2011	21473.14	9428
	Summer 2012	11388.34	5348
Flying time per area watched (hr/hahr)	Summer 2011	0.0009218913	0.0004144823
	Summer 2012	0.0004348770	0.0001909900
Proportional flying time per area watched (hr/hahr)	Summer 2011	0.000114	0.000050
	Summer 2012	0.000060	0.000028
Proportional time in wind farm	Summer 2011	0.066390	0.029150
	Summer 2012	0.034889	0.016385

Furthermore, the CRA is based on the biological parameters in Table 20 below.

Table 20. Biological parameters used - great skua

Bird length (m)[8]	0.56
Wingspan (m)[6]	1.36
Bird speed (m/s)[9]	16
Hours per day present (summer)	15.5
Days per season present (summer)	183
Avoidance rate (%, Furness 2015**)**	99
Avoidance rate (%, Furness 2015**)**	99.5

Arctic Skua

Arctic skua are present on Beaw mid-April until end of August (appr. 138 days) and are diurnal. As arctic skua flightlines are generally more randomly distributed than flightlines of e.g. divers and geese which follow a pattern, the approach for birds using the wind farm airspace was used (Band et al., 2005).

During the **summer season 2011**, a total of 102 flightlines involving arctic skua (12,239s) were recorded from VPs overlooking the site, of which 19 flightlines involving a total of 30 birds (1,768s) entered the proposed turbine sweep + 500m at risk height. Records involved between one and three birds. Only birds recorded from VPs overlooking the site and seen within the 2km viewshed of the associated VP were included in the calculation. For the summer season 2011 this applied to 10 flights involving 17 birds.

During the **summer season 2012**, a total of 105 flightlines involving 137 arctic skua (6,345s) were recorded from VPs overlooking the site, of which 18 flightlines involving a total of 25 birds (733s) entered the proposed turbine sweep + 500m at risk height. Records involved between one and five birds. Only birds recorded from VPs overlooking

[8] http://app.bto.org/birdfacts/results/bob4850.htm, accessed 29/12/2015
[9] María Mateos-Rodríguez, Bruno Bruderer (2012) Flight speeds of migrating seabirds in the Strait of Gibraltar and their relation to wind. Journal of Ornithology, 153 (3), 881-889;
Q. Ashton Acton: Issues in Life Sciences—Zoology: 2013 Edition, Atlanta Georgia

the site and seen within the 2km viewshed of the associated VP were included in the calculation. For the summer season 2012 this applied to 16 flights involving 23 birds.

Table 21. Summary of Arctic skua flightlines recorded

	Season	Total	Risk height
Flight time within collision risk window (s)	Summer 2011	2054.803	888
	Summer 2012	1249.331	533
Flying time per area watched (hr/hahr)	Summer 2011	0.0000693880	0.0000284021
	Summer 2012	0.0000551559	0.0000212090
Proportional flying time per area watched (hr/hahr)	Summer 2011	0.000011	0.000005
	Summer 2012	0.000007	0.000003
Proportional time in wind farm	Summer 2011	0.006353	0.002747
	Summer 2012	0.003827	0.001634

Furthermore, the CRA is based on the biological parameters in Table 20 below.

Table 22. Biological parameters used - Arctic skua

Bird length (m)[10]	0.44
Wingspan (m)[6]	1.18
Bird speed (m/s)	12
Hours per day present (summer)	15.5
Days per season present (summer)	138
Avoidance rate (%, SNH**)**	98

Probability of a bird flying through the rotor swept area

Identifying the flight risk volume

The "flight risk volume" of the wind farm (W) is the area of the wind farm multiplied by the maximum height of the highest turbine, i.e. 5,800,000m^2 x 145m:

$$V_W = 841{,}000{,}000 m^3$$

Calculating the volume swept out by the rotors

The combined volume swept out by the wind farm rotors is:

$$V_r = N \times \pi R^2 \times (d + l) = 17 \times \pi \times (108m/2)^2 \times (3.852m + 0.275m)$$

Where N is the number of wind turbines = 17, d is the depth of the rotor back to front = 3.852m, and l is the length of the bird (m). Results for all species are given in table 23.

[10] http://app.bto.org/birdfacts/results/bob4850.htm, accessed 29/12/2015

Bird occupancy

Subsequently, the bird occupancy (n, hrs/season) within the flight risk volume is estimated by the number of al birds present multiplied by the time spent flying in the flight risk volume, within the period (summer season/winter season) for which the estimate is being made.

The bird occupancy of rotor swept volume (b in s/season) in bird-seconds, where n is bird occupancy, from above:

$$b = n \times (V_r/V_w).$$

The time taken for a bird to fly through the rotors and completely clear the rotors is then

$$t = (d + l) / v,$$

Transits through rotors

Where v (m/s) is the average speed of the bird.

The number of birds passing through the rotors is the result of

$$n \times (V_r / V_w) / t$$

The results of the bird occupancy, bird occupancy of rotor swept volume, bird transit time and the number of transits through the rotors for all species are provided in table 23.

