Edinbane Windfarm:

Ornithological Monitoring 2007-2014

A review of the spatial use of the area by birds of prey.

January 2015

Haworth Conservation Ltd
Bunessan
Isle of Mull
PA67 6DU

Summary

1. Observations have been gathered between January 2007 and December 2014. Three main VPs were used throughout; a fourth was added in 2008 to target a potential white-tailed eagle roost and a fifth in 2010 to provide better coverage of the Ben Aketil wind farm.
2. Observations comprised more than 100 hours of survey effort per annum at each of the four main VPs, plus 36 hours per annum from the roost VP.
3. Flight data were digitised and quantified for each 4 ha area of the wind farm that fell within the VP viewsheds.
4. Flight data were analysed on a month by month and annual basis.
5. Surveys for raptors breeding within 2 km of the consented Edinbane wind farm were undertaken each year between 2007 and 2014.
6. Surveys of all Golden Eagle territories on the Isle of Skye were undertaken each year between 2007 and 2014.
7. In 2014 (from all five VPs not clipped to view sheds) there were 248 golden eagle flights with a total length of 487.5 km, 196 white-tailed eagle flights (576.7 km), and seven hen harrier flights (9.6 km).
8. The amount of activity varied between months. Golden eagles showed peaks in activity in spring and autumn with considerably less activity in winter and summer. White-tailed eagle activity peaked in April with particularly reduced activity between September and January. These annual trends are relatively consistent between the years.
9. Spatial and temporal patterns of usage were investigated using a grid of 4 ha cells. Flights were clipped to exclude sections outside of potential viewsheds. The total lengths of digitised flight lines that intersected each cell were calculated separately for each month. Similarly the total number of surveying hours was calculated for each grid cell by overlapping the viewsheds on to the grid. Usage is expressed as metres of flight per 10 hours of observation.
10. Activity, recorded from the three main VPs (A, B and C) as the mean flight length per 4ha grid cell, has varied considerably between years, VP and species.
11. Over the three continuously monitored VPs, golden eagle activity showed a sharp decline up to 2009 which was maintained into 2010. There was a subsequent

increase in 2011 and 2012 followed by a decline in 2013. However, in 2014 there was a large increase back to a level that was almost identical to that recorded in 2007.

12. However, changes over the years are inconsistent across the VPs. Between 2007 and 2009, the largest decline was recorded from VP A which covers the northern part of the Edinbane wind farm. However, in 2014 recorded activity was the highest recorded.

13. Activity from VP C, which covers the southern part of the Edinbane wind farm, has been variable but any declines have been smaller than elsewhere. Activity from VP B, which covers the Ben Aketil wind farm and Ben Aketil and Ben Sca, declined sharply in 2009 and has never recovered to the 2007 and 2008 figures.

14. Activity from VP B, which covers the Ben Aketil wind farm and Ben Aketil and Ben Sca, declined sharply in 2009 and has never recovered to the 2007 and 2008 figures.

15. At Edinbane construction activity spanned 2008-2010 and flight activity declined during those years, particularly in 2009 and 2010. Since then there has been some recovery with little difference between the 2007 and 2014 golden eagle data.

16. If the ratio of mean use per grid cell between the two wind farms and the surveyed areas outside of the wind farms is greater than one, the mean use per 4ha grid cell is greater in a wind farm area than outside of the wind farm. For example, in 2007 the level of golden eagle flight activity was 1.6 times greater within the proposed, but unconstructed, Edinbane wind farm than in the non-wind farm area. This almost certainly reflects differences in the distribution of suitable topography between the two areas.

17. If either wind farm has a displacement/avoidance impact on golden eagles this ratio should decline over time and there is evidence for avoidance or displacement during the construction periods.

18. Since construction ended at the Edinbane wind farm the ratio has increased suggesting that construction effects are greater than the operational effects. In 2013 the ratio exceeded that pre-construction figure and the use maps suggest more activity within the wind farm than outside it.

19. The earlier, but similar, trend at Ben Aketil supported this interpretation but in 2013 and 2104 there was little activity within the Ben Aketil wind farm and the ratio of

the means suggests that there has been displacement which is also supported by the flight maps.

20. White-tailed eagle use has increased over the eight survey years particularly in the VP C Edinbane view shed. There were similar increases, but with less activity recorded, in the other view sheds. The main exception is 2009 when there was relatively little activity.

21. The mean level of white-tailed eagle activity has generally been similar or greater in the wind farms compared with the surrounding habitat. This is particularly obvious in the southern part of the Edinbane wind farm where there was an enormous increase in the activity. There is very little evidence for any displacement of white-tailed eagle flight activity by either wind farm.

22. Hen harrier activity has been very varied but in most years the mean activity has been largest in the wind farm areas. The annual habitat use maps provide no evidence for avoidance or displacement and the descriptions of flights also suggest a lack of avoidance.

23. Almost certainly differences between years and regions reflect the locations of successful harrier nest sites.

24. When use within the wind farms was expressed as a ratio of that outside of the wind farm, thus removing the large annual differences in the amount of activity, there is little evidence that hen harriers demonstrate any avoidance. There is, however, considerable between-year variability at both wind farms.

25. It might be tempting to describe the ratio declines of 2011 and 2012 at Ben Aketil as evidence of the development of avoidance but the same cannot be true at Edinbane where 2012 saw the second largest ratio following the apparent decline in 2010 and 2011.

26. In 2007 29 ranges were occupied by golden eagles but only nine young eagles successfully fledged. In 2008 29 ranges were occupied by golden eagles and 17 young eagles fledged. In 2009 29 ranges were occupied by golden eagles and 13 young eagles fledged. In 2010 29 ranges were again occupied by golden eagles and 15 young eagles fledged. In 2011 29 ranges were again occupied by golden eagles and 10 young eagles fledged. The very wet, cold and windy weather in May and early June 2011 seems to have been the proximal cause for the large number of failures.

27. In 2012 30 ranges were occupied by golden eagles and only eight young eagles fledged. This is the smallest number since 1982. One set of twins fledged in 2012. This compares with one set of twins in 2007 and two each in 2008, 2009 and 2010 and none in 2011. These are lower than the long term average (2.8) over the period 1982-2000.

28. In 2013 30 ranges were occupied by golden eagles and thirteen young eagles fledged from eleven successful ranges. There were two sets of twins fledged in 2013.

29. In 2014 30 ranges were again occupied by golden eagles and twelve young eagles fledged from eleven successful ranges. One set of twins was fledged in 2014.

30. A pair of white-tailed eagles built a ground nest south of the Edinbane wind farm in 2013. There was another nesting attempt in 2014 in a conifer plantation. Both breeding attempts failed to produce any young.

31. In 2007 eleven hen harrier territories were active with nine nests being located. Of these, six failed completely and three successful breeding attempts produced a total of ten young. In 2008 there were eleven active territories and ten nests were located. Of these, seven failed completely and three produced a total of nine young. In 2009 there were seven active territories and six nests were located. Of these five failed completely and two produced a total of nine young. In 2010 12 active territories were identified and nests found at ten. Ten young were fledged with the majority of failures thought be due to fox predation. In 2011 13 active territories were identified and nests found at ten. Fifteen young were fledged.

32. 2012 was a rather poor year with only five active territories and nests from which eight young were fledged. In 2012, although a pair was seen 'skydancing' and displaying over a wide area including the Ben Aketil 'Turbine' site, no pair returned to the area to breed. One successful nest site was within 800 metres of turbines on the Edinbane site in 2011, and in 2012, the pair moved on to moorland and nested within 400 metres of Turbine 4. This site failed due to fox predation.

33. In 2013 there were only three hen harrier breeding attempts. 2014 was a better year (six ranges occupied with five nests, two failed and the other three fledged 10 young). There were no nests in the vicinity of either wind farm in either year.

34. 2011 was the first year in which neither wind farm was subject to any construction activities. The indications of increases in golden eagle use of the operational Edinbane wind farm, compared with its construction period, may be evidence that

there is less avoidance of working turbines compared with their construction period.

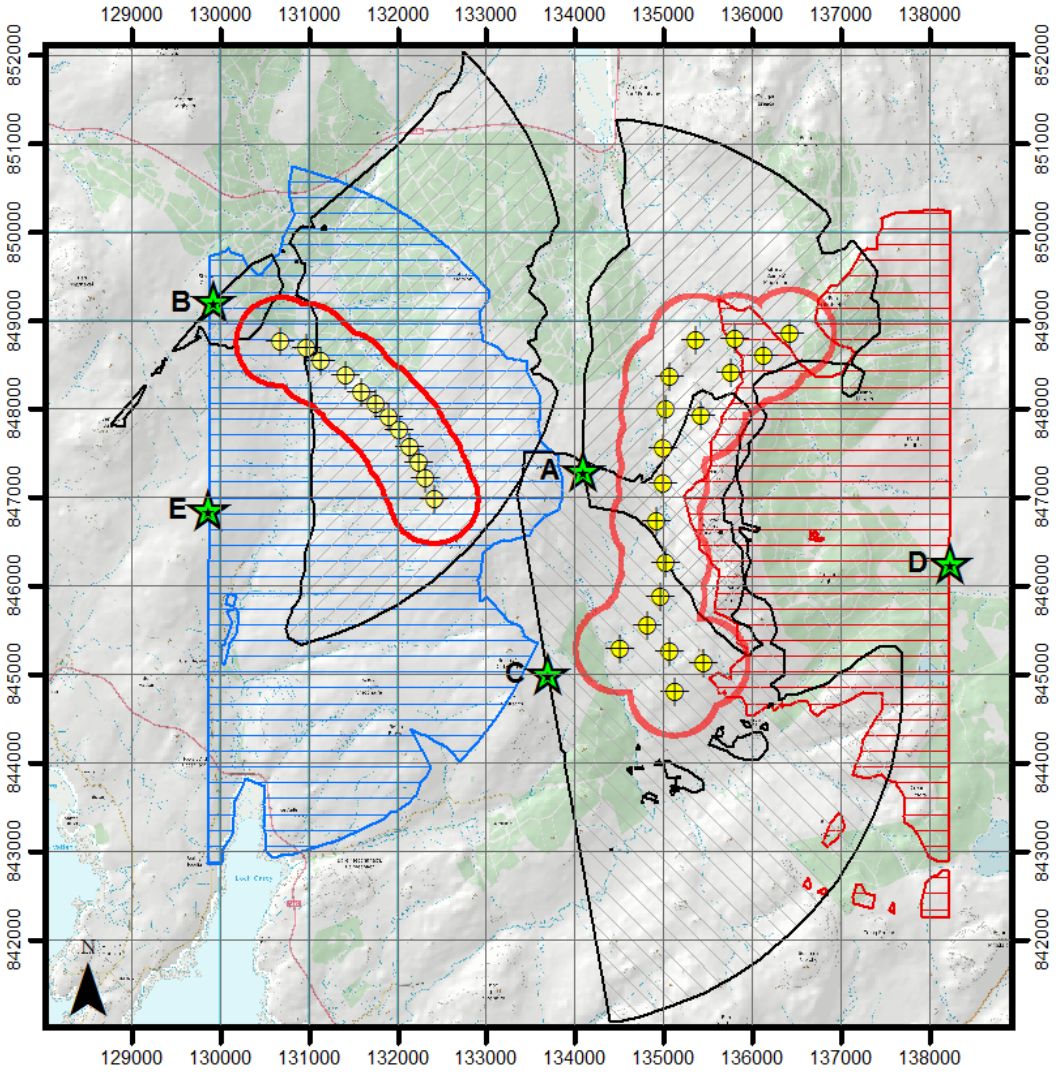
35. **Despite their geographic proximity it is clear that it would be difficult to use the results from one wind farm to predict bird behaviour at the other and that any similarities or differences are not true for all species. A greater understanding of how birds use habitat at quite small scales is needed before more robust models of bird-wind farm interactions can be fully understood.**

Background

1 Bird observations were collected, in and around the Edinbane and Ben Aketil wind farms, by Ken Crane and Kate Nellist using three, four and, later, five vantage points (Fig. 1).

2 Data collection started on 16th January 2007 using vantage points A (1,085.8 ha view shed), B (1,380.3 ha) and C (1,740.5 ha). Vantage point D (1,378.3 ha) was added in January 2008 to record habitat use associated with a possible white-tailed eagle roost site. Vantage point E (2,237.1 ha) was added in January 2010 to provide better coverage of the Ben Aketil wind farm.

Figure 1. Vantage Points (A,B,C, D and E) and viewsheds (30 m vertical offset, 180° window and 4,000 m horizontal threshold). The red line shows the boundary of a buffer drawn 500 m around the actual or proposed turbines. (Contains Ordnance Survey data © Crown copyright and database right 2010). Note that previous reports used a 6,000 m detection threshold.



3 This report uses data up to 31st December 2014 (Table 1). In total, since 2007, there were 544 surveys (2,335 hours).

4 Flight data were recorded for golden eagle *Aquila chrysaetos*, white-tailed eagle *Haliaeetus albicilla*, hen harrier *Circus cyaneus*, merlin *Falco columbarius* and peregrine falcon *Falco peregrinus*.

5 Two Ben Aketil turbines had been constructed by 19/09/2007, rising to five by the 2nd October and nine by the 20th October. On the 3rd November 2007 all ten were complete with eight functioning. An additional two turbines were installed during spring 2010.

6 At Edinbane, preliminary construction commenced in early 2008, whilst main site works commenced during August 2008. Wind turbines started to arrive during late summer 2009 and construction was completed during June 2010. All turbine bases, for the original 13, had been completed by 20/06/2009, with the first turbine complete by July 15th. Construction was slower than Ben Aketil and six were complete, with four more under construction, by the 6th October 2009. By the date of the survey on the 28th November the 13 were complete and construction had started on the five bases for the later extension. Work on all turbines was completed by June 2010.

7 Therefore, all bird data collected from July 2010 were unaffected by construction activities.

8 Over the entire survey period 3,412 flights were recorded, of which, 2,015 (5,829.4 km in length) were by golden eagle, 1,048 (2992.6 km) by white tailed eagle and 315 (548.7 km) by the hen harrier. The remaining flights were by buzzard, merlin and peregrine falcon (less than 20 of each).

9 Fine scale spatial and temporal patterns of use are investigated using a grid of cells 200 m by 200 m (4 ha).

10 The total lengths of digitised flight lines, that intersected each cell, were calculated after clipping flights at the edge of the relevant VP's view shed. Flights seen from VPs D and E are excluded from some analyses because these VPs were not used until 2010.

11 Similarly the total number of surveying hours per year was calculated for each 4ha grid cell by overlapping the view sheds (Fig. 1) on to the grid. Some 4ha grid cells were in

more than one view shed. Use of a grid cell by a bird is expressed as kilometres or metres of flight per 10 hours of observation.

