Appendix 10.1: Collision Risk Calculations

1   Definition of the Risk Window

The majority of goose flights which crossed the risk zone did so in a south to north direction (Figure 10.4 in the 2015 ES Chapter 10, Ornithology). The width of the risk window for the Proposed Varied Development was calculated as the distance between the outer turbine positions plus two blade lengths, at right angles to this flight direction, and was measured in GIS as 1,620m. This gave a total risk window width of 1,753.4m (i.e. 1,620m plus two 66.7m blade lengths).

The height of the risk zone is taken as 169.9m, the maximum tip height of the largest turbines (149.9m), plus a 20m buffer. Because the upper limit of the penultimate flight height band ended at 150m, it was assumed as a worst case scenario that any flights recorded above this height were considered to have occurred in the risk zone. The height of the risk zone, multiplied by its width (above), gave the frontal area of the risk window. This was calculated to be 297,902.7m^2.

2   The Risk of Passing through the Rotor Swept Area

It is assumed in the SNH collision risk model (Band *et al*. 2007) that the risk of a goose passing through one of the rotor swept areas of a turbine is proportional to the percentage of the risk window frontal area taken up by the rotor swept area of all turbines combined. This was calculated from the area of a single rotor swept area, multiplied by the number of turbines and expressed as a proportion of the area of the risk window. With a single blade length of 66.7m, and 11 proposed turbines, the total rotor swept area was measured as 153,742.6m.

3   The Number of Geese at Risk of Collision

The numbers of geese recorded flying through the risk window were taken from the highlighted records in Tables 10.9 and 10.11 in the 2015 ES Chapter 10, Ornithology. The geese were recorded during 51 hours of observation during the goose wintering season. No flights were added or omitted compared to the calculations carried out for the Original Assessment.

4   The Number of Hours when Geese were Active

Data on day length were obtained from standard tables for the latitude of the site and the time of sunrise and sunset determined for the middle of each week between mid-September and mid-April. The goose active day was taken to start half-an-hour before sunrise and end half-an-hour after sunset. Observations at the Loch of Strathbeg (I.J. Patterson, unpublished data) and measurements made on radio-tagged pink-footed geese at the Ythan estuary, Aberdeenshire (Giroux and Patterson 1995) showed that most geese were active between these times. One hour was therefore added to the sunrise to sunset times to give the length of the goose active day and the total number of goose active hours during the goose wintering season (late September to the end of April). This value was unchanged from that used in the 2015 ES.

5   Collision Risk

The probability of collision (excluding avoidance) for a greylag goose and a pink-footed goose flying through a turbine rotor swept area (8.59% and 7.84% respectively) was calculated from the SNH collision risk model (Band *et al*. 2007), using the following values; turbine variables supplied by the Applicant, bird dimensions from Cramp and Simmons (1977), and flight speed information from

Alerstam *et al.* (2007) for greylag goose, which was used as a surrogate for pink-footed goose (no data).

Table 1: Turbine Variables

	Hub Height	**Rotor Diameter**	**Blade Tip Height**	**Maximum Chord**	**Pitch**	**Rotation Period**
V105-3.3	81.9 – 86.9m	136m	149.9m	4.0m	16 deg	3.4 sec

Table 2: Bird variables

	Length	**Wing Span**	**Flight Speed**
Greylag Goose	0.83m	1.64m	17.1m/sec
Pink-footed Goose	0.68m	1.53m	17.1m/sec

6 Calculations

The workings in the calculation of collision risk are as shown in Table 3:

Table 3: Collision risk calculations (variables in blue are supplied; those in black are calculated)

Variable	Value
1. Height of risk zone (m)	169.9
2. Width of wind farm (m)	1,753.4
3. Area of risk window (m^2)	297902.7
4. Blade length (m)	66.7
5. Area of one rotor swept area (m^2)	13,976.6
6. Number of turbines	11
7. Total area of rotor discs (m^2)	153,742.6
8. Proportion of the risk window occupied by rotor discs	0.5161

Variable	Greylag goose	Pink-footed goose
9. Mean number of geese per hour passing through risk window	1.78	11.88
10. Number of hours in the goose wintering season	2,349	2,349
11. Total number of geese passing through the risk window	4,191	27,912
12. Number of geese passing through rotor swept area	2,163	14,405
13. Proportion of geese passing through rotors likely to collide, from SNH model	0.086	0.078
14. Estimated number of collisions per season, in the absence of avoidance	186	1,130
15. Estimated number of collisions per season, assuming 99.8% avoidance	0.37	2.26

7 References

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