Table 23. Rotor swept volume, bird occupancy, transit time and number of transits per season

	Season	Curlew	Golden Plover	Great Skua	Arctic Skua
Combined volume swept out by rotors, **Vr** (m^3)		685545.61	642718.47	687102.96	668414.75
Bird occupancy, **n** (hrs/season)	winter 2010/11	3.024	4.928	n/a	n/a
	summer 2011	2.311	8.941	89.300	6.346
	winter 2011/12	1.542	10.060	n/a	n/a
	summer 2012	12.932	11.506	50.193	3.774
Bird occupancy of rotor swept volume, **b** (s/season)	winter 2010/11	8.873	13.558	n/a	n/a
	summer 2011	6.782	24.599	262.652	18.157
	winter 2011/12	4.524	27.677	n/a	n/a
	summer 2012	37.951	31.655	147.630	10.799
Bird transit time, **t** (s)	all seasons	0.282	0.231	0.276	0.358

	Season	Curlew	Golden Plover	Great Skua	Arctic Skua
Number of birds passing through rotors	winter 2010/11	31.446	58.804	n/a	n/a
	summer 2011	24.034	106.691	952.500	50.764
	winter 2011/12	16.031	120.045	n/a	n/a
(per season)	summer 2012	134.492	137.298	535.377	30.194

Probability of a bird being hit when flying through the rotors

SNH provide a spreadsheet for ease of calculation of these probabilities, and calculation methods are fully explained in Band *et al.* (2005). Results of calculations are presented below.

Table 24. Curlew collision probabilities, based on supplied turbine statistics. Birds assumed to mainly flap.

Rotation period, s	%p, upwind	%p, downwind	%p, mean
3	16.5	10.7	13.6
6	10.0	4.7	7.3

Table 25. Golden plover collision probabilities, based on supplied turbine statistics. Birds assumed to mainly flap.

Rotation period, s	%p, upwind	%p, downwind	%p, mean
3	13.3	7.6	10.4
6	8.5	3.4	6.0

Table 26. Great skua collision probabilities, based on supplied turbine statistics

Rotation period, s	%p, upwind	%p, downwind	%p, mean
3, flapping bird	16.4	10.6	13.5
6, gliding bird	9.7	4.4	7.1

Table 27. Arctic skua collision probabilities, based on supplied turbine statistics

Rotation period, s	%p, upwind	%p, downwind	%p, mean
3, flapping bird	19.6	13.7	16.7
6, gliding bird	11.4	5.8	8.6

Translating these metrics into bird collisions per season and allowing for a species specific avoidance gives the two extremes for each scenario:

Table 28. Estimated collisions before and after allowing for avoidance per season

<table>
<tr><th></th><th></th><th colspan="2">Curlew</th><th colspan="2">Golden plover</th><th colspan="2">Great skua</th><th colspan="2">Arctic skua</th></tr>
<tr><th></th><th></th><th>high risk</th><th>low risk</th><th>high risk</th><th>low risk</th><th>high risk</th><th>low risk</th><th>high risk</th><th>low risk</th></tr>
<tr><td rowspan="4">Estimated no. of collisions</td><td>winter 2010/11</td><td>3.624</td><td>1.961</td><td>5.216</td><td>2.985</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>summer 2011</td><td>2.770</td><td>1.499</td><td>9.464</td><td>5.416</td><td>109.306</td><td>57.296</td><td>7.199</td><td>3.700</td></tr>
<tr><td>winter 2011/12</td><td>1.847</td><td>1.000</td><td>10.649</td><td>6.094</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>summer 2012</td><td>15.499</td><td>8.389</td><td>12.179</td><td>6.970</td><td>61.438</td><td>32.205</td><td>4.282</td><td>2.201</td></tr>
<tr><td rowspan="4">After allowing for 98% avoidance</td><td>winter 2010/11</td><td>0.072</td><td>0.039</td><td>0.104</td><td>0.060</td><td rowspan="4" colspan="2">n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>summer 2011</td><td>0.055</td><td>0.030</td><td>0.189</td><td>0.108</td><td>0.144</td><td>0.074</td></tr>
<tr><td>winter 2011/12</td><td>0.037</td><td>0.020</td><td>0.213</td><td>0.122</td><td>n/a</td><td>n/a</td></tr>
<tr><td>summer 2012</td><td>0.310</td><td>0.168</td><td>0.244</td><td>0.139</td><td>0.086</td><td>0.044</td></tr>
<tr><td rowspan="4">After allowing for 99% avoidance</td><td>winter 2010/11</td><td rowspan="8" colspan="2">n/a</td><td rowspan="8" colspan="2">n/a</td><td>n/a</td><td>n/a</td><td rowspan="8" colspan="2">n/a</td></tr>
<tr><td>summer 2011</td><td>1.093</td><td>0.573</td></tr>
<tr><td>winter 2011/12</td><td>n/a</td><td>n/a</td></tr>
<tr><td>summer 2012</td><td>0.614</td><td>0.322</td></tr>
<tr><td rowspan="4">After allowing for 99.5% avoidance</td><td>winter 2010/11</td><td>n/a</td><td>n/a</td></tr>
<tr><td>summer 2011</td><td>0.547</td><td>0.286</td></tr>
<tr><td>winter 2011/12</td><td>n/a</td><td>n/a</td></tr>
<tr><td>summer 2012</td><td>0.307</td><td>0.161</td></tr>
</table>

