Technical Appendix 8.4: Collision Risk Modelling Report

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8.4.1 Introduction

8.4.1.1 This appendix of the Environmental Impact Assessment (EIA) presents the results of ornithological survey work conducted by Ramboll for the proposed repowering of Novar 1 Wind Farm (hereafter referred to as the Proposed Development). The Site is located approximately 10 km west of Alness in the Scottish Highlands (4.4400516°W 57.7180965°N) and includes the proposed installation of 9 turbines to replace 34 existing smaller turbines.

8.4.1.2 Ramboll conducted collision risk modelling (CRM) to provide a numerative estimate of the collision risk posed to avian species by the Proposed Development. Modelling detailed herein was conducted in accordance with the methodology outlined by NatureScot[1] which expresses collision risk as the estimated number of birds which may collide with wind turbine rotors over a specified period of time. The model includes a level of uncertainty which accounts for variability in the model input parameters. Model input parameters include:

- The number of birds flying through or around the Site, and their flight height (derived from bird surveys conducted at the Site between September 2023 and September 2024);
- Predicted or likely changes in the behaviour of birds;
- The number, size, and rotation speed of wind turbine blades; and
- Physical details on size and flight speed of target species.

8.4.1.3 Vantage point (VP) watches, which are designed to quantify the level of flight activity and its distribution over a survey area for CRM, were used to record the number of birds flying through or around the Site, and their flight height. Four VP watch locations were established and were restricted to an arc of observation 2 km from the VP location. The VP locations and viewsheds are shown on **Figure 8.2: Ornithology Flight Activity Survey Locations (EIAR Volume 3a)**. Each VP location was watched for 6 hours per month over a year, for a total of 72 hours of observation at each VP. VP watches were located at:

- VP1: 4.4095323°W 57.7122118°N, viewing WSW;
- VP2: 4.4287188°W 57.7106343°N, viewing NNW;
- VP3: 4.4504343°W 57.7223234°N viewing NNE; and
- VP4: 4.4575802°W 57.7248082°N viewing NNW.

8.4.2 Stage A: Flight Activity

8.4.2.1 In Stage A, field data was used from the Site to estimate flight activity at risk within the rotor-swept window. The method for Stage A depends on whether the bird's flight activity is directional, such as commuting or migrating, or whether the activity is more random, such as during hunting activity.

8.4.2.2 During the VP surveys, a total of 10 species were recorded. Three species had frequent flight activity (defined here as more than 3 flights recorded during VP surveys) and therefore became the focal species for collision risk modelling:

- Red kite (Milvus milvus);
- Golden eagle (*Aquila chrysaetos*); and
- Hen harrier (*Circus cyaenus*).

8.4.2.3 The remaining species recorded during VP surveys had low frequency of flights (3 or fewer flights) with little time at potential collision risk height, therefore collision risk is likely to be negligible:

- Golden plover (*Pluvialis apricaria*) – two flights of this species recorded, 24 birds total, however, about half of flight time was at heights above PCH (over 200 m);
- Merlin (*Falco columbarius*) – two flights of this species recorded;
- Osprey (*Pandion haliaetus*) – one flight of this species recorded;
- Peregrine falcon (*Falco peregrinus*) – two flights of this species recorded;
- Pink-footed goose (*Anser brachyrhynchus*) – one flight of 40 birds recorded. The flight occurred above PCH (over 200 m);
- Sparrowhawk (*Accipiter nisus*) – one flight of this species recorded; and
- White-tailed eagle (*Haliaeetus albicilla*) – three flights of 11 birds recorded which totalled 7.5 minutes at PCH across the survey period.

Flight Height

8.4.2.4 Some flight activity was not at risk of collision, even within the flight risk area, because it occurred below the rotor-swept height (RSH) of the proposed turbines (<18 m) or above the RSH of the proposed turbines (>180 m). The proportion of birds flying at risk height (Q2R) is the proportion of birds between the lowest and highest points of a rotor relative to the rotor base. Q2R can be derived as either 1) a proportion, between 0 and 1, of total flight activity that occurs at RSH, or 2) if bird density (DA) is calculated using only the duration of observed flight activity at RSH, Q2R is set to a value of 1 (100%) in the spreadsheet. In this CRA, option (2) was used because height bands recorded in the field did not match the turbine rotor swept height, and preliminary calculations to translate flight activity to density were needed (see below).

8.4.2.5 Before calculating bird density, the five height zones recorded in the field were mapped onto the rotor swept height (18-180 m) as laid out in Table 8.4.1, such that 10% of the flight time at height band 1 (0-20 m) was considered to be at risk height, 100% of the flight time at height band 2 (20-50 m) was considered to be at risk height, and so on.

Table 8.4.1: Percentage at risk by height band

Bands	**1**	**2**	**3**	**4**	**5**
(m)	0-20	20-50	50-150	150-200	>200
% at risk height	10	100	100	60	0

Bird Density

8.4.2.6 Red kites, golden eagles, and hen harriers use the area for foraging and therefore have more non-direct flight activity for which estimating density using a non-directional method is the appropriate model. Areal bird density (DA) was calculated from flight activity as follows:

$D_A = b/(t \times A)$ birds km^{-2}

where:

1 NatureScot (2024). Guidance on using an updated collision risk model to assess bird collision risk at onshore wind farms. NatureScot Guidance Note. https://www.nature.scot/doc/guidance-using-updated-collision-risk-model-assess-bird-collision-risk-onshore-wind-farms. [Accessed in April 2025].

(b) is the number of flight seconds at risk height observed within the flight risk area;

(t) is the time (in seconds) that the flight risk area was watched during the period;

(A) is the total area of the flight risk buffers.

8.4.2.7 Collision risk calculations were done using the latest NatureScot guidance and Excel template for collision risk modelling (NatureScot, 2024)[2]. Due to significant overlap of VPs and variation in flight activity between VPs, we calculated bird density for each VP in each month and then averaged the result. Survey data were then aggregated by month and analysed by season (breeding and non-breeding) as well as annually.

Red Kite

8.4.2.8 The observed flight activity of red kites is shown in Table 8.4.2. Flight data was used to quantify seconds at risk height derive bird density for the CRM.

Table 8.4.2: Observed red kite flight activity across entire survey period and entire VP area[3].