Table 1. Summary of hours surveyed from five vantage points.

2007	J	F	M	A	M	J	J	A	S	O	N	D	Year
A	13.5	4.5	9.0	9.0	10.0	9.0	9.0	6.0	9.0	9.0	9.0	9.0	106.0
B	9.3	9.5	9.1	9.0	10.0	9.0	10.0	8.0	8.0	9.3	9.0	4.5	104.7
C	12.0	4.5	9.0	9.0	6.0	7.0	9.0	9.0	9.0	9.5	9.3	9.0	102.3
2008													
A	9.0	9.0	9.3	9.0	10.0	9.0	9.5	9.0	9.0	9.0	9.0	9.0	109.8
B	9.0	9.0	9.0	9.0	10.0	9.0	9.0	9.0	9.0	9.0	9.5	9.0	109.5
C	9.0	9.0	10.0	9.0	10.0	9.0	9.3	9.5	9.0	9.0	9.0	9.0	110.8
D	3.0	4.6	3.3	3.0	5.0	3.0	3.0	3.0	3.0	3.0	3.3	3.3	40.5
2009													
A	9.0	10.0	9.0	9.0	9.5	9.0	9.0	9.0	9.0	9.0	9.0	9.0	109.5
B	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	108.0
C	9.5	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	108.5
D	3.0	3.0	3.0	3.7	3.5	3.0	3.0	3.5	3.5	3.0	3.1	3.2	38.5
2010													
A	9.0	9.5	9.0	9.0	9.0	9.0	9.0	9.0	8.0	9.0	13.5	9.0	112.0
B	9.0	9.0	9.0	9.0	9.0	9.0	9.5	8.0	8.0	8.5	4.5	8.5	101.0
C	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.3	9.0	9.0	9.0	108.3
D	3.1	3.0	3.3	3.0	3.0	3.5	3.0	3.0	3.0	3.3	3.0	3.0	37.2
E	7.6	9.0	9.0	9.0	9.0	9.0	9.0	8.0	9.0	9.0	8.0	9.0	104.6
2011													
A	9.0	9.0	9.0	9.0	9.0	9.0	8.5	8.0	9.0	9.0	4.5	4.5	97.5
B	9.0	9.0	9.0	10.5	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	109.5
C	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.5	9.0	13.5	9.0	113.0
D	3.0	2.5	3.0	7.5	3.0	3.0	3.3	3.0	3.0	3.0	3.0	3.0	40.3
E	9.0	9.0	8.5	4.5	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	103.0
2012													
A	9.0	9.0	9.0	9.0	9.0	9.0	8.7	9.0	9.0	9.0	9.0	13.5	112.2
B	9.0	9.0	9.0	9.0	9.0	9.0	9.0	8.9	9.0	9.0	9.0	9.0	107.9
C	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.3	108.3
D	3.0	3.1	3.0	3.0	3.3	3.0	3.0	3.0	3.0	3.0	3.0	3.0	36.4
E	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.3	108.3
2013													
A	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	108.0
B	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	108.0
C	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	108.0
D	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	36.0
E	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	108.0
2014													
A	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	108.0
B	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	108.0
C	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	108.0
D	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	36.0
E	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	108.0

12 Note that flights were clipped to the edge of their view shed. Thus, any part of a flight over ground that could not be seen (to a lower limit of 30 m) from the vantage point, was removed prior to calculation of these summaries.

13 For regional comparisons, e.g. between wind farms or between view sheds, mean flight length per region was used to remove the effects of differences in area.

14 Activity, recorded from the three main VPs (A, B and C) as the mean flight length per 4ha grid cell, has varied considerably between years, VP and species (Table 2).

Table 2. Summary of total fight lengths (km per 10 hour surveying) across all 200 m grid cells in a view shed for three species over eight years. A, B & C are the main vantage points.

	Year	A	B	C	D	E	A, B & C
Golden Eagle	2007	184.6	81.4	249.7			515.7
	2008	139.3	127.0	167.7	20.0		433.9
	2009	21.7	29.2	174.8	5.6		225.6
	2010	46.5	53.8	113.8	15.4	200.2	214.1
	2011	54.3	49.1	244.8	1.6	268.4	348.2
	2012	112.6	42.6	173.1	3.2	240.2	328.2
	2013	96.1	18.7	166.3	5.0	106.2	281.1
	2014	213.5	59.2	235.7	3.9	180.1	508.4
White-tailed Eagle	2007	32.8	19.8	58.3			111.0
	2008	51.8	12.9	72.7	2.3		137.4
	2009	12.7	14.2	63.1	0.1		89.9
	2010	11.3	1.6	129.1	4.0	31.5	142.0
	2011	19.8	15.8	128.5	16.9	80.3	164.0
	2012	30.1	63.7	101.3	11.6	73.5	195.1
	2013	42.7	17.8	334.4	2.0	164.2	394.9
	2014	9.5	58.2	224.9	19.4	178.1	292.7
Hen Harrier	2007	5.8	10.6	5.6			22.0
	2008	9.4	22.3	38.4	3.0		70.1
	2009	15.8	12.8	10.1	3.0		38.6
	2010	25.7	20.5	7.6	0.0	24.4	53.8
	2011	27.4	25.1	6.4	13.2	29.1	58.9
	2012	4.7	8.6	15.9	5.3	2.7	29.2
	2013	0.0	0.0	0.0	0.0	0.0	0.0
	2014	1.8	0.0	0.3	0.0	0.2	2.1

15 Over the three continuously monitored VPs, golden eagle activity showed a sharp decline up to 2009 which was maintained into 2010 (Table 2). There was a subsequent increase

in 2011 and 2012 followed by a decline in 2013. However, in 2014 there was a large increase back to a level that was almost identical to that recorded in 2007.

16 However, changes over the years are inconsistent across the VPs. Between 2007 and 2009, the largest decline was recorded from VP A which covers the northern part of the Edinbane wind farm. However, in 2014 activity was the highest recorded. Activity from VP C, which covers the southern part of the Edinbane wind farm, has been variable but any declines have been smaller than elsewhere. Activity from VP B, which covers the Ben Aketil wind farm and Ben Aketil and Ben Sca, declined sharply in 2009 and has never recovered to the 2007 and 2008 figures.

17 Over the three continuously monitored VPs, white-tailed eagle activity underwent a small decline in 2009 but subsequently increased year on year and in 2014 it was more than double that recorded in 2007 (Table 2) despite a considerable decline from the 2013 peak.

18 Most white-tailed activity was recorded from VP C, which covers the southern part of the Edinbane wind farm. Activity from VPs A and B, which cover the northern part of the Edinbane wind farm and the Ben Aketil wind farm and its surroundings respectively, has never been large.

19 Over the three continuously monitored VPs, hen harrier activity initially showed quite large increases from 2007 levels. Following a collapse in activity recorded from VP A and, to a lesser extent, VP B in 2012, there was no flight activity recorded in 2013 and very little in 2014 (Table 2).

20 The amount of activity has varied considerably between months for all three main species (Table 3, Figure 2). Golden eagles, white-tailed eagles and hen harriers all showed seasonal peaks in activity. Golden eagles, in particular, showed clear spring/early summer autumn increases in activity. These peaks and troughs are reflected in both flight length and number of flights. Hen Harrier and white-tailed eagles peaks in late spring/early summer. Similar patterns are observed if flight length replaces the number of flights.

21 Across all years, 79% of the golden eagle flights could be attributed to an age class. The majority (64%) were by adults. The relative proportions of adults were relatively constant

at approximately 62% between 2007 and 2010. In 2011 this declined to 51% but has consistently risen since then (63%, 72% and 80% respectively).

22 In the case of white-tailed eagles 68% of birds were aged and proportions were approximately equal for adults (48%) sub-adults (59%). Relative proportions have varied greatly over the years from a low of 35% adults in 2008 to a maximum of 64% in 2009.

Figure 2. Total flight length (km) per month (2007-2014 combined) for three species from vantage points A, B and C. (only parts of flights completely within the view sheds are included).

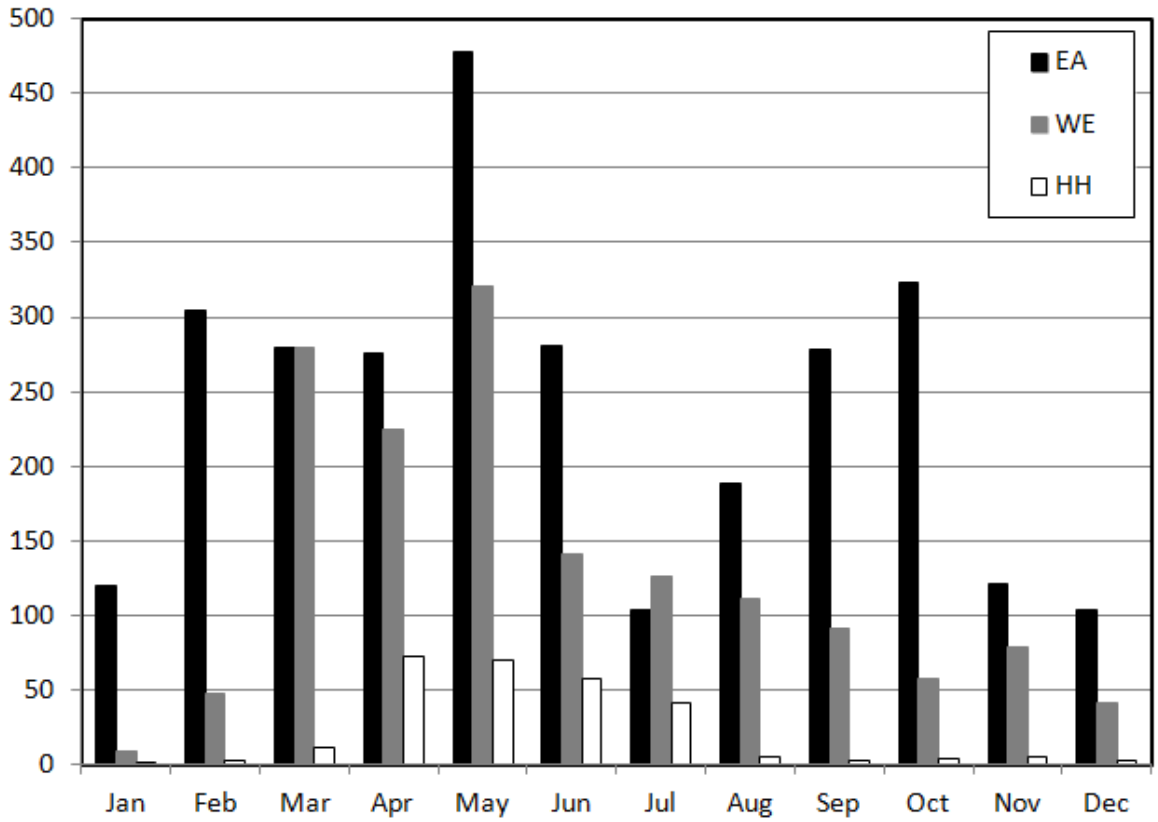


Table 3. Number of recorded flights per month per year for three species from VPs A,B &C (only flights completely or partially within the view sheds are included).

Spp	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All
EA	2007	182	142	416	300	366	425	26	179	182	556	73	101	2948
	2008	32	353	164	205	457	129	136	174	320	389	114	32	2505
	2009	68	227	285	93	171	63	104	13	101	65	76	51	1317
	2010	45	217	54	229	129	106	21	96	64	152	25	40	1178
	2011	52	144	174	169	122	320	129	112	161	171	42	118	1714
	2012	39	124	190	191	416	46	103	116	70	179	48	54	1576
	2013	16	52	217	103	350	2	36	4	352	30	99	72	1333
	2014	254	305	41	209	363	358	0	295	176	223	206	101	2531
Total		688	1564	1541	1499	2374	1449	555	989	1426	1765	683	569	15102
HH	2007	0	20	0	63	17	0	47	0	0	0	0	0	147
	2008	0	0	5	38	201	119	33	7	0	0	0	0	403
	2009	5	0	24	150	21	0	37	0	3	0	5	8	253
	2010	4	0	0	71	105	101	22	0	0	0	28	0	331
	2011	3	0	42	110	48	59	58	0	0	10	4	8	342
	2012	0	0	0	45	0	44	49	23	7	0	0	0	168
	2014	0	0	0	0	0	0	0	0	0	12	0	0	12
Total		12	20	71	477	392	323	246	30	10	22	37	16	1656
WE	2007	0	66	4	38	184	151	90	33	43	25	69	0	703
	2008	0	0	134	205	98	77	46	32	93	108	17	5	815
	2009	0	0	224	62	193	0	18	14	0	2	0	22	535
	2010	0	0	0	40	284	124	40	43	213	0	28	3	775
	2011	8	6	16	178	250	108	13	48	53	35	128	22	865
	2012	13	34	155	150	24	48	202	113	68	10	84	84	985
	2013	0	148	254	214	484	195	127	212	32	156	70	77	1969
	2014	23	36	539	324	129	99	141	43	40	0	49	22	1445
Total		44	290	1326	1211	1646	802	677	538	542	336	445	235	8092

Spatial and temporal patterns

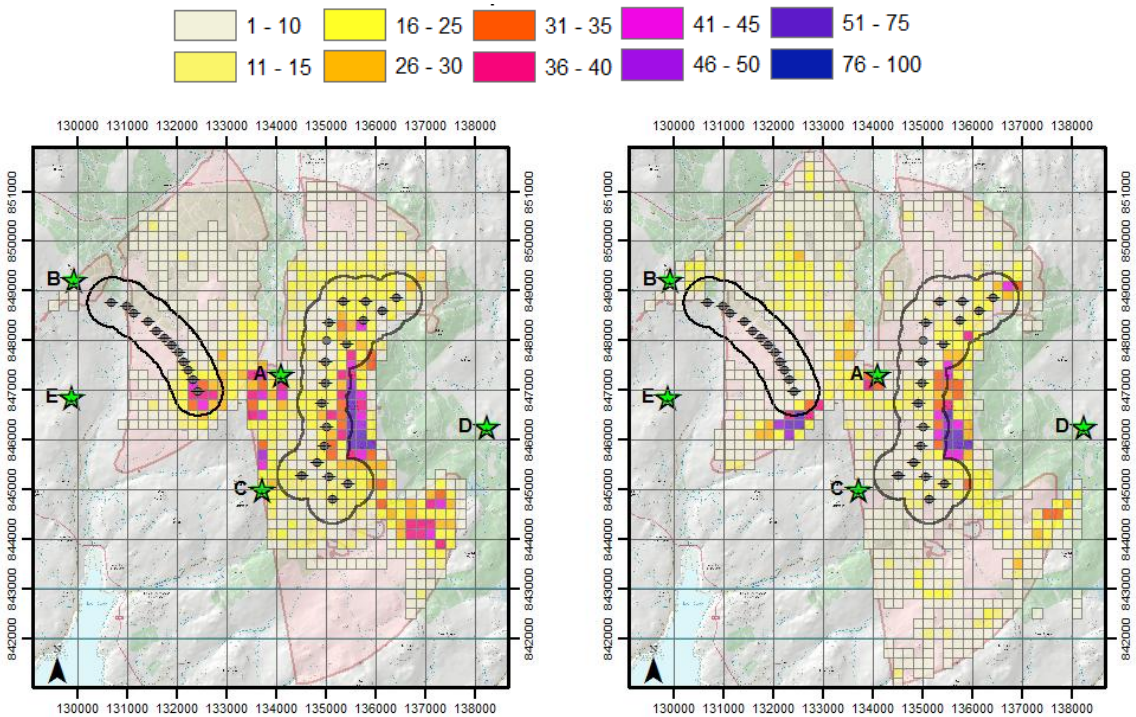
23 Maps have been created for each combination of year and species (golden and white-tailed eagle and hen harrier: Figs. 3, 8, 11).