Table 29. Estimated collisions before and after allowing for avoidance per year

		Curlew		Golden plover		Great skua		Arctic skua	
		high risk	**low risk**	**high risk**	**low risk**	**high risk**	**low risk**	**high risk**	**low risk**
Estimated no. of collisions	Winter 2010/11 & Summer 2011	6.394	**3.460**	14.680	**8.401**	**109.306**	57.296	**7.199**	3.700
	Winter 2011/12 & Summer 2012	**17.346**	9.389	**22.828**	13.064	61.438	**32.205**	4.282	**2.201**
After allowing for 98% avoidance	Winter 2010/11 & Summer 2011	0.127	***0.069***	0.293	***0.168***	n/a		***0.144***	0.074
	Winter 2011/12 & Summer 2012	***0.347***	0.188	***0.457***	0.261			0.086	***0.044***
After allowing for 99% avoidance	Winter 2010/11 & Summer 2011	n/a		n/a		***1.093***	0.573	n/a	
	Winter 2011/12 & Summer 2012					0.614	***0.322***		
After allowing for 99.5% avoidance	Winter 2010/11 & Summer 2011	n/a		n/a		***0.547***	0.286	n/a	
	Winter 2011/12 & Summer 2012					0.307	***0.161***		

With curlew in the Turbine Area mainly present in the summer breeding season and to a much lesser extent in the winter, considering the birds mainly flap and rarely glide, taking the precautionary 98% avoidance factor and assuming no evasive behaviour, the collision risk per year results in between 0.347 collisions per year in worst-case (one bird every 2.9 years) and 0.069 collisions per year in best-case (one bird every 14.5 years).

With golden plover in the Turbine Area throughout the year, considering the birds mainly flap and rarely glide, taking the precautionary 98% avoidance factor and assuming no evasive behaviour, the collision risk per year results in between 0.46 collisions per year in worst-case (one bird every 2.2 years) and 0.168 collisions per year best-case (one bird every 6.0 years).

With great skua being present in the Turbine Area in summer, taking the precautionary 99% avoidance factor and assuming no evasive behaviour, the collision risk per year results in between 1.09 collisions per year in worst-case (one bird every 0.9 years) and 0.32 collisions per year in best-case (one bird every 3.1 years). However, Furness (2015) reported that the highly precautionary 99% avoidance rate should be used until generality of the results can be established, but that it would be consistent with evidence from Orkney and overseas to also adopt a 99.5% avoidance rate. Using the 99.5% avoidance rate results in CRA predictions of 0.55 collisions per year in worst-case (one bird every 1.8 year) and 0.16 collisions per year in best-case (one bird every 6.3 years).

Arctic skua are only present in the Turbine Area from April until end of August. Taking the precautionary 98% avoidance factor and assuming no evasive behaviour, the collision risk per year results in between 0.144 collisions per year in worst-case (one bird every 6.9 years) and 0.044 collisions per year in best-case (one bird every 22.7 years).

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Red-throated diver – collision_V90_max_risk

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	3.852	m
Pitch (degrees)	45	
BirdLength	0.61	m
Wingspan	1.11	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	21.1	,
RotorDiam	108	m
RotationPeriod	3.00	sec
Bird aspect ratioo: b	0.55	

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

			Upwind:			Downwind:		
r/R radius	c/C chord	a alpha	collide length	p(collision)	contribution from radius r	collide length	p(collision)	contribution from radius
0.025	0.575	7.46	21.54	1.00	0.00125	18.41	0.87	0.00109
0.075	0.575	2.49	8.22	0.39	0.00292	5.09	0.24	0.00181
0.125	0.702	1.49	6.42	0.30	0.00380	2.60	0.12	0.00154
0.175	0.860	1.07	6.02	0.29	0.00500	1.34	0.06	0.00111
0.225	0.994	0.83	5.87	0.28	0.00626	1.38	0.07	0.00147
0.275	0.947	0.68	5.08	0.24	0.00662	1.58	0.07	0.00206
0.325	0.899	0.57	4.49	0.21	0.00692	1.68	0.08	0.00259
0.375	0.851	0.50	4.08	0.19	0.00725	1.78	0.08	0.00315
0.425	0.804	0.44	3.76	0.18	0.00757	1.84	0.09	0.00370
0.475	0.756	0.39	3.48	0.16	0.00783	1.86	0.09	0.00419
0.525	0.708	0.36	3.22	0.15	0.00802	1.85	0.09	0.00461
0.575	0.660	0.32	2.99	0.14	0.00816	1.83	0.09	0.00497
0.625	0.613	0.30	2.78	0.13	0.00823	1.78	0.08	0.00527
0.675	0.565	0.28	2.57	0.12	0.00824	1.72	0.08	0.00551
0.725	0.517	0.26	2.38	0.11	0.00818	1.66	0.08	0.00569
0.775	0.470	0.24	2.20	0.10	0.00807	1.58	0.07	0.00581
0.825	0.422	0.23	2.02	0.10	0.00789	1.50	0.07	0.00586
0.875	0.374	0.21	1.85	0.09	0.00766	1.41	0.07	0.00586
0.925	0.327	0.20	1.68	0.08	0.00736	1.32	0.06	0.00579
0.975	0.279	0.19	1.51	0.07	0.00700	1.22	0.06	0.00566
	Overall p(collision) =			**Upwind**	**13.4%**		**Downwind**	**7.8%**
					Average	**10.6%**		

Red-throated diver – collision_V90_min_risk

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	3.852	m
Pitch (degrees)	45	
BirdLength	0.61	m
Wingspan	1.11	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	21.1	,
RotorDiam	108	m
RotationPeriod	6.00	sec
Bird aspect ratioo: b	0.55	