Date	Time	VP	No. of birds	Duration (seconds)	Duration * no. birds (seconds)	Duration of flight at RSH[1] (seconds * no. birds)	Season
2023-09-17	12:14	3	1	386	386	335.6	Nonbreeding
2023-09-18	15:34	1	1	63	63	49.5	Nonbreeding
2023-09-18	12:26	2	2	63	126	120.6	Nonbreeding
2023-09-21	15:23	2	1	38	38	38	Nonbreeding
2023-09-22	11:16	3	1	12	12	1.2	Nonbreeding
2023-10-09	14:16	2	1	156	156	0	Nonbreeding
2023-10-14	10:53	2	1	18	18	15.3	Nonbreeding
2023-10-31	9:55	3	1	50	50	50	Nonbreeding
2023-11-14	10:59	2	1	68	68	20.3	Nonbreeding
2023-11-15	11:13	3	1	69	69	6.9	Nonbreeding
2024-01-25	11:03	4	1	32	32	32	Nonbreeding
2024-01-29	13:02	1	1	56	56	56	Nonbreeding
2024-02-19	10:55	4	1	30	30	18	Nonbreeding
2024-02-19	11:05	4	1	44	44	44	Nonbreeding
2024-02-19	11:31	4	1	21	21	7.5	Nonbreeding
2024-02-19	11:45	4	1	71	71	71	Nonbreeding
2024-02-21	10:44	3	2	61	122	122	Nonbreeding
2024-02-21	10:03	3	1	17	17	1.7	Nonbreeding
2024-02-22	12:01	1	1	107	107	93.5	Nonbreeding
2024-02-22	12:01	1	1	80	80	62	Nonbreeding
2024-02-22	12:03	1	1	121	121	9.6	Nonbreeding

Table 8.4.2: Observed red kite flight activity across entire survey period and entire VP area[3].

Date	Time	VP	No. of birds	Duration (seconds)	Duration * no. birds (seconds)	Duration of flight at RSH[1] (seconds * no. birds)	Season
2024-02-26	10:33	1	1	84	84	84	Nonbreeding
2024-02-26	10:58	1	1	59	59	53	Nonbreeding
2024-03-04	9:32	1	2	157	314	140.4	Breeding
2024-03-04	9:59	1	1	204	204	111	Breeding
2024-03-04	10:24	1	1	154	154	142	Breeding
2024-03-04	10:24	1	1	36	36	21.6	Breeding
2024-03-04	10:38	1	1	96	96	96	Breeding
2024-03-04	11:46	2	1	97	97	76.2	Breeding
2024-03-04	11:50	2	2	41	82	82	Breeding
2024-03-04	11:51	2	3	211	633	189	Breeding
2024-03-04	11:51	2	2	170	340	312	Breeding
2024-03-04	11:52	2	2	37	74	74	Breeding
2024-03-04	12:09	2	1	344	344	344	Breeding
2024-03-04	12:26	2	1	197	197	197	Breeding
2024-03-04	13:03	2	1	147	147	136.2	Breeding
2024-03-04	13:40	2	2	56	112	112	Breeding
2024-03-04	13:49	2	2	71	142	106.2	Breeding
2024-03-05	8:35	2	1	99	99	99	Breeding
2024-03-05	11:31	4	1	15	15	15	Breeding
2024-03-05	13:25	4	1	61	61	61	Breeding
2024-03-25	12:16	1	2	73	146	146	Breeding
2024-04-06	10:59	2	1	200	200	173	Breeding
2024-04-06	12:48	3	2	65	130	130	Breeding
2024-04-06	13:14	3	1	42	42	17.7	Breeding
2024-04-09	13:46	3	1	133	133	133	Breeding
2024-04-09	13:47	3	1	30	30	30	Breeding
2024-04-09	13:52	3	1	5	5	5	Breeding
2024-04-10	10:22	1	1	81	81	35.1	Breeding
2024-04-17	15:45	1	1	84	84	84	Breeding
2024-04-17	16:37	1	1	93	93	93	Breeding
2024-04-19	12:05	2	1	76	76	76	Breeding
2024-04-19	14:23	2	1	63	63	63	Breeding

[2] Ibid

[3] Note that duration of flight at RSH is only shown for flights within the flight risk area (turbine + 580 m) that were considered in CRM model.

Table 8.4.2: Observed red kite flight activity across entire survey period and entire VP area[3].

Date	Time	VP	No. of birds	Duration (seconds)	Duration * no. birds (seconds)	Duration of flight at RSH[1] (seconds * no. birds)	Season
2024-04-19	14:23	2	1	194	194	140.9	Breeding
2024-05-02	14:06	1	1	8	8	0.8	Breeding
2024-05-02	14:23	1	1	60	60	60	Breeding
2024-05-02	16:13	1	1	16	16	16	Breeding
2024-05-02	12:10	2	1	119	119	95.4	Breeding
2024-05-02	12:35	2	1	53	53	32.3	Breeding
2024-06-04	13:11	2	1	195	195	124.8	Breeding
2024-06-04	13:27	2	1	121	121	91.3	Breeding
2024-06-13	12:16	4	1	55	55	35.2	Breeding
2024-06-13	12:27	4	1	56	56	56	Breeding
2024-06-16	12:35	3	1	37	37	37	Breeding
2024-07-08	10:59	3	1	220	220	179.5	Nonbreeding
2024-07-08	10:05	3	2	557	1114	660.4	Nonbreeding
2024-07-09	16:13	3	1	110	110	11	Nonbreeding
2024-07-09	16:22	3	1	83	83	33.5	Nonbreeding
2024-07-11	13:53	4	1	90	90	9	Nonbreeding
2024-08-15	15:30	2	1	41	41	4.1	Nonbreeding
2024-08-25	14:07	4	1	67	67	6.7	Nonbreeding

8.4.2.9 For the red kite flights that intersected the flight risk window, total flight time (duration * birds) was 8,699 seconds, of which 6,186 seconds or 71.1% was at rotor-swept height.

8.4.2.10 Tables 8.4.3 and 8.4.4 show the calculation of red kite density in the breeding and nonbreeding seasons (SNH, *Breeding Seasons for Scotland's Birds*, 2014[4]) based on the observations between September 2023 to September 2024.

Table 8.4.3: Red kite flight activity density in the VP area during the breeding season (March to July)

Month	Year		VP area[1] (km²) (*A*)	Watch duration (hours)	Watch duration (seconds) (*t*)	Duration in flight at RSH (bird-secs) (*b*)	Density at RSH (birds/km²) (D_A)
Mar	2024	1	3.65360301	6	21600	657	0.008325115
Apr	2024	1	3.65360301	6	21600	212.1	0.002687606
May	2024	1	3.65360301	6	21600	76.8	0.000973164

Table 8.4.3: Red kite flight activity density in the VP area during the breeding season (March to July)

Month	Year		VP area[1] (km²) (*A*)	Watch duration (hours)	Watch duration (seconds) (*t*)	Duration in flight at RSH (bird-secs) (*b*)	Density at RSH (birds/km²) (D_A)
Jun	2024	1	3.65360301	6	21600	0	0
Jul	2024	1	3.65360301	6	21600	0	0
Mar	2024	2	3.82366482	6	21600	1727.6	0.020917493
Apr	2024	2	3.82366482	6	21600	452.9	0.005483638
May	2024	2	3.82366482	6	21600	127.7	0.00154617
Jun	2024	2	3.82366482	6	21600	216.1	0.002616503
Jul	2024	2	3.82366482	6	21600	0	0
Mar	2024	3	3.56322208	6	21600	0	0
Apr	2024	3	3.56322208	6	21600	315.7	0.004101833
May	2024	3	3.56322208	6	21600	0	0
Jun	2024	3	3.56322208	6	21600	37	0.000480734
Jul	2024	3	3.56322208	6	21600	884.4	0.011490848
Mar	2024	4	3.57191963	6	21600	76	0.00098505
Apr	2024	4	3.57191963	6	21600	0	0
May	2024	4	3.57191963	6	21600	0	0
Jun	2024	4	3.56322208	6	21600	91.2	0.001184945
Jul	2024	4	3.57191963	6	21600	9	0.000116651
Average bird density							**0003045**
SD							**0.005233**
Upper estimate of bird density (average + 1SD)							**0.008279**

