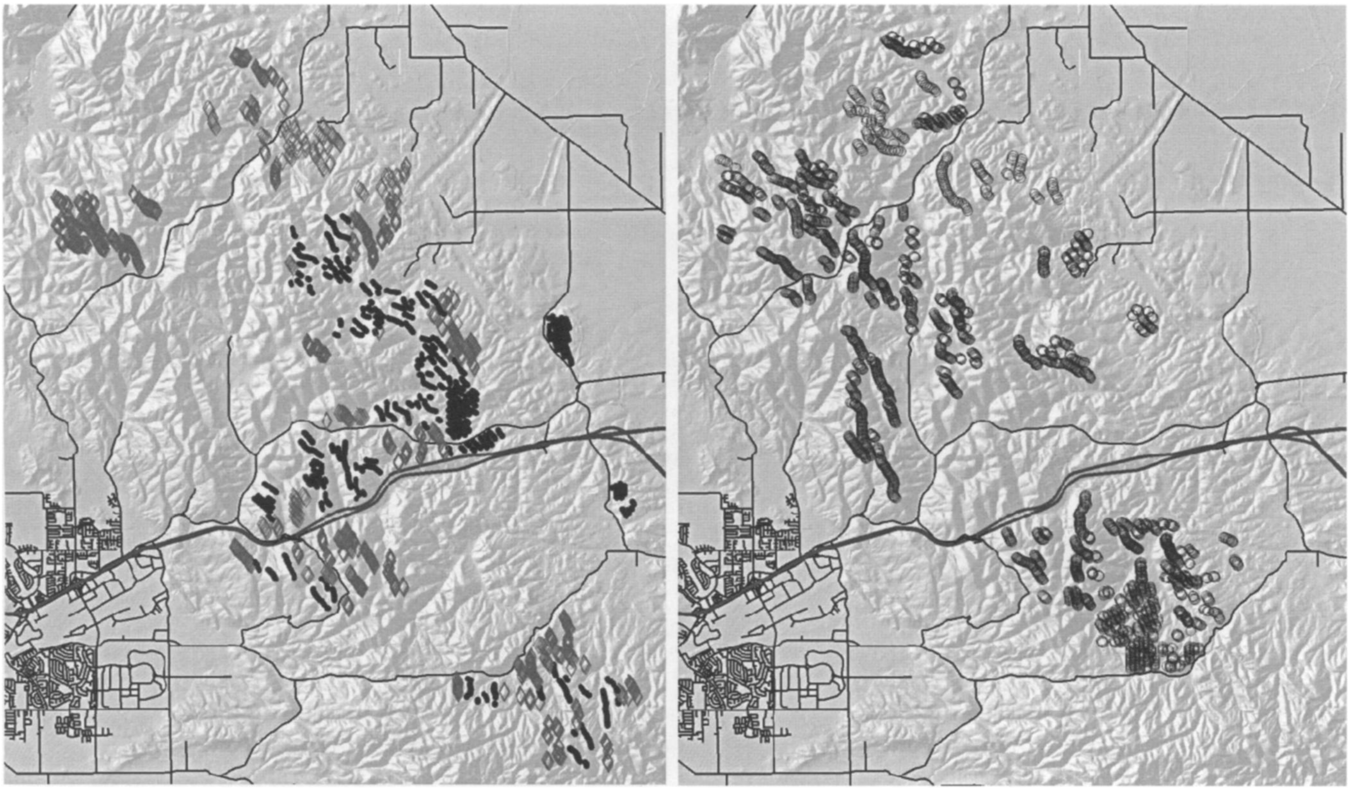


Figure 1. Relative search effort devoted to each wind turbine in the study in the Altamont Pass Wind Resource Area (APWRA), California, USA. In the left map solid circles denote turbines searched between March 1998 and September 2002 (set 1) and open diamonds denote wind turbines not searched (set 3), and in the right map open circles denote turbines searched November 2002 until May 2003 (set 2). Livermore appears at the lower left corners, and the thick line cutting through the APWRA from Livermore is Highway 580. Other lines represent paved roads in the area. The east–west extent of each map is about 17.7 km.

and ridgelines extending down toward ephemeral streams. Wind turbine rows also occupied slopes, valleys, and hill peaks and all operated in winds from any direction, although most winds originated from the northwest or southwest. Wind turbines in the APWRA included KCS-56 100-kW turbines on lattice towers (Kenetech Windpower Inc., Livermore, CA), 120-kW and 150-kW turbines on tubular towers (Bonus Wind Turbines, Inc., Brande, Denmark), 150-kW and 250-kW vertical axis turbines (FloWind Corp., San Rafael, CA), 40-kW turbines on lattice towers (Enertech Corporation, Norwich, VT), and Micon 65-kW turbines on tubular towers (Moerup Manfacturing Co., Randers, Denmark). Others on tubular towers included 330-kW (James Howden and Company, Renfrew, Scotland), 110-kW (Danwin A/S, Helsingor, Denmark), 65-kW (Nordtank Energy Group, Balle, Denmark), 250-kW (Wind Energy Group, Ltd., Southall, Middlesex, England), Polenko 100-kW (Holec Power Systems, Inc., Livermore, CA), and 75-kW to 300-kW turbines (Windmaster, Byron, CA). Others on lattice towers included 65-kW (Windmatic, Herring, Denmark) and 100-kW turbines (Vestas Wind Systems A/S, Randers, Denmark). KVS-33 400-kW turbines (Kenetech Windpower Inc.) occurred on both lattice and tubular towers. Tower heights ranged from 14 m to 43.1 m above ground, with blades extending from 4 m to 52 m above ground at their lowest and highest reaches, respectively.

METHODS

We searched for bird carcasses at 1,526 wind turbines in 182 rows from March 1998 through September 2002 (hereafter set 1). We added groups of wind turbines into set 1 as we gained access, and we searched all of them 6–34 ($\bar{x} = 18$) times. From November 2002 until May 2003 we searched another 2,548 turbines arranged in 380 rows (hereafter set 2). We accessed set 2 turbines 6 months before our study ended, and searched them only twice. We selected set 2 turbines systematically from the unsearched turbines to achieve maximal north–south, east–west representation of the APWRA and to intersperse the unsearched turbines (hereafter set 3). In total, we searched for bird fatalities at 75% of the APWRA's wind turbines (Fig. 1), and we performed 32,439 fatality searches, where a fatality search was one search covering 50 m around one turbine.

Because wind turbines in our study area were arranged in rows, we searched them efficiently by walking strip transects along both sides and around the ends. Two field biologists explored the ground, maintaining about 4–6 m between parallel transect segments, which extended to 50 m away from the centerline of the wind turbine row. An earlier study in the APWRA found 96% of the carcasses deposited by wind turbines were $\leq$50 m from the turbine (Orloff and Flannery 1992), and we found 85–88% of the carcasses $\leq$50 m from the turbine (Smallwood and Thelander 2004). Our

Table 1. Status and summary of birds found killed by wind turbines in the Altamont Pass Wind Resources Area, California, USA, May 1998–May 2003.[a]

Species or taxonomic group	Species name	Status	All wind turbine–caused fatalities	Carcasses used in mortality estimates
Golden eagle	*Aquila chrysaetos*	BGEPA, CSC, CFP, PBP	54	29
Red-tailed hawk	*Buteo jamaicensis*	PBP	213	156
Ferruginous hawk	*Buteo regalis*	CSC, PBP	2	2
Buteo spp.	*Buteo* spp.	PBP	23	0
Northern harrier	*Circus cyaneus*	CSC, PBP	3	3
White-tailed kite	*Elanus leucurus*	CFP, PBP	1	0
Prairie falcon	*Falco mexicanus*	CSC, PBP	3	3
American kestrel	*Falco sparverius*	PBP	59	55
Turkey vulture	*Cathartes aura*	PBP	6	3
Barn owl	*Tyto alba*	PBP	50	40
Great horned owl	*Bubo virginianus*	PBP	18	11
Burrowing owl	*Athene cunicularia hypugaea*	PBP	70	67
Raptors		PBP	17	4
Double-crested cormorant	*Phalacrocorax auritus*	CSC	1	1
Black-crowned night heron	*Nycticorax nycticorax*		2	2
Cattle egret	*Bubulcus ibis*	exotic	1	1
Mallard	*Anas platyrhynchos*		35	26
Ring-necked duck	*Aythya collaris*		1	1
American avocet	*Recurvirostra americana*		3	3
Lesser yellowlegs	*Tringa flavipes*		1	1
Ring-billed gull	*Larus delawarensis*		4	4
California gull	*Larus californicus*	CSC	7	7
Gulls	*Larus* spp.		18	8
Northern flicker	*Colaptes auratus*		6	6
Mourning dove	*Zenaida macroura*		34	34
Rock dove	*Columba livia*	exotic	196	183
Wild turkey	*Meleagris gallopavo*	exotic	1	1
Common raven	*Corvus corax*		12	9
American crow	*Corvus brachyrhynchos*		5	4
Brown-headed cowbird	*Molothrus ater*		2	2
Brewer's blackbird	*Euphagus cyanocephalus*		13	13
Red-winged blackbird	*Agelaius phoeniceus*		12	12
Tricolored blackbird	*Agelaius tricolor*	CSC	1	1
Blackbirds			1	1
European starling	*Sturnus vulgaris*	exotic	67	57
California horned lark	*Eremophila alpestris actia*	CSC	23	22
Western meadowlark	*Sturnella neglecta*		96	96
Western kingbird	*Tyrannus verticalis*		1	1
Pacific-slope flycatcher	*Empidonax difficilis*		1	1
Loggerhead shrike	*Lanius ludovicianus*	CSC	5	4
Cliff swallow	*Hirundo pyrrhonota*		5	5
Violet-green swallow	*Tachycineta thalassina*		1	1
Northern mockingbird	*Mimus polyglottos*		1	1
Mountain bluebird	*Sialia currucoides*		5	4
Yellow warbler	*Dendroica petechia brewsteri*	CSC	1	1
Savannah sparrow	*Passerculus sandwichensis*		2	2
House finch	*Carpodacus mexicanus*		14	12
House sparrow	*Passer domesticus*	exotic	1	1
Cockatiel	*Nymphicus hollandicus*	exotic	1	1
Passerine			16	12
Unknown small birds			42	27
Raptors as a group		PBP	519	373
All birds as a group			1,157	941

[a] The following abbreviations represent special status of the species: BGEPA = Bald and Golden Eagle Protection Act, CFP = California Fully Protected, CSC = California Department of Fish and Game listing of California Species of Concern, and PBP = Protection of Birds of Prey under California Fish and Game Code 3503.5. The Migratory Bird Treaty Act protects all species in the table except wild turkey, rock dove, European starling, house sparrow, and cockatiel.

carcass searches averaged 8–10 minutes per wind turbine, which we performed 5 hours per day using 2-person crews, so each crew searched 30–40 wind turbines per day. Most set 1 turbines were given roughly similar search effort over the time spans searched ($\bar{x} = 7.2$ searches/yr).