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

			Upwind:			Downwind:		
r/R radius	c/C chord	a alpha	collide length	p(collision)	contribution from radius r	collide length	p(collision)	contribution from radius
0.025	0.575	14.93	41.51	0.98	0.00123	38.38	0.91	0.00114
0.075	0.575	4.98	14.88	0.35	0.00264	11.75	0.28	0.00209
0.125	0.702	2.99	10.93	0.26	0.00324	7.11	0.17	0.00210
0.175	0.860	2.13	9.70	0.23	0.00402	5.02	0.12	0.00208
0.225	0.994	1.66	9.04	0.21	0.00482	3.62	0.09	0.00193
0.275	0.947	1.36	7.58	0.18	0.00494	2.43	0.06	0.00158
0.325	0.899	1.15	6.53	0.15	0.00503	1.64	0.04	0.00126
0.375	0.851	1.00	5.73	0.14	0.00509	1.12	0.03	0.00099
0.425	0.804	0.88	5.08	0.12	0.00512	1.24	0.03	0.00125
0.475	0.756	0.79	4.55	0.11	0.00512	1.31	0.03	0.00148
0.525	0.708	0.71	4.09	0.10	0.00509	1.35	0.03	0.00168
0.575	0.660	0.65	3.69	0.09	0.00502	1.35	0.03	0.00184
0.625	0.613	0.60	3.33	0.08	0.00493	1.34	0.03	0.00198
0.675	0.565	0.55	3.00	0.07	0.00480	1.30	0.03	0.00208
0.725	0.517	0.51	2.74	0.07	0.00471	1.29	0.03	0.00222
0.775	0.470	0.48	2.51	0.06	0.00460	1.27	0.03	0.00234
0.825	0.422	0.45	2.28	0.05	0.00446	1.24	0.03	0.00242
0.875	0.374	0.43	2.06	0.05	0.00428	1.19	0.03	0.00248
0.925	0.327	0.40	1.86	0.04	0.00407	1.14	0.03	0.00250
0.975	0.279	0.38	1.66	0.04	0.00384	1.08	0.03	0.00249
	Overall p(collision) =			**Upwind**	**8.7%**		**Downwind**	**3.8%**
					Average	**6.3%**		

Greylag goose – collision_V90_max_risk

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	3.852	m
Pitch (degrees)	45	
BirdLength	0.82	m
Wingspan	1.64	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	19	,
RotorDiam	108	m
RotationPeriod	3.00	sec
Bird aspect ratioo: b	0.50	

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

			Upwind:			Downwind:		
r/R radius	c/C chord	a alpha	collide length	p(collision)	contribution from radius r	collide length	p(collision)	contribution from radius
0.025	0.575	6.72	23.11	1.00	0.00125	19.98	1.00	0.00125
0.075	0.575	2.24	8.75	0.46	0.00345	5.62	0.30	0.00222
0.125	0.702	1.34	6.68	0.35	0.00440	2.86	0.15	0.00188
0.175	0.860	0.96	6.17	0.32	0.00568	1.67	0.09	0.00154
0.225	0.994	0.75	5.96	0.31	0.00705	1.91	0.10	0.00226
0.275	0.947	0.61	5.16	0.27	0.00746	2.01	0.11	0.00290
0.325	0.899	0.52	4.56	0.24	0.00780	2.03	0.11	0.00347
0.375	0.851	0.45	4.18	0.22	0.00824	2.10	0.11	0.00414
0.425	0.804	0.40	3.87	0.20	0.00867	2.14	0.11	0.00479
0.475	0.756	0.35	3.61	0.19	0.00902	2.15	0.11	0.00538
0.525	0.708	0.32	3.37	0.18	0.00930	2.13	0.11	0.00589
0.575	0.660	0.29	3.14	0.17	0.00952	2.09	0.11	0.00634
0.625	0.613	0.27	2.94	0.15	0.00966	2.04	0.11	0.00671
0.675	0.565	0.25	2.74	0.14	0.00974	1.98	0.10	0.00702
0.725	0.517	0.23	2.56	0.13	0.00975	1.90	0.10	0.00726
0.775	0.470	0.22	2.38	0.13	0.00969	1.82	0.10	0.00743
0.825	0.422	0.20	2.20	0.12	0.00957	1.74	0.09	0.00753
0.875	0.374	0.19	2.04	0.11	0.00937	1.64	0.09	0.00757
0.925	0.327	0.18	1.87	0.10	0.00911	1.55	0.08	0.00754
0.975	0.279	0.17	1.71	0.09	0.00878	1.45	0.08	0.00743
	Overall p(collision) =			**Upwind**	**15.8%**		**Downwind**	**10.1%**
					Average	**12.9%**		

Greylag Goose – collision_V90_min_risk

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	3.852	m
Pitch (degrees)	15	
BirdLength	0.82	m
Wingspan	1.64	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	19	,
RotorDiam	108	m
RotationPeriod	6.00	sec
Bird aspect ratioo: b	0.50	

