

Technical Appendix 11.2: Estimation of Collision Risk

Red-throated Diver

Flight activity values for 200x200 m cells centred on each proposed turbine. Data converted from kilometres flown per year to hours flown per year using a mean flight speed of 17.5 m/s.

Quadrant	Turbine	Activity within 200x200 m tiles (hrs/yr)			
		Total activity		Activity at RSH	
		Breeders	Non-breeders	Breeders	Non-breeders
Delting	1	0.000	0.000	0.000	0.000
Delting	2	0.000	0.000	0.000	0.000
Delting	3	0.252	0.243	0.169	0.163
Delting	4	0.162	0.992	0.109	0.666
Delting	5	1.027	1.040	0.689	0.698
Delting	6	0.571	0.100	0.383	0.067
Delting	7	1.027	0.167	0.689	0.112
Delting	8	2.892	0.524	1.940	0.352
Delting	9	0.591	0.051	0.397	0.034
Delting	10	0.577	1.077	0.387	0.722
Delting	11	0.049	0.056	0.033	0.038
Delting	12	0.000	0.000	0.000	0.000
Delting	13	0.319	0.320	0.214	0.215
Delting	14	0.017	0.017	0.011	0.011
Delting	15	0.108	0.108	0.072	0.072
Delting	16	0.000	0.000	0.000	0.000
Delting	17	0.261	0.827	0.175	0.555
Delting	18	0.789	0.701	0.529	0.471
Delting	19	0.084	0.283	0.056	0.190
Delting	20	1.899	0.272	1.274	0.183
Delting	21	0.072	0.087	0.049	0.058
Delting	22	0.390	0.282	0.262	0.189
Delting	23	0.102	0.424	0.068	0.284
Delting	24	0.222	0.083	0.149	0.055
Delting	25	0.060	0.832	0.040	0.558
Delting	26	0.095	0.303	0.064	0.203
Delting	27	0.003	0.003	0.002	0.002
Delting	28	0.633	0.089	0.425	0.060
Delting	29	0.076	0.751	0.051	0.504
Delting	30	0.102	0.427	0.068	0.286
Delting	31	0.309	0.773	0.207	0.519
Delting	32	0.040	0.232	0.027	0.156
Delting	33	0.237	1.433	0.159	0.962
Collafirth	34	0.009	0.021	0.006	0.014
Collafirth	35	0.312	0.275	0.209	0.184
Collafirth	36	0.128	0.432	0.086	0.290
Collafirth	37	0.430	0.158	0.289	0.106
Collafirth	38	0.096	0.035	0.065	0.024
Collafirth	39	0.000	0.000	0.000	0.000
Collafirth	40	0.114	0.030	0.077	0.020
Collafirth	41	0.080	0.146	0.054	0.098
Kergord	42	0.000	0.000	0.000	0.000
Kergord	43	0.000	0.000	0.000	0.000
Kergord	44	0.000	0.000	0.000	0.000
Kergord	45	0.000	0.000	0.000	0.000
Kergord	46	0.241	0.241	0.162	0.162
Kergord	47	0.032	0.032	0.022	0.022
Kergord	48	0.076	0.076	0.051	0.051
Kergord	49	0.667	0.216	0.448	0.145
Kergord	50	0.000	0.000	0.000	0.000

