



Bloch Wind Farm

Technical Appendix 8.5: Collision Risk Reporting

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1 Introduction

- 1.1.1 This Technical Appendix sets out the collision risk modelling that has been undertaken to support the ornithological assessment of the proposed Bloch Wind Farm (the proposed development). The collision risk modelling was carried out for all the key target species (as per SNH guidance 2018) recorded flying through the collision risk zone at rotor height.
- 1.1.2 A rotor height envelope of 30-230m above the ground was used for the modelling, to take into account the variation in hub height across the site: actual rotor height would be 30-180m for the lowest turbines, up to 80-230m for the highest ones.
- 1.1.3 The modelling included five target raptor species (goshawk, red kite, hen harrier, peregrine and merlin) and three breeding waders (curlew, lapwing and snipe). The collision risk for each of these species was modelled using the non-direct flight model. In addition, wintering/migrating whooper swans, greylag geese, barnacle geese, pink-footed geese, golden plover, dunlin and herring gulls were observed flying through the collision risk zone and were also modelled to determine their collision risk. As their flights were largely direct ones through the site, the direct flight model was applied. No other key species was recorded flying through the collision risk zone at rotor height.
- 1.1.4 The collision risk model used in this assessment (Band et al. 2007) was run as a two-stage process. Firstly, the risk is calculated making the assumption that flight patterns are unaffected by the presence of the wind turbines, i.e. that no avoidance action is taken. This is essentially a mechanistic calculation, with the collision risk calculated as the product of (i) the probability of a bird flying through the rotor swept area, and (ii) the probability of a bird colliding if it does so. This probability is then multiplied by the estimated numbers of bird movements through the rotors at the risk height (i.e. the height of the rotating rotor blades) in order to estimate the theoretical numbers at risk of collision if they take no avoiding action.
- 1.1.5 The second stage then incorporates the probability that the birds, rather than flying blindly into the turbines, will actually take a degree of avoiding action, as has been shown to occur in all studies of birds at existing wind farms. NatureScot has recommended a precautionary

approach, using a value of 98% as a general default avoidance rate, 99% for some larger raptors (including red kite and hen harrier) and 99.8% for geese (SNH 2017). This precautionary approach is useful as an initial filter to identify sites where collision risk is clearly not an issue, but does not necessarily provide a realistic estimate of actual likely collision rates when compared with data from existing wind farms. The magnitude of the impact was determined as a percentage increase in the existing baseline mortality (to put the potential wind farm mortality into the ecological context of the birds' population dynamics), though professional judgement was also applied in the assessment of any non-negligible magnitude collision risks predicted.

- 1.1.6 Body sizes and baseline mortality rates were taken from Robinson (2005) and flight speeds from Alerstam *et al.* (2007).

2 Band Model Spreadsheets (Stage 1)

- 2.1.1 Firstly, the standard Band model spreadsheets (Band *et al.* 2007) are presented for each species modelled in turn. These provide the information used to calculate the risk that individuals of each species would face if they flew through the proposed development rotor swept area. For the first species, for example, whooper swan, this gives an overall 7.2% chance of collision.