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

			Upwind:			Downwind:		
r/R radius	c/C chord	a alpha	collide length	p(collision)	contribution from radius r	collide length	p(collision)	contribution from radius
0.025	0.575	13.44	51.37	1.00	0.00125	50.22	1.00	0.00125
0.075	0.575	4.48	17.50	0.46	0.00345	16.36	0.43	0.00323
0.125	0.702	2.69	12.12	0.32	0.00399	10.72	0.28	0.00353
0.175	0.860	1.92	10.15	0.27	0.00467	8.44	0.22	0.00388
0.225	0.994	1.49	8.97	0.24	0.00531	6.98	0.18	0.00413
0.275	0.947	1.22	7.25	0.19	0.00525	5.36	0.14	0.00388
0.325	0.899	1.03	6.05	0.16	0.00517	4.26	0.11	0.00364
0.375	0.851	0.90	5.16	0.14	0.00509	3.46	0.09	0.00341
0.425	0.804	0.79	4.46	0.12	0.00499	2.86	0.08	0.00320
0.475	0.756	0.71	3.90	0.10	0.00488	2.40	0.06	0.00299
0.525	0.708	0.64	3.44	0.09	0.00476	2.03	0.05	0.00280
0.575	0.660	0.58	3.05	0.08	0.00462	1.74	0.05	0.00263
0.625	0.613	0.54	2.72	0.07	0.00447	1.50	0.04	0.00246
0.675	0.565	0.50	2.43	0.06	0.00432	1.30	0.03	0.00231
0.725	0.517	0.46	2.23	0.06	0.00425	1.20	0.03	0.00228
0.775	0.470	0.43	2.05	0.05	0.00417	1.11	0.03	0.00226
0.825	0.422	0.41	1.88	0.05	0.00408	1.04	0.03	0.00226
0.875	0.374	0.38	1.73	0.05	0.00398	0.98	0.03	0.00226
0.925	0.327	0.36	1.59	0.04	0.00386	0.94	0.02	0.00228
0.975	0.279	0.34	1.46	0.04	0.00373	0.90	0.02	0.00231
	Overall p(collision) =			**Upwind**	**8.6%**		**Downwind**	**5.7%**
					Average	**7.2%**		

Curlew – collision_V90_max_risk

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	3.852	m
Pitch (degrees)	45	
BirdLength	0.55	m
Wingspan	0.9	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	15.6	m/sec
RotorDiam	108	m
RotationPeriod	3.00	sec
Bird aspect ratioo: b	0.61	

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

			Upwind:			Downwind:		
r/R	c/C	a	collide		contribution	collide		contribution from radius
radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	r
0.025	0.575	5.52	15.17	0.97	0.00122	12.04	0.77	0.00096
0.075	0.575	1.84	6.10	0.39	0.00293	2.97	0.19	0.00143
0.125	0.702	1.10	5.01	0.32	0.00402	1.19	0.08	0.00095
0.175	0.860	0.79	4.90	0.31	0.00550	1.21	0.08	0.00135
0.225	0.994	0.61	4.92	0.32	0.00710	1.60	0.10	0.00231
0.275	0.947	0.50	4.42	0.28	0.00779	1.84	0.12	0.00324
0.325	0.899	0.42	4.04	0.26	0.00841	1.96	0.13	0.00408
0.375	0.851	0.37	3.72	0.24	0.00895	2.02	0.13	0.00485
0.425	0.804	0.32	3.45	0.22	0.00940	2.03	0.13	0.00553
0.475	0.756	0.29	3.21	0.21	0.00976	2.01	0.13	0.00612
0.525	0.708	0.26	2.99	0.19	0.01005	1.97	0.13	0.00664
0.575	0.660	0.24	2.78	0.18	0.01025	1.92	0.12	0.00707
0.625	0.613	0.22	2.59	0.17	0.01037	1.85	0.12	0.00741
0.675	0.565	0.20	2.40	0.15	0.01040	1.77	0.11	0.00768
0.725	0.517	0.19	2.23	0.14	0.01035	1.69	0.11	0.00786
0.775	0.470	0.18	2.06	0.13	0.01022	1.60	0.10	0.00796
0.825	0.422	0.17	1.89	0.12	0.01000	1.51	0.10	0.00797
0.875	0.374	0.16	1.73	0.11	0.00970	1.41	0.09	0.00790
0.925	0.327	0.15	1.57	0.10	0.00932	1.31	0.08	0.00775
0.975	0.279	0.14	1.42	0.09	0.00886	1.20	0.08	0.00751
	Overall p(collision) =			**Upwind**	**16.5%**		**Downwind**	**10.7%**
					Average	**13.6%**		

Curlew – collision_V90_min_risk

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	3.852	m
Pitch (degrees)	45	
BirdLength	0.55	m
Wingspan	0.9	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	15.6	m/sec
RotorDiam	108	m
RotationPeriod	6.00	sec
Bird aspect ratioo: b	0.61	

