PREDICTED COLLISIONS AT EDINBANE, JAN-JUL

SUMMARY

Collision risk models based on observed flight activity at 20-100m elevation during the period January to July were constructed using data provided by S. Lawrence. It was assumed that the windfarm comprised 27 x V66 type turbines. The models indicated that approximately 0.45 golden eagles would be killed per year during the period January to July. Similarly, it was predicted that one white-tailed eagle would be killed every 18.2 years and one hen harrier would be killed every 15.9 years during the period January to July.

Combining the results of the January to July models with those for the months of August to December (Madders 2006) indicated that 1.1 golden eagles and 0.1 white-tailed eagles and hen harriers would be killed per year. Turbine-type had considerable influence on predicted mortality, with golden eagle strike rates varying from 0.85 to 1.1 per year. A predicted rate of 0.6 golden eagle strikes per year is achievable if the number of turbines is reduced to around 19, depending on turbine type.

MODEL RESULTS

1 The Band collision risk model (CRM) (Band et al. 2005) was used to estimate golden eagle collision risk during the period January to July. The analyses were undertaken by Mike Madders, based on field observation data for the period February to July 2005 supplied by Simon Lawrence. These data have been reported previously Lawrence (2005). The model was based on eagle activity levels and flight behaviour, the proposed Edinbane turbine numbers and specifications, and golden eagle biometrics.

2 Observations of birds flying at 20-100m were used in the analyses, with the percentage flight activity at rotor height determined by making an arithmetic adjustment based on rotor diameter.

3 Following current best practice (Band et al. 2005) eagle flight activity per hectare per hour was calculated separately for each VP, with the unweighted average taken to represent activity across the whole site.

4 It was assumed that golden eagles were ‘available’ to collision during the period under consideration for 212 days per year and 10 hours per day. An array of 27 turbines was assumed. Turbines were assumed to be inoperative for 13% of the time due to wind speed and maintenance activities. Eagle biometrics were averaged across the sexes, and a flight speed of 13 m/s was used. An avoidance rate of 98% was used, as specified by SNH for the purpose of this analysis.

5 The CRM was run for four categories of golden eagle, based on age. These were:

- Adults
- Sub-adults,
- Immatures
- Unaged birds

The results for each class were combined to determine overall collision rate.

6 The model was run using turbine specifications for a V66 turbine with a modal hub height of 67m. The Stage 2 calculation of the probability of collision for the proposed turbines gave a value of 13.1%.

7 The combined Stage 1 and Stage 2 calculations for each age class are given in Tables 1-5. For the seven month period under consideration, using an avoidance rate of 98%, the CRM predicted a sub-adult strike every 6.9 years and an immature strike every 3.6 years. Additional strikes relating to unaged eagles were predicted once every 37.1 years. No adult strikes were predicted. Considering all ages of golden eagle 0.45 strikes per year were predicted, or one bird every 2.2 years (Table 6).

8 Iterating the CRM using data for white-tailed eagle indicated there would be an adult strike every 157.2 years, a sub-adult strike every 123.6 years and an immature strike every 47.9 years. Additional strikes relating to unaged eagles were predicted once every 50.8 years. Considering all ages of white-tailed eagle 0.05 strikes per year, or one bird every 18.2 years, were predicted during the Jan-Jul period (Table 7).

9 Similarly, it was predicted there would be strikes by adult male hen harriers every 19.7 years and strikes by female / immature harriers every 82.4 years. Overall, 0.06 hen harrier strikes per year were predicted (equivalent to one bird every 15.9 years) during the Jan-Jul period (Table 8).

PREDICTED ANNUAL COLLISIONS

10 The predicted mortality rates due to turbine collision during the period January to July were combined with the results of models covering the months August to December (Madders 2006). This indicated that 1.09 golden eagles, 0.08 white-tailed eagles and 0.06 hen harriers would be killed per year (Tables 9 and 10).

EFFECT OF TURBINE TYPE

11 Collision models for three alternative turbine-types were constructed using the observational data for golden eagles (Table 11). The predicted number of annual strikes per year (January to December) varied from 0.85 (Nordex N60 turbines) to 0.89 (Siemens 1.3). The number of turbines required to produce a standardised rate of 0.6 golden eagle collisions per year was 18 to 19, depending on type. This rate would be achievable using 15 x V66 type turbines.

REFERENCES

Band W, Madders M & Whitfield DP (2005) Developing field and analytical methods to assess avian collision risk at wind farms. In: de Lucas, M, Janss, G. & Ferrer, M. (eds). Birds and Wind Power. Lynx Edicions, Barcelona.

