Avian and Bat Mortality at the Big Horn Wind Energy Project, Klickitat County, Washington

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The Big Horn Wind Energy Project was constructed as planned, consisting of 133 1.5-MW capacity GE wind turbines arranged in 15 rows. PPM Energy, Inc. was the developer, and prepared the SEPA Checklist for the Big Horn Wind Energy Project in order to obtain the permit to build and operate it. As part of the SEPA Checklist, PPM Energy predicted project impacts, and so provided an opportunity to check on the accuracy of the predictions after a year of fatality monitoring.

PPM Energy predicted the project's impacts to birds and bats would be low (Table 1), based on the low mortality estimates that had been reported by other northwestern wind farms that had already been operating, and based on the findings of the Klickitat County Final Environmental Impact Statement (FEIS). The Klickitat County FEIS divided the County into six strata of relative raptor abundance, and the Big Horn project was located in the lowest stratum.

Table 1. Predicted impacts due to wind turbine collisions in the Big Horn Wind Energy Project. The estimates of impacts for subgroups of raptors was derived from percentages of each group among pre-construction observations, so assuming that species would be killed in proportion to their relative abundance based on visual scans. Bats were estimated by projecting rates reported from other wind farms in the Pacific Northwest.

Species group	Annual Project Fatalities	Fatalities per MW
Raptors	3-4	0.015 – 0.020
American kestrels	1.986-2.648	0.00993-0.01324
Large falcons, i.e. prairie falcons	0.294-0.392	0.00147-0.00196
Buteos	0.165-0.22	0.00083-0.0011
Eagles	0.114-0.152	0.00057-0.00076
Northern harriers	0.078-0.104	0.00039-0.00052
Passerines	267	1.338
Waterfowl	0 to few	~0
Waterbirds/Shorebirds	0 to few	~0
Bats	200	1.0025

The SEPA Checklist also provided predictions of cumulative impacts for Klickitat County, relying on WEST (2004) (Table 2). Those who prepared the Checklist assumed an eventual build-out of 1,000 MW of capacity in Klickitat County. To predict cumulative impacts, they extrapolated mortality estimates among US wind farms to this 1,000 MW of capacity. The estimates had been summarized in Erickson et al. (2001) for birds and Erickson et al. (2002) for bats, and projections of mortality for Klickitat County had been made by WEST (2004).

Table 2. Predicted cumulative impacts due to wind turbine collisions in 1,000 MW of capacity anticipated in Klickitat County, Washington (based on WEST 2004).

Species group	Annual Project Fatalities	Fatalities per MW
Raptors	33	0.033
American kestrels	21.846	0.021846
Large falcons, i.e. prairie falcons	3.234	0.003234
Buteos	1.815	0.001815
Eagles	1.254	0.001254
Northern harriers	0.858	0.000858
Total birds	1,461	1.461
Bats	467-600	0.467-0.600

My objective was to compare estimates of observed mortality after a year of fatality monitoring to the predicted fatality rates. However, I found substantial gaps in the report of the first year of fatality monitoring, which I attempted to resolve with my analysis of the data. Also, some of the methods differed from those I would have used, so I applied my own methodology (Smallwood 2007, Smallwood and Thelander 2008).

METHODS

Kronner et al. (2008) provided no fatality definition, or an explanation of how bird or bat remains were determined to be those of fatalities likely caused by wind turbines. I assumed that standards applied in other wind farm fatality monitoring efforts were applied by Kronner et al. (2008).

I had to assume that the seasons attributed to fatalities were the seasons when the carcasses were found, and not when the bird or bat may have actually died. Because the appendix listing the fatalities did not include estimates of time since death, I could not backdate the carcasses to the season when the fatality likely occurred. I expect there was some unknown level of error in this assumption.

I maintained Kronner et al.'s (2008) omission of fatalities discovered during their clean-up searches from 16-25 October, including two songbirds and one bat. I also used Kronner et al.'s (2008) seasonal search detection rates (Table 6 in Kronner et al. 2008), and I approximated the standard errors of these rates by taking the mean standard errors that could be calculated between the reported 2.5th and 97.5th quantile values. These values differed between the 2.5th and 97.5th quantiles, but only slightly. I ignored the results of the dog trials for searcher detection, because they were small in scope and did not differ from the human search detection rates due to small sample sizes.

I decided not to rely on the scavenger removal trial results that were reported in Kronner et al. (2008), who estimated mean days to carcass removal. I found that mean days to carcass removal is prone to bias, and this bias results in lower estimates of fatality rates (Smallwood 2007). Not only was mean days to carcass removal prone to bias, but the estimates reported by Kronner et al. (2008) were considerably longer than reported by anyone else in the U.S. (Smallwood 2007).