We documented as fatalities all carcasses or body parts we found, such as groups of flight feathers, head, wings, tarsi, and tail feathers. When possible, we identified carcasses to species, age class, and sex, and we classified each species as either small-bodied ($\leq$38 cm in body length) or large-bodied ($>$38 cm). We assigned each carcass a probable cause of death based on injuries and proximity to hazards such as wind turbines, roads, or electric distribution poles. We attributed predation to carcasses with feathers plucked and scattered. Wind turbine injuries included severed or twisted torso, decapitation, severed wing(s), tail, or leg(s), and other forms of blunt force trauma. We estimated the number of days since death by assessing carcass condition. Generally we assumed carcasses older than 90 days if the enamel on culmen and talons had separated from the bone, flesh was gone, and bones and feathers were bleached, but we used considerable judgment because carcass decomposition rates vary according to environmental conditions. The presence of blood generally indicates <4 days since death, but the onset of rigor mortis, odor, and maggots or other insect larvae vary greatly with temperature, so we had to use these signs as guides in the context of current environmental conditions to estimate the number of days since death. We photographed most carcasses upon discovery, and we placed some in cages in the field to monitor decomposition. We reported all fatalities to the wind turbine owners, who collected the carcasses and deposited them with the United States Fish and Wildlife Service.

Within each turbine row we expressed unadjusted mortality (M_{U}) as number of fatalities/MW/year, where MW was the sum of the megawatts of rated power outputs for all of the wind turbines in the row surveyed. Although individual turbines killed birds, we used the wind turbine row as our study unit because we believed birds often sensed and reacted to the wind turbine row as a barrier or threat. We added 3 months to the number of years used in the mortality estimate, to represent the time period when carcasses could have accumulated before our first search. We excluded from mortality estimates all fatalities estimated to have occurred >90 days before discovery, and we excluded 9 carcasses found incidentally after all search rotations had ceased at a particular row. We included carcasses found outside the search radius during searches because we assumed the likelihood of seeing carcasses outside the search radius would not vary significantly among turbine rows in the APWRA's short-stature grassland.

We adjusted our mortality estimate, M_{A}, for carcasses not found due to searcher detection error and scavenger removals as

$$M_{\text{A}} = \frac{M_{\text{U}}}{pR} \qquad (1)$$

where M_{U} was unadjusted mortality expressed as number of fatalities/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 scavenger removal trials (Smallwood 1997). We calculated its standard error, SE[M_{A}], using the delta method (Goodman 1960):

$$\text{SE}[M_{\text{A}}] = \left[\left(\frac{1}{pR} \times \text{SE}[M_{\text{U}}]\right)^2 \times \left(\frac{M_{\text{U}}}{p} \times \frac{-1}{R^2} \times \text{SE}[R]\right)^2 \times \left(\frac{M_{\text{U}}}{R} \times \frac{-1}{p^2} \times \text{SE}[p]\right)^2\right]^{1/2}. \qquad (2)$$

We did not perform searcher efficiency and scavenger removal trials in the APWRA but instead used estimators of searcher detection and scavenger removal rates developed by Smallwood (1997), who synthesized results from reported searcher detection and scavenger removal trials performed in wind farms throughout the United States.

Search detection rates were 51% (SE = 2.133%) for small nonraptor birds, 78% (SE = 5.384%) for medium and large nonraptor birds (including rock doves [*Columba livia*]), 75% (SE = 9.129%) for small raptors, and 100% (SE = 0%) for large raptors, based on averages among reports of searcher detection trials in grasslands across the United States (Smallwood 1997). To predict the proportion of carcasses remaining after each successive day into scavenger removal trials or into the periods intervening fatality searches, we used logarithmic models developed using least squares regression for small-bodied nonraptor birds (SE = 0.158), medium and large-bodied nonraptor birds (SE = 0.129), small-bodied raptors (SE = 0.040), and large-bodied raptors (SE = 0.089), and we used a linear model developed for rock dove (SE = 0.080; Smallwood 1997, table 4).

Assuming wind turbines will deposit carcasses at a steady state, for each species group we averaged the above model predictions across the number of days equaling the average number of days between fatality searches for all set 1 and set 2 turbines:

$$R_{\text{C}} = \frac{\sum_{I}^{i=1} R_i}{I \times 100} \qquad (3)$$

where R_{C} was the cumulative carcasses remaining, R_i was the percent of carcasses remaining by the ith day following the initiation of a scavenger removal trial and corresponding with the number of days since the last fatality search, and I was the average number of days between fatality searches among set 1 and set 2 turbines.

We made no adjustment for background mortality, which is usually small, nor did we adjust estimates for crippling bias, search radius bias, and carcasses removed by wind turbine maintenance personnel or by administrators of the Wildlife Response and Reporting System (WRRS), which was the industry's system of reporting of carcasses found incidentally by turbine maintenance personnel. Background mortality is mortality caused by factors independent of the wind turbines and their supporting infrastructure. Crippling bias refers to number of birds mortally injured by the wind turbines but which die undetected somewhere else. Search radius bias refers to number of birds killed by wind turbines but thrown beyond the search radius and not found. Most of these potential adjustments would increase mortality estimates by unknown degrees by adding undiscovered fatalities to the total. Another potential source of error is the proportion of turbine rows where we recorded zero fatalities but where scavengers might have removed carcasses prior to our searches, or where our searches missed carcasses. We did not adjust these zero-values for searcher detection and scavenger removal errors because zero divided by p or R equals zero.

For each species, we estimated mortality separately for set 1 and set 2 turbines, even though mortality did not differ between the sets for 75% of the species. We calculated the APWRA-wide mean mortality as the weighted mean from sets 1 and 2:

$$M_{A,3} = \frac{(M_{A,1} \times 153.25 \text{ MW}) + (M_{A,2} \times 267.09 \text{ MW})}{418.255 \text{ MW}} \quad (4)$$

where $M_{A,1}$, $M_{A,2}$, and $M_{A,3}$ were adjusted mortality estimates for turbine sets 1, 2, and 3, respectively, and set 3 represented the 25% of the turbines not searched and which equaled the weighted mean adjusted mortality across the APWRA. Set 1 wind turbines composed 153.25 MW of rated capacity and set 2 composed 267.09 MW. The set 3 wind turbines were interspersed with the turbines we searched (Fig. 1), and they were of the same models. We treated the set 2 mortality estimates as if they were annual estimates, but we did not search the set 2 turbines during summer. All mortality estimates represented mortality caused directly by wind turbines and did not include fatalities caused by electrocution on the power collection system, collisions with overhead power lines, or collisions with automobiles traveling the wind turbine service roads.

RESULTS

We found 1,157 bird fatalities attributed to wind turbine collisions (Table 1). Of these, we excluded 216 from mortality estimations because they were either estimated to have been killed >90 days before discovery or they were found after the last of the searches at a particular wind turbine row (Table 1). To the unadjusted mortality estimates (Table 2), we used equations 1–3 to factor in search detection and scavenger removal rates quantified from other studies to arrive at adjusted mortality estimates (Table 3).

Adjusted mortality differed significantly between sets 1 and 2 for American crow (*Corvus brachyrhynchos*), California gull (*Larus californicus*), cliff swallow (*Hirundo pyrrhonota*), great horned owl (*Bubo virginianus*), house finch (*Carpodacus mexicanus*), California horned lark (*Eremophila alpestris actia*), mallard (*Anas platyrhynchos*), mourning dove (*Zenaida macroura*), ring-billed gull (*Larus delawarensis*), rock dove, red-winged blackbird (*Agelaius phoeniceus*), and turkey vulture (*Cathartes aura*; $P < 0.05$ in each case), so we used equation 4 to calculate APWRA-wide adjusted mortality as the weighted mean between turbine sets 1 and 2. Before adjusting mortality estimates for searcher detection and scavenger removal rates, we estimated the APWRA's wind turbines annually killed ≥56 golden eagles, 168 red-tailed hawks (*Buteo jamaicensis*), 55 American kestrels (*Falco sparverius*), 80 burrowing owls (*Athene cunicularia hypugaea*), 434 raptors, and 1,058 birds (Table 3). After adjusting estimates for searcher detection and scavenger removal rates, we estimated wind turbine collisions in the APWRA annually killed 67 (80% CI = 25–109) golden eagles, 188 (80% CI = 116–259) red-tailed hawks, 348 (80% CI = −49 to 749) American kestrels, 440 (80% CI = −133 to 1,013) burrowing owls, 1,127 (80% CI = −23 to 2,277) raptors, and 2,710 (80% CI = −6,100 to 11,520) birds (Table 3).