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

			Upwind:			Downwind:		
r/R radius	c/C chord	a alpha	collide length	p(collision)	contribution from radius r	collide length	p(collision)	contribution from radius r
0.025	0.575	11.03	28.78	0.92	0.00115	25.65	0.82	0.00103
0.075	0.575	3.68	10.64	0.34	0.00256	7.51	0.24	0.00180
0.125	0.702	2.21	8.11	0.26	0.00325	4.29	0.14	0.00172
0.175	0.860	1.58	7.45	0.24	0.00418	2.77	0.09	0.00155
0.225	0.994	1.23	7.13	0.23	0.00514	1.72	0.05	0.00124
0.275	0.947	1.00	6.07	0.19	0.00535	0.91	0.03	0.00080
0.325	0.899	0.85	5.29	0.17	0.00551	1.13	0.04	0.00118
0.375	0.851	0.74	4.69	0.15	0.00563	1.28	0.04	0.00153
0.425	0.804	0.65	4.19	0.13	0.00571	1.35	0.04	0.00184
0.475	0.756	0.58	3.80	0.12	0.00579	1.41	0.05	0.00215
0.525	0.708	0.53	3.49	0.11	0.00588	1.47	0.05	0.00247
0.575	0.660	0.48	3.21	0.10	0.00592	1.49	0.05	0.00274
0.625	0.613	0.44	2.96	0.09	0.00592	1.48	0.05	0.00297
0.675	0.565	0.41	2.72	0.09	0.00588	1.46	0.05	0.00316
0.725	0.517	0.38	2.50	0.08	0.00580	1.42	0.05	0.00331
0.775	0.470	0.36	2.28	0.07	0.00567	1.37	0.04	0.00341
0.825	0.422	0.33	2.08	0.07	0.00551	1.31	0.04	0.00348
0.875	0.374	0.32	1.89	0.06	0.00530	1.25	0.04	0.00350
0.925	0.327	0.30	1.70	0.05	0.00505	1.17	0.04	0.00348
0.975	0.279	0.28	1.52	0.05	0.00476	1.09	0.04	0.00342
	Overall p(collision) =			**Upwind**	**10.0%**		**Downwind**	**4.7%**
					Average	**7.3%**		

Golden plover – collision_V90_max_risk

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	3.852	m
Pitch (degrees)	45	
BirdLength	0.275	m
Wingspan	0.715	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	17.9	,
RotorDiam	108	m
RotationPeriod	3.00	sec
Bird aspect ratioo: b	0.38	

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

			Upwind:			Downwind:		
r/R radius	c/C chord	a alpha	collide length	p(collision)	contribution from radius r	collide length	p(collision)	contribution from radius
0.025	0.575	6.33	16.01	0.89	0.00112	12.88	0.72	0.00090
0.075	0.575	2.11	6.38	0.36	0.00267	3.25	0.18	0.00136
0.125	0.702	1.27	5.24	0.29	0.00366	1.41	0.08	0.00099
0.175	0.860	0.90	5.11	0.29	0.00499	0.87	0.05	0.00085
0.225	0.994	0.70	5.12	0.29	0.00643	1.31	0.07	0.00164
0.275	0.947	0.58	4.47	0.25	0.00687	1.51	0.08	0.00231
0.325	0.899	0.49	3.99	0.22	0.00724	1.60	0.09	0.00291
0.375	0.851	0.42	3.60	0.20	0.00754	1.64	0.09	0.00344
0.425	0.804	0.37	3.28	0.18	0.00778	1.65	0.09	0.00391
0.475	0.756	0.33	3.02	0.17	0.00801	1.65	0.09	0.00437
0.525	0.708	0.30	2.79	0.16	0.00817	1.62	0.09	0.00476
0.575	0.660	0.28	2.57	0.14	0.00825	1.58	0.09	0.00507
0.625	0.613	0.25	2.37	0.13	0.00826	1.52	0.08	0.00531
0.675	0.565	0.23	2.17	0.12	0.00820	1.45	0.08	0.00548
0.725	0.517	0.22	1.99	0.11	0.00807	1.38	0.08	0.00558
0.775	0.470	0.20	1.82	0.10	0.00786	1.29	0.07	0.00560
0.825	0.422	0.19	1.64	0.09	0.00758	1.20	0.07	0.00555
0.875	0.374	0.18	1.48	0.08	0.00723	1.11	0.06	0.00543
0.925	0.327	0.17	1.32	0.07	0.00680	1.01	0.06	0.00523
0.975	0.279	0.16	1.16	0.06	0.00631	0.91	0.05	0.00496
	Overall p(collision) =			**Upwind**	**13.3%**		**Downwind**	**7.6%**
					Average	**10.4%**		

Golden plover – collision_V90_min_risk

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	3.852	m
Pitch (degrees)	45	
BirdLength	0.275	m
Wingspan	0.715	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	17.9	,
RotorDiam	108	m
RotationPeriod	6.00	sec
Bird aspect ratioo: b	0.38	

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

			Upwind:			Downwind:		
r/R radius	c/C chord	a alpha	collide length	p(collision)	contribution from radius r	collide length	p(collision)	contribution from radius
0.025	0.575	12.66	30.45	0.85	0.00106	27.32	0.76	0.00095
0.075	0.575	4.22	11.19	0.31	0.00235	8.06	0.23	0.00169
0.125	0.702	2.53	8.56	0.24	0.00299	4.74	0.13	0.00165
0.175	0.860	1.81	7.87	0.22	0.00385	3.19	0.09	0.00156
0.225	0.994	1.41	7.52	0.21	0.00473	2.11	0.06	0.00132
0.275	0.947	1.15	6.37	0.18	0.00489	1.21	0.03	0.00093
0.325	0.899	0.97	5.53	0.15	0.00502	0.76	0.02	0.00069
0.375	0.851	0.84	4.88	0.14	0.00511	0.96	0.03	0.00101
0.425	0.804	0.74	4.35	0.12	0.00517	1.09	0.03	0.00130
0.475	0.756	0.67	3.91	0.11	0.00518	1.16	0.03	0.00154
0.525	0.708	0.60	3.52	0.10	0.00517	1.20	0.03	0.00176
0.575	0.660	0.55	3.18	0.09	0.00511	1.20	0.03	0.00193
0.625	0.613	0.51	2.88	0.08	0.00502	1.19	0.03	0.00207
0.675	0.565	0.47	2.60	0.07	0.00489	1.15	0.03	0.00217
0.725	0.517	0.44	2.34	0.07	0.00473	1.11	0.03	0.00224
0.775	0.470	0.41	2.09	0.06	0.00453	1.05	0.03	0.00227
0.825	0.422	0.38	1.87	0.05	0.00430	0.98	0.03	0.00227
0.875	0.374	0.36	1.66	0.05	0.00406	0.93	0.03	0.00226
0.925	0.327	0.34	1.47	0.04	0.00380	0.86	0.02	0.00222
0.975	0.279	0.32	1.28	0.04	0.00349	0.79	0.02	0.00215
	Overall p(collision) =			**Upwind**	**8.5%**		**Downwind**	**3.4%**
					Average	**6.0%**		