Further yet, Kronner et al. used game hen chicks as surrogates for bats in scavenger removal trials, and non-endemic species as surrogates for birds. The use of game hens and surrogate species in general can bias the results of scavenger removal trials (Smallwood 2007). To adjust the estimates of fatality rates for scavenger removal, I used Appendix 1 values in Smallwood (2007) corresponding with 14 and 28 day search intervals used by Kronner et al. (2008). For bats, I used small bird removal rates in Smallwood (2007), acknowledging that I, too, had to rely on a surrogate species for bats. Based on the bat removal rates that have been reported from wind farm studies, it was likely that my use of small bird removal rates biased my estimates of bat fatality rates low.

No adjustment was apparently made for the nearness of wind turbines to property boundaries where searches were not allowed on the other side of the boundary. The 90 m search radius was not achievable for some unknown number of turbines, and the extent to which searches were not possible was not reported. I used a map of wind turbines and property boundaries depicted in the SEPA Checklist (CH2MHILL 2004) to measure distances between wind turbines and property boundaries of the turbine rows Kronner et al. (2008) reportedly ran into trouble with the boundaries.

I also decided to use a different estimator and a different means of obtaining error terms associated with the unadjusted estimates of fatality rates. The authors used bootstrapping to estimate variance for the unadjusted mortality estimate. They reportedly used bootstrapping because their monitoring amounted to a census of all the turbines. However, the Big Horn turbines were arranged in rows, so I estimated the standard error of mean fatality rates among rows of wind turbines. I adjusted my estimates of fatality rate, M_A, as:

$$M_A = \frac{M_U}{p \times R \times A}, \qquad \text{eq 1}$$

where M_U was unadjusted mortality expressed as number of fatalities per MW of rated capacity per year, p was the proportion of turbine-caused bird fatalities found by searchers during searcher detection trials, R was the estimated proportion of carcasses remaining since the last fatality search and estimated by a compilation of scavenger removal trials across the U.S. (Smallwood 2007), and A was the proportion of the search area that was actually searched. I calculated the standard error of the adjusted fatality rate by using the delta method to carry the error terms associated with p and R (Goodman 1960).

RESULTS

Adjusted fatality rates tallied to 446 bats, 49 raptors, and 704 birds (Table 1). My estimates were larger than those of Kronner et al. (2008) for most species groups, especially for raptors (Table 2). My estimate of raptor fatality rate was 1.6 times greater than estimated by Kronner et al. (2008). My estimates were also higher than the fatality rates predicted by WEST (2004) before the wind turbines were installed (Table 3). The estimate for the observed raptor fatality rate was 12 to 16 times greater than predicted at the project level, and nearly 1.5 times greater than predicted cumulatively in the County (by CH2MHILL 2004). The estimate for the observed American kestrel fatality rate was 13 to 17 times greater than predicted at the project level, and

1.6 times greater than predicted cumulatively in the County. In its first year, the Big Horn project killed 16 to 21 times the predicted number of Buteo hawks, and already doubled the predicted Buteo fatality rate for the County upon build-out of wind farms. It killed at least twice the number of bats that were forecast at the project level, and most of the predicted number of bats upon build-out of wind farms in the County.

DISCUSSION

The pre-project predictions of fatality rates made by WEST (2004) and repeated in the SEPA Checklist were too low. They were inaccurate on which species would be killed. For example, northern harriers were predicted to be killed, even though they have a history of leaving wind farms once the turbines are installed and they usually fly too low to encounter the rotor planes of modern wind turbines. WEST's (2004) predictions were grossly low for raptors, missing by factors of 12, 13, and 16, depending on the species and species group. Inaccuracies of this magnitude warrant reconsideration of the approach used to make the predictions. Either the estimates from other wind farms in the northwest were themselves much lower than reality, or there was some methodological problem with the predictions.

My estimates of fatality rates at Big Horn in some cases exceeded CH2MHILL's (2004) pre-project predictions of cumulative impacts resulting from an anticipated build-out of 1,000 MW of capacity in Klickitat County. According to the SEPA Checklist, the projected build-out of 1,000 MW of wind turbines would kill about 33 raptors per year. However, extrapolating the Big Horn fatality rate to 1,000 MW would lead to a prediction of 243 raptor fatalities per year. This prediction is remarkable because the Big Horn project was located in the stratum of Klickitat County rated to be the least used of the six strata composing the County (see SEPA Checklist). This would lead one to consider a prediction of 243 raptors per year as conservative; a more realistic prediction should be a much higher fatality rate.

According to the SEPA Checklist (CH2MHILL 2004), "These additional cumulative mortalities are relatively insignificant compared to the total bird and bat populations present and represent a small increase in the overall causes of bird mortality…" This conclusion might have been considered reasonable had the impacts been anywhere close to those predicted. However, the estimates of fatality rates following post-construction monitoring suggest that at least 243 raptors will be killed annually in Klickitat County, and more than double the number of bats than were predicted. I do not know what biological impacts these fatality rates will cause, but I would not classify them as "relatively insignificant." There is probably no other human source of mortality that comes close to these levels in Klickitat County.