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Whooper Swan											
Only enter input parameters in blue											
K: [1D or [3D] (0 or 1)	1	Calculation of alpha and p(collision) as a function of r radius									
NoBlades	3	Upwind:						Downwind:			
MaxChord	4.1	m	r/R	c/C	a	collide	contribution	collide	contribution	collide	contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	1.52	m	0.025	0.575	11.01	51.02	1.00	0.00125	49.80	1.00	0.00125
Wingspan	2.3	m	0.075	0.575	3.67	17.41	0.40	0.00302	16.19	0.37	0.00281
F: Flapping (0) or gliding (+1)	0		0.125	0.702	2.20	11.93	0.28	0.00345	10.44	0.24	0.00302
			0.175	0.860	1.57	9.89	0.23	0.00400	8.07	0.19	0.00326
Bird speed	17.3	m/sec	0.225	0.994	1.22	8.69	0.20	0.00452	6.58	0.15	0.00342
RotorDiam	150	m	0.275	0.947	1.00	7.06	0.16	0.00449	5.05	0.12	0.00321
RotationPeriod	7.50	sec	0.325	0.899	0.85	5.92	0.14	0.00445	4.01	0.09	0.00301
			0.375	0.851	0.73	5.07	0.12	0.00439	3.26	0.08	0.00283
			0.425	0.804	0.65	4.43	0.10	0.00436	2.73	0.06	0.00268
			0.475	0.756	0.58	4.06	0.09	0.00446	2.45	0.06	0.00269
Bird aspect ratio: b	0.66		0.525	0.708	0.52	3.74	0.09	0.00454	2.24	0.05	0.00272
			0.575	0.660	0.48	3.47	0.08	0.00462	2.07	0.05	0.00275
			0.625	0.613	0.44	3.24	0.07	0.00468	1.94	0.04	0.00280
			0.675	0.565	0.41	3.03	0.07	0.00473	1.83	0.04	0.00286
			0.725	0.517	0.38	2.85	0.07	0.00477	1.75	0.04	0.00293
			0.775	0.470	0.36	2.68	0.06	0.00480	1.68	0.04	0.00301
			0.825	0.422	0.33	2.53	0.06	0.00482	1.63	0.04	0.00311
			0.875	0.374	0.31	2.38	0.06	0.00482	1.59	0.04	0.00322
			0.925	0.327	0.30	2.25	0.05	0.00482	1.56	0.04	0.00333
			0.975	0.279	0.28	2.13	0.05	0.00480	1.54	0.04	0.00346
			Overall p(collision) =				Upwind	8.6%		Downwind	5.8%
								Average	7.2%		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Greylag Goose											
Only enter input parameters in blue											
K: [1D or [3D] (0 or 1)	1	Calculation of alpha and p(collision) as a function of radius									
NoBlades	3	Upwind:						Downwind:			
MaxChord	4.1	m	r/R	c/C	a	collide	contribution	collide	contribution		
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.82	m	0.025	0.575	10.89	43.25	1.00	0.00125	42.03	0.98	0.00123
Wingspan	1.64	m	0.075	0.575	3.63	14.82	0.35	0.00260	13.60	0.32	0.00239
F: Flapping (0) or gliding (+1)	0		0.125	0.702	2.18	10.36	0.24	0.00303	8.87	0.21	0.00260
			0.175	0.860	1.56	8.76	0.20	0.00359	6.94	0.16	0.00284
Bird speed	17.1	m/sec	0.225	0.994	1.21	7.80	0.18	0.00411	5.69	0.13	0.00300
RotorDiam	150	m	0.275	0.947	0.99	6.34	0.15	0.00408	4.33	0.10	0.00278
RotationPeriod	7.50	sec	0.325	0.899	0.84	5.31	0.12	0.00404	3.40	0.08	0.00259
			0.375	0.851	0.73	4.54	0.11	0.00398	2.73	0.06	0.00240
			0.425	0.804	0.64	3.94	0.09	0.00392	2.24	0.05	0.00222
			0.475	0.756	0.57	3.46	0.08	0.00384	1.85	0.04	0.00206
Bird aspect ratio: b	0.50		0.525	0.708	0.52	3.06	0.07	0.00375	1.55	0.04	0.00191
			0.575	0.660	0.47	2.76	0.06	0.00371	1.36	0.03	0.00183
			0.625	0.613	0.44	2.53	0.06	0.00369	1.23	0.03	0.00179
			0.675	0.565	0.40	2.32	0.05	0.00367	1.12	0.03	0.00177
			0.725	0.517	0.38	2.14	0.05	0.00363	1.04	0.02	0.00176
			0.775	0.470	0.35	1.97	0.05	0.00357	0.97	0.02	0.00177
			0.825	0.422	0.33	1.82	0.04	0.00351	0.92	0.02	0.00178
			0.875	0.374	0.31	1.68	0.04	0.00343	0.88	0.02	0.00181
			0.925	0.327	0.29	1.55	0.04	0.00335	0.85	0.02	0.00185
			0.975	0.279	0.28	1.42	0.03	0.00325	0.83	0.02	0.00190
							Upwind	7.0%		Downwind	4.2%
								Average	5.6%		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA												
Pink-footed Goose												
Only enter input parameters in blue												
K: [1D or [3D] (0 or 1)	1	Calculation of alpha and p(collision) as a function of radius										
NoBlades	3						Upwind:			Downwind:		
MaxChord	4.1	m	r/R	c/C	a	collide		contribution	collide		contribution	
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r	
BirdLength	0.68	m	0.025	0.575	11.01	42.43	0.98	0.00123	41.21	0.95	0.00119	
Wingspan	1.52	m	0.075	0.575	3.67	14.55	0.34	0.00252	13.33	0.31	0.00231	
F: Flapping (0) or gliding (+1)	0		0.125	0.702	2.20	10.21	0.24	0.00295	8.72	0.20	0.00252	
			0.175	0.860	1.57	8.66	0.20	0.00351	6.84	0.16	0.00277	
Bird speed	17.3	m/sec	0.225	0.994	1.22	7.73	0.18	0.00402	5.62	0.13	0.00293	
RotorDiam	150	m	0.275	0.947	1.00	6.28	0.15	0.00399	4.27	0.10	0.00272	
RotationPeriod	7.50	sec	0.325	0.899	0.85	5.26	0.12	0.00395	3.35	0.08	0.00252	
			0.375	0.851	0.73	4.49	0.10	0.00390	2.69	0.06	0.00233	
			0.425	0.804	0.65	3.90	0.09	0.00383	2.19	0.05	0.00216	
			0.475	0.756	0.58	3.42	0.08	0.00375	1.81	0.04	0.00199	
Bird aspect ratio: b	0.45		0.525	0.708	0.52	3.02	0.07	0.00367	1.52	0.04	0.00184	
			0.575	0.660	0.48	2.68	0.06	0.00356	1.28	0.03	0.00170	
			0.625	0.613	0.44	2.40	0.06	0.00347	1.10	0.03	0.00159	
			0.675	0.565	0.41	2.19	0.05	0.00342	0.99	0.02	0.00155	
			0.725	0.517	0.38	2.01	0.05	0.00336	0.91	0.02	0.00152	
			0.775	0.470	0.36	1.84	0.04	0.00330	0.84	0.02	0.00151	
			0.825	0.422	0.33	1.69	0.04	0.00322	0.79	0.02	0.00151	
			0.875	0.374	0.31	1.54	0.04	0.00312	0.75	0.02	0.00152	
			0.925	0.327	0.30	1.41	0.03	0.00302	0.72	0.02	0.00154	
			0.975	0.279	0.28	1.29	0.03	0.00290	0.70	0.02	0.00157	
			Overall p(collision) =				Upwind	6.7%		Downwind	3.9%	
							Average	5.3%				