Kergord	51	0.000	0.000	0.000	0.000
Kergord	52	0.000	0.000	0.000	0.000
Kergord	53	0.000	0.000	0.000	0.000
Kergord	54	0.000	0.000	0.000	0.000
Kergord	55	0.000	0.000	0.000	0.000
Kergord	56	0.008	0.008	0.005	0.005
Kergord	57	0.000	0.000	0.000	0.000
Kergord	58	0.000	0.000	0.000	0.000
Kergord	59	0.000	0.000	0.000	0.000
Kergord	60	0.000	0.000	0.000	0.000
Kergord	61	0.000	0.000	0.000	0.000
Kergord	62	0.063	0.063	0.042	0.042
Kergord	63	0.031	0.018	0.021	0.012
Kergord	64	0.072	0.092	0.048	0.062
Kergord	65	0.082	0.049	0.055	0.033
Kergord	66	0.080	0.197	0.053	0.132
Kergord	67	0.393	0.144	0.263	0.097
Kergord	68	0.167	0.105	0.112	0.070
Kergord	69	0.049	0.035	0.033	0.023
Kergord	70	0.061	0.060	0.041	0.041
Kergord	71	0.025	0.036	0.017	0.024
Kergord	72	0.090	0.368	0.061	0.247
Kergord	73	0.005	0.008	0.004	0.005
Kergord	74	0.000	0.000	0.000	0.000
Kergord	75	0.231	0.062	0.155	0.042
Kergord	76	0.452	0.487	0.304	0.327
Kergord	77	0.291	0.211	0.195	0.141
Kergord	78	0.040	0.141	0.027	0.095
Kergord	79	0.018	0.026	0.012	0.017
Kergord	80	0.000	0.000	0.000	0.000
Kergord	81	0.000	0.000	0.000	0.000
Kergord	82	0.000	0.000	0.000	0.000
Kergord	83	0.010	0.010	0.007	0.007
Kergord	84	0.000	0.000	0.000	0.000
Kergord	85	0.000	0.000	0.000	0.000
Kergord	86	0.000	0.000	0.000	0.000
Kergord	87	0.000	0.000	0.000	0.000
Kergord	88	0.000	0.000	0.000	0.000
Nesting	89	0.083	0.470	0.056	0.316
Nesting	90	0.044	0.044	0.030	0.030
Nesting	91	0.000	0.000	0.000	0.000
Nesting	92	0.279	0.054	0.187	0.036
Nesting	93	0.034	0.060	0.023	0.041
Nesting	94	0.183	0.153	0.122	0.103
Nesting	95	0.000	0.000	0.000	0.000
Nesting	96	0.195	0.051	0.131	0.034
Nesting	97	0.248	0.044	0.166	0.030
Nesting	98	0.416	0.295	0.279	0.198
Nesting	99	0.149	0.097	0.100	0.065
Nesting	100	0.055	1.044	0.037	0.700

Nesting	101	0.078	1.156	0.052	0.775
Nesting	102	0.022	0.379	0.015	0.255
Nesting	103	0.054	0.301	0.036	0.202
Nesting	104	0.013	0.100	0.009	0.067
Nesting	105	0.224	0.502	0.151	0.337
Nesting	106	0.073	0.063	0.049	0.043
Nesting	107	0.048	0.417	0.032	0.280
Nesting	108	0.191	0.270	0.128	0.181
Nesting	109	0.043	0.694	0.029	0.465
Nesting	110	0.137	0.343	0.092	0.230
Nesting	111	0.044	0.141	0.030	0.094
Nesting	112	0.076	0.132	0.051	0.089
Nesting	113	0.102	0.726	0.068	0.487
Nesting	114	0.067	1.200	0.045	0.805
Nesting	115	0.287	0.168	0.192	0.113
Nesting	116	0.230	1.275	0.154	0.855
Nesting	117	0.157	0.948	0.105	0.636
Nesting	118	0.192	0.216	0.129	0.145
Nesting	119	0.152	0.133	0.102	0.089
Nesting	120	0.450	0.470	0.302	0.315
Nesting	121	0.278	0.275	0.186	0.184
Nesting	122	0.647	0.770	0.434	0.516
Nesting	123	0.046	0.084	0.031	0.056
Nesting	124	0.037	0.031	0.025	0.021
Nesting	125	0.192	0.824	0.129	0.553
Nesting	126	0.002	0.002	0.001	0.001
Nesting	127	0.183	0.349	0.123	0.234
Nesting	128	0.003	0.007	0.002	0.005
Nesting	129	0.279	0.234	0.187	0.157
Nesting	130	0.058	0.031	0.039	0.021
Nesting	131	0.265	0.170	0.178	0.114
Nesting	132	0.118	0.352	0.079	0.236
Nesting	133	0.000	0.000	0.000	0.000
Nesting	134	0.000	0.000	0.000	0.000
Nesting	135	0.038	0.177	0.026	0.119
Nesting	136	0.041	0.098	0.028	0.066
Nesting	137	0.178	0.060	0.120	0.041
Nesting	138	0.000	0.000	0.000	0.000
Nesting	139	0.099	0.278	0.066	0.186
Nesting	140	0.041	0.041	0.028	0.028
Nesting	141	0.000	0.000	0.000	0.000
Nesting	142	0.032	0.032	0.022	0.022
Nesting	143	0.008	0.008	0.005	0.005
Nesting	144	0.020	0.113	0.014	0.076
Nesting	145	0.026	0.151	0.018	0.101
Nesting	146	0.108	0.054	0.072	0.036
Nesting	147	0.000	0.000	0.000	0.000
Nesting	148	0.035	0.092	0.023	0.062
Nesting	149	0.079	0.297	0.053	0.199
Nesting	150	0.127	0.086	0.085	0.058

Band model Stage 2 calculation for the probability of collision by red-throated divers.

