Appendix 9.2 Ornithology Collision Risk Modelling

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Introduction

1.1. Birds that are not displaced would be potentially vulnerable to collision with the proposed Development turbines. The level of collision with wind turbines is presumed to be dependent on the level of flight activity over the proposed Development and the ability of birds to detect and manoeuvre around rotating turbine blades. Birds that collide with a turbine are likely to be killed or fatally injured. This may in turn affect the maintenance of bird populations.

1.2. Further studies in the field of bird-windfarm research are required to establish with certainty the extent to which birds are able to avoid collision with wind turbines, although an increasing body of evidence suggests that avoidance capacity is very high (Whitfield & Madders 2006, Urquhart & Whitfield 2016, SNH 2017). The indications from studies are that collisions are rare events and occur mainly at sites where there are unusual concentrations of birds and turbines, or where the behaviour of the birds concerned leads to high-risk situations (eg Gill *et al*. 1996, Percival 1998, de Lucas *et al.* 2007). Examples include migration flyways, and where the food resource, and therefore level of bird activity, is exceptional.

1.3. Band *et al.* (2007) described a method by which field data on bird flight activity can be gathered and used to quantify crudely the likelihood of collisions with turbines: the 'Band' Collision Risk Model (CRM). This method is more suitable for some species than others (Madders & Whitfield 2006). For example, fast moving raptors like merlin and most songbirds are difficult to detect beyond a distance of a few hundred metres and nocturnal species are difficult to detect at all. As a result, it is rarely possible to generate reliable estimates of flight activity for these species and collision risk is best determined qualitatively.

1.4. The Band CRM involves two methods to predict estimated collision fatalities, depending on the pattern of flight of the species involved: 'predictable' and 'unpredictable' flight methods. The predictable flight method (PFM) is appropriate when birds tend to move through an area in a relatively consistent direction, such as during migration or when moving between localised feeding and roosting sites. The unpredictable flight method (UFM) is more appropriate when flights are not in any particular direction and assumes that they are random. These two methods also differ in their field data requirements (see **Technical Appendix 9.1**).

1.5. The two methods differ in the unit of exposure to collision risk. The PFM estimates a horizontal risk area which is the area of the turbine rotors facing a bird as it flies towards (with the 'intention' of flying through) the Proposed Development. The extent of the Risk Area is given by the horizontal span of the proposed turbine array facing the bird on its typical flight direction multiplied by the vertical span of the proposed turbine rotors.

1.6. The UFM employs an estimated risk volume, in keeping with the assumption that flight directions are random in space. The UFM of the Band CRM was used to estimate collision risk on hen harrier in the breeding season, short-eared owl during the breeding season, and golden eagle in both the breeding and non-breeding season, based on flight activity levels and behaviour, turbine numbers and dimensions, and bird biometrics and flight characteristics. Dimensions and operational parameters of the candidate turbine model were used to populate the CRM, including an assumed hub height of 105 m and a rotor diameter of 150 m (see Chapter 4 Description of proposed Development). The appropriate recorded flight height band was therefore 30 m – 200 m. (**Table 1**).

1.7. Data on bird flight speed and biometrics were taken from Bruderer & Boldt (2001) and Snow & Perrins (1998), and the published avoidance rates was used (SNH 2017). For each season, day length was calculated using the method of Forsythe *et al*. (1995).

1.8. Utilising all flight observations collected across the study area from all GVPs was likely to result in underestimates or overestimates of collision risk because data were collected for areas in which no turbines were (ultimately) proposed. Therefore, it was appropriate to employ only those observations in which flights were liable to incur a potential risk of collision; i.e., within the areas occupied by proposed turbines. Consequently, the CRM used only observations collected within a flight activity assessment area (FA), comprising a 500 m buffer (centred on the turbine tower) around proposed turbine locations. This size of buffer encompasses rotor blade length, possible shifts in proposed turbine location due to micro-siting and, crucially, potential spatial errors in flight recording accuracy due to the effects of parallax. Flight time within this buffer was calculated from the proportion of the length of each flight which fell within the 50 m buffer multiplied by the total duration of each flight (i.e. effectively assuming a constant speed for each flight). Time spent at different flight heights was estimated from time-interval data on height. To ensure that the CRM used robust measures of flight activity, a 2 km distance truncation was assumed in the area visible from each VP.

1.9. The UFM of the Band CRM was used to estimate collision risk for hen harrier during the year. Following the analyses described above a total of sixteen flights were included in the CRM. The model was completed for the breeding season and non-breeding season flights separately. Data on hen harrier flight speed (12 m/s) was taken from Bruderer & Boldt (2001) and biometrics (0.48 m length, 1.10 m wingspan) from Snow & Perrins (1998) and a 99% avoidance rate was used (SNH 2017) (**Table 2**).

1.10. The UFM estimated 0.005 non-breeding season hen harrier collisions or one collision every 186 years (**Table 3**) and for the breeding season no flights occurred at risk height. Therefore, the annual collision risk for hen harrier is predicted as 0.004 birds per year or one bird every 246 years.