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Barnacle Goose											
Only enter input parameters in blue											
K: [1D or [3D] (0 or 1)	1	Calculation of alpha and p(collision) as a function of radius									
NoBlades	3	Upwind:						Downwind:			
MaxChord	4.1	m	r/R	c/C	a	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.64	m	0.025	0.575	10.82	40.19	0.95	0.00118	38.97	0.92	0.00115
Wingspan	1.38	m	0.075	0.575	3.61	13.80	0.32	0.00244	12.58	0.30	0.00222
F: Flapping (0) or gliding (+1)	0		0.125	0.702	2.16	9.74	0.23	0.00287	8.26	0.19	0.00243
			0.175	0.860	1.55	8.31	0.20	0.00342	6.49	0.15	0.00267
Bird speed	17	m/sec	0.225	0.994	1.20	7.45	0.18	0.00394	5.34	0.13	0.00283
RotorDiam	150	m	0.275	0.947	0.98	6.05	0.14	0.00392	4.04	0.10	0.00262
RotationPeriod	7.50	sec	0.325	0.899	0.83	5.07	0.12	0.00387	3.16	0.07	0.00242
			0.375	0.851	0.72	4.33	0.10	0.00382	2.52	0.06	0.00223
			0.425	0.804	0.64	3.76	0.09	0.00376	2.05	0.05	0.00205
			0.475	0.756	0.57	3.29	0.08	0.00368	1.69	0.04	0.00189
Bird aspect ratio: b	0.46		0.525	0.708	0.52	2.91	0.07	0.00359	1.41	0.03	0.00174
			0.575	0.660	0.47	2.58	0.06	0.00349	1.18	0.03	0.00160
			0.625	0.613	0.43	2.34	0.06	0.00344	1.04	0.02	0.00153
			0.675	0.565	0.40	2.14	0.05	0.00339	0.94	0.02	0.00149
			0.725	0.517	0.37	1.95	0.05	0.00333	0.86	0.02	0.00146
			0.775	0.470	0.35	1.79	0.04	0.00326	0.79	0.02	0.00144
			0.825	0.422	0.33	1.64	0.04	0.00318	0.74	0.02	0.00144
			0.875	0.374	0.31	1.50	0.04	0.00308	0.70	0.02	0.00144
			0.925	0.327	0.29	1.36	0.03	0.00297	0.67	0.02	0.00146
			0.975	0.279	0.28	1.24	0.03	0.00285	0.65	0.02	0.00149
			Overall p(collision) =				Upwind	6.5%	Downwind		3.8%
							Average		5.2%		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA												
Red Kite												
Only enter input parameters in blue												
K: [1D or [3D] (0 or 1)	1	Calculation of alpha and p(collision) as a function of radius										
NoBlades	3	Upwind:						Downwind:				
MaxChord	4.1 m	r/R	c/C	a	collide	contribution	collide	contribution				
Pitch (degrees)	15	radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r		
BirdLength	0.63 m	0.025	0.575	7.64	32.14	1.00	0.00125	30.92	1.00	0.00125		
Wingspan	1.85 m	0.075	0.575	2.55	11.12	0.37	0.00278	9.90	0.33	0.00247		
F: Flapping (0) or gliding (+1)	0	0.125	0.702	1.53	7.82	0.26	0.00326	6.33	0.21	0.00264		
		0.175	0.860	1.09	6.65	0.22	0.00388	4.82	0.16	0.00281		
Bird speed	12 m/sec	0.225	0.994	0.85	5.97	0.20	0.00448	3.86	0.13	0.00289		
RotorDiam	150 m	0.275	0.947	0.69	4.89	0.16	0.00449	2.88	0.10	0.00264		
RotationPeriod	7.50 sec	0.325	0.899	0.59	4.13	0.14	0.00448	2.23	0.07	0.00241		
		0.375	0.851	0.51	3.56	0.12	0.00445	1.76	0.06	0.00219		
		0.425	0.804	0.45	3.11	0.10	0.00441	1.41	0.05	0.00200		
		0.475	0.756	0.40	2.75	0.09	0.00435	1.15	0.04	0.00181		
Bird aspect ratio: b	0.34	0.525	0.708	0.36	2.44	0.08	0.00428	0.94	0.03	0.00165		
		0.575	0.660	0.33	2.20	0.07	0.00422	0.80	0.03	0.00153		
		0.625	0.613	0.31	2.02	0.07	0.00421	0.72	0.02	0.00150		
		0.675	0.565	0.28	1.86	0.06	0.00419	0.66	0.02	0.00149		
		0.725	0.517	0.26	1.72	0.06	0.00415	0.64	0.02	0.00154		
		0.775	0.470	0.25	1.59	0.05	0.00410	0.67	0.02	0.00173		
		0.825	0.422	0.23	1.46	0.05	0.00403	0.69	0.02	0.00190		
		0.875	0.374	0.22	1.35	0.05	0.00394	0.70	0.02	0.00205		
		0.925	0.327	0.21	1.24	0.04	0.00383	0.71	0.02	0.00219		
		0.975	0.279	0.20	1.14	0.04	0.00371	0.71	0.02	0.00231		
		Overall p(collision) =				Upwind	7.8%	Downwind	4.1%			
							Average	6.0%				