K: [1D or 3D] (0 or 1)		Calculation of alpha and p(collision) as a function of radius										
NoBlades							Upwind:			Downwind:		
MaxChord		r/R	c/C	\int	collide	p(collision)	contribution	collide	p(collision)	contribution		
Pitch (degrees)		radius	chord	alpha	length		from radius r	length		from radius r		
BirdLength	0.71 m	0.025	0.575	9.36	29.63	1.00	0.00125	28.70	1.00	0.00125		
Wingspan	1.1 m	0.075	0.575	3.12	10.19	0.38	0.00284	9.26	0.34	0.00258		
F: Flapping (0) or gliding (+1)	0	0.125	0.702	1.87	7.23	0.27	0.00335	6.10	0.23	0.00283		
		0.175	0.860	1.34	6.20	0.23	0.00403	4.81	0.18	0.00312		
Bird speed	18 m/sec	0.225	0.994	1.04	5.58	0.21	0.00466	3.97	0.15	0.00331		
RotorDiam	110 m	0.275	0.947	0.85	4.53	0.17	0.00462	2.99	0.11	0.00306		
RotationPeriod	4.62 sec	0.325	0.899	0.72	3.79	0.14	0.00457	2.33	0.09	0.00281		
		0.375	0.851	0.62	3.26	0.12	0.00454	1.88	0.07	0.00262		
		0.425	0.804	0.55	2.91	0.11	0.00459	1.61	0.06	0.00254		
		0.475	0.756	0.49	2.63	0.10	0.00463	1.40	0.05	0.00247		
Bird aspect ratio: \int	0.65	0.525	0.708	0.45	2.39	0.09	0.00466	1.24	0.05	0.00242		
		0.575	0.660	0.41	2.19	0.08	0.00467	1.12	0.04	0.00238		
		0.625	0.613	0.37	2.01	0.07	0.00466	1.02	0.04	0.00236		
		0.675	0.565	0.35	1.85	0.07	0.00465	0.94	0.03	0.00235		
		0.725	0.517	0.32	1.71	0.06	0.00461	0.88	0.03	0.00236		
		0.775	0.470	0.30	1.59	0.06	0.00457	0.83	0.03	0.00238		
		0.825	0.422	0.28	1.47	0.05	0.00450	0.79	0.03	0.00241		
		0.875	0.374	0.27	1.36	0.05	0.00443	0.76	0.03	0.00246		
		0.925	0.327	0.25	1.26	0.05	0.00434	0.74	0.03	0.00252		
		0.975	0.279	0.24	1.17	0.04	0.00423	0.72	0.03	0.00260		
Overall p(collision) =					Upwind	8.4%	Downwind	5.1%				
					Average		6.8%					

Sample collision calculation for a single turbine, using flight activity data for the surrounding 200x200 m cell. Data shown are for breeding divers and Turbine #3 (Delting Quadrant)

Turbine parameters	
Size of activity envelope	4 ha
Rotor diameter	110 m
Max. rotor depth in metres	4.2 m
Max. chord	3.60 m
Pitch	13.0 degrees
Rotation period	4.62 s
Turbine operation time	85%

RH parameters	
Length	0.71 m
Wingspan	1.1 m
Assumed flight speed	17.5 ms ⁻¹
Activity at RSH	67.1%

Collision probability	6.8%
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Mortality estimate	
Flight risk volume (Vw)	4400000 m ³
Rotor swept area (Ar)	9503 m ²
Rotor swept volume (Vr) = Ar*(d+l)	46661 m ³
Bird occupancy (n)	0.169 hr/yr
Bird occupancy of rotor swept vol (b)	6.47 bird-secs
Bird transit time (t)	0.3 secs
No. of transits through rotors	23.04 per year
Estimated no. of collisions	1.33 per year