Lawrence, ES (2005), Edinbane Wind Farm Eagle Activity Assessment, October 2005 Unpublished report to AMEC Wind Energy.

Madders M (2006) Eagle studies at Edinbane, Aug-Dec 2006. Unpublished report to Amec Wind Energy.

Table 1. Estimated annual mortality of adult golden eagles during the period Jan-Jul. Data for 27 x V66 turbines.

	Watch data			Flying time (s)	
VP	**Area (ha)**	**Time (hrs)**	**HaHr^-1**	**Total**	**20-100m**
1	509.00	83.32	42409.88		0
2	249.00	73.06	18191.94		0
4	502.00	70.72	35501.44		0
Totals	1260.00	227.10	96103.26		0

	Flying time ha^-1 hr^-1	
VP	**Total**	**20-100m**
1		0
2		0
4		0
Overall		0

	Mean activity hr^-1 in wind farm	
Total		
20-100m	0.00000	0.0000%
Rotor height	0.00000	0.0000%

ESTIMATED COLLISION RISK

1	Flight risk volume (Vw)	551694000 m^3
	Rotor radius^2	1089 m
	Combined rotor swept volume (Vr)	92372 m^3
2	Vr * (d + l)	263261 m^3
3	Bird occupancy (n)	0.00 hrs / yr
4	Bird occupancy of rotor swept vol (b)	0.00 bird-secs
5	Bird transit time (t)	0.22 secs
6	No. of transits through rotors	0.00 per year
	Estimated no. of collisions	0.00 per year
	After allowing for avoidance	0.00000 per year

WIND FARM DATA	
Wind farm area (ha)	835.90
No. of turbines	27
Rotor diameter (m)	66.0
(% of 20-100m height band)	82.5
Max. rotor depth in metres (d)	2
Turbine operation time %	87

BIRD DATA	
Length in metres (l)	0.85
Flight speed (ms^-1)	13
Hours per day bird present	10
Days per year bird present	212

OUTPUT FROM COLLISION MODEL	
% transits that will collide	13.07%
% after turbine shut down	11.37%

AVOIDANCE	
% non-avoidance (estimate)	2
(% avoidance)	98

Table 2. Estimated annual mortality of sub-adult golden eagles during the period Jan-Jul. Data for 27 x V66 turbines.

	Watch data			Flying time (s)	
VP	**Area (ha)**	**Time (hrs)**	**HaHr^-1**	**Total**	**20-100m**
1	509.00	83.32	42409.88		795
2	249.00	73.06	18191.94		240
4	502.00	70.72	35501.44		990
Totals	1260.00	227.10	96103.26		2025

	Flying time ha^-1 hr^-1	
VP	**Total**	**20-100m**
1		5.20712E-06
2		3.66463E-06
4		7.74616E-06
Overall		5.5393E-06

	Mean activity hr^-1 in wind farm	
Total		
20-100m	0.00463	0.4630%
Rotor height	0.00382	0.3820%

ESTIMATED COLLISION RISK

1	Flight risk volume (Vw)	551694000	m^3
	Rotor radius^2	1089	m
	Combined rotor swept volume (Vr)	92372	m^3
2	Vr * (d + l)	263261	m^3
3	Bird occupancy (n)	8.10	hrs / yr
4	Bird occupancy of rotor swept vol (b)	13.91	bird-secs
5	Bird transit time (t)	0.22	secs
6	No. of transits through rotors	63.46	per year
	Estimated no. of collisions	7.21	per year
	After allowing for avoidance	0.14426	per year

WIND FARM DATA	
Wind farm area (ha)	835.90
No. of turbines	27
Rotor diameter (m)	66.0
(% of 20-100m height band)	82.5
Max. rotor depth in metres (d)	2
Turbine operation time %	87

BIRD DATA	
Length in metres (l)	0.85
Flight speed (ms^-1)	13
Hours per day bird present	10
Days per year bird present	212

OUTPUT FROM COLLISION MODEL	
% transits that will collide	13.07%
% after turbine shut down	11.37%

AVOIDANCE	
% non-avoidance (estimate)	2
(% avoidance)	98

Table 3. Estimated annual mortality of immature golden eagles during the period Jan-Jul. Data for 27 x V66 turbines.