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA														
Peregrine														
Only enter input parameters in blue														
K: [1D or [3D] (0 or 1)	1	Calculation of alpha and p(collision) as a function of radius												
NoBlades	3	Upwind:						Downwind:						
MaxChord	4.1	m	r/R	c/C	a	collide		contribution	collide		contribution			
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r			
BirdLength	0.42	m	0.025	0.575	7.70	26.01	0.86	0.00107	24.79	0.82	0.00102			
Wingspan	1.02	m	0.075	0.575	2.57	9.08	0.30	0.00225	7.86	0.26	0.00195			
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.54	6.60	0.22	0.00273	5.11	0.17	0.00211			
			0.175	0.860	1.10	5.78	0.19	0.00335	3.96	0.13	0.00229			
Bird speed	12.1	m/sec	0.225	0.994	0.86	5.30	0.18	0.00394	3.19	0.11	0.00237			
RotorDiam	150	m	0.275	0.947	0.70	4.34	0.14	0.00395	2.34	0.08	0.00212			
RotationPeriod	7.50	sec	0.325	0.899	0.59	3.67	0.12	0.00394	1.76	0.06	0.00189			
			0.375	0.851	0.51	3.16	0.10	0.00392	1.35	0.04	0.00168			
			0.425	0.804	0.45	2.76	0.09	0.00387	1.05	0.03	0.00148			
			0.475	0.756	0.41	2.44	0.08	0.00382	0.83	0.03	0.00131			
Bird aspect ratio: b	0.41		0.525	0.708	0.37	2.20	0.07	0.00382	0.70	0.02	0.00121			
			0.575	0.660	0.33	2.00	0.07	0.00380	0.60	0.02	0.00113			
			0.625	0.613	0.31	1.82	0.06	0.00376	0.52	0.02	0.00107			
			0.675	0.565	0.29	1.66	0.05	0.00370	0.46	0.02	0.00102			
			0.725	0.517	0.27	1.51	0.05	0.00363	0.42	0.01	0.00102			
			0.775	0.470	0.25	1.38	0.05	0.00354	0.46	0.02	0.00117			
			0.825	0.422	0.23	1.26	0.04	0.00343	0.48	0.02	0.00130			
			0.875	0.374	0.22	1.14	0.04	0.00331	0.49	0.02	0.00142			
			0.925	0.327	0.21	1.04	0.03	0.00317	0.50	0.02	0.00152			
			0.975	0.279	0.20	0.93	0.03	0.00301	0.50	0.02	0.00160			
			Overall p(collision) =				Upwind		6.8%		Downwind		3.1%	
								Average		4.9%				