DISCUSSION

We estimated collisions with wind turbines in the APWRA killed 434 raptors and 1,058 birds before factoring in carcasses not found due to searcher detection error and scavenger removal. Factoring in search detection and scavenger removal, we estimated the APWRA's wind turbines killed 1,127 raptors and 2,710 birds, and possibly as many as 2,277 raptors and 11,520 birds. Follow-up fatality monitoring in the APWRA in 2005–2006, using similar methods and assumptions, preliminarily supported equal if not greater estimates of wind turbine–caused mortality of raptors and other birds (W. P. Erickson, WEST, Inc., unpublished data), so levels of mortality we detected have continued into 2006. However, because the follow-up monitoring used similar methods, uncertainty ranges will be similarly large.

Even though we performed many more fatality searches over twice as long a time period compared to past research efforts in the APWRA, our mortality estimates were imprecise. The lower bound annual mortality estimate of most species was <0. A principal source of our imprecision was long intervals between fatality searches, averaging 53 days between searches in set 1 and 90 days in set 2. Scavenger removal trials indicated that our average search interval among set 1 turbines would on average present our fatality searchers with only 21% of small-bodied bird carcasses and 18% of small-bodied raptor carcasses deposited by the wind turbines since the previous fatality search (Smallwood 1997). Scavenger removal trials indicated our search interval among set 2 turbines would on average present fatality searchers with only 12% of small-bodied bird carcasses and 11% of small-bodied raptor carcasses. Thus, mortality estimates for these groups of birds were increased 5- to 10-fold due to scavenger removal, but only at wind turbine rows where we found ≥1 carcass. We made no adjustments at the many wind turbine rows where we found zero birds.

Our mortality estimates are not alone in their imprecision. Most of the lower limit estimates of the 90% confidence interval were <0 at the Tehachapi and San Gorgonio Wind Resource Areas, California, even though these mortality estimates were made for multispecies groups such as raptors, waterbirds, and passerines (Anderson et al. 2004, 2005). Most of the lower limits of the 95% confidence interval were <0 at Foote Creek Rim Wind Plant, Wyoming, USA (Young et al. 2003). All of the mortality estimates of multispecies groups in the APWRA during 1989–1991 were associated with 95% confidence interval lower limits <0 (Orloff and Flannery 1992). It appears mortality monitoring at wind farms has repeatedly produced imprecise mortality

Table 2. Summary of unadjusted mortality estimates for 2 sets of wind turbines in the Altamont Pass Wind Resources Area, California, USA, searched at different time periods and for different durations and intersearch intervals.[a]

Species or taxonomic group	Mortality (deaths/MW/yr)					
	Set 1 turbine rows		Set 2 turbine rows		All turbine rows	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Golden eagle	0.0359	0.0118	0.1384	0.0679	0.0967	0.0477
Red-tailed hawk	0.3245	0.0656	0.2652	0.0885	0.2893	0.0805
Ferruginous hawk	0.0000	0.0000	0.0382	0.0273	0.0227	0.0175
Northern harrier	0.0029	0.0018	0.0000	0.0000	0.0012	0.0007
Prairie falcon	0.0047	0.0030	0.0000	0.0000	0.0019	0.0011
American kestrel	0.0703	0.0166	0.1115	0.0390	0.0947	0.0310
Turkey vulture	0.0108	0.0064	0.0000	0.0000	0.0044	0.0023
Barn owl	0.0720	0.0256	0.0315	0.0161	0.0480	0.0197
Great horned owl	0.0309	0.0128	0.0043	0.0043	0.0151	0.0074
Burrowing owl	0.1789	0.0325	0.1110	0.0692	0.1386	0.0561
Raptor spp.	0.0000	0.0000	0.0605	0.0346	0.0359	0.0221
Double-crested cormorant	0.0037	0.0037	0.0000	0.0000	0.0015	0.0014
Black-crowned night heron	0.0020	0.0014	0.0000	0.0000	0.0008	0.0005
Cattle egret	0.0000	0.0000	0.0027	0.0027	0.0016	0.0017
Mallard	0.0697	0.0258	0.0121	0.0121	0.0356	0.0172
Ring-necked duck	0.0000	0.0000	0.0036	0.0036	0.0021	0.0023
American avocet	0.0121	0.0102	0.0000	0.0000	0.0049	0.0037
Lesser yellowlegs	0.0010	0.0010	0.0000	0.0000	0.0004	0.0004
Ring-billed gull	0.0155	0.0095	0.0000	0.0000	0.0063	0.0035
California gull	0.0158	0.0073	0.0000	0.0000	0.0064	0.0027
Gull spp.	0.0076	0.0042	0.0137	0.0087	0.0112	0.0071
Northern flicker	0.0152	0.0096	0.0204	0.0169	0.0183	0.0143
Mourning dove	0.1705	0.0571	0.0231	0.0122	0.0830	0.0287
Rock dove	0.5244	0.1120	0.1248	0.0468	0.2873	0.0709
Wild turkey	0.0028	0.0028	0.0000	0.0000	0.0011	0.0010
Common raven	0.0230	0.0148	0.0097	0.0097	0.0151	0.0116
American crow	0.0284	0.0169	0.0000	0.0000	0.0115	0.0062
Brown-headed cowbird	0.0033	0.0033	0.0241	0.0241	0.0157	0.0166
Brewer's blackbird	0.0230	0.0106	0.0512	0.0342	0.0397	0.0257
Red-winged blackbird	0.0399	0.0135	0.0000	0.0000	0.0162	0.0050
Tricolored blackbird	0.0020	0.0020	0.0000	0.0000	0.0008	0.0007
Blackbird spp.	0.0049	0.0049	0.0000	0.0000	0.0020	0.0018
European starling	0.1329	0.0302	0.1362	0.0657	0.1349	0.0530
Horned lark	0.0468	0.0122	0.0000	0.0000	0.0190	0.0045
Western meadowlark	0.2197	0.0440	0.2024	0.0783	0.2095	0.0661
Western kingbird	0.0013	0.0013	0.0000	0.0000	0.0005	0.0005
Pacific-slope flycatcher	0.0033	0.0033	0.0000	0.0000	0.0013	0.0012
Loggerhead shrike	0.0218	0.0150	0.0000	0.0000	0.0089	0.0055
Cliff swallow	0.0154	0.0079	0.0000	0.0000	0.0063	0.0029
Violet-green swallow	0.0012	0.0012	0.0000	0.0000	0.0005	0.0005
Northern mockingbird	0.0048	0.0048	0.0000	0.0000	0.0019	0.0018
Mountain bluebird	0.0056	0.0049	0.0183	0.0150	0.0131	0.0114
Yellow warbler	0.0018	0.0018	0.0000	0.0000	0.0008	0.0007
Savannah sparrow	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043
House finch	0.0515	0.0198	0.0000	0.0000	0.0209	0.0072
House sparrow	0.0000	0.0000	0.0080	0.0080	0.0048	0.0051
Cockatiel	0.0015	0.0015	0.0000	0.0000	0.0006	0.0006
Passerine spp.	0.0370	0.0142	0.0256	0.0231	0.0302	0.0199
Unknown small bird	0.0420	0.0130	0.0654	0.0243	0.0559	0.0203
All raptors as a group	0.7309	0.1761	0.7604	0.3469	0.7484	0.2860
All birds as a group	2.2869	0.6661	1.5060	0.7365	1.8236	0.7144

[a] Set 1 included 153.25 MW of rated capacity from 1,526 wind turbines in the search rotation through May 1998 September 2002. Set 2 included 267.09 MW from 2,538 wind turbines in the November 2002 through May 2003 rotation. We calculated the values in the all turbine rows columns as the weighted means from sets 1 and 2.

estimates. The methodology needs to be changed (see Management Implications).

Our mortality estimates did not include birds killed by autos, guyed meteorological towers, and the power collection system (i.e., overhead power lines and energized pole-mounted equipment), though we did record these fatalities when we found them. Our estimates also did not include injured birds dying undetected elsewhere or birds removed by the wind turbine owners without our knowledge. (A postproject review of WRRS indicated some birds were

Table 3. Summary of adjusted mortality estimates for two sets of wind turbines in the Altamont Pass Wind Resources Area, California, USA, searched at different time periods and for different durations and intersearch intervals.[a]