Table 8.4.4: Red Kite flight activity density in the VP survey area during the non-breeding season (August to February)

Month	Year	VP	Flight risk area[1] (km²) (*A*)	Watch duration (hours)	Watch duration (seconds) (*t*)	Duration in flight at RSH (bird-secs) (*b*)	Density at RSH (birds/km²) (D_A)
Sep	2023	1	3.65360301	6	21600	49.5	0.000627235
Oct	2023	1	3.65360301	6	21600	0	0
Nov	2023	1	3.65360301	6	21600	0	0
Dec	2023	1	3.65360301	6	21600	0	0
Jan	2024	1	3.65360301	6	21600	56	0.000709599

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Table 8.4.4: Red Kite flight activity density in the VP survey area during the non-breeding season (August to February)

Month	Year	VP	Flight risk area[1] (km²) (*A*)	Watch duration (hours)	Watch duration (seconds) (*t*)	Duration in flight at RSH (bird-secs) (*b*)	Density at RSH (birds/km²) (D_A)
Feb	2024	1	3.65360301	6	21600	302.1	0.003828033
Aug	2024	1	3.65360301	6	21600	0	0
Sep	2023	2	3.82366482	6	21600	158.6	0.001920302
Oct	2023	2	3.82366482	6	21600	15.3	0.00018525
Nov	2023	2	3.82366482	6	21600	20.3	0.000245789
Dec	2023	2	3.82366482	6	21600	0	0
Jan	2024	2	3.82366482	6	21600	0	0
Feb	2024	2	3.82366482	6	21600	0	0
Aug	2024	2	3.82366482	6	21600	4.1	4.96421E-05
Sep	2023	3	3.56322208	6	21600	336.8	0.004375981
Oct	2023	3	3.56322208	6	21600	50	0.000649641
Nov	2023	3	3.56322208	6	21600	6.9	8.96504E-05
Dec	2023	3	3.56322208	6	21600	0	0
Jan	2024	3	3.56322208	6	21600	0	0
Feb	2024	3	3.56322208	6	21600	123.7	0.001607212
Aug	2024	3	3.56322208	6	21600	0	0
Sep	2023	4	3.57191963	6	21600	0	0
Oct	2023	4	3.57191963	6	21600	0	0
Nov	2023	4	3.57191963	6	21600	0	0
Dec	2023	4	3.57191963	6	21600	0	0
Jan	2024	4	3.57191963	6	21600	32	0.000414758
Feb	2024	4	3.57191963	6	21600	140.5	0.001821046
Aug	2024	4	3.56322208	6	21600	6.7	8.70519E-05
						Mean bird density	**0.000593257**
						SD	**0.00114081**
						Upper estimate of bird density (average + 1 SD)	**0.001734**

Golden eagle

8.4.2.11 The observed flight activity of golden eagles is shown in Table 8.4.5 Flight data was used to quantify seconds at risk height and derive bird density for the CRM.

Table 8.4.5: Observed golden eagle flight activity across entire survey period and entire VP area.

Date	Time	VP	No. of birds	Duration (seconds)	Duration * no. birds (seconds)	Duration of flight at RSH (seconds * no. birds)	Season
2023-09-28	12:47	4	1	95	95	90.5	Nonbreeding
2023-09-28	12:47	4	1	153	153	0	Nonbreeding
2023-10-14	12:16	2	1	26	26	26	Nonbreeding
2023-10-14	12:46	2	2	94	188	176	Nonbreeding
2023-10-31	12:03	3	1	95	95	95	Nonbreeding
2023-11-08	12:13	4	1	185	185	185	Nonbreeding
2024-01-26	13:18	4	1	71	71	71	Nonbreeding
2024-02-19	11:33	4	2	19	38	38	Breeding
2024-02-19	11:40	4	1	68	68	58.8	Breeding
2024-03-01	10:56	4	1	189	189	105	Breeding
2024-03-01	10:57	4	1	87	87	63	Breeding
2024-03-05	11:30	4	1	95	95	95	Breeding
2024-04-06	10:46	2	1	108	108	84	Breeding
2024-05-03	9:40	1	1	103	103	97.8	Breeding
2024-05-03	9:13	4	2	270	540	412.2	Breeding
2024-06-13	12:54	4	1	208	208	111.8	Breeding
2024-07-08	10:32	3	1	153	153	106.2	Breeding
2024-07-11	17:24	4	1	65	65	6.5	Breeding

8.4.2.12 For the golden eagle, total flight time (duration * birds) was 2,467 seconds, of which 1,821 seconds or 73.8% was at rotor-swept height.

8.4.2.13 Tables 8.4.6 and 8.4.7 show the calculation of golden eagle density in the breeding and nonbreeding seasons based on the observations between September 2023 to September 2024.

Table 8.4.6: Golden eagle flight activity density in the VP survey area during the breeding season (March to July)

Month	Year	VP	VP area (km²) (A)	Watch duration (hours)	Watch duration (seconds) (t)	Duration in flight at RSH (bird-secs) (b)	Density at RSH (birds/km²) (D_A)
Feb	2024	1	3.65360301	6	21600	0	0
Mar	2024	1	3.65360301	6	21600	0	0
Apr	2024	1	3.65360301	6	21600	0	0
May	2024	1	3.65360301	6	21600	97.8	0.001239264
Jun	2024	1	3.65360301	6	21600	0	0
Jul	2024	1	3.65360301	6	21600	0	0
Aug	2024	1	3.65360301	6	21600	0	0
Feb	2024	2	3.82366482	6	21600	0	0

Table 8.4.6: Golden eagle flight activity density in the VP survey area during the breeding season (March to July)

Month	Year	VP	VP area (km²) (A)	Watch duration (hours)	Watch duration (seconds) (t)	Duration in flight at RSH (bird-secs) (b)	Density at RSH (birds/km²) (D_A)
Mar	2024	2	3.82366482	6	21600	0	0
Apr	2024	2	3.82366482	6	21600	84	0.001017058
May	2024	2	3.82366482	6	21600	0	0
Jun	2024	2	3.82366482	6	21600	0	0
Jul	2024	2	3.82366482	6	21600	0	0
Aug	2024	2	3.82366482	6	21600	0	0
Feb	2024	3	3.56322208	6	21600	0	0
Mar	2024	3	3.56322208	6	21600	0	0
Apr	2024	3	3.56322208	6	21600	0	0
May	2024	3	3.56322208	6	21600	0	0
Jun	2024	3	3.56322208	6	21600	0	0
Jul	2024	3	3.56322208	6	21600	106.2	0.001379837
Aug	2024	3	3.56322208	6	21600	0	0
Feb	2024	4	3.57191963	6	21600	96.8	0.001254642
Mar	2024	4	3.57191963	6	21600	263	0.003408791
Apr	2024	4	3.57191963	6	21600	0	0
May	2024	4	3.57191963	6	21600	412.2	0.005342599
Jun	2024	4	3.56322208	6	21600	111.8	0.001452597
Jul	2024	4	3.57191963	6	21600	6.5	8.42477E-05
Aug	2024	4	3.57191963	6	21600	0	0
Mean bird density							**0.000562186**
SD							**0.001237167**
Upper estimate of bird density (average + 1 SD)							**0.001799**