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA												
Golden Plover												
Only enter input parameters in blue												
K: [1D or [3D] (0 or 1)	1	Calculation of alpha and p(collision) as a function of radius										
NoBlades	3						Upwind:			Downwind:		
MaxChord	4.1	m	r/R	c/C	a	collide		contribution	collide		contribution	
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r	
BirdLength	0.28	m	0.025	0.575	8.72	26.75	0.78	0.00098	25.53	0.75	0.00093	
Wingspan	0.72	m	0.075	0.575	2.91	9.32	0.27	0.00204	8.10	0.24	0.00177	
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.74	6.85	0.20	0.00250	5.36	0.16	0.00196	
			0.175	0.860	1.25	6.05	0.18	0.00309	4.23	0.12	0.00216	
Bird speed	13.7	m/sec	0.225	0.994	0.97	5.57	0.16	0.00366	3.46	0.10	0.00227	
RotorDiam	150	m	0.275	0.947	0.79	4.55	0.13	0.00365	2.54	0.07	0.00204	
RotationPeriod	7.50	sec	0.325	0.899	0.67	3.83	0.11	0.00363	1.92	0.06	0.00182	
			0.375	0.851	0.58	3.28	0.10	0.00359	1.48	0.04	0.00162	
			0.425	0.804	0.51	2.85	0.08	0.00354	1.15	0.03	0.00143	
			0.475	0.756	0.46	2.51	0.07	0.00348	0.90	0.03	0.00125	
Bird aspect ratio: b	0.39		0.525	0.708	0.42	2.22	0.06	0.00340	0.71	0.02	0.00109	
			0.575	0.660	0.38	1.97	0.06	0.00331	0.57	0.02	0.00096	
			0.625	0.613	0.35	1.78	0.05	0.00324	0.48	0.01	0.00087	
			0.675	0.565	0.32	1.60	0.05	0.00316	0.40	0.01	0.00079	
			0.725	0.517	0.30	1.45	0.04	0.00306	0.35	0.01	0.00073	
			0.775	0.470	0.28	1.30	0.04	0.00295	0.30	0.01	0.00069	
			0.825	0.422	0.26	1.17	0.03	0.00282	0.29	0.01	0.00069	
			0.875	0.374	0.25	1.05	0.03	0.00267	0.31	0.01	0.00079	
			0.925	0.327	0.24	0.93	0.03	0.00252	0.32	0.01	0.00087	
			0.975	0.279	0.22	0.82	0.02	0.00234	0.33	0.01	0.00094	
			Overall p(collision) =				Upwind	6.0%		Downwind	2.6%	
							Average	4.3%				