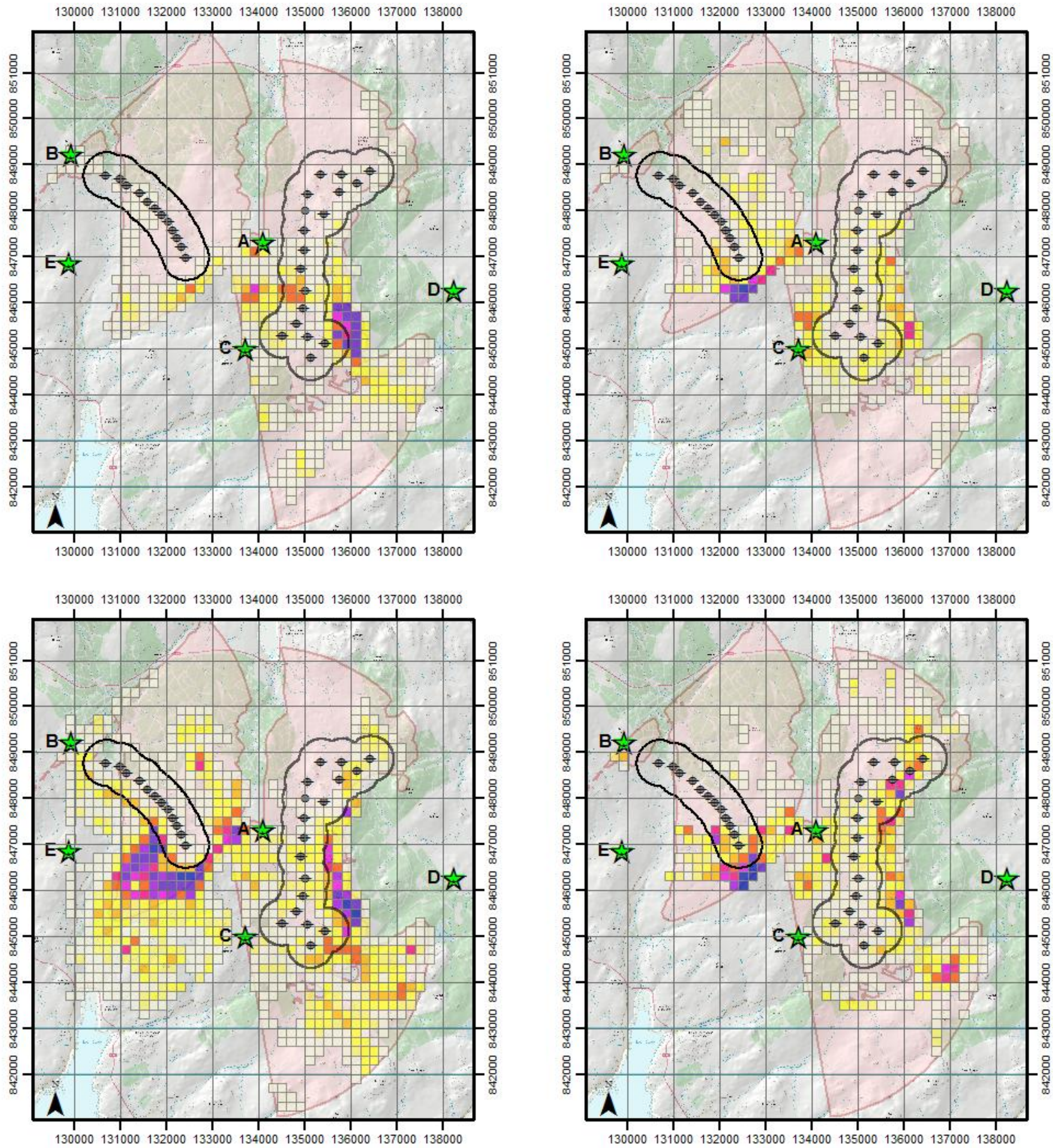
24 There is evidence of some shifts in spatial use by golden eagle (Fig. 3) with a reduction in use of the ridges to the east of the Edinbane wind farm but an increase in use of the ridges south of the Ben Aketil wind farm. The largest shifts were associated with construction activity. In 2014, apart from some possible displacement from the Ben Aketil wind farm, there is little evidence of any significant shift in activity compared with 2007.

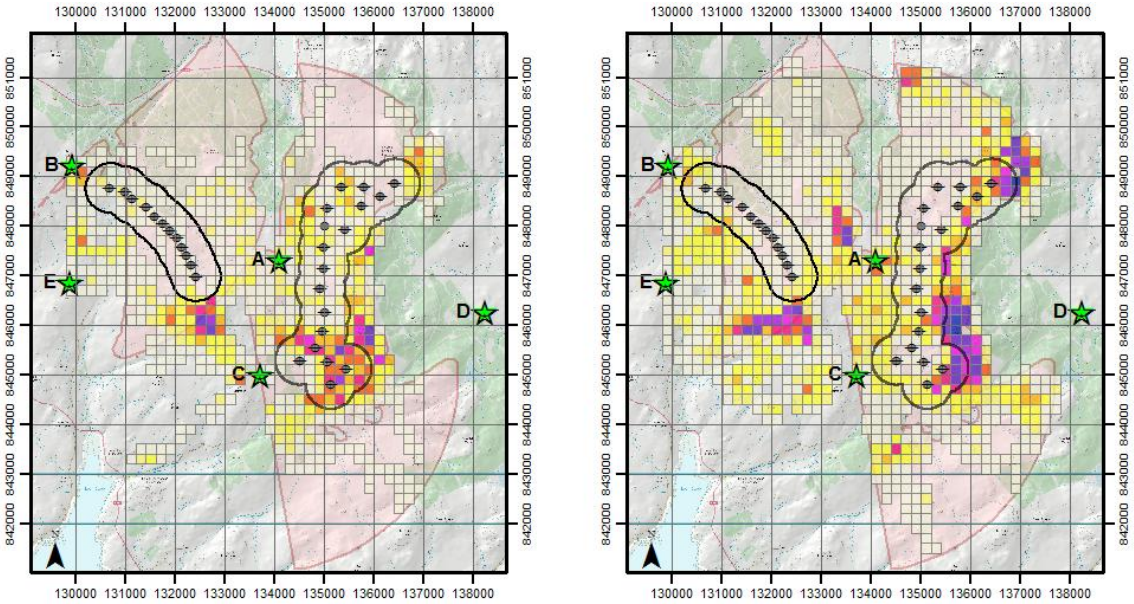
25 Changes to the amount of use in the two wind farm areas are confounded by changes in the overall activity in the region (Table 2 and Fig. 4). Thus, increases or decreases around wind farms could simply reflect differences between years in the wider landscape. This issue is addressed by using internal (within-area) and external (wind farm - non wind farm) comparisons.

26 In addition to the overall use patterns shown in Fig. 3, flight data were analysed separately for each VP by calculating separate mean use values for VPs A, B and C (Fig. 4). VP A covers the northern section of the Edinbane wind farm and VP C its southern section. VP B covers most of the Ben Aketil wind farm (Fig. 1). These three VPs have been used since 2007 so provide a continuous run of eight years of surveying from the same VPs by the same surveyors and cover periods before, during and after construction.

Figure 3. Habitat use by golden eagles recorded from three vantage points (A,B and C). Values are meters of flight (all altitudes) per 10 hours of observation rescaled to 0-100 where 100 is the maximum value over all years. Maps are: row 1 - 2007, 2008; row 2 - 2009, 2010; row 3 - 2011, 2012; row 4-2013, 2014. The view shed extent is shown as transparent pink shading. (Contains Ordnance Survey data © Crown copyright and database right 2010).




130000 131000 132000 133000 134000 135000 136000 137000 138000
842000 843000 844000 845000 846000 847000 848000 849000 850000 851000
A
B
C
D
E



27 In Fig. 5 the mean activity by golden eagles, per grid cell, is calculated for view shed regions inside (500 m turbine buffer) and outside of the wind farm.

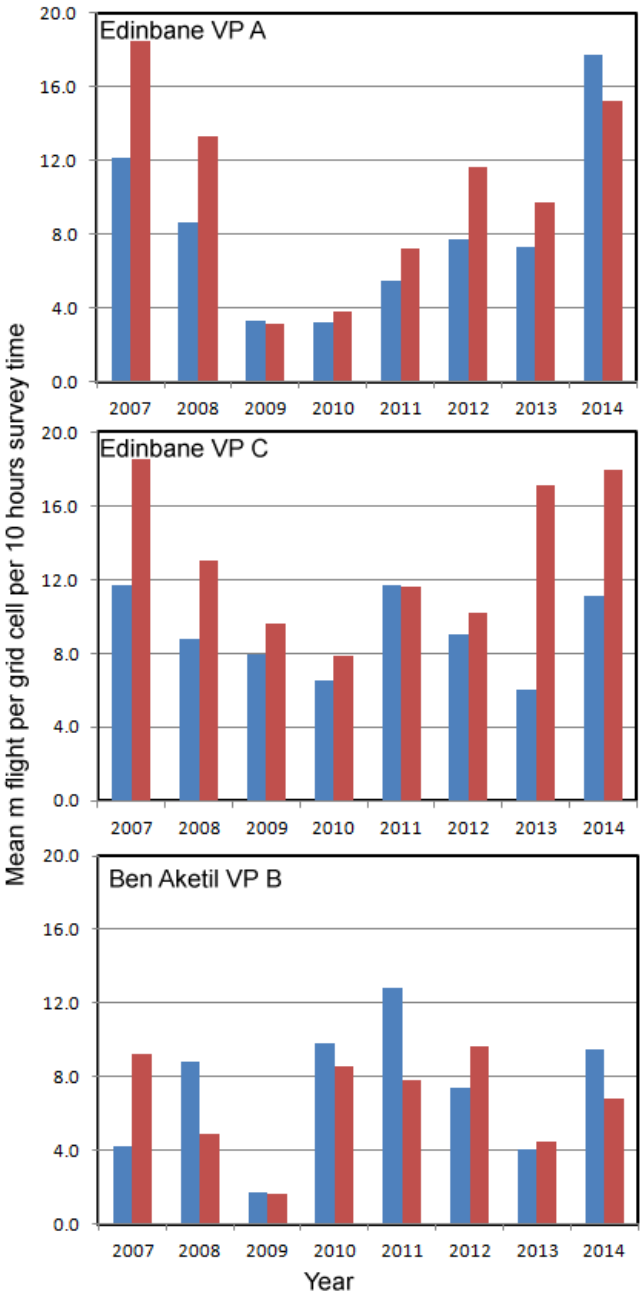
28 Data collected from VP A show a very clear pattern both inside and outside of the wind farm with low usage in 2009 and 2010 which coincides with the peak of construction activity. This is also shown in Fig. 3. Prior to construction there was more activity in the region now occupied by the wind farm and, despite large changes in the amount of activity, this continued until 2014. There does not appear to be much evidence for avoidance of the operational Edinbane wind farm, at least for data collected from VP A.

29 The data collected from VP C are broadly similar to those collected from VP A except that, apart from 2011, the mean level of golden eagle flight activity was always greater inside the wind farm. This is particularly true for 2013 and 2014. The mean figures for 2014 are very similar to the 2007 pre-construction values (11.7 and 18.5 outside and inside in 2007 compared with 11.1 and 18.0 in 2014). Again, there does not appear to be much evidence for avoidance of the operational Edinbane wind farm.

30 The data from VP B, which covers the Ben Aketil wind farm, do not follow the broad patterns seen in the VP A and C data. The Ben Aketil wind farm was constructed in 2007 with two additional turbines installed at the northern end in 2010. 2010 was the only year when the mean activity recorded from VP B, within the wind farm, exceeded that

recorded from both of the Edinbane VPs. It is unclear if this is related to the simultaneous construction activity at Edinbane and at the northern end of Ben Aketil. Fig 3 suggests that there was very little, if any, activity around the northern turbines of the Ben Aketil wind farm.

Figure 4. Golden eagle habitat use (mean m of flight per grid cell per 10 hours of observation) inside (dark red) and outside (blue) of the Edinbane and Ben Aketil wind farms from three VPs.



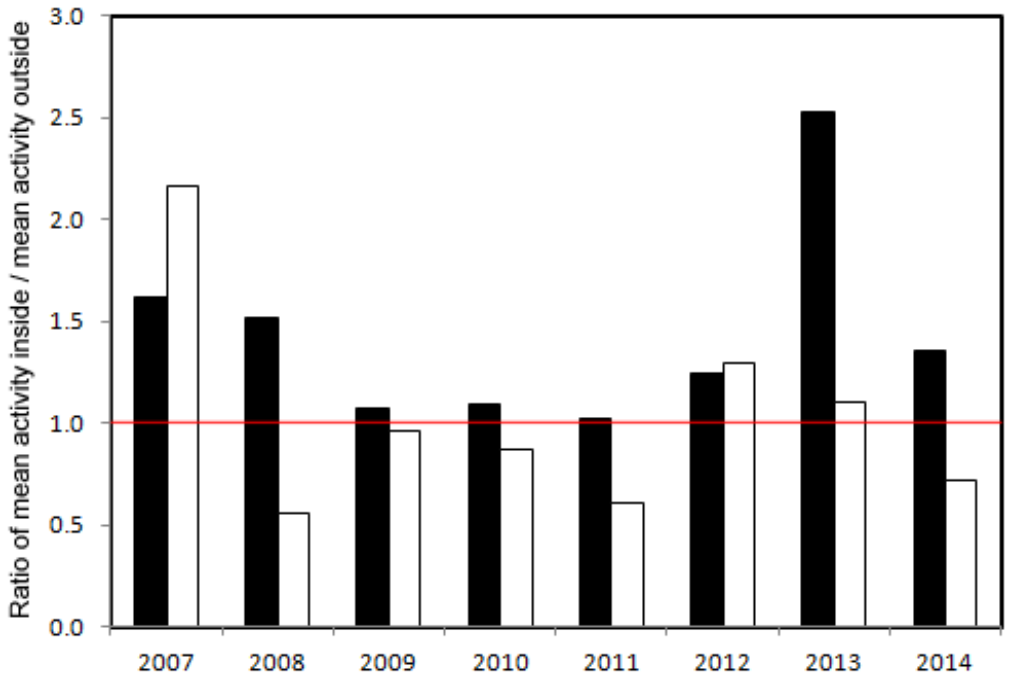
31 In Figure 5 differences between years have been removed by expressing activity within and outside of the wind farm as a ratio. Ratios greater than one indicate a larger mean

inside the wind farm. In addition, the data from VPs A and C at Edinbane have been pooled to provide a simpler comparison.