Great skua – collision_V90_max_risk

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	3.852	m
Pitch (degrees)	45	
BirdLength	0.56	m
Wingspan	1.36	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	16	,
RotorDiam	108	m
RotationPeriod	3.00	sec
Bird aspect ratioo: ⍰	0.41	

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

			Upwind:			Downwind:		
r/R radius	c/C chord	⍰ alpha	collide length	p(collision)	contribution from radius r	collide length	p(collision)	contribution from radius
0.025	0.575	5.66	18.12	1.00	0.00125	14.99	0.94	0.00117
0.075	0.575	1.89	7.09	0.44	0.00332	3.95	0.25	0.00185
0.125	0.702	1.13	5.61	0.35	0.00438	1.79	0.11	0.00140
0.175	0.860	0.81	5.34	0.33	0.00584	1.55	0.10	0.00169
0.225	0.994	0.63	5.27	0.33	0.00741	1.86	0.12	0.00262
0.275	0.947	0.51	4.60	0.29	0.00791	1.95	0.12	0.00335
0.325	0.899	0.44	4.11	0.26	0.00834	1.97	0.12	0.00401
0.375	0.851	0.38	3.75	0.23	0.00880	2.00	0.13	0.00470
0.425	0.804	0.33	3.48	0.22	0.00924	2.02	0.13	0.00537
0.475	0.756	0.30	3.23	0.20	0.00959	2.01	0.13	0.00595
0.525	0.708	0.27	3.01	0.19	0.00987	1.97	0.12	0.00646
0.575	0.660	0.25	2.80	0.18	0.01007	1.92	0.12	0.00689
0.625	0.613	0.23	2.61	0.16	0.01018	1.85	0.12	0.00723
0.675	0.565	0.21	2.42	0.15	0.01022	1.78	0.11	0.00749
0.725	0.517	0.20	2.24	0.14	0.01017	1.69	0.11	0.00768
0.775	0.470	0.18	2.07	0.13	0.01004	1.61	0.10	0.00778
0.825	0.422	0.17	1.91	0.12	0.00983	1.51	0.09	0.00780
0.875	0.374	0.16	1.74	0.11	0.00954	1.41	0.09	0.00774
0.925	0.327	0.15	1.59	0.10	0.00917	1.31	0.08	0.00759
0.975	0.279	0.15	1.43	0.09	0.00871	1.21	0.08	0.00737
	Overall p(collision) =			**Upwind**	**16.4%**		**Downwind**	**10.6%**
					Average	**13.5%**		

Great skua – collision_V90_min_risk

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	3.852	m
Pitch (degrees)	45	
BirdLength	0.56	m
Wingspan	1.36	m
F: Flapping (0) or gliding (+1)	1	
Bird speed	16	,
RotorDiam	108	m
RotationPeriod	6.00	sec
Bird aspect ratioo: b	0.41	

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

			Upwind:			Downwind:		
r/R radius	c/C chord	a alpha	collide length	p(collision)	contribution from radius r	collide length	p(collision)	contribution from radius
0.025	0.575	11.32	29.09	0.91	0.00114	25.96	0.81	0.00101
0.075	0.575	3.77	10.74	0.34	0.00252	7.61	0.24	0.00178
0.125	0.702	2.26	8.20	0.26	0.00320	4.37	0.14	0.00171
0.175	0.860	1.62	7.53	0.24	0.00412	2.84	0.09	0.00156
0.225	0.994	1.26	7.20	0.23	0.00506	1.79	0.06	0.00126
0.275	0.947	1.03	6.12	0.19	0.00526	0.97	0.03	0.00083
0.325	0.899	0.87	5.33	0.17	0.00542	1.07	0.03	0.00109
0.375	0.851	0.75	4.72	0.15	0.00553	1.22	0.04	0.00143
0.425	0.804	0.67	4.22	0.13	0.00561	1.31	0.04	0.00174
0.475	0.756	0.60	3.80	0.12	0.00564	1.35	0.04	0.00200
0.525	0.708	0.54	3.43	0.11	0.00564	1.36	0.04	0.00222
0.575	0.660	0.49	3.11	0.10	0.00559	1.34	0.04	0.00241
0.625	0.613	0.45	2.82	0.09	0.00550	1.31	0.04	0.00255
0.675	0.565	0.42	2.55	0.08	0.00537	1.26	0.04	0.00265
0.725	0.517	0.39	2.52	0.08	0.00571	1.42	0.04	0.00322
0.775	0.470	0.37	2.31	0.07	0.00559	1.37	0.04	0.00332
0.825	0.422	0.34	2.10	0.07	0.00542	1.32	0.04	0.00339
0.875	0.374	0.32	1.91	0.06	0.00522	1.25	0.04	0.00342
0.925	0.327	0.31	1.72	0.05	0.00498	1.18	0.04	0.00340
0.975	0.279	0.29	1.54	0.05	0.00469	1.10	0.03	0.00335
	Overall p(collision) =			**Upwind**	**9.7%**		**Downwind**	**4.4%**
					Average	**7.1%**		