Table 8.4.7: Golden eagle flight activity density in the VP survey area during the non-breeding season (August to February)

Month	Year	VP	VP area (km²) (*A*)	Watch duration (hours)	Watch duration (seconds) (*t*)	Duration in flight at RSH (bird-secs) (*b*)	Density at RSH (birds/km²) (D_A)
Sep	2023	1	3.65360301	6	21600	0	0
Oct	2023	1	3.65360301	6	21600	0	0
Nov	2023	1	3.65360301	6	21600	0	0
Dec	2023	1	3.65360301	6	21600	0	0

Table 8.4.7: Golden eagle flight activity density in the VP survey area during the non-breeding season (August to February)

Month	Year	VP	VP area (km²) (*A*)	Watch duration (hours)	Watch duration (seconds) (*t*)	Duration in flight at RSH (bird-secs) (*b*)	Density at RSH (birds/km²) (D_A)
Jan	2024	1	3.65360301	6	21600	0	0
Sep	2023	2	3.82366482	6	21600	0	0
Oct	2023	2	3.82366482	6	21600	202	0.002445782
Nov	2023	2	3.82366482	6	21600	0	0
Dec	2023	2	3.82366482	6	21600	0	0
Jan	2024	2	3.82366482	6	21600	0	0
Sep	2023	3	3.56322208	6	21600	0	0
Oct	2023	3	3.56322208	6	21600	95	0.001234318
Nov	2023	3	3.56322208	6	21600	0	0
Dec	2023	3	3.56322208	6	21600	0	0
Jan	2024	3	3.56322208	6	21600	0	0
Sep	2023	4	3.57191963	6	21600	90.5	0.001172987
Oct	2023	4	3.57191963	6	21600	0	0
Nov	2023	4	3.57191963	6	21600	185	0.002397818
Dec	2023	4	3.57191963	6	21600	0	0
Jan	2024	4	3.57191963	6	21600	71	0.000920244
Mean bird density							**0.000408557**
SD							**0.000799318**
Upper estimate of bird density (average + 1 SD)							**0.001208**

Hen harrier

8.4.2.14 The observed flight activity of hen harrier is shown in Table 8.4.8 Flight data was used to quantify seconds at risk height and derive bird density for the CRM.

Table 8.4.8: Observed hen harrier flight activity across entire survey period and entire VP area.

Date	Time	VP	No. of birds	Duration (seconds)	Duration * no. birds (seconds)	Duration of flight at RSH (seconds * no. birds)	Season
2024-04-02	11:39	4	1	124	124	39.4	Breeding
2024-04-02	11:52	4	1	173	173	71.3	Breeding
2024-04-09	15:47	4	1	78	78	7.8	Breeding
2024-04-10	7:51	1	1	80	80	80	Breeding
2024-04-10	8:44	1	1	517	517	517	Breeding
2024-04-10	9:53	1	1	348	348	267	Breeding

Table 8.4.8: Observed hen harrier flight activity across entire survey period and entire VP area.

Date	Time	VP	No. of birds	Duration (seconds)	Duration * no. birds (seconds)	Duration of flight at RSH (seconds * no. birds)	Season
2024-04-10	10:16	1	1	131	131	131	Breeding
2024-05-01	10:34	3	1	65	65	6.5	Breeding
2024-05-01	10:41	3	1	206	206	161	Breeding
2024-05-01	10:58	3	1	235	235	184.6	Breeding
2024-05-01	11:54	3	1	211	211	84.1	Breeding
2024-05-03	8:58	4	1	179	179	179	Breeding
2024-05-04	10:42	4	1	124	124	12.4	Breeding

8.4.2.15 For flights that intersected the flight risk window, total flight time (duration * birds) was 2,471 seconds, of which 1,741 seconds or 70.5% was at rotor-swept height.

8.4.2.16 Table 8.4.9 shows the calculation of hen harrier density in the breeding season, based on the observations between September 2023 to September 2024. Note that hen harriers were not present during the non-breeding season.

Table 8.4.9: Hen harrier flight activity density in the VP surveys during the breeding season (March to July)

Month	Year	VP	VP area (km²) (*A*)	Watch duration (hours)	Watch duration (seconds) (*t*)	Duration in flight at RSH (bird-secs) (*b*)	Density at RSH (birds/km²) (D_A)
Mar	2024	1	3.65360301	6	21600	0	0
Apr	2024	1	3.65360301	6	21600	0	0
May	2024	1	3.65360301	6	21600	0	0
Jun	2024	1	3.65360301	6	21600	0	0
Jul	2024	1	3.65360301	6	21600	0	0
Aug	2024	1	3.65360301	6	21600	0	0
Mar	2024	2	3.82366482	6	21600	0	0
Apr	2024	2	3.82366482	6	21600	0	0
May	2024	2	3.82366482	6	21600	0	0
Jun	2024	2	3.82366482	6	21600	0	0
Jul	2024	2	3.82366482	6	21600	0	0
Aug	2024	2	3.82366482	6	21600	0	0
Mar	2024	3	3.56322208	6	21600	0	0
Apr	2024	3	3.56322208	6	21600	0	0
May	2024	3	3.56322208	6	21600	436.2	0.005667467
Jun	2024	3	3.56322208	6	21600	0	0
Jul	2024	3	3.56322208	6	21600	0	0
Aug	2024	3	3.56322208	6	21600	0	0
Mar	2024	4	3.57191963	6	21600	0	0
Apr	2024	4	3.57191963	6	21600	118.5	0.0015359
May	2024	4	3.57191963	6	21600	191.4	0.00248077
Jun	2024	4	3.56322208	6	21600	0	0
Jul	2024	4	3.57191963	6	21600	0	0
Aug	2024	4	3.57191963	6	21600	0	0
Mean bird density							**0.000403506**
SD							**0.001263635**
Upper estimate of bird density (average + 1 SD)							**0.001667**

Stage A CRM Bird Density

8.4.2.17 Table 8.4.10 shows the monthly bird densities (DA) which were input to the model spreadsheet. Q2R was set to 1 (see Flight Height).