32 At Edinbane construction activity spanned 2008-2010 and the relative activity was lowest in the period 2009-2011. In 2013 there was relatively much more activity within the Edinbane wind farm than there was in the combined VP A and C view sheds outside of the wind farm although the excess was reduced in 2014 it was still greater inside the wind farm.

33 At the Ben Aketil wind farm there was over twice as much activity inside the wind farm in 2007. Subsequently there have been relatively less, or approximately equal, levels of activity inside the Ben Aketil wind farm (Fig. 5). It appears that golden eagles' responses to the Ben Aketil and Edinbane wind farms are inconsistent.

Figure 5. Golden eagle habitat use inside the Ben Aketil (white fill) and Edinbane (black fill) wind farms compared with the mean activity outside of the wind farms. A ratio of 1 (equal use) is marked by the red line.



34 If either wind farm has a displacement/avoidance impact this ratio should decline over time and, prior to 2013, there was some evidence for avoidance or displacement. In both wind farms the ratios declined (Fig. 5). The effect was more obvious in the Edinbane wind farm but this probably reflects differences in topography between the Edinbane and Ben Aketil wind farms (Fig. 9). Since construction ended at the Edinbane wind farm the ratio has increased suggesting that construction effects are greater than the operational effects.

35 Walker *et al* (2005) has detailed descriptions and analyses of the changes in golden eagle flight patterns following construction of the Beinn an Tuirc wind farm. Following construction they only recorded one flight out of 811 in the wind farm and at collision altitude. Even then there was evidence of avoidance on a micro-scale in that it passed between the two discrete turbine clusters. They suggest that three of the four eagle flights over or through the windfarm were also associated with intruding eagles rather than foraging in the open spaces between turbines, i.e. there was 100% displacement of foraging birds. This is clearly not the case on Skye, particularly at the Edinbane wind farm, as evidenced by some of the flight descriptions (Table 4).

Table 4. Details of close encounters between golden eagles and turbines.

18/01/2011 *10.47 head and shoulders of perched EA on small rocky outcrop SW side CGVA. 11.04 suddenly dropped down slope <10 as if hunting. Appeared to strike, missed and then swung N and continued <10 in slow glide following contours passing just east of turbines and close to line of small crags, clearly hunting. Swung <10 back and forth across face of BU. 11.12 lost sight just south of BU against background of a heathery ride in trees, at a point where I was watching bird through crossing of blades of 3 of turbines. Possibly landed in ride. Bird not seen again. It looked a good adult with a prominent line of light across top of its wings.* *26/02/2011* *13.00 juv EA into view >100 over BA in glide from east. It dropped 10-100 over trig and hung briefly in wind then continued 10-100 and did a parallel flight along W side of top 7 turbines only pulling away from turbines as it came close over anemometer before 8th turbine.* *10.58 ad EA, 10-100 from E of Ben Aketil between 2 of working turbines at blade height and then briefly swung close to W side of Cruachan Beinn a Chearcaill then landed on small grassy knoll on skyline 11.01.* *14/06/2011* *13.05 Imm EA flapping 10-100 from SE slope Ben Sca towards turbines, passing turbines 8 (stationary) and 7 (in operation) close on west side, below level of lower blade tips. Flew across windfarm road to west slope CGVA where it flew <10 to SW side* *05/09/2011* *11.01 Ad EA 10-100 over Beinn a Chearcaill in slow glide NW. It was just <100 as it passed slowly and very close over 2 of working turbines, no more than 4m above blade tips.*

14.18 Ad EA 10-100 over Cruachan Beinn a Chearcaill gliding west. Quickly turned S along line of turbine road then back north all >100 above line of turbines all in a slow glide and then back over CBaC and then slow glide north dropping o/s 14.28 E of Beinn a Chearcaill. As with flight 1 bird appeared to be just a few metres above top of turbine blades, but was a different Ad EA.
09/12/2011
12.32 EA both circled up 10-100 and drifted further north circling close amongst the 3 turbines closest to Ben Uigshader, only one of which was stationary. ..... Interestingly in the glide to the crag they both went parallel to and within a few metres of the turbine blades of the east most turbine, which was working. Certainly the closest encounter I have seen so far.
07/02/2012
11.00 Juv EA hanging into wind 10-100 to N E of first turbine at level of cockpit. Glided E passing second turbine on S side and continued towards knoll above inbye fence and o/s 11.03
23/03/2012
11.59 Ad EA 10-100 hanging into wind between turbines 1 and 2. Dropped lower to south east of CGVA o/s 12.01. 12.02 Probably same Ad EA into view from east slightly higher than last sighting. Rose, moving round to south west slope of CGVA with group of mobbing RN. Set off flying 10-100 passing turbine 3 on the west side, across Allt Ruairidh then dropped to <10 and flew downhill past the AR plantation close to the boundary fence, still with attendant RNs, continued over the gate on the moor and dropped o/s below AC 12.06. 12.08 Ad EA reappeared above AC rising 10-100. Displayed 3 steep dives above AC. 12.11 Set off in fast flight 10-100 across AR, circled south of turbine 4 then flew east passing 10-100 on north side of turbine 3 as far as the windfarm road where it appeared to circle <10 above some heaps of gravel along the roadside. Rose 10-100, circled, then flew back west across AR, passing 10-100 on south side of turbine 6, continued flying across top AR and to the saddle south of BA.
03/05/2012
10.03 ad EA appeared <10 along top of Beinn a Chearcaill drifting and hanging in wind close to ground as if hunting until 10.09 when it landed on a small rocky outcrop at North end of BaC and started to groom. 10.44 took off and circled <10 close to turbines. 10.45 it was 10-100 and slowly circling close to a stationary turbine drifting towards Ben Uigshader. It very slowly continued to circle and drift North then swung back over BaC still 10-100.
22/09/2012
13.50 Imm EA with attendant HC and RNs circling low SW slope CGVA <10 above turbine road verge between two turbine access side roads. Appeared to land o/s on low crag 13.54. Dived at by 2 RNs. When RNs flew off 3 HCs arrived and perched on cragtop making occasional dives at supposed perched EA.
5/10/2012
12.21 Ad EA arrived unseen on top of cairn. 12.47 off perch and quickly circled up >100 and drifted west. Then it circled out over the turbines. 12.49 it went into a series of 5 shallow displays in a tight circle over the bealach turbines, before drifting west still >100. Soon started to circle up again. Then again drifting west losing some height and occasionally flapping. 12.53 o/s close to Ben Aketil.
12.03 EA soaring >100 to east of Ben Sca summit. Set off in flight passing between turbines 11 and 10 and over Cruachan Beinn a Chearcaill dropping below summit on east side o/s 12.06.
12.52 Ad EA rising over east slope Ben Sca. Set off flying to east, passing between turbines 9 and 10. Began undulating as it passed them and continued over Beinn a Chearcaill where it dived steeply two or three times then dropped o/s on east side 12.59.
07/12/2012
13.26 to 13.30 EA appeared <10 without the RN and was clearly working the ground (hunting) on the west side of BaC. It slowly worked its way north and low between the turbines then back over the same area and o/s east of BaC. No apparent fear of the turbines that were all still turning very quickly in the strong wind.

13.32 until 13.37 EA back in view still <10 and hunting across the top of BaC and worked its way slowly down between the same turbines as before and then back along the west side of BaC and dropped suddenly o/s into the heather, probably a strike at prey.
27/12/2012
09.46 2EA perched close together on the skyline of Beinn a Chearcaill. 09.55 one EA dropped off its perch and went between the 9th and 10th turbines <10 o/s skimming through the heather at 09.56 just as the 2nd EA came off its perch and copied the same flight o/s 09.57. (Looked like very low hunting flights with the target out of my sight).
23/04/2013
12.20 until 12.43 had 2EA (prb SK42 pair which have a new ml this year, and do not appear to be nesting) They were wide circling and sweeping fast close to each over >100 over the area of 5 south turbines. Clearly enjoying the fresh west wind, but possibly having a good look at the large group of ewes and the odd lamb below this group of turbines. At 12.42 they suddenly both went into fast steady glides NW in close formation and low o/s around the north of Ben Sca 12.43. 12.48 Ad EA flying <10 around the north west side Ben Sca, flew close to the hillside to Ben Aketil and around the north west side BA where it dipped at a second Ad EA taking the same flight path below it. 12.51 They both glided out over the north west slope and then flew >100 north over the turbines and the west edge of the windfarm plantation where they both hung into the wind and one bird glided further west of the turbines. It then flew back over the turbines and was lost as it headed over the plantation dropping lower. The other EA stayed higher and flew north and was flew over the plantation north side of the road, east of Sron nan Aighean lost 13.00. (Prob SK 42 pair).
12/07/2013
10.53 one Juv and one Ad EA,10-100 circling close together and flapping as they slowly came from N and made their way between N turbines, Ad closely following Juv to start. As they got S of turbines Ad moved ahead and Juv followed. 10.56 both >100.
13/09/2013
11.48 Ad EA slowly gliding 10-100 from E over Beinn a Chearcaill, hung over top and then dropped to <10 as it glided along top and landed beside cairn on Cruachan Beinn a Chearcaill 11.49. 11.52 EA suddenly attracted by small unidentified bird of prey over W side of Beinn a Chearcaill and took off quickly, flying 10-100 towards bird which rose up higher as EA went into a display of 9 dives repeatedly turning back on itself 10-100 above W slope of Beinn a Chearcaill. EA flew fast along W slope as if still intent on chasing something unseen, dropped to <10 over windfarm road and flew close to base of tower on W side of turbine 17 at 12.03. EA continued S over inbye where a flock of RNs was congregating. EA flew amongst RNs without chasing them and circled out over area of farm.
11/12/2013
10.07 Ad EA 10-100 W of Cruachan Glen Vic Askill, moving very slowly into wind and stopping regularly & hanging motionless for almost a minute each time. 10.15 reached as far as turbine 18, which was stationary and bird again hung in wind but this time just above height of blades. 10.16 drifted just S of turbines and again hung into wind scanning ground below for 8th time. 10.18 moved a short distance twice more and again hang hunting. By 10.20 it had drifted almost as far as power station and then swung W in a continuous very slow glide low over plantation 10-100 possibly dropping into trees o/s 12.24. Although clearly looking like it was hunting it was not seen to drop as if to strike at any time.
10.49 Ad EA swung quickly in from W and again started to hang hover >100 over still stationary turbine. This time bird had a very prominent full crop. Possibly same bird as No. 1 but after a feed. It hovered there moving very little until 10.52 when it widened its wings and swung up >100 and above turbine 17 then made 3 steep display dives heading over Cruachan Glen Vic Askill then suddenly dropped into a steep dive E of CGVA as if giving chase, o/s 10.55.
01/01/2014

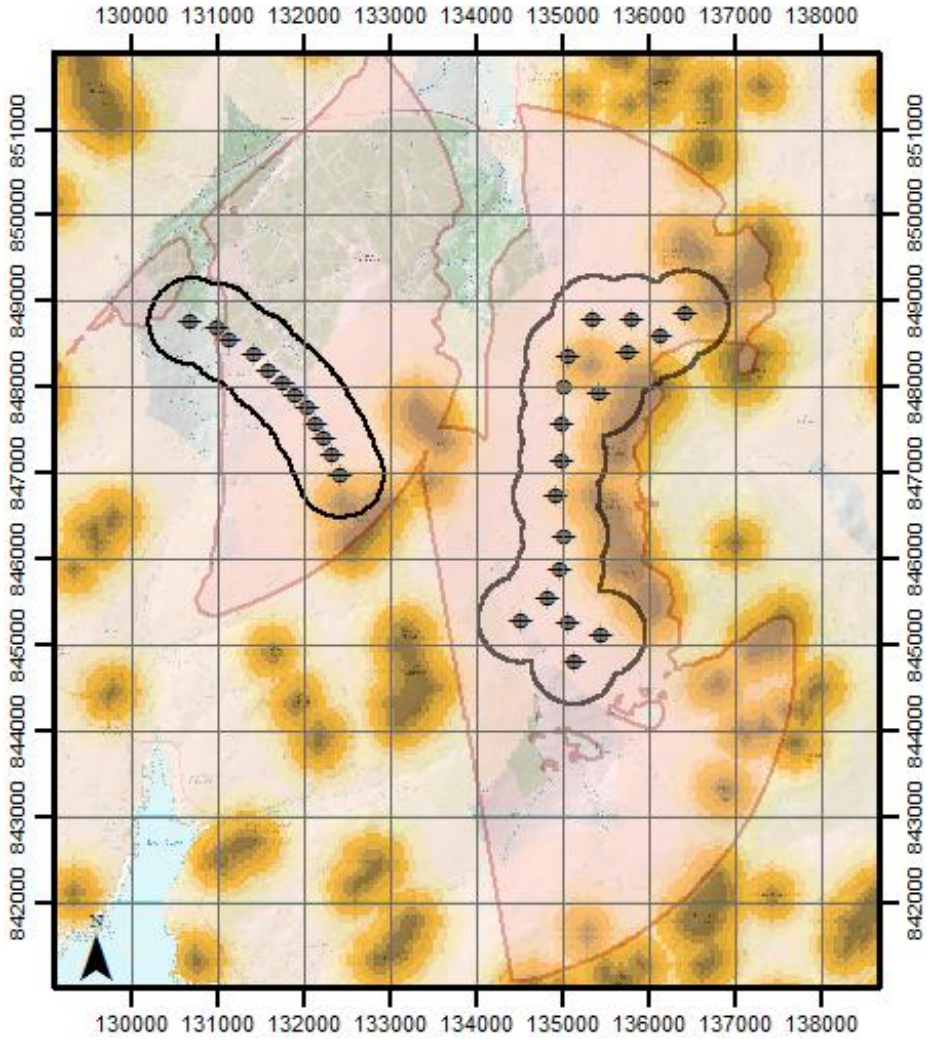
10.37 Ad EA, sweeping up 10-100 into view close to 2nd turbine from S. Briefly circled between 1st and 2nd turbine 10-100 until 10.39 when it set off in a sweeping low flight <10 NE
07/02/2014
13.38 Ad EA circling 10-100 just W of CGVA. 13.40 went into a slow glide W turning S and o/s 13.41 towards An Cleireach after passing close to 4 of turbines all at blade height.
21/04/2014
14.33 Ad EA 10-100 from N close to W side of turbines. As it came alongside stationary turbine it swung E very close to blades and crossed over to CGVA and swung <10 across face and around hill to E o/s 14.36.
08/05/2014
13.57 Ad EA flying <10 heading S through Gleann Eoghainn. Passed over Rageary Burn and continued to head of Aketil Burn where it slowly rose, passing >100 over turbines and plantation and flew >100 E over Mullach Ben Sca and towards low hills to N of Ben Uigshader, lost 14.14.
16/05/2014
10.01 Ad EA being dived at by a RN heading N along top of CGVA 10-100. EA swung quickly W still 10-100 passing between 7th and 8th turbines losing RN as it dropped <10 across ground 10.03, working its way slowly o/s over saddle S of Ben Aketil 10.05.
01/09/2014
11.40 Imm EA with prominent crop. It briefly hung in wind on corner of Ben Sca then went into a slow steady glide E between 2 of turbines at blade height then continued E.11.46 It was 10-100 over N end of BaC and started to drift slowly N and dropped <10 between N turbines and continued on low over heather just W of plantation fence still <10 and probably hunting 11.50. 11.51 It appeared to pick up some freshening wind and quickly swung up 10-100 and drifted back S as suddenly a Juv EA came diving down at it from S. They both swung S and chased each other <10 just W of Uigshader and E of turbines. 11.53 Skimming close together low through tree tops they turned back and continued close together <10 over moor. 11.55 They quickly circled up 10-100 close together and set off S in a long glide back over Ben Uigshader and then continued S dropping quickly low over plantation and o/s together E of Beinn a Chearcaill 11.56, (several times appearing very close to Ben Uigshader turbine but appeared not to take any avoiding action).