Species or taxonomic group	Unadjusted annual deaths	Adjusted mortality (deaths/MW/yr)		Adjusted annual deaths		
		$\bar{x}$	SE	$\bar{x}$	Lower bound of 80% CI	Upper bound of 80% CI
Golden eagle	56.1	0.115	0.056	66.7	24.7	108.7
Red-tailed hawk	167.8	0.324	0.096	187.8	116.4	259.3
Ferruginous hawk	13.2	0.028	0.021	16.1	0.5	31.7
Northern harrier	0.7	0.001	0.001	0.7	0.1	1.2
Prairie falcon	1.1	0.002	0.001	1.1	0.2	2.0
American kestrel	54.9	0.599	0.540	347.6	−53.7	748.8
Turkey vulture	2.6	0.004	0.003	2.5	0.6	4.5
Barn owl	27.8	0.052	0.022	30.2	13.5	46.9
Great horned owl	8.8	0.016	0.008	9.1	2.9	15.3
Burrowing owl	80.4	0.759	0.771	440.0	−133.4	1013.4
Raptor spp.	20.8	0.044	0.027	25.5	5.4	45.5
Double-crested cormorant	0.9	0.002	0.004	1.3	−1.4	4.0
Black-crowned night heron	0.5	0.001	0.001	0.7	−0.3	1.7
Cattle egret	0.9	0.003	0.006	2.0	−2.5	6.5
Mallard	20.6	0.058	0.052	33.8	−4.8	72.3
Ring-necked duck	1.2	0.005	0.008	2.7	−3.4	8.7
American avocet	2.8	0.007	0.010	4.2	−3.3	11.7
Lesser yellowlegs	0.2	0.001	0.001	0.3	−0.4	1.1
Ring-billed gull	3.7	0.010	0.009	5.5	−1.3	12.4
California gull	3.7	0.010	0.007	5.6	0.3	10.9
Gull spp.	6.5	0.022	0.025	12.9	−5.4	31.1
Northern flicker	10.6	0.066	0.361	38.3	−230.5	307.1
Mourning dove	48.1	0.208	0.594	120.7	−320.9	562.3
Rock dove	166.6	0.325	0.157	188.6	72.2	305.0
Wild turkey	0.6	0.002	0.003	1.0	−1.0	3.0
Common raven	8.8	0.027	0.035	15.4	−10.7	41.4
American crow	6.7	0.017	0.017	9.8	−2.7	22.4
Brown-headed cowbird	9.1	0.065	0.427	37.9	−279.3	355.1
Brewer's blackbird	23.0	0.153	0.831	88.6	−529.4	706.5
Red-winged blackbird	9.4	0.035	0.060	20.1	−24.7	65.0
Tricolored blackbird	0.5	0.002	0.007	1.0	−4.2	6.2
Blackbird spp.	1.2	0.004	0.017	2.5	−10.3	15.2
European starling	78.2	0.469	2.177	271.8	−1346.9	1890.5
Horned lark	11.0	0.041	0.062	23.6	−22.5	69.8
Western meadowlark	121.5	0.716	3.193	415.1	−1959.1	2789.3
Western kingbird	0.3	0.001	0.005	0.7	−2.7	4.0
Pacific-slope flycatcher	0.8	0.003	0.011	1.7	−6.9	10.2
Loggerhead shrike	5.2	0.019	0.055	11.0	−29.7	51.7
Cliff swallow	3.7	0.013	0.031	7.8	−15.1	30.6
Violet-green swallow	0.3	0.001	0.004	0.6	−2.6	3.8
Northern mockingbird	1.1	0.004	0.017	2.4	−10.0	14.8
Mountain bluebird	7.6	0.052	0.310	30.3	−200.1	260.8
Yellow warbler	0.5	0.002	0.006	0.9	−3.9	5.7
Savannah sparrow	2.5	0.015	0.087	8.6	−55.7	73.0
House finch	12.1	0.045	0.084	26.0	−36.3	88.3
House sparrow	2.8	0.021	0.140	12.0	−92.3	116.3
Cockatiel	0.3	0.001	0.005	0.8	−3.2	4.7
Passerine spp.	17.5	0.099	0.483	57.1	−302.2	416.5
Unknown small bird	32.4	0.206	1.000	119.5	−623.9	862.9
All raptors as a group	434.1	1.943		1,127.2	−22.8	2,277.2
All birds as a group	1,057.7	4.672		2,710.0	−6,099.8	11,519.8

[a] Set 1 included 153.25 MW of rated capacity from 1,526 wind turbines in the search rotation through May 1998 September 2002. Set 2 included 267.09 MW from 2,538 wind turbines in the November 2002 through May 2003 rotation.

removed without our knowledge.) Therefore, our estimates were incomplete in their representation of the APWRA's overall impacts on birds. Furthermore, we were unable to assess how the fatalities affected local or regional bird populations or whether the birds killed were residents or migrants.

Hunt (2002) concluded the local golden eagle population appeared stable during his 1994–2000 study, which overlapped ours, despite the wind turbine–caused mortality. W. G. Hunt (Santa Cruz Predatory Bird Research Group, personal communication) also concluded the golden eagles killed in the APWRA were local birds. However, we have not seen evidence refuting the possibility that many of the golden eagles killed by APWRA wind turbines may have been floaters from populations elsewhere in the western United States, Mexico, and Canada. If recruitment from other populations can continue to replace members of the local nesting population, despite the number killed by wind turbines, then the local number of nesting pairs may not change noticeably. If local bird populations produce fewer birds than the numbers killed by the wind turbines, then we would regard the APWRA as an ecological sink because more birds would be coming into the APWRA than leaving it.

Smallwood et al. (2007) concluded the APWRA might serve as an ecological sink to burrowing owls because turbine-caused mortality might equal or exceed local production. However, Smallwood et al. (2007) estimated annual mortality of 99–380 burrowing owls in the APWRA, which was lower than our estimate of 345–1,219. Our estimate is greater because Smallwood et al. (2007) relied on results of a scavenger removal trial using surrogate, nonraptor species in eastern Oregon, USA (W. P. Erickson and J. Jeffrey, WEST, Inc., unpublished data), whereas we relied on a recently developed predictive model (Smallwood 1997) based on a removal trial using small-bodied raptor species in the APRWA (Orloff and Flannery 1992).

Our incorporation of the set 2 turbines likely introduced a seasonal bias to our mortality estimates because we conducted no fatality searches during summer. Also, the longer search interval used among set 2 turbines usually produced larger standard errors for species and species groups found at both set 1 and set 2 turbines. However, we felt the bias and statistical error introduced by incorporating set 2 turbines were offset by the spatial distribution of these turbines across the full north–south and east–west extent of the APWRA. Including the set 2 turbines offset the bias of extrapolating the mortality estimates from the set 1 turbines, which were clustered in the east-central portion of the study area.

MANAGEMENT IMPLICATIONS

Despite low precision in estimated numbers of birds killed annually by APWRA wind turbines, our fatality counts and resulting mortality estimates demonstrated that ongoing operations kill relatively large numbers of raptors and other birds protected by the MBTA and other environmental laws. Regulatory agencies and the public need to decide whether to enforce laws intended to protect species killed by APWRA wind turbines, and whether to enforce the wind power companies' compliance with their conditional use permits. Alternative, safer wind turbine designs could be explored, as well as preproject site screening for likely wildlife impacts. Replacing the existing wind turbines with new-generation models on taller towers might reduce the APWRA's bird mortality $\geq$70% (K. S. Smallwood, unpublished data; W. P. Erickson, unpublished data). Unavoidable impacts could be compensated through habitat protections.

Assessments of proposed new wind power projects should regard existing reports of mortality as imprecise and likely lower than actual mortality levels. Until the uncertainties and biases of mortality estimates can be reduced through directed research, mitigation plans should account for the imprecision in mortality estimates by using adaptive management principles. Funds are needed to support monitoring and research and could be provided as part of the cost of wind farm development and operation. To improve precision of mortality estimates, fatality monitoring should include shorter search intervals (e.g., every other day at a sufficient sample of turbines), and needs to last $\geq$3 years. Fatality monitoring needs species-specific scavenger removal rates based on methods improved through directed research, and the extent of crippling bias needs to be learned. Mortality estimates should be expressed in terms of kilowatt-hours, so fatality monitors should be provided power output data from each wind turbine on a schedule corresponding with the fatality searches. Developing technologies to remotely detect collisions could vastly improve mortality estimation, while also cutting costs. Also, resident birds need to be tagged and monitored to learn the extent to which wind turbine collisions affect local populations.

ACKNOWLEDGMENTS

This project was funded by the National Renewable Energy Laboratory (NREL) and California Energy Commission (CEC). We thank L. Spiegel, the CEC's manager for the Public Interest Energy Research Environmental Area (PIEREA) avian program, K. Sinclair, NREL's Senior Project Leader, and R. Thresher, Director of NREL's National Wind Technology Center, for their guidance and support. We thank the field biologists who participated on the project: S. Anderson, A. Ballard, L. Burkholder, C. Burton, J. Cain, J. Camp, G. Charping, S. Clark, A. Harbin, E. Harrington, S. Hoover, B. Karas (Field Team Leader), H. Kirk, L. Lacunza, T. Lim, J. McBroom, M. Munnecke, J. Phan, D. Queheillalt, J. Quinn, T. Rettinghouse, D. Rios, M. Rowan, L. Rugge (Field Team Leader), P. Sheatsley, C. Szafranski, D. Tsao, N. Tuatoo-Bartley, E. Van Mantgen, J. Weisman, and S. Wilson. We thank S. Sutherland and L. Neher for Geographic Information System and Global Positioning System support, and M. L. Morrison for assistance with research design. We thank J. Yee for statistical advice, and 2 anonymous reviewers for their helpful comments. Finally, we thank Green Ridge Services and the APWRA wind power companies for providing logistical support and permission to access wind turbines.

LITERATURE CITED

Anderson, R., N. Neumann, J. Tom, W. P. Erickson, M. D. Strickland, M. Bourassa, K. J. Bay, and K. J. Sernka. 2004. Avian monitoring and risk assessment at the Tehachapi Pass Wind Resource Area: period of performance: October 2, 1996–May 27, 1998. National Renewable Energy Laboratory NREL/SR-500-36416, Golden, Colorado, USA.