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Dunlin											
Only enter input parameters in blue											
K: [1D or [3D] (0 or 1)	1	Calculation of alpha and p(collision) as a function of radius									
NoBlades	3	Upwind:					Downwind:				
MaxChord	4.1 m	r/R	c/C	a	collide	contribution	collide	contribution			
Pitch (degrees)	15	radius	chord	alpha	length	p(collision)	length	p(collision)	from radius r	from radius r	
BirdLength	0.16 m	0.025	0.575	9.74	26.69	0.70	0.00087	25.47	0.67	0.00083	
Wingspan	0.4 m	0.075	0.575	3.25	9.30	0.24	0.00182	8.08	0.21	0.00158	
F: Flapping (0) or gliding (+1)	0	0.125	0.702	1.95	6.94	0.18	0.00227	5.45	0.14	0.00178	
		0.175	0.860	1.39	6.21	0.16	0.00284	4.38	0.11	0.00201	
Bird speed	15.3 m/sec	0.225	0.994	1.08	5.75	0.15	0.00338	3.64	0.10	0.00214	
RotorDiam	150 m	0.275	0.947	0.89	4.68	0.12	0.00336	2.67	0.07	0.00192	
RotationPeriod	7.50 sec	0.325	0.899	0.75	3.92	0.10	0.00333	2.01	0.05	0.00171	
		0.375	0.851	0.65	3.35	0.09	0.00329	1.55	0.04	0.00152	
		0.425	0.804	0.57	2.91	0.08	0.00323	1.20	0.03	0.00133	
		0.475	0.756	0.51	2.54	0.07	0.00316	0.94	0.02	0.00116	
Bird aspect ratio: b	0.40	0.525	0.708	0.46	2.24	0.06	0.00307	0.73	0.02	0.00101	
		0.575	0.660	0.42	1.98	0.05	0.00297	0.58	0.02	0.00087	
		0.625	0.613	0.39	1.76	0.05	0.00287	0.46	0.01	0.00074	
		0.675	0.565	0.36	1.57	0.04	0.00277	0.37	0.01	0.00065	
		0.725	0.517	0.34	1.40	0.04	0.00265	0.30	0.01	0.00057	
		0.775	0.470	0.31	1.24	0.03	0.00252	0.25	0.01	0.00050	
		0.825	0.422	0.30	1.10	0.03	0.00237	0.21	0.01	0.00044	
		0.875	0.374	0.28	0.97	0.03	0.00222	0.18	0.00	0.00040	
		0.925	0.327	0.26	0.85	0.02	0.00205	0.17	0.00	0.00040	
		0.975	0.279	0.25	0.73	0.02	0.00187	0.18	0.00	0.00046	
				Overall p(collision) =	Upwind	5.3%	Downwind	2.2%			
							Average	3.7%			