36 It is clear from the above analyses that the use of the Edinbane and Ben Aketil wind farms by golden eagles differs markedly. One explanation for this is the uneven distribution of ridge habitat (Fig. 6).

37 Ridges appear to be very important to eagle flight in Scotland (McLeod *et al*., 2002). Therefore it would be helpful if they could be mapped throughout the study region. This was achieved by writing a script for the open source R statistical software (R version 2.15.1-- "Roasted Marshmallows" (C) 2012 The R Foundation for Statistical Computing, ISBN 3-900051-07-0). Briefly, the algorithm uses a 50m DTM and examines the relative height of a central pixel with opposing test pixels 200 m apart. If the combined difference in altitude between the central pixel and the test pixels is greater than a user-supplied threshold the central pixel is a ridge. Four comparisons, horizontal, vertical and both

diagonals are made and the central pixel only needs to pass the threshold test for one of these directions to achieve ridge status.

Figure 6. Weighted distances to ridges and the combined view sheds from VPs A, B & C shown with the Ben Aketil and Edinbane wind farms. (Contains Ordnance Survey data © Crown copyright and database right 2010).

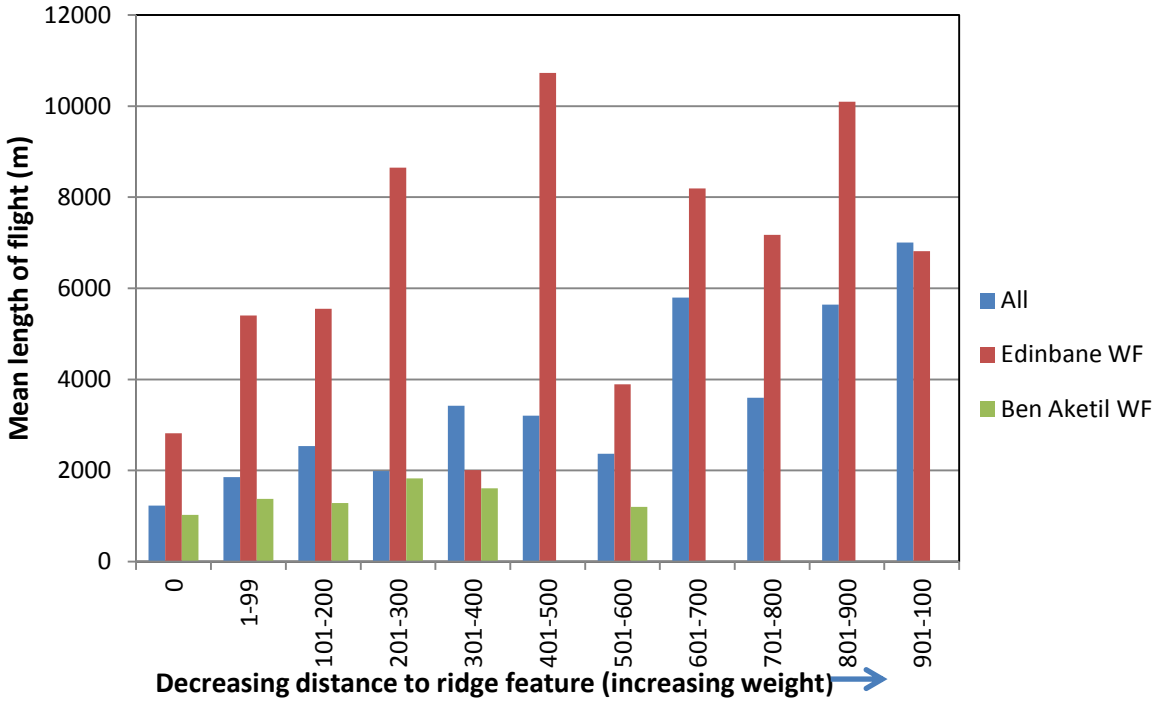


38 One of the key elements of the PAT eagle ranging model (McLeod *et al*., 2002) is the weighted distance to a ridge (Fig. 4 in McLeod *et al*., 2002). The weighting is needed because the PAT model assumes a non-linear decay in the use of ridges out to a maximum of 1,200 m from a ridge. Beyond 1,200 m the weighted distance is 0, i.e. unused. The applied weightings for distances (m) to a ridge feature are: 0 m - 1000; 1-100 m - 430; 100-200 m - 249; 200-300 m - 167; 300-400 m - 110; 400-500 m - 77; 500-600 m - 70; 600-1200 m - 65; above 1200 m - 0. A weighted distance-to-ridge map has been created for the whole of Scotland and northern England. This was clipped to the study area for these analyses (Fig. 6).

39 The distribution of ridges is not the same across the whole site or between wind farms (Fig. 6). The Ben Aketil wind farm has fewer habitats close to ridge features with only the southernmost turbines overlapping with ridge habitat. Conversely most of the eastern boundary of the Edinbane wind farm is ridge habitat as is the land south of the Ben Aketil wind farm that has seen a recent rise is use by both golden and white tailed eagles.

40 Overall, and at Edinbane, there is a significant trend to increasing use as the weighted ridge distance increases (Fig. 7, note that the weighted distance is an ordinal and not a linear scale). Therefore, differences in use, and the ways in which golden eagles interact with turbines, may be influenced by the amount and distribution of ridge habitat.

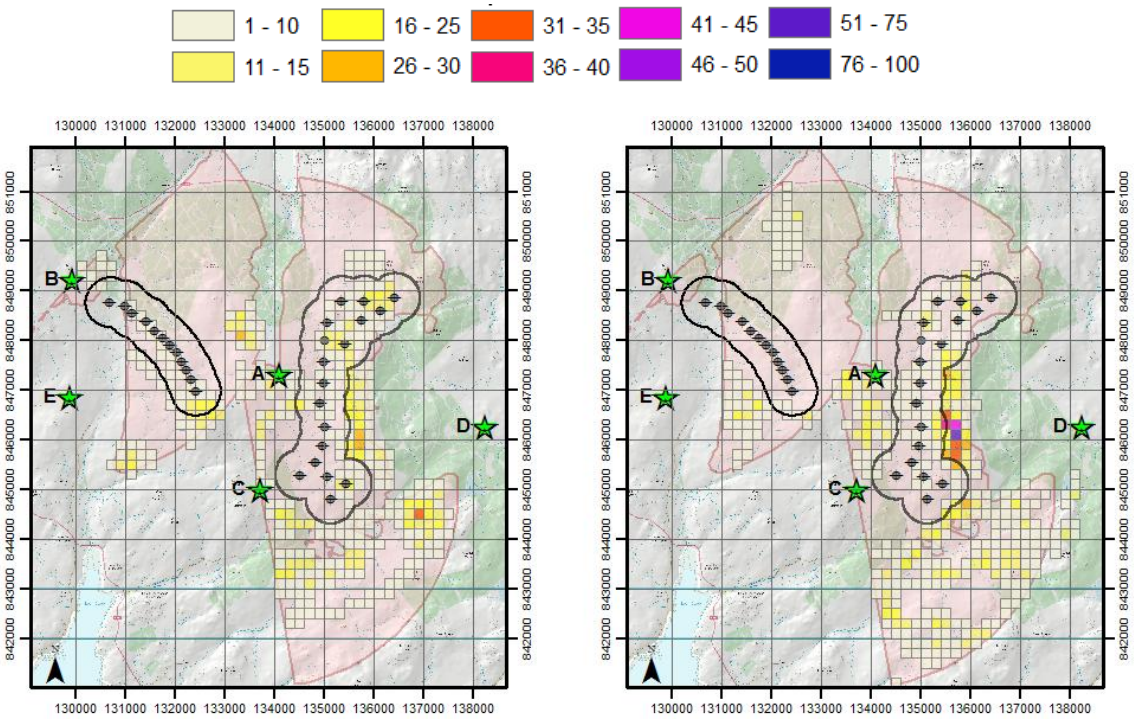
Figure 7. Golden eagle habitat use in relation to weighted distances to ridges across all years pooled (larger values are closer to ridges).

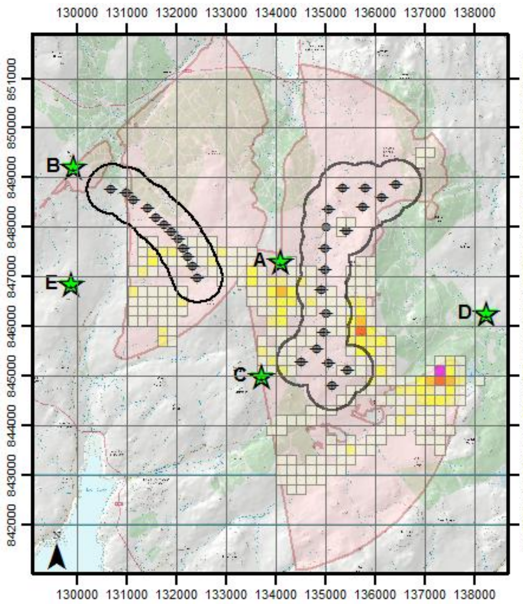


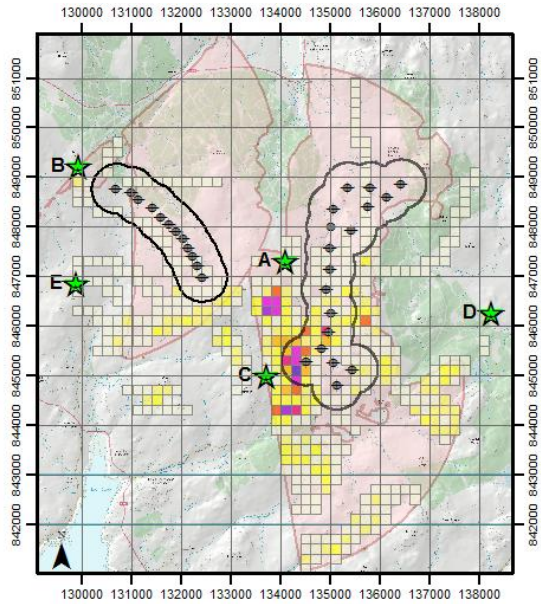
41 White-tailed eagle flight activity has increased over the eight survey years (Table 2) particularly in the VP C Edinbane view shed (Figs. 8 & 9). There were similar increases, but with less activity recorded, in the other view sheds (Figs. 8 & 9). The main exception is 2009 when there was relatively little activity. The increase almost certainly reflects the expanding white-tailed eagle population in this part of Scotland.

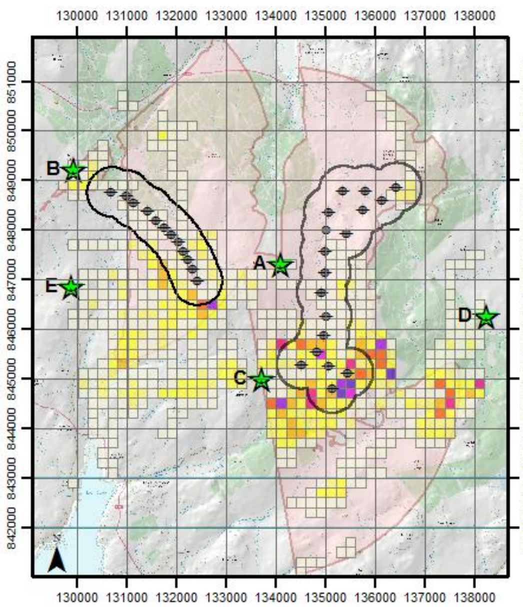
42 The mean level of recorded activity has generally been similar or greater in the wind farms compared with the surrounding habitat. This is particularly obvious in the southern part of the Edinbane wind farm where there was an enormous increase in the activity (Fig. 8). There is very little evidence for any displacement of white-tailed eagle flight activity by either wind farm (Figs. 8 & 9).

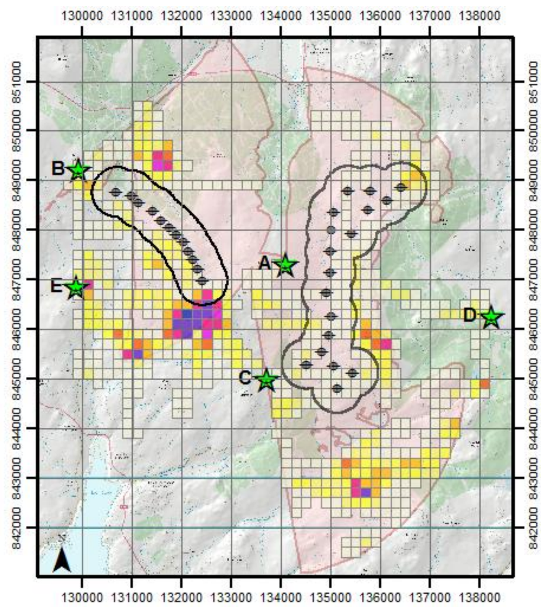
Figure 8. Habitat use by white-tailed eagles recorded from three vantage points (A,B and C). Values are meters of flight (all altitudes) per 10 hours of observation rescaled to 0-100 where 100 is the maximum value over all years. Maps are: row 1 - 2007, 2008; row 2 - 2009, 2010; row 3 - 2011, 2012; row 4-2013, 2014. The view shed extent is shown as transparent pink shading. (Contains Ordnance Survey data © Crown copyright and database right 2010).