Anderson, R., J. Tom, N. Neumann, W. Erickson, D. Strickland, M. Bourassa, K. J. Bay, and K. J. Sernka. 2005. Avian monitoring and risk assessment at the San Gorgonio Wind Resource Area. National

Renewable Energy Laboratory NREL/SR-500-38054, Golden, Colorado, USA.
Barclay, R. M. R., E. F. Baerwald, and J. C. Gruver. 2007. Variation in bat and bird fatalities at wind energy facilities: assessing the effects of rotor size and tower height. Canadian Journal of Zoology 85:381–387.
Erickson, W. P., G. D. Johnson, M. D. Strickland, D. P. Young, Jr., K. J. Sernka, and R. E. Good. 2001. Avian collisions with wind turbines: a summary of existing studies and comparisons to other sources of avian collision mortality in the United States. National Wind Coordinating Committee, c/o RESOLVE, Washington, D.C., USA.
Goodman, L. A. 1960. On the exact variance of products. Journal American Statistical Association 55:708–713.
Hunt, G. 2002. Golden eagles in a perilous landscape: predicting the effects of mitigation for wind turbine blade-strike mortality. Consultant Report to California Energy Commission, Sacramento, California, USA.
Hunt, W. G., R. E. Jackman, T. L. Hunt, D. E. Driscoll, and L. Culp. 1999. A population study of golden eagles in the Altamont Pass Wind Resource Area: population trend analysis 1997. National Renewable Energy Laboratory NREL/SR-500-26092, Golden, Colorado, USA.
Madders, M., and D. P. Whitfield. 2006. Upland raptors and the assessment of wind farm impacts. Ibis 148:43–56.
Orloff, S., and A. Flannery. 1992. Wind turbine effects on avian activity, habitat use, and mortality in Altamont Pass and Solano County Wind Resource Areas: 1989–1991. Report to California Energy Commission, Sacramento, California, USA.
Smallwood, K. S. 2007. Estimating wind turbine-caused bird mortality. Journal of Wildlife Management 71(8):2781–2791.
Smallwood, K. S., and C. Thelander. 2004. Developing methods to reduce bird mortality in the Altamont Pass Wind Resource Area. Final Report to the California Energy Commission, Public Interest Energy Research–Environmental Area, Contract No. 500-01-019, Sacramento, California, USA.
Smallwood, K. S., and C. Thelander. 2005. Bird mortality at the Altamont Pass Wind Resource Area, March 1998–September 2001 Final Report. National Renewable Energy Laboratory NREL/SR-500-36973, Golden, Colorado, USA.
Smallwood, K. S., C. G. Thelander, M. L. Morrison, and L. M. Rugge. 2007. Burrowing owl mortality in the Altamont Pass Wind Resource Area. Journal of Wildlife Management 71:1513–1524.
Young, D. P., Jr., W. P. Erickson, M. D. Strickland, R. E. Good, and K. J. Sernka. 2003. Comparison of avian responses to UV-light-reflective paint on wind turbines. Subcontract report July 1999–December 2000. National Renewable Energy Laboratory NREL/SR-500-32840, Golden, Colorado, USA.

Associate Editor: Morrison.

Subcontractor Report

December 2003 • NREL/SR-500-33829

Bird Risk Behaviors and Fatalities at the Altamont Pass Wind Resource Area

Period of Performance: March 1998–December 2000

C.G. Thelander, K.S. Smallwood, and L. Rugge
BioResource Consultants
Ojai, California

NREL

National Renewable Energy Laboratory

1617 Cole Boulevard
Golden, Colorado 80401-3393

NREL is a U.S. Department of Energy Laboratory
Operated by Midwest Research Institute • Battelle

Contract No. DE-AC36-99-GO10337

December 2003 • NREL/SR-500-33829

Bird Risk Behaviors and Fatalities at the Altamont Pass Wind Resource Area

Period of Performance: March 1998–December 2000

C.G. Thelander, K.S. Smallwood, and L. Rugge
BioResource Consultants
Ojai, California

NREL Technical Monitor: K. Sinclair

Prepared under Subcontract No. LAT-1-30222-01

National Renewable Energy Laboratory

1617 Cole Boulevard
Golden, Colorado 80401-3393

NREL is a U.S. Department of Energy Laboratory
Operated by Midwest Research Institute • Battelle

Contract No. DE-AC36-99-GO10337

Available electronically at http://www.osti.gov/bridge

Available for a processing fee to U.S. Department of Energy
and its contractors, in paper, from:
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: reports@adonis.osti.gov

Available for sale to the public, in paper, from:
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

Printed on paper containing at least 50% wastepaper, including 20% postconsumer waste

TABLE OF CONTENTS

EXECUTIVE SUMMARY

It has been documented that wind turbine operations at the Altamont Pass Wind Resource Area kill large numbers of birds of multiple species, including raptors. We initiated a study that integrates research on bird behaviors, raptor prey availability, turbine design, inter-turbine distribution, landscape attributes, and range management practices to explain the variation in avian mortality at two levels of analysis: the turbine and the string of turbines. We found that inter-specific differences in intensities of use of airspace within close proximity did not explain the variation in mortality among species. Some species, however, spent more time flying within 50 m of turbines than expected based on the area within this proximity zone, and they spent less time within 51-100 m or 101-300 m, indicating that these species were drawn into the lands near turbines for some reason(s).

Unique suites of attributes relate to mortality of each species, so species-specific analyses are required to understand the factors that underlie turbine-caused fatalities. We found that golden eagles are killed by turbines located in the canyons and that rock piles produced during preparation of the wind tower laydown areas related positively to eagle mortality, perhaps due to the use of these rock piles as cover by desert cottontails. The degree of clustering of pocket gophers around wind towers related positively to red-tailed hawk mortality, and the degree of clustering of gophers appeared to be greatest on steeper slopes into which laydown areas and access roads were cut, thereby producing increased lateral and vertical edge (which gophers prefer for constructing their burrow systems).

Tubular towers killed more red-tailed hawks and other raptors than would be expected from their numbers within our study area, and this pattern was even stronger for areas in which the tubular towers occurred on ridge tops and other landscape features that produced strong declivity winds. Rotor speed correlated positively with mortality, as did rotor height above the ground and rotor diameter. The windswept area of the turbine string, meaning the cumulative rotor-swept areas of all turbines in the string, correlated positively with mortality of several avian species. Factoring in the windswept area eliminated the effect of turbine position in the string, which some had thought to be an important factor for avian mortality, and which was verified by our data prior to factoring in the windswept area. Raptor fatalities did not correspond well with the distribution of California ground squirrels. Other similar relationships between fatalities and environmental factors are identified and discussed. The tasks remaining to complete the project are summarized.

1.0 INTRODUCTION

Research has consistently documented since about 1989 that wind turbines in the Altamont Pass Wind Resource Area (APWRA) kill a large number of birds, especially raptors (Orloff and Flannery 1992, 1996; Howell 1997; Howell and DiDonato 1991). Early researchers mainly focused on locating kills and quantifying bird fatality rates. Although these researchers hypothesized various causes and mechanisms associated with these fatalities, their research results were too cursory to lend much confidence even to the hypothesis tests that were performed. It soon became evident that if solutions to the problem were to be developed, then it would be necessary to conduct a risk assessment and a risk reduction study (Anderson et al., 1999).

In March 1998, the National Renewable Energy Laboratory (NREL) initiated research to address some complex questions that affect both wind energy development and wildlife conservation. What is the full extent of bird fatalities in the APWRA? What are the underlying causes of the fatalities? Are these events non-random and therefore, predictable? If they are, then what management options might be developed to reduce risk? In an effort to reduce the complexity surrounding these questions, we present the following framework for addressing and interpreting factors related to bird fatalities at the APWRA.

Step 1	Natural behaviors, geographic distributions, and ecological relationships that predispose wildlife to harm due to turbine operations	⇒	Sensitivity
Step 2	Placement and operation of wind farm structures and related management activities that pose threats to wildlife	⇒	Vulnerability
Step 3	Mortality due to wind farm operations; proportions of populations killed (risk)	⇒	Impacts
Step 4	Reliable prediction of impacts from indicators of sensitivity and vulnerability	⇒	Solutions

In the above framework, the integration of Steps 1 through 3 leads to Step 4 and its solutions. An empirical model developed in Step 4 can be broadly applied to predict *impacts* using quantitative measurements of factors that relate to *sensitivity* and *vulnerability*, terms which are drawn from the ecological indicators framework (Rapport, Reiger, and Hutchinson 1985; Cairns and McCormick 1992; O'Neill et al., 1994; Rotmans et al., 1994; Schultze et al., 1994; USDA 1994; Battaglin and Goolsby 1995; for an example, see Zhang, Geng, and Smallwood 1998) and defined below.

These terms are useful for our purposes because, although we would like to estimate levels of risk for each bird species at the APWRA, we cannot do so because we cannot enumerate each species at and around the APWRA. A true estimate of risk requires that the estimate of mortality be put into context with the total population size. Whereas the risk per species would be the preferred product of our research, solutions to avian mortality at the APWRA can be efficiently derived from the above framework.

1.1 Natural Behaviors and Ecological Relationships: Sensitivity

Birds die when attempting to pass through the rotor plane or when flying into guy wires or perching atop electrical distribution poles that service the wind farm. These attempts to fly through the rotor plane ultimately express natural behaviors, but in an artificial context in which the rotor plane has been introduced along with the other land uses and structures that are characteristic of wind farms. Natural behaviors and ecological relationships of birds contribute to their inherent sensitivity to wind turbines. Since each bird species exhibits unique suites of behaviors, geographic distributions, and ecological relationships, each also possesses unique sensitivities to wind farms. For example, if golden eagles (*Aquila chysaetos*) spend most of their foraging time in canyons, then they may be more sensitive to the placement of wind turbines in canyons. Red-tailed hawks (*Buteo jamaicensis*) may be less sensitive to turbine placement in canyons and perhaps more sensitive to turbines placed on ridgelines, if ridgelines happen to be where they fly most often. Burrowing owls (*Athene cunicularia*) might be most sensitive to turbine placement in areas where they conduct most of their courtship displays or where their foraging takes them into the altitudes of the rotating turbine blades. Thus, sensitivity is estimated by measuring and comparing behaviors that could cause individual species to collide with wind turbines should these behaviors continue unaltered after wind turbines are placed into operation.

Orloff and Flannery (1996) suggested that some birds try to pass through the rotor plane because they simply cannot see rotating turbine blades, or in the case of raptors, because they are fixated on a perch or prey item situated beyond the blades. Raptors may identify a perch or prey item and continuously observe it until they capture or land on it. If the raptor's target is located behind the rotating blades of a turbine, then the raptor may not see the blades or may see them when it is too late to avoid them. The relative effects of retinal smear (Hodos et al., 2001) versus fixed focus on prey items remains unknown, as does the degree to which these two factors might interact. But the frequent fatalities of non-raptorial birds summarized in this report indicate that fixed focus on prey items is not the only reason birds attempt to pass through the rotor plane.