Kergord	51	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	52	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	53	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	55	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	56	0.04	0.00	0.00	0.04	0.00	0.00	0.00
Kergord	57	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	58	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	59	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	61	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	62	0.33	0.01	0.00	0.33	0.01	0.00	0.01
Kergord	63	0.16	0.00	0.00	0.09	0.00	0.00	0.01
Kergord	64	0.38	0.01	0.00	0.49	0.01	0.00	0.02
Kergord	65	0.43	0.01	0.00	0.26	0.01	0.00	0.01
Kergord	66	0.42	0.01	0.00	1.04	0.02	0.01	0.03
Kergord	67	2.07	0.04	0.02	0.76	0.02	0.01	0.06
Kergord	68	0.88	0.02	0.01	0.55	0.01	0.01	0.03
Kergord	69	0.26	0.01	0.00	0.18	0.00	0.00	0.01
Kergord	70	0.32	0.01	0.00	0.32	0.01	0.00	0.01
Kergord	71	0.13	0.00	0.00	0.19	0.00	0.00	0.01
Kergord	72	0.48	0.01	0.00	1.94	0.04	0.02	0.05
Kergord	73	0.03	0.00	0.00	0.04	0.00	0.00	0.00
Kergord	74	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	75	1.22	0.02	0.01	0.33	0.01	0.00	0.03
Kergord	76	2.39	0.05	0.02	2.57	0.05	0.03	0.10
Kergord	77	1.53	0.03	0.02	1.11	0.02	0.01	0.05
Kergord	78	0.21	0.00	0.00	0.75	0.01	0.01	0.02
Kergord	79	0.09	0.00	0.00	0.14	0.00	0.00	0.00
Kergord	80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	81	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	82	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	83	0.05	0.00	0.00	0.05	0.00	0.00	0.00
Kergord	84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	85	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	87	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kergord	88	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nesting	89	0.44	0.01	0.00	2.48	0.05	0.02	0.06
Nesting	90	0.23	0.00	0.00	0.23	0.00	0.00	0.01
Nesting	91	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nesting	92	1.47	0.03	0.01	0.28	0.01	0.00	0.04
Nesting	93	0.18	0.00	0.00	0.32	0.01	0.00	0.01
Nesting	94	0.96	0.02	0.01	0.81	0.02	0.01	0.04
Nesting	95	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nesting	96	1.03	0.02	0.01	0.27	0.01	0.00	0.03
Nesting	97	1.31	0.03	0.01	0.23	0.00	0.00	0.03
Nesting	98	2.19	0.04	0.02	1.56	0.03	0.02	0.08
Nesting	99	0.79	0.02	0.01	0.51	0.01	0.01	0.03
Nesting	100	0.29	0.01	0.00	5.51	0.11	0.06	0.12

Nesting	101	0.41	0.01	0.00	6.10	0.12	0.06	0.13
Nesting	102	0.12	0.00	0.00	2.00	0.04	0.02	0.04
Nesting	103	0.28	0.01	0.00	1.59	0.03	0.02	0.04
Nesting	104	0.07	0.00	0.00	0.53	0.01	0.01	0.01
Nesting	105	1.18	0.02	0.01	2.65	0.05	0.03	0.08
Nesting	106	0.39	0.01	0.00	0.34	0.01	0.00	0.01
Nesting	107	0.25	0.01	0.00	2.20	0.04	0.02	0.05
Nesting	108	1.01	0.02	0.01	1.43	0.03	0.01	0.05
Nesting	109	0.23	0.00	0.00	3.66	0.07	0.04	0.08
Nesting	110	0.72	0.01	0.01	1.81	0.04	0.02	0.05
Nesting	111	0.23	0.00	0.00	0.74	0.01	0.01	0.02
Nesting	112	0.40	0.01	0.00	0.70	0.01	0.01	0.02
Nesting	113	0.54	0.01	0.01	3.83	0.08	0.04	0.09
Nesting	114	0.36	0.01	0.00	6.33	0.13	0.06	0.13
Nesting	115	1.51	0.03	0.02	0.89	0.02	0.01	0.05
Nesting	116	1.21	0.02	0.01	6.73	0.13	0.07	0.16
Nesting	117	0.83	0.02	0.01	5.00	0.10	0.05	0.12
Nesting	118	1.01	0.02	0.01	1.14	0.02	0.01	0.04
Nesting	119	0.80	0.02	0.01	0.70	0.01	0.01	0.03
Nesting	120	2.38	0.05	0.02	2.48	0.05	0.02	0.10
Nesting	121	1.47	0.03	0.01	1.45	0.03	0.01	0.06
Nesting	122	3.42	0.07	0.03	4.06	0.08	0.04	0.15
Nesting	123	0.24	0.00	0.00	0.44	0.01	0.00	0.01
Nesting	124	0.19	0.00	0.00	0.16	0.00	0.00	0.01
Nesting	125	1.01	0.02	0.01	4.35	0.09	0.04	0.11
Nesting	126	0.01	0.00	0.00	0.01	0.00	0.00	0.00
Nesting	127	0.97	0.02	0.01	1.84	0.04	0.02	0.06
Nesting	128	0.02	0.00	0.00	0.04	0.00	0.00	0.00
Nesting	129	1.47	0.03	0.01	1.24	0.02	0.01	0.05
Nesting	130	0.31	0.01	0.00	0.16	0.00	0.00	0.01
Nesting	131	1.40	0.03	0.01	0.90	0.02	0.01	0.05
Nesting	132	0.62	0.01	0.01	1.86	0.04	0.02	0.05
Nesting	133	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nesting	134	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nesting	135	0.20	0.00	0.00	0.93	0.02	0.01	0.02
Nesting	136	0.22	0.00	0.00	0.52	0.01	0.01	0.01
Nesting	137	0.94	0.02	0.01	0.32	0.01	0.00	0.03
Nesting	138	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nesting	139	0.52	0.01	0.01	1.47	0.03	0.01	0.04
Nesting	140	0.22	0.00	0.00	0.22	0.00	0.00	0.01
Nesting	141	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nesting	142	0.17	0.00	0.00	0.17	0.00	0.00	0.01
Nesting	143	0.04	0.00	0.00	0.04	0.00	0.00	0.00
Nesting	144	0.11	0.00	0.00	0.60	0.01	0.01	0.01
Nesting	145	0.14	0.00	0.00	0.79	0.02	0.01	0.02
Nesting	146	0.57	0.01	0.01	0.28	0.01	0.00	0.02
Nesting	147	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nesting	148	0.18	0.00	0.00	0.48	0.01	0.00	0.01
Nesting	149	0.42	0.01	0.00	1.57	0.03	0.02	0.04
Nesting	150	0.67	0.01	0.01	0.46	0.01	0.00	0.02
Totals		129.76	<u>2.60</u>	1.30	173.29	<u>3.47</u>	1.73	<u>6.06</u>