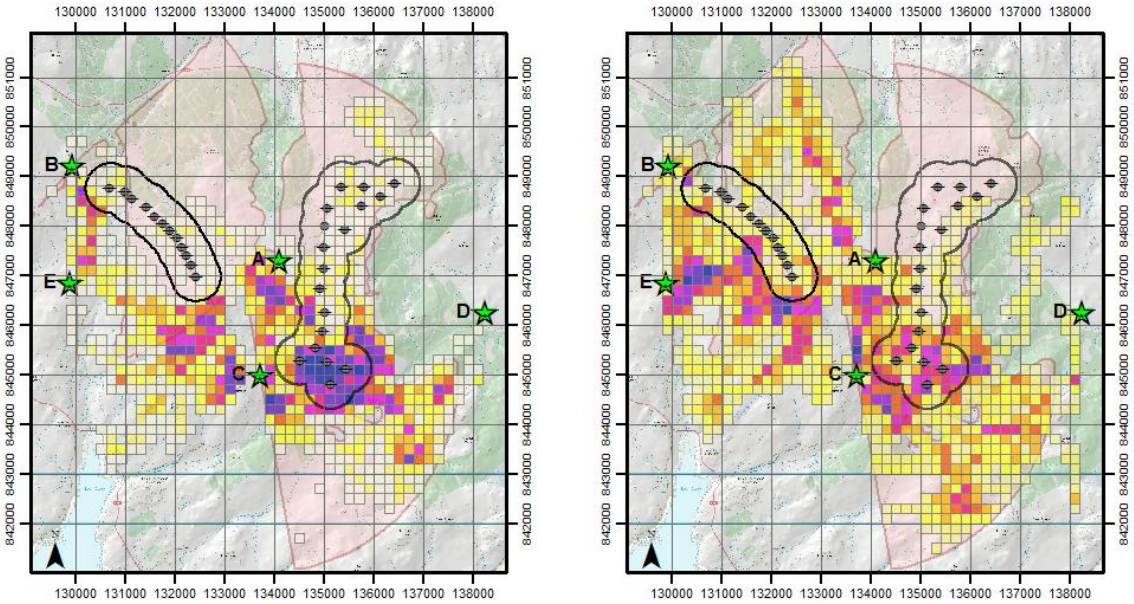



130000 131000 132000 133000 134000 135000 136000 137000 138000
842000 843000 844000 845000 846000 847000 848000 849000 850000 851000
A
B
C
D
E


130000 131000 132000 133000 134000 135000 136000 137000 138000
842000 843000 844000 845000 846000 847000 848000 849000 850000 851000
A
B
C
D
E


130000 131000 132000 133000 134000 135000 136000 137000 138000
842000 843000 844000 845000 846000 847000 848000 849000 850000 851000
A
B
C
D
E


130000 131000 132000 133000 134000 135000 136000 137000 138000
842000 843000 844000 845000 846000 847000 848000 849000 850000 851000
A
B
C
D
E



43 When use within the wind farms was expressed as a ratio of that outside of the wind farm, thus removing the large annual differences in the amount of activity, there is little evidence that white tailed eagles demonstrate any avoidance (Fig. 10). Instead there is considerable between-year variability at both wind farms.

44 Our observations of a lack of evidence for any significant displacement of white-tailed eagles by the operational wind farms supports the findings of work at the 68 turbine Smøla wind farm (May *et al.,* 2010) which suggests that white-tailed eagles avoid turbines less than golden eagles, supporting the view that the avoidance rate in collision modelling for white-tailed eagles should be kept at 95%. However, they also note that the low avoidance, and subsequent collisions at the Smøla wind farm factor, "*probably results from high levels of flight and breeding display activity, as demonstrated at the Smøla wind-power plant, where numerous collisions have occurred*."

Figure 9. White-tailed eagle habitat use (mean m of flight per grid cell per 10 hours of observation) inside (dark red) and outside (blue) of the Edinbane and Ben Aketil wind farms from three VPs.

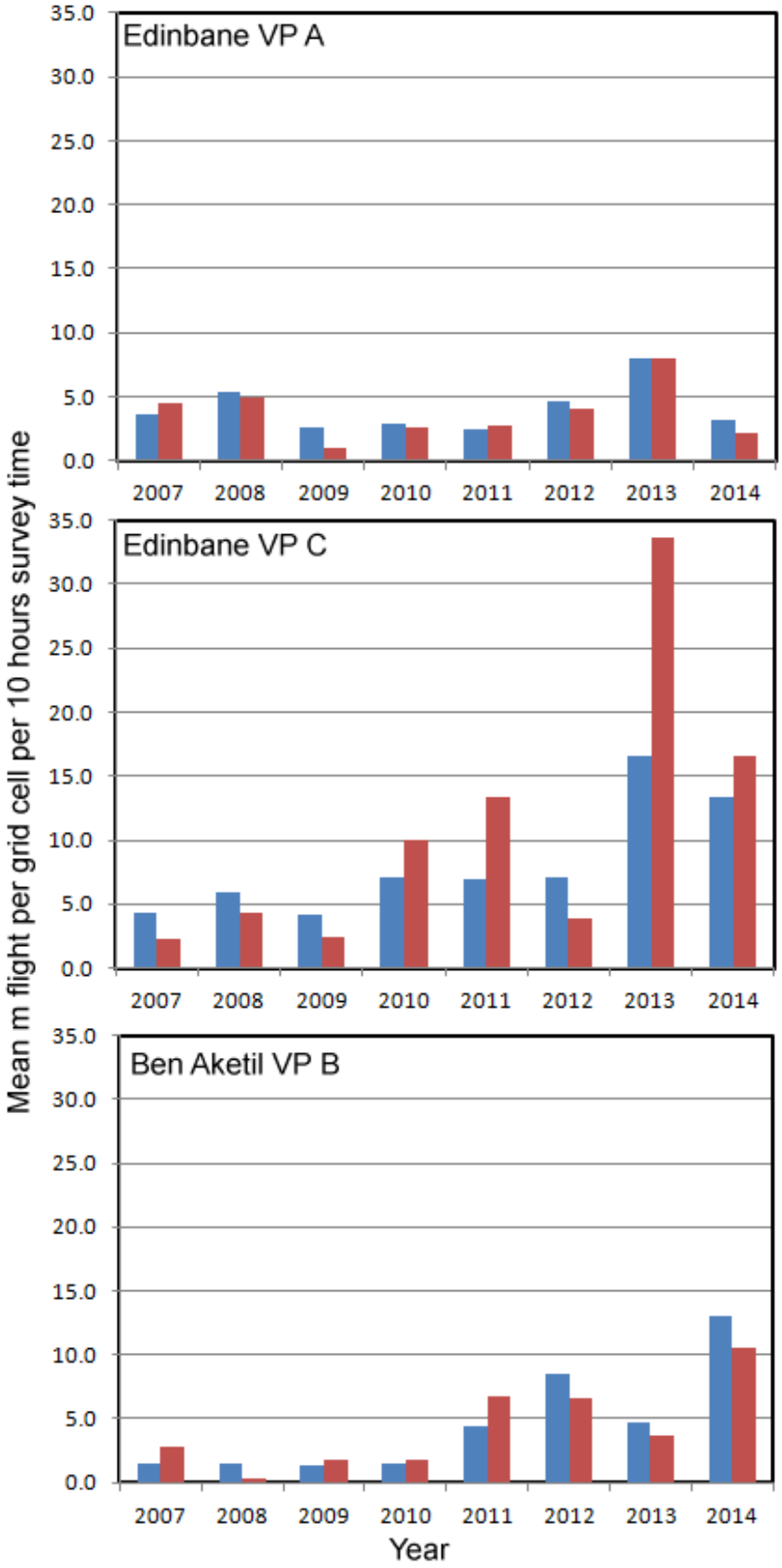
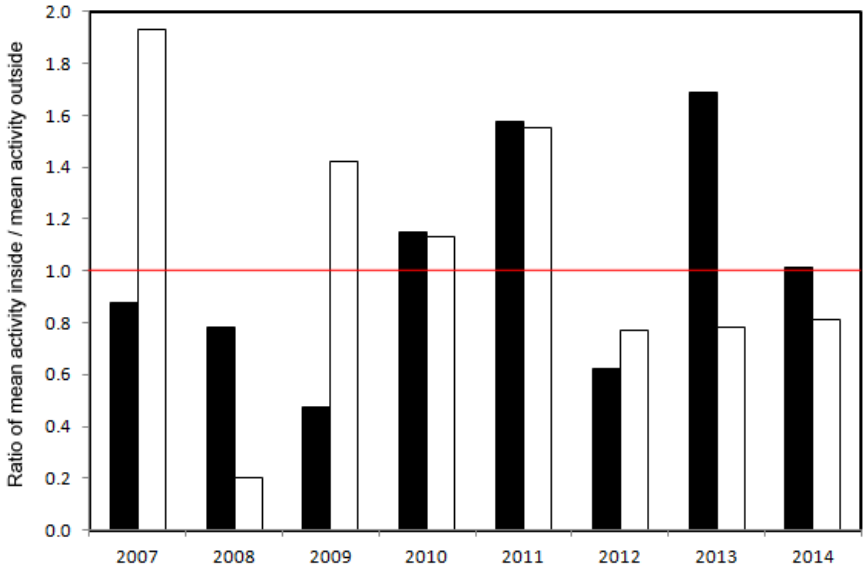


Figure 10. White-tailed eagle habitat use inside the Ben Aketil (white fill) and Edinbane (black fill) wind farms compared with the mean activity outside of the wind farms. A ratio of 1 (equal use) is marked by the red line.



45 This apparent absence of significant avoidance of turbines by white-tailed eagles is backed up by the descriptions of flights close to turbines (Table 5).

Table 5. Details of close encounters between white-tailed eagles and hen harriers and turbines.

11/05/2011 *09.14 Ad WE 10-100 gliding towards turbine 11 from east. Flew past turbine 12 at level of cockpit and continued slowly gliding <10 across rising ground heading SW* *19/06/2011* *10.40 Ml HH carrying prey <10 along fence N of VP towards turbines. Rose >100 as it continued over Gleann Eoghainn then dropped to 10-100 as it approached turbine 9 and flew round tower on west side, passing close to tower within blade's length but below tip. It continued to plantation edge and flew N over trees, lost between Red Burn and windfarm road 10.48.* *11.20 Ml HH carrying prey flying 10-100 east of fence, similar place to previous sighting. Flew straight for turbine 11 and for approx a minute was seen flying in line with tower. As it flew near it dropped a little lower and flew wide round west side of tower, below but within length of rotating blade.* *12.21 Ml HH carrying prey 10-100 from direction of Allt Ruairidh north of VP. Headed towards turbine 11, rose as it flew so that it was seen against turbine cockpit then dropped back 10-100, round east side of tower, passing close to tower. Flew over plantation and appeared to drop into treetops along E bank of Red Burn o/s 12.29.* *19/08/2011* *13.12 Juv WE, no tags, gliding over forestry SE side Sron nan Aighean to forest east of Stone Geers, dropped o/s 13.20 as it flew down hill. 13.24 reappeared flying 10-100 above windfarm road which bends between turbines 8 and 9, then flew along verge beside windfarm road as far as site hut, where it dropped <10 and flew between turbines 7 and 8, and <10 out over moor where sheep were grazing, and landed within c120m of turbine 5. 14.09 flew <10 to a perch in new*