Certain flight behaviors might influence a species' sensitivity to wind turbines, such as their long-distance flight behaviors during migration and their use of declivity winds, which are strong winds passing over ridge tops as they are forced upslope. Patterns of perching might connote various levels of sensitivity, if, for example, certain birds are prone to perching on wind towers because these towers simulate trees with which the species is familiar. Certain mating behaviors might distract individuals regardless of whether turbines are operating in the vicinity. Nocturnal predators may be more sensitive than diurnal predators due to differences in sensory perception relied upon by animals during the night versus the day. Lastly, some bird species that occur in relatively high numbers in the study area may only fly at heights well above the current rotor blades, thus indicating low sensitivity to the wind farm. For these and other potential inter-specific differences in sensitivity associated with flight behaviors, future changes in turbine design, operation, and placement might yield different mortalities among bird species at the APWRA.

The best approach for estimating sensitivity is to do so in a study with a before-after control impact (BACI) design with replication of impact and control treatments (Anderson et al., 1999). However, our study could not implement such a design because we were working with wind towers that were developed prior to the initiation of our study. In the absence of the ideal study design, in which we characterize bird behaviors at the APWRA prior to wind turbine operations, we made what inferences we could about sensitivity of bird species to placement and operation of wind turbines (summarized in the Preliminary Results section).

1.2 Exposure to Wind Farm Operations: Vulnerability

The placement and operation of wind turbines can make birds vulnerable to turbine collisions when and where these birds are already sensitive to turbines due to relative abundance, behaviors, and ecological relationships (e.g., predator-prey interactions). Vulnerability is a relative term that requires the measurement of sensitivity and impact across ranges of environmental conditions within the study area. Quantifying vulnerability requires a comparison of both the bird use of the environment near turbines and bird deaths to the availability of wind turbines within the environmental elements of interest, such as types of physical relief, seasons, and proximity to prey species.

Measures of vulnerability can be based on relative abundance near wind turbines and/or on the relative mortality of avian species at turbines with particular attributes. In both cases, a use-and-availability analysis using chi-square test statistics is an effective means of testing whether particular levels of vulnerability are significant.

As an example of applying use-and-availability analysis, relative abundance can be measured as the proportion of the sampling periods that each bird species is observed flying over landscape element A, and this proportion of flight time is related to the proportion of landscape element A occurring within the study area. Bird mortality can be measured as the proportion of the sample of individuals killed at turbines of a particular type or environmental setting relative to the proportion of those types or settings in which the turbines in the study area occur.

Vulnerability due to placement of wind turbines on certain landscape elements (as an example of any environmental element that one wishes to measure) can be expressed by the following model:

$$\frac{\chi^2 \ Observed}{\chi^2 \ Expected} = \frac{n_i}{N p_i},$$

where, in the case of measuring use of the areas near turbines, n = flight time of a particular species near turbines on landscape element i, N = total flight time of the species on the sampled landscape; and where, in the case of measuring mortality, n_i = number of individuals of the species killed at wind turbines on landscape element i, and N = total number of the species killed within the landscape area being sampled; and in both cases, p_i = proportion of the sampled landscape composed of landscape element i. In summary, our study attempts to identify the vulnerability of bird species to strikes with wind turbines based on our weighted measurements of sensitivity and impacts.

1.2.1 Wind Tower Design, Location, and Operation

Orloff and Flannery (1992, 1996) and Hunt (1994) suggested that wind turbines placed near gullies and turbines located at the ends of strings might be more dangerous to birds. The inter-tower spacing and the height of turbine towers and rotor diameters might interact to affect a species' vulnerability to turbine collisions. In addition, the percent of time that wind turbines operate may also be an important factor in bird collisions (Orloff and Flannery 1996).

Orloff and Flannery (1992) suggested that birds perched on certain turbine/tower configurations more often than they did on others, thus increasing the birds' risk at these sites because of the proximity to the turbines' rotating blades. In their comparative analysis of fatality rates among five tower configurations (lattice towers, horizontal cross, vertical axis, guyed pipe, and tubular), Orloff and Flannery (1992) reported significantly higher fatality rates at sites with horizontal lattice towers (i.e., at Kenetech 56-100 units). Certain characteristics of these facilities are believed to have contributed to high bird mortality, including numerous potential raptor perch sites created by the horizontal reinforcing crossbars, a high percentage of time in operation, and a relatively fast "tip speed," which is the rotational velocity of the tip of the rotor blade.

Wind turbines may be especially dangerous during unsettled weather conditions or in periods of poor visibility, such as during fog, rain, darkness, dusk, or dawn (Avery, Springer, and Cassel 1977; Taylor and Kershner 1986; Morrison 1996). Even inoperative turbines may be dangerous. Furthermore, during spring or fall bird migrations, the absolute number of bird fatalities might increase simply in proportion to the larger number of individuals passing through the APWRA, or migrants may be more or less sensitive to turbines than are residents. (Note that migrating raptors often fly at much lower altitudes than migrating passerines.)

The development of wind resource areas can sometimes bring with it numerous additional artificial perching and nesting sites, such as wires that support wind towers, the towers themselves, electrical distribution poles, meteorological towers, and transmission lines. These facilities could attract birds to a wind resource area, thus bringing them closer to turbine blades (Orloff and Flannery 1992). Some of these facilities of the wind resource area pose potential additional hazards to that of rotating turbine blades, such as stationary obstacles encountered during flight and energized elements used for perching.

Some researchers have suggested that modifying the structure or color of the towers or the turbine blades may reduce bird fatalities. For example, modifying towers might reduce perching, and painting disruptive patterns on turbine blades might make them more evident to birds (Kerlinger and Curry 1997). A recently proposed rotor blade painting scheme might enable birds to more clearly see rotating blades at shorter distances than unpainted rotating blades (Hodos et. al, 2001). Reducing golden eagle prey populations in the APWRA through intensive ground squirrel population control programs might modify that species' habitat use and thus might reduce risk of being killed by a turbine (Kerlinger and Curry 1997; G. Hunt, pers. comm.), although the overall risk of death to the eagle might increase as local prey availability declines. These suggestions have not been sufficiently tested to justify their implementation as solutions.

1.2.2 Altered Prey Availability

The development of the APWRA likely affected the distributions, abundance, and availability of prey species (Morrison 1996). Soil disturbance may have increased the numbers of ground squirrels (*Spermophilus beecheyi*), and the reduction of grass height in the presence of cattle grazing may have increased squirrel vulnerability to raptors (Morrison 1996). It may be possible to use habitat alterations to reduce prey vulnerability near turbines, thereby reducing raptor use of these areas as well as fatalities. This suggestion also remains untested.

Raptor mortality at wind turbines has been attributed to the occurrence of prey species near the wind turbines. At the APWRA, the principal prey species of interest to past researchers has been California ground squirrels, based on its status as a major prey item of golden eagles in central California (University of California, 1998). However, pocket gophers (*Thomomys bottae*) are abundant throughout the APWRA, whereas ground squirrels have an uneven, patchy distribution, as we will demonstrate with data in this and future reports. Red-tailed hawks and great horned owls rely heavily on pocket gophers (Fitch, Swenson, and Tillotson 1946; Craighead and Craighead 1956; Orians and Kuhlman 1956), whereas golden eagles rely more heavily on larger prey items, such as ground squirrels and lagomorphs (Carnie 1954, Olendorff 1976). California vole (*Microtus californicus*) populations likely also influence the distributions of raptor species, as likely do small reptiles, amphibians, and arthropods, which are fed upon by burrowing owls and American kestrels, as examples. Each raptor species foraging in the APWRA responds uniquely to prey species availability and thus requires independent analysis. (Previous studies have tended to group species into *raptors* and *nonraptors* for analysis.)

1.3 Measuring Effects on Birds: Impacts

Avian mortality studies conducted at wind resource areas have produced a variety of mortality estimates. Howell and DiDonato (1991) sampled the APWRA's turbines in 1988-89 and reported 0.05 deaths per turbine per year (n = 17 fatalities). Orloff and Flannery (1996) conservatively estimated that 39 golden eagles were killed during a 1-year period in the APWRA, and they estimated raptor mortality to range from 0.02-0.05 deaths/turbine/year. During a 1-year period, Howell (1997) confirmed 72 turbine-caused fatalities during an 18-month period at two wind resource areas, the APWRA and the Montezuma Hills WRA. Bird fatalities consisted of 44 raptors and 28 non-raptors with a mean raptor mortality of 0.03 deaths/turbine/year.

The effects of turbine operations on birds can be interpreted from two perspectives: legal and biological. From a legal perspective, individual fatalities can be considered significant effects and subject to civil or criminal penalties. Federal laws protecting raptors specifically include the Migratory Bird Treaty Act (MBTA), the Bald Eagle and Golden Eagle Protection Act, and the Endangered Species Act. Raptors are also protected under California Fish and Game Code 3503.5, which makes it illegal to take, possess, or destroy any bird in the Order Falconiformes or Strigiformes. The MBTA prohibits killing any bird species designated as fully protected. The U.S. Fish and Wildlife Service (USFWS) considers "take" to be any injury or fatality of any raptor from a collision with a wind turbine or ancillary facilities in the APWRA, and therefore, a violation of the MBTA (S. Pearson, pers. comm.., Senior Resident Agent, USFWS). Bird fatalities attributable to wind turbines are significant effects, from a legal perspective, because they violate the MBTA.

Comparing the turbine-caused mortality to both the natural mortality and the recruitment rate of each affected species effectively measures the biological importance of turbine-caused fatalities. Doing so yields estimates of the degree to which wind turbines adversely affect a species' population size, stability, and distribution. However, to do so requires extensive information about the distribution and demographic structure of populations occurring at and around the APWRA. Simply counting living birds at the APWRA would be inadequate for this purpose because the numbers of multiple species would change dramatically throughout the year due to migrations. The numerical estimates made at the APWRA would be, in multiple cases, contaminated by individuals that live most or part of their lives elsewhere. The APWRA may directly affect any number of bird species that occur over a broad geographic area. Thus, the geographic scale required for estimating impacts to avian species would be much larger than the APWRA itself. Our scope of study will not allow inferences of population-level or regional impact assessments to be made, but it is important to consider that these impacts are possible and should be estimated by additional research.