Other species

Sample collision risk calculation for other species, using flight activity data (hours per ha per year) corrected for detection bias. The example shows the rate at which whimbrels are predicted to collide with a generic turbine in the Delting quadrant (0.06 per year). There are 33 turbines proposed in the Delting quadrant and therefore the total number of collisions is estimated to be 2.0 per year.

MORTALITY ESTIMATE	
Flight risk volume (Vw)	1100000 m ³
Rotor radius ²	3025 m ²
Combined rotor swept area (Ar)	9503 m ²
Comined rotor swept volume (Vr) = Ar*(d+l)	44190 m ³
Bird occupancy (n)	0.14 hrs / yr
Bird occupancy of rotor swept vol (b)	20.25 bird-secs
Bird transit time (t)	0.36 secs
No. of transits through rotors	56.61 per year
Estimated no. of collisions	3.06 per year
After allowing for avoidance	0.06111 per year
i.e. equivalent to one bird every	16.37 years

Summary of predicated collision rates for species mentioned in the text.

	Unit	Greylag	Merlin	Golden Plover	Dunlin	Curlew	Whimbrel	Arctic Skua	Great Skua
Length	m	0.83	0.28	0.28	0.18	0.55	0.45	0.60	0.56
Wingspan	m	1.64	0.56	0.72	0.41	0.90	0.80	1.10	1.33
Assumed flight speed	ms ⁻¹	16	14	14	13	13	13	12	12
Collision probability		7.7%	5.3%	5.5%	4.9%	6.9%	6.3%	7.5%	7.4%
Assumed avoidance rate		99%	98%	98%	98%	98%	98%	98%	98%
NW - Delting									
No. of turbines		33	33	33	33	33	33	33	33
Flight activity at RSH	hrs/ha/yr	0.28	0.02	0.89	0.14	0.59	0.14	0.10	0.93
Estimated no. of collisions	per year	3.00	0.23	11.80	1.59	9.10	2.00	1.50	14.30
NE - Collafirth									
No. of turbines		8	8	8	8	8	8	8	8
Flight activity at RSH	hrs/ha/yr	0.10	0.003	0.62	0.16	0.67	0.20	0.11	0.65
Estimated no. of collisions	per year	0.25	0.01	2.00	0.44	2.50	0.70	0.43	2.40
SW - Kergord									
No. of turbines		47	47	47	47	47	47	47	47
Flight activity at RSH	hrs/ha/yr	0.15	0.003	1.00	0.20	1.12	0.15	0.09	1.20
Estimated no. of collisions	per year	2.30	0.05	18.90	3.18	24.70	3.01	2.00	26.50
SE - Nesting									
No. of turbines		62	62	62	62	62	62	62	62
Flight activity at RSH	hrs/ha/yr	0.04	0.003	1.19	0.39	0.76	0.18	0.21	0.59
Estimated no. of collisions	per year	0.87	0.07	29.76	8.20	22.10	4.80	6.16	17.00
Combined									
No. of turbines		150	150	150	150	150	150	150	150
Flight activity at RSH	hrs/ha/yr	0.14	0.01	0.93	0.22	0.79	0.17	0.13	0.84
Estimated no. of collisions	per year	6.42	0.36	62.46	13.41	58.40	10.51	10.09	60.20