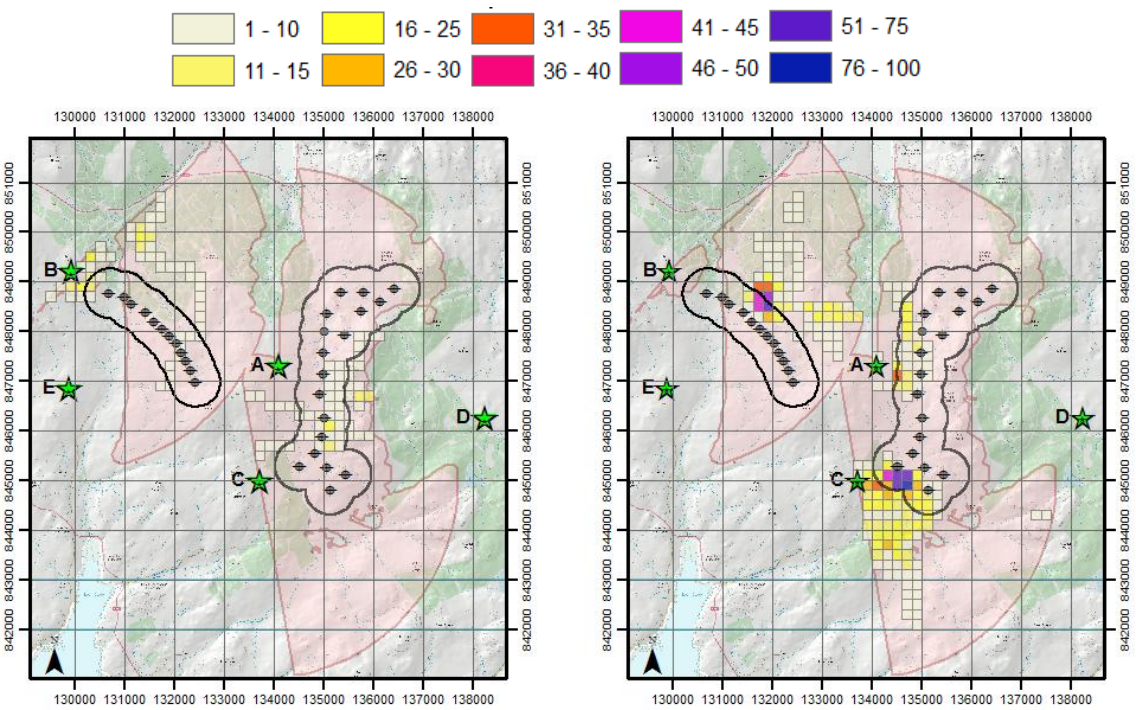
position c20m from Feorlig hill track within c100m of turbine 3.
28/10/2011
13.23 Ad WE 2 white tags, dropping and rising 10-100 between turbines 1 and 2. Bird kept its legs lowered and seemed to be playing in wind rising up slope. 13.32 Second Ad WE, also 2 white tags, hanging 10-100 into wind nearer to 1st turbine. Second bird dropped <10 as it flew downslope and was soon lost. First bird stayed 10-100 and drifted closer to tower, at about level of lowest blade tip (turning rapidly).
07/02/2012
10.51 Ad WE hanging into wind to E of tower of turbine 1, at level of lowest rotating blade tip. Dropped down wind and o/s on SE side of tower 10.52.
11/04/2012
11.06-11.12 Ml HH hunting <10 along Eastern edge of plantation. It continued hunting <10 through stationary turbines then on across E corner of Beinn a Chearcaill o/s.
11.17-21 Ml HH hunting <10 along Southern edge of plantation then close along edge of windfarm road then between turbines and o/s E side of Glac na Brothaig Airde.
06/07/2012
11.20 Juv WE appeared 10-100 over top An Cleireach and glided back and forth to Beinn a Chleirich, then by 11.25 moved out over VP, still gliding and circling. 11.28 Returned to AC and rose >100. 11.34 off in glide to E, passing S of turbine 17, and as it drew level it began flapping heavily as if working hard to keep clear of turbine. Dropped 10-100 round S E knoll of CGVA o/s 11.39.
12/09/2012
11.44-11.48 Ad WE no tags 10-100 slow glide into wind over Beinn a Chearcaill continued 10-100 between 4 stationary turbines and close over maintenance vans.
24/11/2012
11.36 WE drifted further E. 11.41 Set off flying through turbines, passing 10-100 on N side of turbine 11 to Cruachan Beinn a Chearcaill where it flew back and forth close to hill, approx. 10m below cairn.
20/02/2013
12.04 Perched WE took off and flew <10 towards turbines, passing turbines 11 and 12 and flew <10 over windfarm road approx. where access road to turbine 13 joins it. It picked up a low contour around SW slope of CGVA passing along a line of low crags and here it joined other Ad WE already in flight 12.07. They flew together into wind S E of turbine 17 still 10-100 then flew back as if to land o/s on low knoll on SE side CGVA 12.10.
01/03/2013
13.33 young untagged WE 10-100 around SW side of Cruachan Glen Vic Askill. Drifting slowly N between turbines and hill. 13.34 It started to circle slowly up and drift over Beinn A Chearcaill >100, 13.37 then briefly swung W then back E over turbines >100. 13.38 Just above top of turbines it started flapping and gliding slowly N. It soon dropped 10-100 just N of turbines 13.39. 13.40 It then started to circle slowly up and drift back over turbines >100. It continued to circle slowly over all N turbines without getting any more height.
23/04/2013
11.14 WE (no tags and no feathers missing) circling up 10-100 over An Cleireach harassed by 2RN. 11.17 set off in a glide close to me and very close to and around the 5 south turbines. 11.19 it weaved between the turbines then started to circle up >100 between me and the turbines. 11.25 still >100 it had drifted just north of me. It then went in a very slow glide SW and finally o/s 11.32.
13.01 WE (prb same one as 5) circling 10-100 over An Cleireach. 13.03 close over me then continued over to the same 5 turbines. It continued 10-100 and passed close between and around the turbines and clearly looked to be briefly hanging over the ewes. 13.06 it circled further east and up >100 then at 13.14 it drifted back into the wind very slowly and over me again 13.17. 13.18 it was back into circling up over AC. 13.20 it started to glide south. Then quickly went into a steady glide SE and o/s dropping low on the south side of Beinn Chait 13.24.

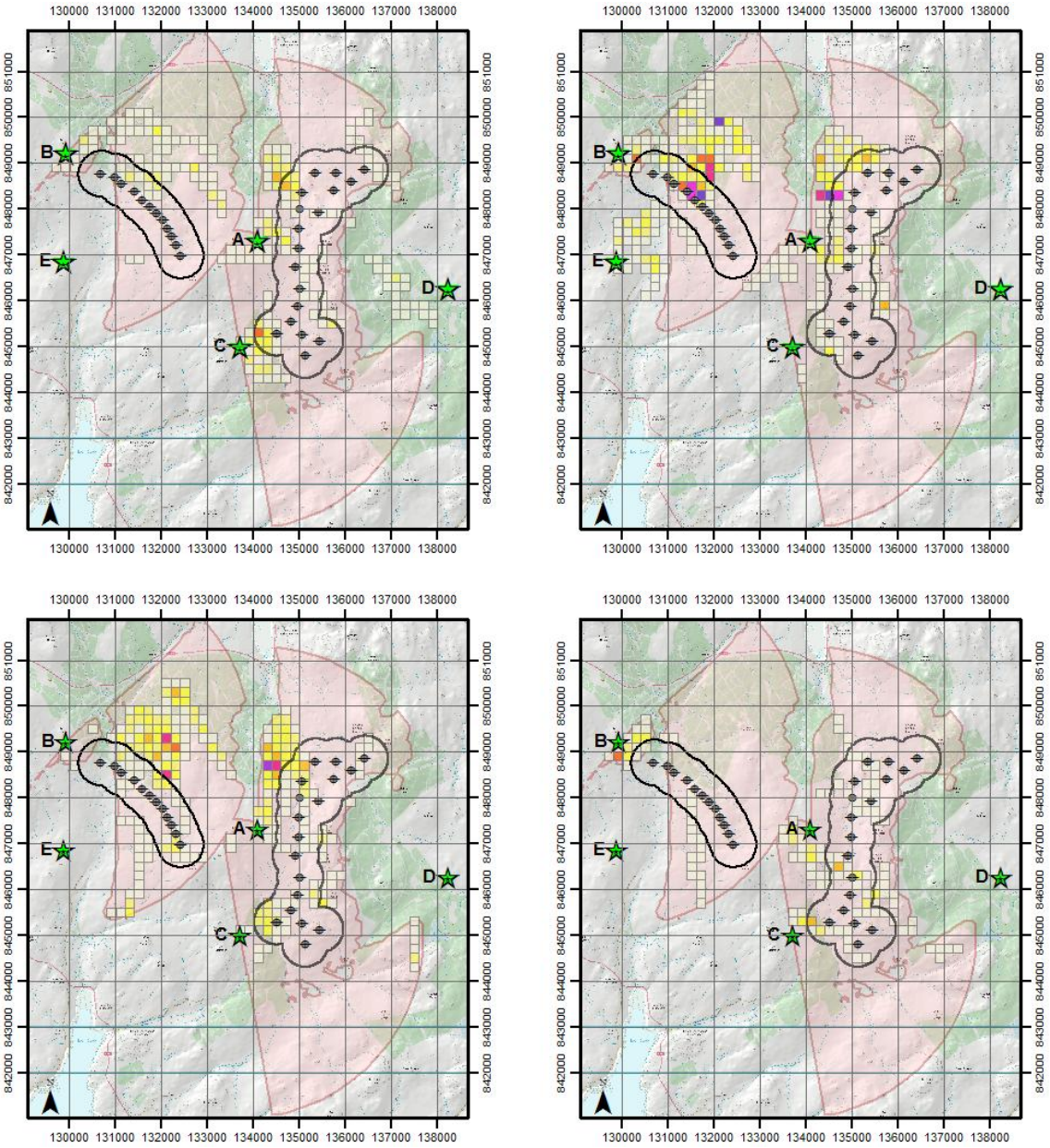
10.23 a third WE appeared 10-100 from the west side B a C, rose and glided along the west side Ben Aketil and continued >100 parallel to the turbines. It hung in the area of turbines 7 & 8 facing into the wind. It then glided over the gap between 7 & 8 and back south along the line of turbines, dropping 10-100 but was lost against the hillside as a shower came on 10.40.
12/07/2013
12.35 Imm WE 10-100 S of turbine 17, passing turbine 18 on N side, continued over plantation, dropping <10 through treetops and S of AC o/s 12.37
12.51 Imm WE perched on SW slope Ben Aketil. 13.06 took off, flew <10 back and forth as it rose up S slope BA, slowly rose >100 above summit. 13.15 Glided across to CGVA passing >100 over turbine road. Circled 10-100 around top CGVA. 13.22 Gradually worked its way N to Beinn a Chearcaill. 13.25 flew 10-100 on W side of turbine 9, then flew 10-100 back and forth between turbines 8 and 6, then flew N W, going o/s 13.28.
09/09/2013
11.02 Untagged young WE into view hanging >100 over stationary turbine. This bird also had a very prominent crop and also it made very little progress, simply being held on spot by strong wind. 11.11 It finally broke into a sweeping glide E and dropped low o/s in direction of Loch Ravag roost 11.13.
13.09 Same WE hanging 10-100 over same turbine almost motionless until 13.25. Then it went into sloW drift imaginable SW still 10-100 until it appeared to drop into area SW of plantation o/s 13.34.
26/12/2013
4 14.07 WE took off and flew constantly flapping towards turbine 17 and flew past it on S side 10-100 below level of hub. Continued its flight passing turbines 16 and 15 in same way, appearing to fly close to them, also below hub height. With turbines facing S this meant bird was parallel to plane of rotating blades. WE continued in steady flapping flight 10-100 across Allt Ruairidh to saddle N of Beinn a Chleirich passing <10 over saddle o/s 14.10
01/01/2014
10.32 WE 10-100 circling and hanging in strengthening wind on SE corner of CGVA until 10.37. It then went into a slow sweeping glide o/s between 2 working turbines at blade height 10.39.
04/02/2014
12.41 Young untagged WE flying 10-100 around east side of Ben Aketil in a slow glide east towards turbines. 12.45 Still 10-100 it swung south along line of turbines until 12.47 when it passed between 4th and 5th turbines from south and turned sharply east. As it passed turbines it then started to hover rising >100 and drift very slowly east as if hunting, closely scanning ground below. At 12.53 it fell into a fast glide o/s south east of Cruachan Glen Vic Askill.
07/02/2014
11.08 SA WE 10-100 flying from Cruachan Beinn a Chearcaill, passed between 2 turbines and began rising >100.
01/09/2014
11.16 Ad WE flying 10-100 from direction of higher ground above AR and headed east towards turbine road. Passed 10-100 between turbines 6 & 7 from the south.
18/11/2014
12.16 Young untagged WE <10 drifting and hanging over perched EA. 12.19 It circled up 10-100 and drifted north. 12.21 It was >100 circling and drifting back south. 12.23 It swung west and dropped to 10-100 as it passed close between 2 turbines and continued west losing height in low flapping flight and o/s 12.25 heading in the direction of the south side of Ben Aketil.
20/12/2014
10.41 Ad WE flapping against wind <10 heading downslope along west side of turbines. It was first spotted in line with turbine 5 and rose 10-100 as it flew along line of turbines. It flew close to mast near bend in road then flew over road between turbines 7 and 8 and continued flying east over Mullach Ben Sca o/s 10.52.

46 Hen harrier activity has been very varied over the six survey years but in most years the mean activity has been largest in the wind farm areas (Figs. 11 and 12). The annual habitat use maps in Fig. 11, and comparisons of activity inside and outside of the wind farms (Fig. 12), provide little evidence of avoidance or displacement and the descriptions of flights (Table 5) also suggest a lack of avoidance. No maps are shown for 2013 and 2014 given the very low levels of activity in those years (Table 2).

47 Almost certainly differences between years and regions reflect the locations of successful harrier nest sites. In a detailed analysis of the possible impact of wind farms on hen harriers Haworth and Fielding (2012) concluded that there was no evidence that the presence of turbines restricted breeding attempts but there was some evidence for displacement from the habitat in the immediate vicinity of turbines.

Figure 11. Habitat use by harriers recorded from three vantage points (A,B and C). Values are meters of flight (all altitudes) per 10 hours of observation rescaled to 0-100 where 100 is the maximum value over all years. Maps are: row 1 - 2007, 2008; row 2 - 2009, 2010; row 3 - 2011, 2012. The view shed extent is shown as transparent pink shading. (Contains Ordnance Survey data © Crown copyright and database right 2010).





48 When use within the wind farms was expressed as a ratio of that outside of the wind farm, thus removing the large annual differences in the amount of activity, there is little evidence that hen harriers demonstrate avoidance (Fig. 13). Instead there is considerable between-year variability at both wind farms.

49 It might be tempting to describe the ratio declines of 2011 and 2012 at Ben Aketil as evidence of the development of avoidance of the operational wind farm but the same cannot be true at Edinbane where 2012 saw the second largest ratio following the apparent decline in 2010 and 2011.

Figure 12. Hen harrier habitat use (mean m of flight per grid cell per 10 hours of observation) inside (dark red) and outside (blue) of the Edinbane and Ben Aketil wind farms from three VPs.