Table 8.4.10: Stage 1 data input to spreadsheet												
Average[1] estimated monthly bird density (bird-secs/km²)												
Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Red kite	0.00059	0.00059	0.00305	0.00305	0.00305	0.00305	0.00305	0.00059	0.00059	0.00059	0.00059	0.00059
Golden eagle	0.00041	0.00056	0.00056	0.00056	0.00056	0.00056	0.00056	0.00056	0.00041	0.00041	0.00041	0.00041
Hen harrier	0.00000	0.00000	0.00000	0.00040	0.00040	0.00040	0.00040	0.00040	0.00000	0.00000	0.00000	0.00000
Upper[2] estimated monthly bird density (bird-secs/km²)												
Red kite	0.00173	0.00173	0.00828	0.00828	0.00828	0.00828	0.00828	0.00173	0.00173	0.00173	0.00173	0.00173
Golden eagle	0.00121	0.00180	0.00180	0.00180	0.00180	0.00180	0.00180	0.00180	0.00121	0.00121	0.00121	0.00121
Hen harrier	0.00000	0.00000	0.00000	0.00167	0.00167	0.00167	0.00167	0.00167	0.00000	0.00000	0.00000	0.00000

[1] Average density from monthly VP density values within each season.

[2] Calculated as average density from month VP density values within each season plus a standard deviation.

8.4.3 Stage B to Stage E: Estimating Collision Risk

Bird Model Parameters

8.4.3.1 Bird biometrics, wind farm parameters, and turbine specifications required by the NatureScot spreadsheet (NatureScot, 2024)[5,6] to estimate the risk of collision are shown in Table 8.4.11 and Table 8.4.12.

Table 8.4.11: Model parameters for bird species			
Parameter	**Red kite**	**Golden eagle**	**Hen harrier**
Breeding season	Mar - Jul	Feb - Aug	Apr to Aug
Non-breeding season	Aug - Feb	Sep - Jan	Sep to Mar
Length (m)	0.63	0.82	0.48
Wingspan (m)	1.85	2.12	1.1
Flight speed (m/s)	11	15	12
Flight type	Gliding	Gliding	Flapping

Table 8.4.11: Model parameters for bird species

Parameter	**Red kite**	**Golden eagle**	**Hen harrier**
% of flights upwind/ downwind (%)	50	50	50
Nocturnal activity factor	1 (0%)	1 (0%)	1 (0%)
Avoidance rate (%)	99	99	99

8.4.3.2 To define breeding and non-breeding seasons, previous guidance from SNH was referenced (now NatureScot) (SNH, Breeding Seasons for Scotland's Birds, 2014)[7]. Monthly daytime and night-time hours during each month were calculated by the NatureScot (2024) spreadsheet using the wind farm latitude.

8.4.3.3 Biological parameters (length and wingspan) were obtained from Provan and Whitfield (2006)[8,9]. Flight speed was also obtained from Provan and Whitfield (2006), except for the Red kite, which was obtained from Aschwanden, Stark, and Liechti (2024)[10]. Red kite and Golden eagle flight was characterised as 'gliding' as they are most likely to be soaring with little use of flapping flight when

[5] NatureScot (2024). Guidance on using an updated collision risk model to assess bird collision risk at onshore wind farms. NatureScot Guidance Note. https://www.nature.scot/doc/guidance-using-updated-collision-risk-model-assess-bird-collision-risk-onshore-wind-farms. [Accessed in April 2025].

[6] Band, W. (2024). Using a collision risk model to assess bird collision risks for onshore wind farms. NatureScot Commissioned Report No. 909.

[7] Scottish Natural Heritage (SNH) (2014). Breeding season dates for key breeding species in Scotland. https://web.archive.org/web/20220613155315/www.nature.scot/sites/default/files/2017-07/A303080%20-%20Bird%20Breeding%20Season%20Dates%20in%20Scotland.pdf. [Accessed in April 2025].

[8] Provan, S. & Whitfield, D.P. (2006). Avian Flight Speeds and Biometrics for Use in Collision Risk Modelling. Unpublished Report to Scottish Natural Heritage. Available from https://www.nature.scot/doc/wind-farm-impacts-birds-flight-speeds-and-biometrics-collision-risk-modelling [Accessed: 17 March 2026]

[9] Urquhart, B. & Whitfield, D.P. (201)6. Derivation of an avoidance rate for red kite Milvus milvus suitable for onshore wind farm collision risk modelling. Natural Research Information Note 7. Natural Research Ltd, Banchory, UK.

[10] Aschwanden, J., Stark, H., and Liechti, F. (2024). Flight behaviour of Red Kites within their breeding area in relation to local weather variables: Conclusions with regard to wind turbine collision mitigation. Journal of Applied Ecology, 00, 1–12. https://doi.org/10.1111/1365-2664.14739

roaming the wind farm area at potential risk height (>18 m). Hen harrier flight was characterised as 'flapping'.

8.4.3.4 Raptors, as highly visual predators, are not expected to make frequent nocturnal flights, so the nocturnal activity factor is set to 1 (0% flight activity at night) for all three species. Avoidance rates were obtained from the sources listed by NatureScot (2024) wind farm parameters[11].

8.4.3.5 The CRM has been conducted using appropriate parameters for the wind farm and candidate turbine, Vestas V162 6.5 MW. No large array correction was applied in the model.

8.4.3.6 Two of the turbine parameters used in the modelling process, the angle of pitch and rotational speed of the rotors, vary depending upon wind conditions. For the purposes of this assessment, turbine parameters with uncertainty were modelled with reasonably conservative assumptions. This assessment uses maximum rotational speed (10 rpm), a moderate pitch angle within the range suggested by NatureScot (15, turbine model can vary from 0-90), and an operational time scenario of 85% (15% downtime).

Table 8.4.12: Model parameters for the wind farm

Parameter	Value
Wind farm latitude (°)	57.71
Wind farm width (km)	2.8
Number of turbines	9
Rotor radius (m)	81
Number of rotor blades per turbine	3
Hub height (m)	99
Max blade width (m)	4
Blade pitch (°)	15
Rotation speed (rpm)	10
Risk height range (m)	18-180
Operational down-time (%)	15%

8.4.4 Collision Risk Modelling Results

Red Kite

8.4.4.1 The results of the collision risk calculations for the three target species are set out in Table 8.4.13 and Table 8.4.14. For detailed CRM outputs, including number of rotor transits and results without avoidance rate applied, see Annex 1: CRM Spreadsheets (attached).

Table 8.4.13: Estimated collision risk - number of collisions per year

	Mid estimate			Upper estimate		
Species	**Breeding season**	**Non-breeding season**	**Annual**	**Breeding season**	**Non-breeding season**	**Annual**
Red kite	0.18	0.02	0.20	0.49	0.09	0.58
Golden eagle	0.05	0.02	0.07	0.14	0.09	0.23
Hen harrier	0.03	0	0.03	0.1	0	0.1

Table 8.4.14: Estimated collision risk - number of years per collision

	Mid estimate			Upper estimate		
Species	**Breeding season**	**Non-breeding season**	**Annual**	**Breeding season**	**Non-breeding season**	**Annual**
Red kite	5.6	50	5	2.0	11.1	1.666667
Golden eagle	20.0	50	10	7.1	11.1	5
Hen harrier	N/A	N/A	N/A	10.0	N/A	10

Uncertainty

8.4.4.2 As described in NatureScot (2024), sources of uncertainty (or variability) may exist in the CRM output, and may include, but are not limited to:

- Variability or imprecision in flight activity data (e.g., flight heigh estimates, assumptions about bird species behaviour, etc.),
- Uncertainty associated with model parameters (e.g., variability in estimating bird dimensions or flight speeds, etc.),
- Uncertainty surrounding operational parameters of turbines yet to be decided (e.g., number and/or size of turbines, or speed of rotors).