	Watch data			Flying time (s)	
VP	**Area (ha)**	**Time (hrs)**	**HaHr^-1**	**Total**	**20-100m**
1	509.00	83.32	42409.88		2175
2	249.00	73.06	18191.94		645
4	502.00	70.72	35501.44		975
Totals	1260.00	227.10	96103.26		3795

	Flying time ha^-1 hr^-1	
VP	**Total**	**20-100m**
1		1.42459E-05
2		9.84868E-06
4		7.6288E-06
Overall		1.05745E-05

	Mean activity hr^-1 in wind farm	
Total		
20-100m	0.00884	0.8839%
Rotor height	0.00729	0.7292%

ESTIMATED COLLISION RISK

1	Flight risk volume (Vw)	551694000	m^3
	Rotor radius^2	1089	m
	Combined rotor swept volume (Vr)	92372	m^3
2	Vr * (d + l)	263261	m^3
3	Bird occupancy (n)	15.46	hrs / yr
4	Bird occupancy of rotor swept vol (b)	26.56	bird-secs
5	Bird transit time (t)	0.22	secs
6	No. of transits through rotors	121.14	per year
	Estimated no. of collisions	13.77	per year
	After allowing for avoidance	0.27539	per year

WIND FARM DATA	
Wind farm area (ha)	835.90
No. of turbines	27
Rotor diameter (m)	66.0
(% of 20-100m height band)	82.5
Max. rotor depth in metres (d)	2
Turbine operation time %	87

BIRD DATA	
Length in metres (l)	0.85
Flight speed (ms^-1)	13
Hours per day bird present	10
Days per year bird present	212

OUTPUT FROM COLLISION MODEL	
% transits that will collide	13.07%
% after turbine shut down	11.37%

AVOIDANCE	
% non-avoidance (estimate)	2
(% avoidance)	98

Table 4. Estimated annual mortality of unaged golden eagles during the period Jan-Jul. Data for 27 x V66 turbines.

	Watch data			Flying time (s)	
VP	**Area (ha)**	**Time (hrs)**	**HaHr^-1**	**Total**	**20-100m**
1	509.00	83.32	42409.88		135
2	249.00	73.06	18191.94		30
4	502.00	70.72	35501.44		225
Totals	1260.00	227.10	96103.26		390

	Flying time ha^-1 hr^-1	
VP	**Total**	**20-100m**
1		8.84228E-07
2		4.58078E-07
4		1.76049E-06
Overall		1.03427E-06

	Mean activity hr^-1 in wind farm	
Total		
20-100m	0.00086	0.0865%
Rotor height	0.00071	0.0713%

ESTIMATED COLLISION RISK

1	Flight risk volume (Vw)	551694000	m^3
	Rotor radius^2	1089	m
	Combined rotor swept volume (Vr)	92372	m^3
2	Vr * (d + l)	263261	m^3
3	Bird occupancy (n)	1.51	hrs / yr
4	Bird occupancy of rotor swept vol (b)	2.60	bird-secs
5	Bird transit time (t)	0.22	secs
6	No. of transits through rotors	11.85	per year
	Estimated no. of collisions	1.35	per year
	After allowing for avoidance	0.02694	per year

WIND FARM DATA	
Wind farm area (ha)	835.90
No. of turbines	27
Rotor diameter (m)	66.0
(% of 20-100m height band)	82.5
Max. rotor depth in metres (d)	2
Turbine operation time %	87

BIRD DATA	
Length in metres (l)	0.85
Flight speed (ms^-1)	13
Hours per day bird present	10
Days per year bird present	212

OUTPUT FROM COLLISION MODEL	
% transits that will collide	13.07%
% after turbine shut down	11.37%

AVOIDANCE	
% non-avoidance (estimate)	2
(% avoidance)	98

Table 5. Stage 1 collision risk model involving golden eagles and V66 turbines.

						Upwind:			Downwind:		
K: [1D or [3D] (0 or 1)	1		r/R	c/C	α	collide		contribution	collide		contribution
NoBlades	3		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
MaxChord	2.8	m									
Pitch (degrees)	15										
BirdLength	0.85	m	0.025	0.575	7.07	25.56	1.00	0.00125	24.73	1.00	0.00125
Wingspan	2	m	0.075	0.575	2.36	8.80	0.72	0.00540	7.96	0.65	0.00489
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.41	6.02	0.49	0.00616	5.00	0.41	0.00512
			0.175	0.860	1.01	4.99	0.41	0.00715	3.75	0.31	0.00537
Bird speed	13	m/sec	0.225	0.994	0.79	4.41	0.36	0.00811	2.96	0.24	0.00546
RotorDiam	66	m	0.275	0.947	0.64	3.62	0.30	0.00814	2.25	0.18	0.00505
RotationPeriod	2.82	sec	0.325	0.899	0.54	3.06	0.25	0.00814	1.76	0.14	0.00468
			0.375	0.851	0.47	2.65	0.22	0.00812	1.41	0.12	0.00433
			0.425	0.804	0.42	2.34	0.19	0.00813	1.17	0.10	0.00408
			0.475	0.756	0.37	2.16	0.18	0.00839	1.06	0.09	0.00413
Bird aspect ratioo: β	0.43		0.525	0.708	0.34	2.01	0.16	0.00863	0.98	0.08	0.00422
			0.575	0.660	0.31	1.88	0.15	0.00884	0.92	0.08	0.00433
			0.625	0.613	0.28	1.76	0.14	0.00902	0.87	0.07	0.00447
			0.675	0.565	0.26	1.66	0.14	0.00917	0.86	0.07	0.00475
			0.725	0.517	0.24	1.57	0.13	0.00929	0.88	0.07	0.00524
			0.775	0.470	0.23	1.48	0.12	0.00939	0.90	0.07	0.00571
			0.825	0.422	0.21	1.40	0.11	0.00945	0.91	0.07	0.00615
			0.875	0.374	0.20	1.33	0.11	0.00949	0.92	0.08	0.00656
			0.925	0.327	0.19	1.26	0.10	0.00950	0.92	0.08	0.00695
			0.975	0.279	0.18	1.19	0.10	0.00949	0.92	0.07	0.00730