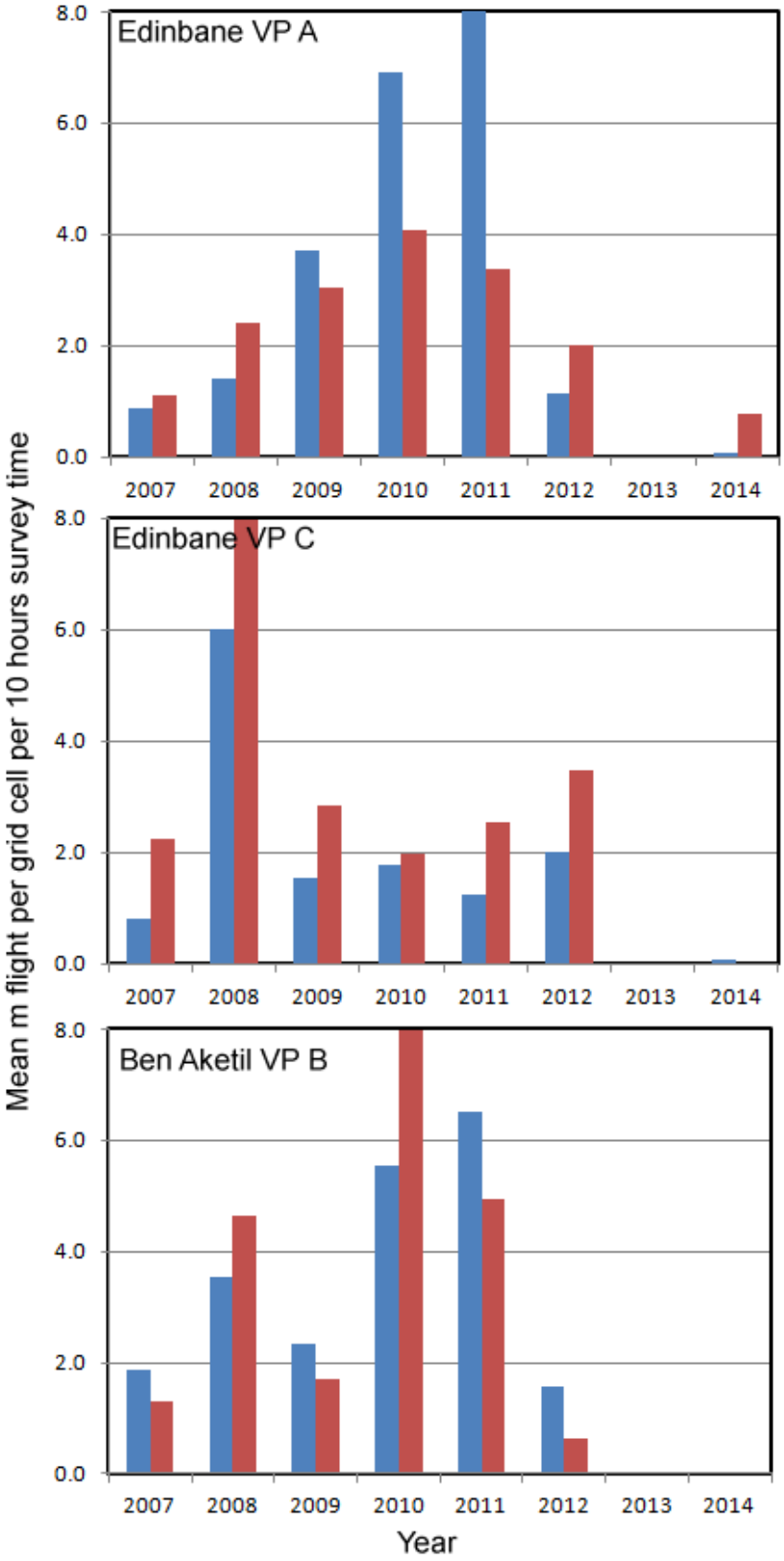
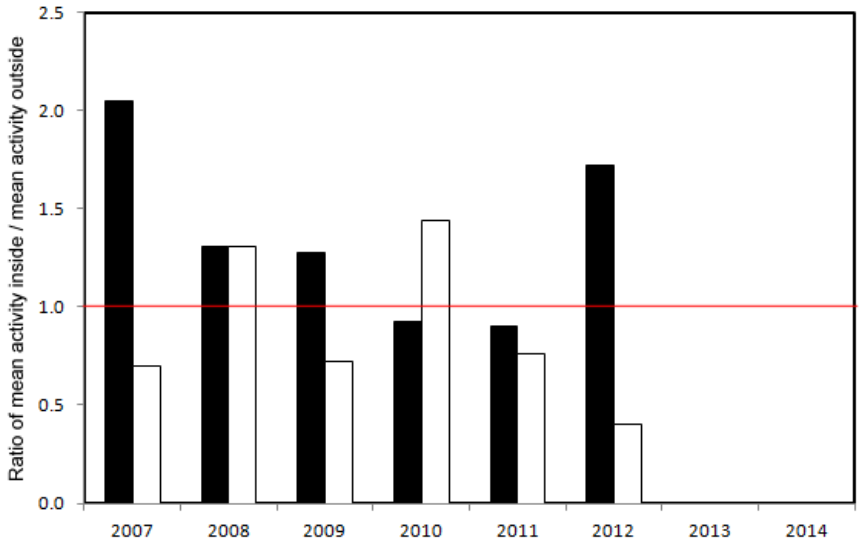


Figure 13. Hen harrier habitat use inside the Ben Aketil (white fill) and Edinbane (black fill) wind farms compared with the mean activity outside of the wind farms. A ratio of 1 (equal use) is marked by the red line.



50 Garvin *et al.* (2011), in a study of an 87 turbine wind farm in the USA, found that raptor abundance post-construction was reduced by 47% compared to pre-construction levels. Although flight behaviour varied by species most individuals remained at a distance of at least 100 m from turbines and above the height of the rotor zone. They found that the abundance of northern (=hen) harrier decreased significantly immediately after construction, but subsequently there was evidence of a temporal lag in any construction related displacement effect. There was also no evidence of a rebound in subsequent years, although it is possible that such a response may occur in the future. The northern (hen) harrier was the only species of conservation concern which declined post-construction in this American study. However, Garvin *et al.* (2011) also concluded that this species appears to be at low risk of collision. The Pearce-Higgins *et al* (2009) study suggested that hen harriers avoided flying within 250 m of turbines, leading to a 53% reduction within 500 m of turbines. Our results do not support either of these displacement observations and conclusions since harrier flights were observed close to turbines at both wind farms, activity has increased within the wind farm 500 m buffer and birds are nesting relatively close to turbines.

51 It is important to understand that 2011 was the first year in which neither wind farm was subject to any construction activities. The indications of an increase in golden eagle use of the operational Edinbane wind farm, compared with its construction period, may be evidence that there is less avoidance of working turbines compared with their construction period. A continuing increase in activity during subsequent years would support that hypothesis.

52 Despite their geographic proximity it is clear that it would be difficult to use the results from one wind farm to predict behaviour at the other and any similarities or differences may not be true for all species. A greater understanding of how birds use habitat at quite small scales is needed before more robust models of bird-wind farm interactions can be fully understood.

Breeding Raptor Surveys

Hen harrier

53 Surveys for breeding raptors in North Skye and the general vicinity of the Edinbane and Ben Aketil wind farms have been undertaken each year between 2007 and 2014 by Bob McMillan.

54 In 2007 eleven hen harrier territories were active with nine nests being located. Of these, six failed completely and three successful breeding attempts produced a total of ten young.

55 In 2008 there were eleven active territories and ten nests were located. Of these, seven failed completely and three produced a total of nine young.

56 In 2009 there were seven active territories and six nests were located. Of these five failed completely and two produced a total of nine young.

57 In 2010 12 active territories were identified and nests found at ten. Ten young were fledged with the majority of failures thought be due to fox predation.

58 In 2011 13 active territories were identified and nests found at ten. Fifteen young were fledged.

59 2012 was a rather poor year with only five active territories and nests from which eight young were fledged. In 2012, although a pair was seen 'skydancing' and displaying over a wide area including the Ben Aketil 'Turbine' site, no pair returned to the area to breed. The successful nest site at Choisleadar 2 was within 800 metres of turbines on the Edinbane site in 2011, and in 2012, the pair moved on to moorland and nested within 400 metres of Turbine 4. This site failed due to fox predation.

60 The decline in hen harrier breeding continued in 2013 with only three breeding pairs, one pair failed and five young were fledged. The successful nest within 400-800 metres of turbines on the Edinbane site in 2011 and 2012 was apparently unoccupied in 2013 although a pair was observed back in this area in the early season but did not remain to breed.

61 2014 was a slightly better year (six ranges occupied with five nests, two failed and the other three fledged 10 young). There were no nests in the vicinity of either wind farm.

Breeding golden eagle surveys

62 Surveys recording the occupancy and breeding productivity of golden eagles across the whole of Skye have been undertaken by Ken Crane and Kate Nellist each year between 2007 and 2014. In 2007 29 ranges were occupied by golden eagles but only nine young eagles successfully fledged. In 2008, 29 ranges were occupied by golden eagles and 17 young eagles fledged. In 2009, 29 ranges were occupied by golden eagles and 13 young eagles fledged.

63 In 2010 ranges were again occupied by golden eagles and 15 young eagles fledged. In 2011 29 ranges were again occupied by golden eagles and 10 young eagles fledged. The very wet, cold and windy weather in May and early June 2011 seems to have been the proximal cause of many failures. It seems likely that more young would have been fledged if nests had not been damaged by very strong winds.

64 In 2012 30 ranges were occupied by golden eagles and only eight young eagles fledged. This is the smallest number since 1982. There was one set of twins fledged in 2012. This compares with one set of twins in 2007 and two each in 2008, 2009 and 2010 and none in 2011. These are lower than the long term average (2.8) over the period 1982-2000.

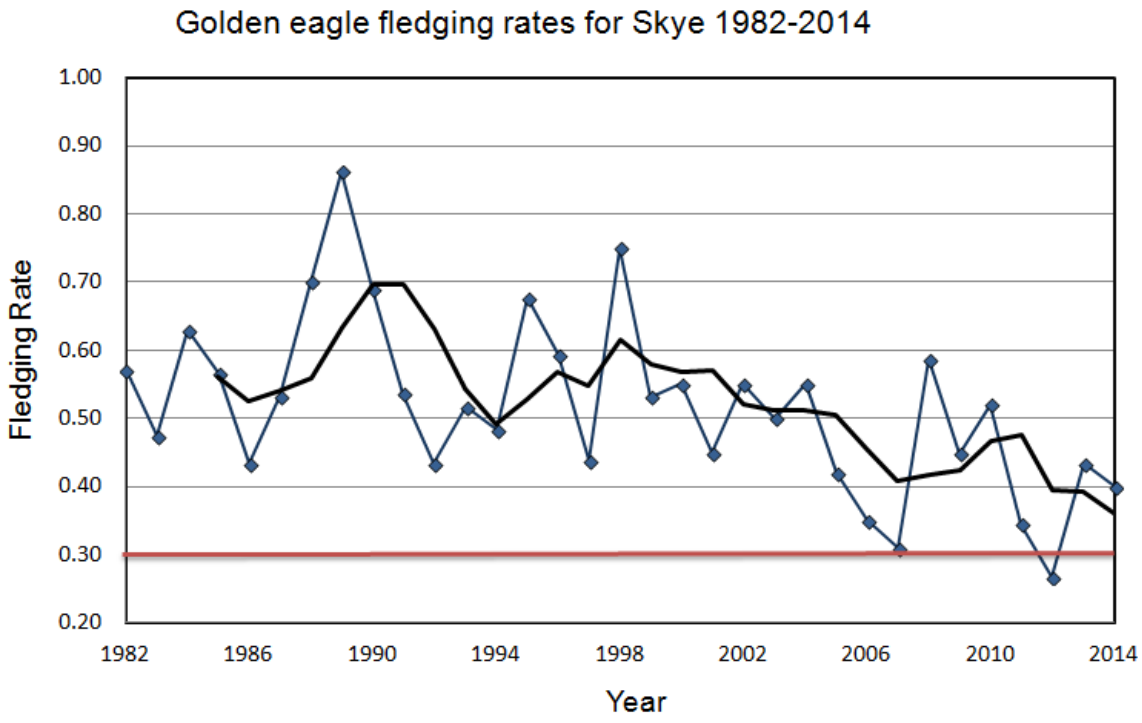
65 In 2013 30 ranges were occupied by golden eagles and thirteen young eagles fledged from eleven successful ranges. There were two sets of twins fledged in 2013.

66 In 2014 30 ranges were again occupied by golden eagles and twelve young eagles fledged from eleven successful ranges. One set of twins was fledged in 2014.

67 When survey and monitoring work started in 2007 29 occupied ranges were identified. In the final year of this monitoring 30 pairs were occupied. Productivity has changed little and any declines are in ranges not associated with the wind farm. There is no evidence that these two wind farms are having any impact on Skye's golden eagle population.

68 Fig. 14 shows the change in productivity over time. Fledging rate is the number of young fledged per pair of golden eagles. 2012 was the first time since recording started that productivity dropped below the 0.3 threshold that is compatible with maintaining favourable conservation status. Fortunately, 2013 and 2014 were better years, although there is a worrying long term trend for reduced productivity that is continuing.

Figure 14. Golden eagle fledging rates for Skye 1982-2014. The solid black line with no data points is a three-year running mean.



White-tailed eagle breeding

69 There are currently no white tailed eagles breeding within the vicinity of either wind farm although a ground nest was constructed south of the wind farm in 2013. There was another nesting attempt in 2014 in a conifer plantation. Both breeding attempts failed to produce any young.

Implications of the Edinbane monitoring results for collision risk modelling

70 Collision risk modelling is based on an assumption of random flight activity. The usage maps (Figs 3, 8 and 11) show clearly that this is not the case in this region. There is no reason to suppose that the assumption is valid elsewhere. Indeed, the PAT eagle ranging model (McLeod *et al.,* 2002) makes an explicit assumption of non-random flight. The comparison of flight activity and distance to ridges suggests that some PAT model assumptions are also applicable to non-breeding eagles and could be factored into impact assessments.

71 In our 2006 review of the possible impacts of the proposed Edinbane wind farm we looked at collision risk on a turbine by turbine basis (Fielding and Haworth, 2006).

72 We pooled data from three surveys and weighted the results in proportion to survey effort. We used Thiessen polygons to assign use (portions of flight) to the nearest turbine and found that almost a quarter of the predicted annual mortality was associated with just two turbines which were both in the south east corner of the wind farm. This is the part of the wind farm that is still experiencing significant use (Fig. 3) and is close to ridge features.

73 Estimates of mortality calculated separately for each turbine may provide a better indication of the likely impacts of a wind farm and suggest areas of a wind farm that should be subjected to more intensive carcass searches.

74 There have been no collisions at either wind farm during the period 2007-14. This is despite the amount of activity within the wind farms. It would seem that the 99% avoidance rate used for golden eagles is quite conservative.

75 If resources are limited for carcass surveys it may be wise to target those times of years when there is the greatest activity since it might be expected that collisions are more likely when there is greater activity. Similarly, on the assumption that collisions are more likely as activity increases, carcass surveying should be weighted to take account of differences in the levels of activity within the wind farm.

References

Fielding, A. H. and Haworth, P. F. 2006. *A review of the impact of the proposed Edinbane wind farm on golden eagles*. Report prepared for AMEC by Haworth Conservation Ltd.

Garvin, J. C., Jennelle, C. S., Drake, D. and Grodsky, S. M. 2011. Response of raptors to a windfarm. *Journal of Applied Ecology*, 48(1) pp 199–209.

Haworth, P. F. and Fielding, A. H. 2012. A review of the impacts of terrestrial wind farms on breeding and wintering hen harriers. Report to Scottish Natural Heritage

May, R., Hoel, P.L., Langston, R., Dahl, E.L., Bevanger, K., Reitan, O., Nygård, T., Pedersen, H.C., Røskaft, E. & Stokke, B.G. 2010. *Collision risk in white-tailed eagles. Modelling collision risk using vantage point observations in Smøla wind-power plant*. NINA Report 639. 25 pp.

Pearce-Higgins, J.W., Stephen, L., Langston, R.H.W., Bainbridge, I.P. and Bullman, R. 2009. The distribution of breeding birds around upland wind farms. *Journal of Applied Ecology*, 46, 1323–1331.

McLeod, D. R. A., Fielding, A. H., Haworth, P. F., Whitfield, D. P., McGrady, M. J., 2002. Predicting home range use by golden eagles *Aquila chrysaetos* in western Scotland. *Journal of Avian Science*, 2:183-198.

Walker, D., McGrady, M., McCluskie, A., Madders, M. and McLeod, D. R. A. 2005. Resident Golden Eagle ranging behaviour before and after construction of a windfarm in Argyll. *Scottish Birds,* 25: 24-40.