Among the raptor species killed in the APWRA, golden eagles and burrowing owls are probably the species of greatest concern because they are California Species of Special Concern. Although no detailed studies are currently underway to address burrowing owls, a recent study of mortality factors and golden eagle population regulation over a broad geographic region specifically included the APWRA within its overall study area (Hunt 1994, 1997, 2002). In recent years, golden eagle deaths in the area have been attributed to wind turbines. Preliminary research results indicate that the additional effect of the turbine-related fatalities might be contributing to a long-term decline in the region's golden eagle population (Hunt 1994, 1997, 2002). Therefore, although turbines might not cause a species to decline across its entire geographic range, the cumulative effect of human-caused fatalities may extirpate a species over a portion of its range.

Until more rigorous research efforts like the one for golden eagles are conducted at the APWRA for each bird species adversely affected by wind turbines, the full environmental impact of the APWRA will remain unknown. We will not know how the killing of *individual* birds affects their *populations*. In lieu of more rigorous research on population-level impacts, it would be prudent to implement effective management practices that will demonstrably reduce the vulnerability of bird species to the APWRA. In addition, demonstrating a reduction in bird fatalities within the APWRA would likely enable Alameda County (1998) to permit an increase in generating capacity that is available to the wind industry.

1.4 Relating Impacts to Causal Variables: Predictions and Solutions

Holding aside effects of season, weather, and turbine design and operation, if individuals of a bird species were randomly killed at wind turbines among measured environmental elements on the APWRA, then the probability of an individual being killed by a turbine occurring on a particular environmental element would equal the proportion of the turbines associated with that environmental element multiplied by the total number of that species killed in the study area. For example, if 20% of the turbines in a study area occurred on southeast-facing slopes, then a random distribution of 100 red-tailed hawk fatalities at wind turbines should have included about 20 birds killed by turbines on southeast-facing slopes. This product of total number killed (N) and the incidence of turbines on the ith landscape element is an expected kill rate at the ith landscape element. The number of fatalities at the ith landscape element can then be compared to the expected number of fatalities, where the distribution of mortality is random. For example, had 40 red-tailed hawks been killed by turbines on southeast-facing slopes, this observed frequency was twice the frequency expected of a random or uniform distribution of fatalities.

When the observed and expected frequencies of fatalities are equal, then the observed frequency cannot be attributed statistically to anything other than turbine numbers. However, when the converse is true, a relationship exists between that environmental element and mortality. If the relationship is less than 1, then there may be an avoidance of one environmental element and the possible selection of another. By identifying environmental elements where mortality exceeded expectations due to turbine numbers alone, we are able to identify which environmental factors might have a causal relationship. This approach allows us to assess vulnerability.

At selected wind turbines within the APWRA, we compiled separate data files for bird behaviors, wind turbine and tower characteristics, fatality searches, fatality search results, maps of rodent burrow systems, and various other physical and biological factors. This progress report summarizes the preliminary results of our integration of these data. This attempt at data integration brings us another step closer to developing a predictive model for bird mortality at wind turbines based on turbine location on the landscape, turbine location relative to other turbines, turbine design and operation, the distribution of raptor prey species near turbines, and other potential predictor variables.

We believe that in the future, such an approach will lead to a model that will reliably predict how many birds per species are likely to be killed at individual turbines or at strings of turbines per year. Most important, such a model can be used as a tool to identify zones of vulnerability when siting new wind turbines in the APWRA.

2.0 OBJECTIVES

The primary objectives of this current phase of the research were: (1) to quantify bird use, including characterizing and quantifying perching and flying behaviors exhibited by individual birds around wind turbines; (2) to evaluate the flying behaviors and the environmental and topographic conditions associated with flight behaviors; and (3) to identify possible relationships among bird mortality and bird behaviors, wind tower design and operations, landscape attributes, and prey availability. A fourth objective, to be achieved after the fieldwork is completed, is to develop a predictive, empirical model that identifies areas or conditions that are associated with high vulnerability. Such a model could one day be used in the APWRA to identify locations and conditions of high versus low vulnerability, or to accurately identify those turbines that have demonstrated their ongoing threat to birds.

We began the project by quantifying bird use and bird fatalities associated with that use. Only about 24% of the APWRA's total turbine population was included in the project due to limited access. We quantified bird flight and perching behaviors at the various turbine types and examined whether the frequencies of these behaviors at turbines were related to environmental factors such as weather, topography, habitat features, prey availability, and others.

As our study progressed, unexpected patterns prompted us to add certain focused subtasks and activities to complement the basic goals of the project. Such patterns included ground squirrel distribution and abundance not relating to raptor mortality; pocket gophers clustering near wind towers on steep ridgelines; and raptors generally avoiding perching on wind towers/turbines. We added research on rodent distribution in relation to tower locations, bird use, and fatality locations. We also examined topographic and landscape features and related these to bird use and bird fatalities. In general, the topics we examined fell into three broad categories: (1) bird flight behaviors; (2) turbine/tower design, placement, and operations; and (3) raptor prey availability and distribution in relation to individual turbines and turbine strings.

3.0 STUDY AREA

The APWRA is located 90 km east of San Francisco, within eastern Alameda and southeastern Contra Costa counties in central California (Figure 1). Within the APWRA, which is the largest wind energy facility in the world, some 8,200 turbines were originally approved with as many as 7,200 installed at one time. When the current study began approximately 5,400 turbines were operating (Alameda County 1998). The output capacity of the installed turbines is about 580 megawatts. They are distributed over approximately 150 km^2 (50,000 acres).

The APWRA facility first reached significant levels of energy generation during the mid-1980s, when most of the wind towers now in existence were erected (Hunt 1997). Turbines are generally grouped under common ownership. At least 13 companies manage the energy that is produced in the APWRA, and a variety of different tower/turbine configurations are installed.

The Altamont Pass region exhibits a wide diversity in topographic relief. Hilltop elevations range from 230-470 m above sea level. Valley elevations range from about 78-188 m above sea level (Howell 1997). Livestock grazing and dry farming constitute the primary land use in the area (University of California, 1998).

Steady winds from the southwest blow across Altamont Pass from about April to October. Differential air temperatures form as the warmer Central Valley east of Altamont Pass draws in cooler, marine air from San Francisco Bay to the west. Winds are more erratic at other times of the year. They can originate from any direction. Wind speeds average 25-45 km/hr between April and September, during which time the APWRA produces 70%-80% of its power. During the summer months, wind speeds are sufficient to operate the turbines beginning about midafternoon and increasing during the evening hours. During winter, wind speeds average 15-25 km/hr. Dense fog can occur in the Altamont Pass during summer and winter. Severe winter fog conditions often linger for many consecutive days.

The vegetation is predominately non-native annual grassland consisting of soft chess (*Bromus hordeaceus*), rip-gut brome (*Bromus diandrus*), foxtail barley (*Hordeum murinum ssp. leporinum*), Italian rye grass (*Lolium multiflorum*), and wild oats (*Avena fatua*). Common forbs include black mustard (*Brassica nigra*), fiddle-neck (*Amsinckia menziesii ssp. intermedia*), chick lupine (*Lupinus microcarpus var. densiflorus*), bush lupine (*Lupinus albifrons*), and wally baskets (*Triteleia laxa*). Grasses and forbs grow during the rainy months of January, February, and March, then die or go dormant by the beginning of June. The APWRA includes the following physiographic elements that harbor characteristic groups of species: annual grassland, alkali meadow, emergent marsh, riparian woodland and scrub, creeks and drainages, stock ponds, cultivated land, and rock outcrops. At least 18 special-status wildlife species occur in the area, including San Joaquin kit fox (*Vulpes macrotis mutica*), California red-legged frogs (*Rana aurora draytonii*), San Joaquin pocket mouse (*Perognathus inornatus inornatus*), American badger (*Taxidea taxus*), Swainson's hawk (*Buteo swainsoni*), peregrine falcon (*Falco peregrinus anatum*), California tiger salamander (*Ambystoma californiense*), two species of fairy shrimp, and others. In addition, the area supports as many as 15 special-status plant species (Alameda County 1998).

4.0 METHODS

Wherever applicable, the methods used in our project adhere to guidelines developed and recommended for such studies by the Avian Subcommittee of the National Wind Coordinating Committee (Anderson et al., 1999).

4.1 Study Plots and Wind Energy Facilities Sampled

We sampled 1,110 individual tower and turbine configurations from March 1998 through December 2000 (Table 1). During the project, we added groups of turbines as they became available to us. In particular, Altamont Infrastructure Company (AIC) wind towers (n = 425) were added to our study much later than the others. By December 2000, we had sampled these turbines only one-third as many times as we did the other turbines in our sample. This differential search effort would confound our analysis if we included all turbines being surveyed as of 31 December 2000. Therefore, we have separated many of the analyses in this report into AIC and non-AIC wind turbines. Unless specifically indicated, the findings presented in this report represent results only for non-AIC turbines/towers (Table 2; n = 685).

4.2 Bird Fatalities

Gauthreaux (1996) suggested that searches for bird fatalities around individual turbines should be circular, with the minimum radius determined by the height of the turbine. Since all wind towers in our study area were arranged in strings, we searched them efficiently by walking strip transects along both sides and around the ends.

Data on each fatality included season, tower type, turbine type, tower location within the string, the aspect of the slope on which the string of turbines was situated, and attributes of the physical relief of the study plot. Except for season and weather, these same variables were recorded for all wind towers and turbines where birds were not killed, as well. We used a global positioning system (GPS) device to record these data. The GPS data dictionary used to collect data is included in the Appendix.

Two people explored the ground around each string of wind towers, using one of two searching methods, one for level terrain and the second for hillsides (Figure 2). In either case, each person walked in line with the string, 50 m away from the first tower and 50 m in the opposite direction away from the string centerline. Previous studies reported that about 77% of all carcasses were found within a 30-40 m radius from the wind towers, mostly in the area behind the rotor (Orloff and Flannery 1992; Munsters, Noordervliet, and Ter Keurs 1996; Howell 1997). Both searchers walked toward and outward from the string line in a zigzag pattern from wind tower to wind tower until they reached the last one.