8.4.4.3 Because it is unlikely that sources of uncertainty can be represented by detailed statistical analysis, the CRM estimate reflects a qualitative range of uncertainty by including a 'best estimate' range of confidence.

8.4.4.4 To reasonably estimate the uncertainty the collision risk was calculated and summarized using both average estimated bird density and an upper estimate of average density plus 1 standard deviation. Both the average and upper estimates have been included in flight risk model results presented in Tables 8.4.13 and 8.4.14. Importantly, the average density estimates minus 1 standard deviation results in zero predicted annual collisions for all three focal species: the Red kite, Golden eagle, and Hen harrier. Additionally, there is variability in pitch, rotational speed, and operational downtime that affect collision risk. We therefore chose conservative, but reasonable, assumptions for these parameters (see section 8.4.3).

[11] NatureScot (2025). Wind farm impacts on birds - Use of Avoidance Rates in the NatureScot Wind Farm Collision Risk Model. Updated: March 2025. https://www.nature.scot/doc/wind-farm-impacts-birds-use-avoidance-rates-naturescot-wind-farm-collision-risk-model. [Accessed in April 2025].

8.4.4.5 The collision risk model shows that, with reasonably conservative operational parameters and considering 1 standard deviation around density estimates, the wind farm may result in 0-0.4 collisions with Red kites per year with an average estimate of **0.2 collisions per year**. For Golden eagles, the wind farm may result in between 0-0.23 collisions with Golden eagles per year with an average estimate of **0.07 collisions per year**. For Hen harriers, the wind farm may result in 0-0.1 collisions with Hen harriers per year with an average estimate of **0.03 collisions per year**. The range of uncertainty is large with Collision Risk Models, and GPS tagging results indicate that large raptors such as Golden eagles avoid operational wind farms (macro-avoidance; Fielding *et al.* 2022) in addition to last minute avoidance of collisions (micro-avoidance) considered in the CRM approach used here.[12] Therefore, even the average estimates may overestimate the risk of mortality to birds. At less than one bird mortality per year on average, the wind farm as proposed is unlikely to have an effect on the populations of any of the three target species.

[12] Fielding *et al* (2022). Responses of dispersing GPS-tagged Golden Eagles (Aquila chrysaetos) to multiple wind farms across Scotland. Available at: https://onlinelibrary.wiley.com/doi/epdf/10.1111/ibi.12996?msockid=0da11fb5b11a6ed6144d0e3eb51a68ea [Accessed September 2026].

Annex 1: CRM Spreadsheets

Collision risk model for red kite using average density estimate

COLLISION RISK MODEL

Required input data is in **orange** boxes
Calculated output is in **blue** boxes
green boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		Red kite	
Bird length	L	0.63	m
Wingspan	W	1.85	m
Bird flight speed	v	11	m s^{-1}
Flight type, flapping or gliding		gliding	
% of flights upwind/downwind		50%	50%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		Novar Repowering	
Latitude		57.71	degrees
No of turbines	T	9	
Width of windfarm	w	2.8	km

		Value	Units
Turbine data			
Model		Vestas V162 6.5MW	
Hub height		99	m
Rotor radius	R	81	m
No of blades	b	3	
Rotation speed	Ω	10	rpm
Max blade width	C	4	m
Blade pitch	λ	15	degrees
Risk height range		18-180	m

normal approach

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A	birds/km^2	0.0017341	0.0017341	0.0082785	0.0082785	0.0082785	0.0082785	0.0082785	0.0017341	0.0017341	0.0017341	0.0017341	0.0017341	0.0045
Proportion at rotor risk height	Q_{2R}	100.00%													
At latitude 57.7		Daylight hours per month	227.1	261.9	365.0	428.9	514.8	538.7	538.5	475.0	386.3	321.7	241.6	207.0	4506.5
		Nighttime hours per month	516.9	410.1	379.0	291.1	229.2	181.3	205.5	269.0	333.7	422.3	478.4	537.0	4253.5

Stage B

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	9														
Rotor radius	R	81 m														
		Total rotor frontal area m^2	185508													
Nocturnal activity factor	f_{night}	0%														
Bird flight speed	v	11 m s^{-1}														
		Projected number of rotor transits		17.9	20.6	137.0	161.0	193.3	202.2	202.2	37.3	30.4	25.3	19.0	16.3	**1062**

Stage C

No of blades	b	3		Bird length	l	0.63	m								
Rotation speed	Ω	10	rpm	Wingspan	w	1.85	m								
Rotor radius	R	81	m	Bird flight speed	v	11	m s^{-1}								
Max blade width	C	4	m	Flight type		gliding									
Pitch	λ	15	degrees	% of flights upwind/downwind		50%	50%								
Blade profile		see Blade profile sheet													
		Single transit risk	upwind	7.77%											
			downwind	4.29%											
			weighted mean	**6.03%**											

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.92	1.06	7.02	8.25	9.91	10.37	10.36	1.91	1.56	1.30	0.97	0.83	**54**

Stage E

Allow for large array correction? No
Width of windfarm w 2.8 km

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
	large array correction		Collision rates allowing for avoidance												
Avoidance rates modelled	95.00%	100.00%	0.05	0.05	0.35	0.41	0.50	0.52	0.52	0.10	0.08	0.06	0.05	0.04	**2.7**
	98.00%	100.00%	0.02	0.02	0.14	0.17	0.20	0.21	0.21	0.04	0.03	0.03	0.02	0.02	**1.1**
	99.00%	100.00%	0.01	0.01	0.07	0.08	0.10	0.10	0.10	0.02	0.02	0.01	0.01	0.01	**0.5**
	99.50%	100.00%	0.00	0.01	0.04	0.04	0.05	0.05	0.05	0.01	0.01	0.01	0.00	0.00	**0.3**

Collison risk model for red kite using upper density estimate

COLLISION RISK MODEL

Required input data is in **orange** boxes
Calculated output is in **blue** boxes
green boxes are for information only, to show variables used at each stage

Bird data		Value	Units
Species name		Red kite	
Bird length	L	0.63	m
Wingspan	W	1.85	m
Bird flight speed	v	11	m s^{-1}
Flight type, flapping or gliding		gliding	
% of flights upwind/downwind		50%	50%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

Windfarm data		Value	Units
Site name		Novar Repowering	
Latitude		57.71	degrees
No of turbines	T	9	
Width of windfarm	w	2.8	km