Input Data and Model Results

Hen harrier non-breeding season flights

Table 1 Input Data

WIND FARM PARAMETERS		
Size of windfarm envelope	589	ha
Number of turbines	11	
Rotor diameter	150	m
Hub height	105	m
Max. rotor depth in metres	2.0	m
Max. chord	4.20	m
Pitch	6.0	degrees
Rotation period	4.60	s
Turbine operation time	87	%

BIRD PARAMETERS		
Length	0.48	m
Wingspan	1.1	m
Flapping (0) or gliding (+1)	0	
Assumed flight speed	12	ms^-1
Number of hours birds potentially present	2070	per year
Assumed avoidance rate	99	%

BAND USED TO DEFINE 'RISK HEIGHT'		
Max height	200	m
Min height	30	m

	Watch Data		Bird Flight Data	
VP	Area (ha)	Time (hrs)	Total (s)	'Risk height' (s)
1	46.3	36.0	127.0	0.0
3	298.9	36.0	0.0	0.0
5	407.3	36.0	1051.0	96.0
Totals	752.5	108.0	1178.0	96.0

Table 2 Collision Probability

K: [1D or [3D] (0 or 1)	1	
NoBlades	3	
MaxChord	4.20	m
Pitch (degrees)	6.0	
BirdLength	0.48	m
Wingspan	1.1	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	12	m/sec
RotorDiam	150	m
RotationPeriod	4.60	sec
integration interval	0.05	
Bird aspect ratioo: β	0.44	

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

			Upwind:			Downwind:		
r/R	c/C	α	collide			collide		
radius	chord	alpha	length	p(collision)	y(x)	length	p(collision)	y(x)
0				1.00	0.000		1.00	0.000
0.05	0.575	2.34	8.46	0.46	0.046	7.95	0.43	0.043
0.1	0.622	1.17	4.61	0.25	0.050	4.06	0.22	0.044
0.15	0.781	0.78	3.75	0.20	0.061	3.06	0.17	0.050
0.2	0.939	0.59	3.35	0.18	0.073	2.53	0.14	0.055
0.25	0.971	0.47	2.84	0.15	0.077	1.99	0.11	0.054
0.3	0.923	0.39	2.39	0.13	0.078	1.58	0.09	0.052
0.35	0.875	0.33	2.09	0.11	0.079	1.32	0.07	0.050
0.4	0.827	0.29	1.86	0.10	0.081	1.13	0.06	0.049
0.45	0.780	0.26	1.67	0.09	0.082	0.99	0.05	0.048
0.5	0.732	0.23	1.52	0.08	0.082	0.87	0.05	0.048
0.55	0.684	0.21	1.39	0.08	0.083	0.79	0.04	0.047
0.6	0.637	0.20	1.28	0.07	0.083	0.72	0.04	0.047
0.65	0.589	0.18	1.18	0.06	0.083	0.66	0.04	0.047
0.7	0.541	0.17	1.10	0.06	0.083	0.62	0.03	0.047
0.75	0.494	0.16	1.02	0.06	0.083	0.59	0.03	0.048
0.8	0.446	0.15	0.95	0.05	0.082	0.56	0.03	0.048
0.85	0.398	0.14	0.88	0.05	0.082	0.53	0.03	0.049
0.9	0.350	0.13	0.82	0.04	0.081	0.52	0.03	0.051
0.95	0.303	0.12	0.77	0.04	0.079	0.50	0.03	0.052
1	0.255	0.12	0.72	0.04	0.078	0.49	0.03	0.054

Overall p(collision) = **Upwind** **7.4%** **Downwind** **4.8%**

Average **6.1%**

Table 3 Model Results (weighted)

Flight Activity Per Unit Time & Area			Weighted By Observation Effort		
VP	**Observation effort (HaHr)**	**Flying time at 'risk height' (Hahr^-1)**	**VP**	**Weighting**	**Adjusted time at 'risk height' (Hahr^-1)**
1	1666.80	0	1	0.062	0
3	10760.40	0	3	0.397	0
5	14662.80	1.81866E-06	5	0.541	9.84373E-07
Totals	*27090.00*	*6.0622E-07*	*Totals*	1.000	9.84373E-07
			Mean activity hr^-1 in wind farm		
				Risk height	0.05798%
				Rotor height	0.05116%

MORTALITY ESTIMATE		
Flight risk volume (Vw)	8.84E+08	m^3
Rotor radius^2	5625	m
Combined rotor swept area (Va)	194386	m^2
Vr = Va * (d + l)	482077	m^3
Bird occupancy (n)	1.06	hrs / yr
Bird occupancy of rotor swept vol (b)	2.08	bird-secs
Bird transit time (t)	0.21	secs
No. of transits through rotors	10.07	per year
Estimated no. of collisions	0.54	per year
After allowing for avoidance	0.005	per year
i.e. equivalent to one bird every	**186.8**	**years**

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