Overall p(collision) = Upwind 16.1% Downwind 10.0%

Average 13.1%

Table 6. Summary of estimated annual mortality of four age classes of golden eagle during the period Jan-Jul. Data for 27 x V66 turbines.

	Annual mortality	
Adult	0.000	per year
Sub-adult	0.144	per year
Immature	0.275	per year
Unaged	0.027	per year
TOTAL	***0.447***	***per year***
One bird every	***2.2***	***years***

Table 7. Summary of estimated annual mortality of four age classes of white-tailed eagle during the period Jan-Jul. Data for 27 x V66 turbines.

	Annual mortality	
Adult	0.006	per year
Sub-adult	0.008	per year
Immature	0.021	per year
Unaged	0.020	per year
TOTAL	***0.055***	***per year***
One bird every	***18.2***	***years***

Table 8. Summary of estimated annual mortality of two sex/age classes of hen harrier during the period Jan-Jul. Data for 27 x V66 turbines.

	Annual mortality	
Adult male	0.051	per year
Female / immature	0.012	per year
TOTAL	***0.063***	***per year***
One bird every	***15.9***	***years***

Table 9. Summary of estimated annual mortality of four age classes of golden eagle during the combined period Jan-Dec. Data for 27 x V66 turbines.

	Annual mortality					
	Jan-Jul		Aug-Dec		Combined	
Adult	0.000	per year	0.091	per year	0.091	per year
Sub-adult	0.144	per year	0.015	per year	0.159	per year
Immature	0.275	per year	0.427	per year	0.702	per year
Unaged	0.027	per year	0.108	per year	0.135	per year
TOTAL	***0.447***	***per year***	***0.641***	***per year***	1.088	***per year***
One bird every	***2.2***	***years***	***1.6***	***years***	***0.92***	***years***

Table 10. Summary of estimated annual mortality of white-tailed eagle and hen harrier during the combined period Jan-Dec. Data for 27 x V66 turbines.

	Annual mortality					
	Jan-Jul		Aug-Dec		Combined	
White-tailed eagle	0.055	per year	0.021	per year	0.076	per year
One bird every	***18.2***	***years***	***47.7***	***years***	13.16	***years***
Hen harrier	0.063	per year	0	per year	0.063	per year
One bird every	***15.9***	***years***		***years***	15.87	***years***

Table 11. Summary of estimated annual mortality of golden eagle (Jan-Dec, all age classes) for four turbine types.

	Nordex N60	V52	Siemens 1.3	V66
No. of turbines	27	27	27	27
Rotor diameter (m)	60	52	62	66
Hub height (m)	60	65	68	67
Max. rotor depth (front to back) (m)	1.6	1.6	1.8	2
Max. chord (m)	2.4	2.3	2.4	2.8
Pitch (degrees)	5	16	5	15
Rotation period (s)	3.13	1.9	3.16	2.82
Turbine operation time (Aug-Dec)	87%	87%	87%	87%
Rotor tip (max)	90	91	99	100
Rotor tip (min)	30	39	37	34
Stage 2 collision rate	12.4%	17.1%	12.1%	13.1%
Predicted collisions (Jan-Jul)	0.35	0.36	0.36	0.45
Predicted collisions (Aug-Dec)	0.50	0.52	0.52	0.64
Predicted Annual collisions	0.85	0.88	0.89	1.09
No. of years to collision	1.2	1.1	1.1	0.9
Annual collisions per turbine	0.03	0.03	0.03	0.04
No. of turbines to produce annual collision rate of 0.6 birds	19	18	18	15