Turbine data		Value	Units
Model		Vestas V162 6.5MW	
Hub height		99	m
Rotor radius	R	81	m
No of blades	b	3	
Rotation speed	Ω	10	rpm
Max blade width	C	4	m
Blade pitch	λ	15	degrees
Risk height range		18-180	m

normal approach

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A		birds/km^2	0.0017341	0.0017341	0.0082785	0.0082785	0.0082785	0.0082785	0.0082785	0.0017341	0.0017341	0.0017341	0.0017341	0.0017341	0.0045
Proportion at rotor risk height	Q_{2R}	100.00%														
At latitude 57.7		Daylight hours per month		227.1	261.9	365.0	428.9	514.8	538.7	538.5	475.0	386.3	321.7	241.6	207.0	4506.5
		Nighttime hours per month		516.9	410.1	379.0	291.1	229.2	181.3	205.5	269.0	333.7	422.3	478.4	537.0	4253.5

Stage B

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	9															
Rotor radius	R	81	m														
		Total rotor frontal area m^2		185508													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	11	m s^{-1}														
		Projected number of rotor transits			17.9	20.6	137.0	161.0	193.3	202.2	202.2	37.3	30.4	25.3	19.0	16.3	**1062**

Stage C

No of blades	b	3		Bird length	l	0.63	m	
Rotation speed	Ω	10	rpm	Wingspan	w	1.85	m	
Rotor radius	R	81	m	Bird flight speed	v	11	m s^{-1}	
Max blade width	C	4	m	Flight type		gliding		
Pitch	λ	15	degrees	% of flights upwind/downwind		50%		50%
Blade profile		see Blade profile sheet						

Single transit risk	upwind	7.77%
	downwind	4.29%
	weighted mean	**6.03%**

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.92	1.06	7.02	8.25	9.91	10.37	10.36	1.91	1.56	1.30	0.97	0.83	**54**

Stage E

Allow for large array correction? No
Width of windfarm w 2.8 km

			large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
				Collision rates allowing for avoidance												
Avoidance rates modelled		95.00%	100.00%	0.05	0.05	0.35	0.41	0.50	0.52	0.52	0.10	0.08	0.06	0.05	0.04	**2.7**
		98.00%	100.00%	0.02	0.02	0.14	0.17	0.20	0.21	0.21	0.04	0.03	0.03	0.02	0.02	**1.1**
		99.00%	100.00%	0.01	0.01	0.07	0.08	0.10	0.10	0.10	0.02	0.02	0.01	0.01	0.01	**0.5**
		99.50%	100.00%	0.00	0.01	0.04	0.04	0.05	0.05	0.05	0.01	0.01	0.01	0.00	0.00	**0.3**

Collision risk model for golden eagle using average density estimate

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

Bird data		Value	Units
Species name		Golden eagle	
Bird length	L	0.82	m
Wingspan	W	2.12	m
Bird flight speed	v	15	m s^{-1}
Flight type, flapping or gliding		gliding	
% of flights upwind/downwind		50%	50%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

Windfarm data		Value	Units
Site name		Novar Repowering	
Latitude		57.71	degrees
No of turbines	T	9	
Width of windfarm	w	2.8	km

Turbine data		Value	Units
Model		Vestas V162 6.5MW	
Hub height		99	m
Rotor radius	R	81	m
No of blades	b	3	
Rotation speed	Ω	10	rpm
Max blade width	C	4	m
Blade pitch	λ	15	degrees
Risk height range		18-180	m

normal approach

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A	birds/km^2	0.0004086	0.0005622	0.0005622	0.0005622	0.0005622	0.0005622	0.0005622	0.0005622	0.0004086	0.0004086	0.0004086	0.0004086	0.0005
Proportion at rotor risk height	Q_{ZR}	100.00%													
At latitude 57.7		Daylight hours per month	227.1	261.9	365.0	428.9	514.8	538.7	538.5	475.0	386.3	321.7	241.6	207.0	4506.5
		Nighttime hours per month	516.9	410.1	379.0	291.1	229.2	181.3	205.5	269.0	333.7	422.3	478.4	537.0	4253.5

Stage B

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	9														
Rotor radius	R	81	m													
		Total rotor frontal area m^2	185508													
Nocturnal activity factor	f_{night}	0%														
Bird flight speed	v	15	m s^{-1}													
		Projected number of rotor transits		5.7	9.1	12.7	14.9	17.9	18.7	18.7	16.5	9.8	8.1	6.1	5.2	**144**

Stage C

No of blades	b	3		Bird length	l	0.82	m
Rotation speed	Ω	10	rpm	Wingspan	w	2.12	m
Rotor radius	R	81	m	Bird flight speed	v	15	m s^{-1}
Max blade width	C	4	m	Flight type		gliding	
Pitch	λ	15	degrees	% of flights upwind/downwind		50%	50%
Blade profile		see Blade profile sheet					
		Single transit risk	upwind	7.77%			
			downwind	4.29%			
			weighted mean	**6.03%**			

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.29	0.47	0.65	0.76	0.92	0.96	0.96	0.85	0.50	0.42	0.31	0.27	**7**

Stage E

Allow for large array correction? No
Width of windfarm w 2.8 km

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
		large array correction	Collision rates allowing for avoidance												
Avoidance rates modelled	95.00%	100.00%	0.01	0.02	0.03	0.04	0.05	0.05	0.05	0.04	0.03	0.02	0.02	0.01	**0.4**
	98.00%	100.00%	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	**0.1**
	99.00%	100.00%	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	**0.1**
	99.50%	100.00%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

Collision risk model for golden eagle using upper density estimate

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

Bird data		Value	Units
Species name		Golden eagle	
Bird length	L	0.82	m
Wingspan	W	2.12	m
Bird flight speed	v	15	m s^{-1}
Flight type, flapping or gliding		gliding	
% of flights upwind/downwind		50%	50%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

Windfarm data		Value	Units
Site name		Novar Repowering	
Latitude		57.71	degrees
No of turbines	T	9	
Width of windfarm	w	2.8	km

Turbine data		Value	Units
Model		Vestas V162 6.5MW	
Hub height		99	m
Rotor radius	R	81	m
No of blades	b	3	
Rotation speed	Ω	10	rpm
Max blade width	C	4	m
Blade pitch	λ	15	degrees
Risk height range		18-180	m

normal approach

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A		birds/km^2	0.0012079	0.0017994	0.0017994	0.0017994	0.0017994	0.0017994	0.0017994	0.0017994	0.0012079	0.0012079	0.0012079	0.0012079	0.0016
Proportion at rotor risk height	Q_{2R}	100.00%														
At latitude 57.7		Daylight hours per month		227.1	261.9	365.0	428.9	514.8	538.7	538.5	475.0	386.3	321.7	241.6	207.0	4506.5
		Nighttime hours per month		516.9	410.1	379.0	291.1	229.2	181.3	205.5	269.0	333.7	422.3	478.4	537.0	4253.5

Stage B

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	9															
Rotor radius	R	81	m														
		Total rotor frontal area m^2		185508													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	15	m s^{-1}														
		Projected number of rotor transits			17.0	29.1	40.6	47.7	57.3	59.9	59.9	52.8	28.9	24.0	18.0	15.5	**451**