Arctic skua – collision_V90_max_risk

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	3.852	m
Pitch (degrees)	45	
BirdLength	0.44	m
Wingspan	1.18	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	12	,
RotorDiam	108	m
RotationPeriod	3.00	sec
Bird aspect ratioo: b	0.37	

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

			Upwind:			Downwind:		
r/R radius	c/C chord	a alpha	collide length	p(collision)	contribution from radius r	collide length	p(collision)	contribution from radius
0.025	0.575	4.24	13.22	1.00	0.00125	10.09	0.84	0.00105
0.075	0.575	1.41	5.45	0.45	0.00341	2.32	0.19	0.00145
0.125	0.702	0.85	4.53	0.38	0.00472	1.29	0.11	0.00134
0.175	0.860	0.61	4.48	0.37	0.00653	1.64	0.14	0.00239
0.225	0.994	0.47	4.54	0.38	0.00852	1.99	0.17	0.00373
0.275	0.947	0.39	4.03	0.34	0.00923	2.04	0.17	0.00467
0.325	0.899	0.33	3.69	0.31	0.00999	2.09	0.17	0.00566
0.375	0.851	0.28	3.41	0.28	0.01067	2.10	0.18	0.00657
0.425	0.804	0.25	3.18	0.26	0.01125	2.08	0.17	0.00737
0.475	0.756	0.22	2.96	0.25	0.01171	2.04	0.17	0.00807
0.525	0.708	0.20	2.76	0.23	0.01207	1.98	0.16	0.00866
0.575	0.660	0.18	2.57	0.21	0.01232	1.91	0.16	0.00914
0.625	0.613	0.17	2.39	0.20	0.01246	1.83	0.15	0.00951
0.675	0.565	0.16	2.22	0.19	0.01249	1.74	0.14	0.00977
0.725	0.517	0.15	2.06	0.17	0.01242	1.64	0.14	0.00993
0.775	0.470	0.14	1.89	0.16	0.01223	1.54	0.13	0.00997
0.825	0.422	0.13	1.74	0.14	0.01194	1.44	0.12	0.00991
0.875	0.374	0.12	1.58	0.13	0.01154	1.34	0.11	0.00974
0.925	0.327	0.11	1.43	0.12	0.01103	1.23	0.10	0.00946
0.975	0.279	0.11	1.28	0.11	0.01042	1.12	0.09	0.00907
	Overall p(collision) =			**Upwind**	**19.6%**		**Downwind**	**13.7%**
					Average	**16.7%**		

Arctic skua – collision_V90_min_risk

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	3.852	m
Pitch (degrees)	45	
BirdLength	0.44	m
Wingspan	1.18	m
F: Flapping (0) or gliding (+1)	1	
Bird speed	12	,
RotorDiam	108	m
RotationPeriod	6.00	sec
Bird aspect ratioo: b	0.37	

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

			Upwind:			Downwind:		
r/R radius	c/C chord	a alpha	collide length	p(collision)	contribution from radius r	collide length	p(collision)	contribution from radius
0.025	0.575	8.49	21.24	0.88	0.00111	18.10	0.75	0.00094
0.075	0.575	2.83	8.12	0.34	0.00254	4.99	0.21	0.00156
0.125	0.702	1.70	6.43	0.27	0.00335	2.61	0.11	0.00136
0.175	0.860	1.21	6.09	0.25	0.00444	1.41	0.06	0.00103
0.225	0.994	0.94	5.97	0.25	0.00560	0.86	0.04	0.00081
0.275	0.947	0.77	5.15	0.21	0.00590	1.17	0.05	0.00134
0.325	0.899	0.65	4.54	0.19	0.00614	1.34	0.06	0.00181
0.375	0.851	0.57	4.06	0.17	0.00634	1.43	0.06	0.00224
0.425	0.804	0.50	3.66	0.15	0.00648	1.47	0.06	0.00260
0.475	0.756	0.45	3.31	0.14	0.00656	1.47	0.06	0.00292
0.525	0.708	0.40	3.01	0.13	0.00659	1.45	0.06	0.00318
0.575	0.660	0.37	2.90	0.12	0.00695	1.58	0.07	0.00377
0.625	0.613	0.34	2.68	0.11	0.00697	1.54	0.06	0.00402
0.675	0.565	0.31	2.46	0.10	0.00693	1.50	0.06	0.00421
0.725	0.517	0.29	2.26	0.09	0.00683	1.44	0.06	0.00434
0.775	0.470	0.27	2.07	0.09	0.00668	1.37	0.06	0.00442
0.825	0.422	0.26	1.88	0.08	0.00648	1.29	0.05	0.00445
0.875	0.374	0.24	1.71	0.07	0.00622	1.21	0.05	0.00442
0.925	0.327	0.23	1.53	0.06	0.00591	1.13	0.05	0.00434
0.975	0.279	0.22	1.36	0.06	0.00554	1.03	0.04	0.00420
	Overall p(collision) =			**Upwind**	**11.4%**		**Downwind**	**5.8%**
					Average	**8.6%**		