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Snipe											
Only enter input parameters in blue											
K: [1D or [3D] (0 or 1)	1	Calculation of alpha and p(collision) as a function of radius									
NoBlades	3	Upwind:						Downwind:			
MaxChord	4.1	m	r/R	c/C	a	collide	contribution	collide	contribution		
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.26	m	0.025	0.575	10.89	30.41	0.71	0.00089	29.19	0.68	0.00085
Wingspan	0.46	m	0.075	0.575	3.63	10.54	0.25	0.00185	9.32	0.22	0.00164
F: Flapping (0) or gliding (+1)	0		0.125	0.702	2.18	7.79	0.18	0.00228	6.31	0.15	0.00184
			0.175	0.860	1.56	6.93	0.16	0.00283	5.10	0.12	0.00209
Bird speed	17.1	m/sec	0.225	0.994	1.21	6.37	0.15	0.00336	4.26	0.10	0.00224
RotorDiam	150	m	0.275	0.947	0.99	5.17	0.12	0.00333	3.16	0.07	0.00203
RotationPeriod	7.50	sec	0.325	0.899	0.84	4.32	0.10	0.00328	2.41	0.06	0.00183
			0.375	0.851	0.73	3.68	0.09	0.00323	1.88	0.04	0.00165
			0.425	0.804	0.64	3.19	0.07	0.00317	1.48	0.03	0.00147
			0.475	0.756	0.57	2.78	0.07	0.00309	1.18	0.03	0.00131
Bird aspect ratio: b	0.57		0.525	0.708	0.52	2.47	0.06	0.00303	0.96	0.02	0.00118
			0.575	0.660	0.47	2.20	0.05	0.00296	0.80	0.02	0.00107
			0.625	0.613	0.44	1.97	0.05	0.00288	0.67	0.02	0.00097
			0.675	0.565	0.40	1.76	0.04	0.00278	0.56	0.01	0.00089
			0.725	0.517	0.38	1.58	0.04	0.00268	0.48	0.01	0.00081
			0.775	0.470	0.35	1.41	0.03	0.00256	0.41	0.01	0.00075
			0.825	0.422	0.33	1.26	0.03	0.00243	0.36	0.01	0.00070
			0.875	0.374	0.31	1.12	0.03	0.00229	0.32	0.01	0.00066
			0.925	0.327	0.29	0.99	0.02	0.00214	0.29	0.01	0.00064
			0.975	0.279	0.28	0.86	0.02	0.00197	0.27	0.01	0.00062
							Upwind	5.3%		Downwind	2.5%
							Average	3.9%			

3 Key Species Flight Activity and Collision Risk: Direct Flight Model (Stage 2)

- 3.1.1 The second section of this Technical Appendix provides example calculations that have been made of the key species flight activity within the collision risk zone.
- 3.1.2 The model was run separately for each of zones across the collision risk area that were visible from each of the two Vantage Points (VPs) (all areas were visible from only a single VP, with no overlap). Bird flight activity within each of these zones was calculated separately.
- 3.1.3 For the direct flight variant of the Band model (used for whooper swan, black-throated diver, greylag goose and pink-footed goose), flight activity was calculated as the total number of flights through each collision zone, estimated from the VP data (clipping mapped flights in ArcGIS to those zones and calculating the numbers of flights per hour at rotor height over each season). An example calculation is given below in Table 8.5.1: Collision risk calculations for pink-footed goose for the 2020-21 and 2021-22 winters using the direct flight Band model. The total risk for the proposed development was calculated as the sum of the risks for each of the two zones, and the last row gives the mean risk over the two winters.

Table 8.5.1: Collision risk calculations for pink-footed goose for the 2020-21 and 2021-22 winters using the direct flight Band model.

BLOCH WIND FARM				
BAND ET AL 2007 COLLISION MODEL (DIRECT FLIGHTS)				
	Pink-footed Goose			
	<i>Winter only</i>			
	2020-21		2021-22	
	Zone A	Zone B	Zone A	Zone B
Collision risk height	209	209	209	209
Risk corridor Width	3,390	2,095	3,390	2,095
Risk corridor Area	708,510	437,855	708,510	437,855
Annual number of flights through collision zone at rotor ht	34,093	0	13,179	22,080
No turbines	13	8	13	8
Rotor diameter	150	150	150	150
Rotor swept area	17671	17671	17671	17671
Allowance for overlap	0%	0%	0%	0%
Proportion of risk window occupied by rotors	32%	32%	32%	32%
Annual no bird rotor passes	11054	0	4273	7129
Band individual collision risk	5.3%	5.3%	5.3%	5.3%
Turbine downtime	15%	15%	15%	15%
Non-avoidance collisions	498	0	192	321
Avoidance rate	99.80%	99.80%	99.80%	99.80%
Predicted collisions per year	0.996	0.000	0.385	0.642
Total annual collision risk		0.996		1.027
			<i>Mean:</i>	<i>1.01</i>