Stage C

No of blades	b	3		Bird length	l	0.82	m
Rotation speed	Ω	10	rpm	Wingspan	w	2.12	m
Rotor radius	R	81	m	Bird flight speed	v	15	m s^{-1}
Max blade width	C	4	m	Flight type		gliding	
Pitch	λ	15	degrees	% of flights upwind/downwind		50%	50%
Blade profile		see Blade profile sheet					
		Single transit risk	upwind	7.77%			
			downwind	4.29%			
			weighted mean	**6.03%**			

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.87	1.49	2.08	2.45	2.94	3.07	3.07	2.71	1.48	1.23	0.92	0.79	**23**

Stage E

Allow for large array correction? No
Width of windfarm w 2.8 km

		large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
			Collision rates allowing for avoidance												
Avoidance rates modelled	95.00%	100.00%	0.04	0.07	0.10	0.12	0.15	0.15	0.15	0.14	0.07	0.06	0.05	0.04	**1.2**
	98.00%	100.00%	0.02	0.03	0.04	0.05	0.06	0.06	0.06	0.05	0.03	0.02	0.02	0.02	**0.5**
	99.00%	100.00%	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.03	0.01	0.01	0.01	0.01	**0.2**
	99.50%	100.00%	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.00	0.00	**0.1**

Collision risk for hen harrier using average density estimate.

COLLISION RISK MODEL

Required input data is in **orange** boxes
Calculated output is in **blue** boxes
green boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		Hen harrier	
Bird length	L	0.48	m
Wingspan	W	1.1	m
Bird flight speed	v	12	m s^{-1}
Flight type, flapping or gliding		flapping	
% of flights upwind/downwind		50%	50%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		Novar Repowering	
Latitude		57.71	degrees
No of turbines	T	9	
Width of windfarm	w	2.8	km

		Value	Units
Turbine data			
Model		Vestas V162 6.5MW	
Hub height		99	m
Rotor radius	R	81	m
No of blades	b	3	
Rotation speed	Ω	10	rpm
Max blade width	C	4	m
Blade pitch	λ	15	degrees
Risk height range		18-180	m

normal approach

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A	birds/km^2	0	0	0	0.0004035	0.0004035	0.0004035	0.0004035	0.0004035	0	0	0	0	0.0002
Proportion at rotor risk height	Q_{2R}	100.00%													
At latitude 57.7		Daylight hours per month	227.1	261.9	365.0	428.9	514.8	538.7	538.5	475.0	386.3	321.7	241.6	207.0	4506.5
		Nighttime hours per month	516.9	410.1	379.0	291.1	229.2	181.3	205.5	269.0	333.7	422.3	478.4	537.0	4253.5

Stage B

No of turbines	T	9													
Rotor radius	R	81	m												
		Total rotor frontal area m^2	185508												
Nocturnal activity factor	f_{night}	0%													
Bird flight speed	v	12	m s^{-1}	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
		Projected number of rotor transits		0.0	0.0	0.0	8.6	10.3	10.8	10.7	9.5	0.0	0.0	0.0	0.0	**50**

Stage C

No of blades	b	3		Bird length	l	0.48	m
Rotation speed	Ω	10	rpm	Wingspan	w	1.1	m
Rotor radius	R	81	m	Bird flight speed	v	12	m s^{-1}
Max blade width	C	4	m	Flight type		flapping	
Pitch	λ	15	degrees	% of flights upwind/downwind		50%	50%
Blade profile		see Blade profile sheet					

Single transit risk	upwind	7.77%
	downwind	4.29%
	weighted mean	**6.03%**

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.00	0.00	0.00	0.44	0.53	0.55	0.55	0.49	0.00	0.00	0.00	0.00	**3**

Stage E

Allow for large array correction?		No													
Width of windfarm	w	2.8	km												
			large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
				Collision rates allowing for avoidance												
Avoidance rates modelled		95.00%	100.00%	0.00	0.00	0.00	0.02	0.03	0.03	0.03	0.02	0.00	0.00	0.00	0.00	**0.1**
		98.00%	100.00%	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	**0.1**
		99.00%	100.00%	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	**0.0**
		99.50%	100.00%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

Collision risk model for hen harrier using upper density estimate

COLLISION RISK MODEL

Required input data is in **orange** boxes
Calculated output is in **blue** boxes
green boxes are for information only, to show variables used at each stage

Bird data		Value	Units
Species name		Hen harrier	
Bird length	L	0.48	m
Wingspan	W	1.1	m
Bird flight speed	v	12	m s^{-1}
Flight type, flapping or gliding		flapping	
% of flights upwind/downwind		50%	50%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

Windfarm data		Value	Units
Site name		Novar Repowering	
Latitude		57.71	degrees
No of turbines	T	9	
Width of windfarm	w	2.8	km

Turbine data		Value	Units
Model		Vestas V162 6.5MW	
Hub height		99	m
Rotor radius	R	81	m
No of blades	b	3	
Rotation speed	Ω	10	rpm
Max blade width	C	4	m
Blade pitch	λ	15	degrees
Risk height range		18-180	m

normal approach

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A	birds/km^2	0	0	0	0.0016671	0.0016671	0.0016671	0.0016671	0.0016671	0	0	0	0	0.0007
Proportion at rotor risk height	Q_{2R}	100.00%													
At latitude 57.7		Daylight hours per month	227.1	261.9	365.0	428.9	514.8	538.7	538.5	475.0	386.3	321.7	241.6	207.0	4506.5
		Nighttime hours per month	516.9	410.1	379.0	291.1	229.2	181.3	205.5	269.0	333.7	422.3	478.4	537.0	4253.5

Stage B

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	9														
Rotor radius	R	81	m													
		Total rotor frontal area m^2	185508													
Nocturnal activity factor	f_{night}	0%														
Bird flight speed	v	12	m s^{-1}													
		Projected number of rotor transits		0.0	0.0	0.0	35.4	42.5	44.4	44.4	39.2	0.0	0.0	0.0	0.0	**206**

Stage C

No of blades	b	3		Bird length	l	0.48	m
Rotation speed	Ω	10	rpm	Wingspan	w	1.1	m
Rotor radius	R	81	m	Bird flight speed	v	12	m s^{-1}
Max blade width	C	4	m	Flight type		flapping	
Pitch	λ	15	degrees	% of flights upwind/downwind		50%	50%
Blade profile		see Blade profile sheet					
		Single transit risk	upwind	7.77%			
			downwind	4.29%			
			weighted mean	**6.03%**			

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.00	0.00	0.00	**1.81**	**2.18**	**2.28**	**2.28**	**2.01**	0.00	0.00	0.00	0.00	**11**

Stage E

Allow for large array correction? No
Width of windfarm w 2.8 km

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
		large array correction	Collision rates allowing for avoidance												
Avoidance rates modelled	95.00%	100.00%	0.00	0.00	0.00	0.09	0.11	**0.11**	**0.11**	0.10	0.00	0.00	0.00	0.00	**0.5**
	98.00%	100.00%	0.00	0.00	0.00	0.04	0.04	0.05	0.05	0.04	0.00	0.00	0.00	0.00	**0.2**
	99.00%	100.00%	0.00	0.00	0.00	0.02	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00	**0.1**
	99.50%	100.00%	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	**0.1**