My estimates of fatality rates were also higher than reported by Kronner et al. (2008). The differences were likely due to Kronner et al.'s (2008) use of mean days to carcass removal in scavenger removal trials. This term can result in estimates that are biased low (Smallwood 2007). There may be additional reasons for the differences, but I cannot determine what they were. One possibility might be the estimated *effective interval* which composes part of the denominator of the equation Kronner et al. used to estimate mortality. I suspect it may have resulted in low estimates, but perhaps I did not understand this term well enough to make this conclusion. The

description of this term in Kronner et al. (2008) was vague, and I remain unclear about what it is supposed to be doing in the equation.

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Table 1. Estimates of wind turbine-caused fatality rates based on monitoring from 30 October 2006 through 29 October 2007 in the Big Horn Wind Power Project, Washington.

	Mean fatality rate, deaths/MW/year		Annual fatalities and 80% CI		
Species	**Unadjusted**	**Adjusted**	**Total**	**LB**	**UB**
Accipter sp.	0.0034	0.0273	5.4	-1.7	12.6
Red-tailed hawk	0.0039	0.0055	1.1	-0.3	2.5
Ferruginous hawk	0.0068	0.0118	2.4	-0.7	5.4
American kestrel	0.0306	0.1730	34.5	4.5	64.5
Long-eared owl	0.0024	0.0035	0.7	-0.2	1.6
Short-eared owl	0.0154	0.0221	4.4	0.7	8.1
Common nighthawk	0.0068	0.0530	10.6	-4.5	25.6
Chukar	0.0323	0.1851	36.9	-14.8	88.6
Gray partridge	0.0785	0.4769	95.1	8.4	181.9
Rock pigeon	0.0190	0.0342	6.8	0.8	12.9
Mourning dove	0.0572	0.4034	80.5	1.8	159.2
Red-shafted flicker	0.0024	0.0134	2.7	-1.1	6.5
Downy woodpecker	0.0034	0.0265	5.3	-2.2	12.8
Horned lark	0.2396	1.2862	256.6	76.2	437.0
Winter wren	0.0039	0.0220	4.4	-1.6	10.4
House wren	0.0046	0.0186	3.7	-1.3	8.8
Mountain bluebird	0.0119	0.0662	13.2	-4.8	31.2
Golden-crowned kinglet	0.0150	0.0835	16.7	0.9	32.4
Ruby-crowned kinglet	0.0136	0.0652	13.0	-4.7	30.7
Thrush sp.	0.0159	0.1236	24.7	-10.4	59.7
Varied thrush	0.0024	0.0134	2.7	-1.1	6.5
Townsend's warbler	0.0116	0.0749	14.9	-5.9	35.8
Yellow warbler	0.0024	0.0185	3.7	-1.6	9.0
Western meadowlark	0.0268	0.1650	32.9	-0.5	66.4
Spotted towhee	0.0037	0.0147	2.9	-1.1	6.9
Dark-eyed junco	0.0128	0.0709	14.2	0.1	28.2
Sparrow sp.	0.0060	0.0239	4.8	-1.7	11.3
Song sparrow	0.0049	0.0273	5.4	-2.0	12.9
Passerine sp.	0.0089	0.0356	7.1	0.1	14.1
Bat sp.	0.0076	0.0306	6.1	0.1	12.1
Big brown bat	0.0024	0.0185	3.7	-1.6	9.0
Silver-haired bat	0.1490	0.8158	162.8	50.8	274.7
Hoary bat	0.2037	1.3699	273.3	77.7	468.9
All bats	0.3627	2.2349	445.9	154.5	737.2
Total raptors	0.0625	0.2432	48.5	2.3	94.7
Total birds	0.6436	3.5236	703.5	32.8	1374.3

Table 2. Comparison of fatality rates at Big Horn Wind Power Project during 30 October 2006 to 29 October 2007 estimated by Kronner et al. (2008) and by me.

Species group	Mean fatality rate, Deaths/MW/Year		Ratio of Smallwood to Kronner et al. estimates of fatality rate
	Kronner et al. (2008)	Smallwood	
Raptors	0.15	0.24	1.6
Doves	0.12	0.43	3.6
Galliforms	0.23	0.66	2.9
Goatsucker	0.01	0.05	5.0
Passerines	1.99	2.54	1.3
Woodpeckers	0.04	0.04	1.0
Total birds	2.54	3.52	1.4
Bats	1.90	2.23	1.2

Table 3. Ratios of observed to predicted fatality rates specific to the Big Horn Wind Power Project and cumulative among anticipated projects in Klickitat County, Washington.

Species group	Ratio of mean observed to predicted impacts	
	Project	Cumulative
Raptors	12.2 to 16.2	1.47
American kestrels	13.1 to 17.4	1.58
Large falcons, i.e. prairie falcons	0	0
Buteos	16 to 21	1.93
Eagles	0	0
Northern harriers	0	0
Passerines	1.9	No prediction
Waterfowl	0	0
Waterbirds/Shorebirds	0	0
Total birds	No prediction	2.41
Bats	2.2	0.74 to 0.95