4 Key Species Flight Activity and Collision Risk: Non-direct Flight Model (Stage 2)

- 4.1.1 As an example, for the variable non-direct flight modelling, the collision risk calculations for hen harrier for each of the winter and breeding baseline periods (breeding 2021 and 2022, winter 2020-21 and 2021-22) is shown in Table 8.5.2: Collision risk calculations for hen harrier for using the non-direct random flight Band model. This requires an estimate of the amount of time that each species was present within the collision risk zone for its bird activity input, calculated from the amount of time observed in each zone during the VP surveys (as the percentage occupancy rate of each zone, i.e. the percentage of observation time that each species was observed flying at rotor height within the zone). This occupancy of the collision risk zone was determined from the flight tracks and divided by the observation time for each month to give the monthly occupancy rate (percentage of time present in the collision zone). The overall occupancy was then calculated for each of the four survey periods (breeding 2021 and 2022, winter 2020-21 and 2021-22). The survey results for these periods are given in Technical Appendices 8.1, 8.2, 8.3 and 8.4 respectively.
- 4.1.2 As for the direct flight model, the total risk for the proposed development was calculated as the sum of the risks for each of the two zones.

Table 8.5.2. Collision risk calculations for hen harrier using the non-direct random flight Band model.

BLOCH WIND FARM								
BAND ET AL 2007 COLLISION MODEL (OCCUPANCY)								
	Hen Harrier							
	Winter		Winter		Breeding		Breeding	
	2020-21		2021-22		2021		2022	
	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B
Collision Zone Area (ha)	605	373	605	373	605	373	605	373
Hub Ht	105	105	105	105	105	105	105	105
Rotor diameter	150	150	150	150	150	150	150	150
Upper rotor ht	21	21	21	21	21	21	21	21
Lower rotor ht	250	250	250	250	250	250	250	250
Percentage of observation time seen flying in collision zone at rotor ht	0.07%	0.10%	0.00%	0.23%	0.19%	0.000%	0.000%	0.082%
Season length	212	212	212	212	153	153	153	153
Activity per day	9.8	9.8	9.8	9.8	15.9	15.9	15.9	15.9
Total flight activity in collision zone at rotor ht	1.486	3.207	0.000	4.691	4.495	0.000	0.000	1.984
Flight risk volume	9.075E+08	5.595E+08	9.075E+08	5.595E+08	9.075E+08	5.595E+08	9.075E+08	5.595E+08
No Turbines	13	8	13	8	13	8	13	8
Rotor radius	75	75	75	75	75	75	75	75
Rotor depth	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Bird length	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Swept volume	1052159	647482	1052159	647482	1052159	647482	1052159	647482
Bird occupancy of swept volume	6.20	13.36	0.00	19.54	18.76	0.00	0.00	8.27
Bird speed	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
Rotor transit time	0.503	0.503	0.503	0.503	0.503	0.503	0.503	0.503
No of rotor transits	12	27	0	39	37	0	0	16
Turbine downtime	15%	15%	15%	15%	15%	15%	15%	15%
Band collision rate	5.9%	5.9%	5.9%	5.9%	5.9%	5.9%	5.9%	5.9%
Non-avoid collisions	0.6	1.3	0.0	1.9	1.9	0.0	0.0	0.8
Avoidance rate	99%	99%	99%	99%	99%	99%	99%	99%
Collision prediction	0.006	0.013	0.000	0.019	0.019	0.000	0.000	0.008
		0.019		0.019		0.019		0.008
OVERALL TOTAL								0.033

5 References

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