On hillsides or steep terrain, the searchers walked parallel to the string line, whereas on level terrain they walked perpendicular to it. The distance between each zigzag characterizes a different approach to this technique as compared with previous fatality search studies (i.e., Orloff and Flannery 1992). In this study, we kept a tight, closed, zigzag pattern, approximately four meters between each turn. The expected advantage of this ground-surveying technique was to increase the probability of detection of all bird remains, including small passerines.

All carcasses or body parts, such as groups of flight feathers, head, wings, tarsi, and tail feathers, found during each search within a 50-m radius of the wind tower were documented and flagged as fatalities. We carefully examined these to determine species, age, sex, and probable cause of death. The time since death was estimated by carefully analyzing the carcass condition (e.g., fresh, weathered, dry, bleached bones) and decomposition level (e.g., flesh color, presence of maggots, odor), using methods and standards described in the following paragraphs.

To determine the cause of death, we evaluated the general condition of intact carcasses. For dismembered or mutilated remains we evaluated carcass position, the distance and compass reading to the nearest wind turbine or electrical distribution pole or wire, and the type(s) of injury. Each fatality was classified as a “fresh kill” or as “old remains” depending on the estimated time since death. Fatalities were considered fresh when carcasses and small remains were found during our searching cycle of from 1 to 60 days. Old remains included highly decomposed and dismembered carcasses with weathered and discolored feathers, missing flesh, and bleached, exposed bones. These carcass characteristics led observers to believe that the time since death was before the start of this project. The above data, as well as the distance and angle to the wind tower closest to the carcass, were recorded on a standard data sheet. Observers photographed each fatality at the time of discovery.

The ground around each wind tower was searched in 8-10 minutes. Five hours per day were devoted to fatality searches, and two-person crews managed to search 30-40 turbines per day. With two to three people searching 120-150 wind towers per week, all 685 turbines were sampled once every five to six weeks, thus completing approximately eight fatality search cycles in 12 months. Not all strings were searched every month due to changes in field strategies or for reasons out of our control, such as fire hazards and flooded roads.

From 26 March 1998 to 29 February 2000, we searched each of 685 wind turbines 16 times. We also present all fatality records through December 2000, but we discontinued collecting flying and perching behaviors after 29 February 2000 due to budget limitations. These additional fatality data are useful for estimating vulnerability for reasons other than behavior.

We analyzed mortality at two levels of resolution. The finest resolution of analysis was at the turbine level, in which we examined the number of fatalities of each species associated with each wind tower. At the turbine level of analysis, we relied on chi-square analysis derived from the model described above. We analyzed turbine-caused mortality among bird species with which we had gathered at least 20 records, except for golden eagles, which had only 12 records but was a principal species of concern in the study due to its rarity, low productivity (University of California, 1998), and special status under environmental laws.

The coarsest resolution of analysis was at the string level. In this case, we examined the number of fatalities of each species associated with entire strings of wind towers. At the string level of analysis, we relied on Pearson correlation and linear, least-square regression analyses. These analyses always started with examination of scatter plots of mortality on the Y-axis and predictor variables on the X-axis in order to identify patterns in the data, and progressed to a systems analysis approach to explaining the variation in fatality rates (Watt 1966, 1992). This systems analysis approach relies on saving unstandardized residuals from linear regression analysis, then systematically plotting these residuals against each of the other predictor variables. Residuals are the vertical, Y-axis distances measured between each data point and the estimated line representing the regression slope. Residuals represent the variation in the dependent variable that is not explained by the predictor variable. The new plots of residuals from one predictor variable plotted against another predictor variable can reveal meaningful patterns in the residual variation of the dependent variable, which can then be explained by both predictor variables in multiple regression analysis (Watt 1966).

The statistics we present in this report are consistent with the objectives of the corresponding hypothesis tests. For example, correlation analyses are summarized by the coefficient of determination, R^2, when prediction is the ultimate objective. They are summarized by Pearson's correlation coefficient when the objective is simply to summarize the degree of correlation. We will report weak and non-significant correlations when doing so meets our objectives.

Because R^2 is based on two independent factors— the steepness of the regression slope and the precision of the data relative to the regression line—we often also include the root mean square error (RMSE), which measures the latter. R^2 alone is an inefficient summary statistic for many of our hypothesis tests.

Although we use analysis of variance (ANOVA) to test some hypotheses in this study, key assumptions of ANOVA cannot be met due to the lack of any sort of block design or related controls on treatment replication or interspersion. Even though we are studying an anthropogenic system, ours is a non-manipulative study. Our "replicates" and our degrees of interspersion of "treatments" were established by the placement of wind towers by the industry prior to our study. As a mensurative study, the chi-square family of statistical tests is most efficient for testing many of our hypotheses (Smallwood 1993, 2002).

In all of our hypothesis testing, we relied on an α-level of significance of 0.05. However, we also took note of P-values less than 0.1 as indicative of trends worthy of further research or consideration. The observed divided by expected values derived from χ^2 tests are used as measures of effect and need to be interpreted based on the P-value of the test, whether the expected number of observations was larger than 5 (smaller than 5 is generally regarded as unreliable), and the magnitude of the ratio. These latter considerations for assessing the significance of particular observed/expected values we leave to the reader.

4.2.1 Scavenging Activities

Orloff and Flannery (1992) reported little evidence of raptor carcass removal by scavengers during their research at Altamont. However, not documenting the full effect of scavenging may cause an underestimation of the number of dead birds found during our searches. We left in the field each bird carcass we found. Having recorded its exact location using GPS and flagging, we then visited each carcass location at least every 3 days or until the proper authorities collected it. During the time the carcass was in the field, we recorded data on the condition of the carcass, amounts of decomposition over time, and any evidence of scavenging at an interval of once per week. Even though the U.S. Fish and Wildlife Service required immediate reporting of carcasses found and endeavored to pick up all of these carcasses from the field soon after reporting, carcasses occasionally remained in the field for up to 1 month before authorized personnel retrieved them. Thus, we conducted a non-systematic scavenging rate evaluation by recording signs of scavenging activity at the time of the finding and occasionally throughout the times that carcasses were left in the field by the U.S. Fish and Wildlife Service.

At our ENRON study site, due to differences in county regulations, carcasses and remains were reported to the supervisor on site but never picked up from the field. This situation presented us with an opportunity to monitor the scavenging and decomposition rates of those carcasses for longer periods than others. Information about change in carcass condition over time and the period carcasses remained in the field helped us assess the effectiveness of fatality searches in discovering fatalities and how long they remain to be discovered. We calibrated our estimates of time since death by comparing the decomposition level of a specific fatality since the known time of death.

4.3 Bird Behaviors

Two biologists spent 303 days in the field collecting bird behavior data within 20 study plots during 26 March 1998 through 30 March 2000. The boundaries of these study plots were determined by including only those wind turbines easily visible to the observers from a fixed observation point. The result of this plot selection process was a mosaic of irregular shaped, non-overlapping polygons, each about 3 km^2 (Table 2).

The plots where we collected behavior data contained 685 turbines, with 25-45 turbines per plot, representing 98% of all turbines accessible to us at that time. We classified each turbine string by slope aspect, average grade, and average elevation. Slope aspect was classified as facing north, northeast, east, southeast, south, southwest, west, northwest, or located in a valley. Average grade was classified as Level 1 = 0%-9% grade, Level 2 = 10%-19%, Level 3 = 20%-29%, and Level 4 = 30%-39%. Average slope elevation was classified into three groups: high elevation, including slopes 250-324 m above sea level; medium elevation slopes (175-249 m); and low elevation slopes (100-174 m).

We also recorded the topography on which turbine strings were situated, such as on ridges, slopes, swales, peaks, or plateaus, and we recorded the direction to which these topographic features face (as described above for individual turbines). Turbine sites refer to the positions of turbines within a string, such as end of the string, second to the end, interior to the string, or separated from other turbines by a gap created by an inoperable turbine or a gully, as examples. Of the turbines sampled, there were 210 end-of-the-row wind towers, 152 second-to-the-end wind towers, 93 third-to-the-end wind towers, and 217 interior wind towers.

We quantified bird behaviors by recording the number of birds detected within specific study plots and categorizing their specific activities while in those plots (Table 3). Within each study plot, a location was selected from which behavioral observations took place. The observation point was a fixed location used for all behavioral data collection and at which the observer had the best view of the wind towers and the surrounding terrain within the study plot. This approach ensured that each bird species was identified and their activities around the turbines documented. Each observer carried maps of the plots in order to identify each turbine by location and number where each bird flew or perched.

Before the behavioral observations commenced, and for the specific purpose of this study, a field data sheet was developed to record many aspects of bird behavior, as well as the environmental conditions at the time of the observation session. Bird behavior was recorded with alphanumeric codes onto a standardized data sheet, along with temperature, wind speed, turbine operations, and cloud cover at the beginning of each 30-min observation session. We measured temperature with a hand-held thermometer. We evaluated wind force by looking at the observable wind characteristics and measured using the Beaufort scale (0-7). The scale numbers were later transformed into km/hr and grouped according to three wind speed levels: low wind speed levels (0-15 km/hr), medium (16-30 km/hr), and high winds (31-50 km/hr). When the wind speed reached > 55 km/hr (near gale winds), the managers of the facilities advised us to leave the premises for safety reasons.

A single observer completed each sampling event with 8x40 binoculars and performing circular visual scans (360^o), also called variable distance circular point observations (Reynolds, Scott, and Nussbaum 1980). Each visual circular-scanning event lasted 30 min and corresponded to one observation session.

Once a bird crossed the boundary into the study plot, we identified it and continuously followed it until it left the plot. For each sighting, we recorded the species, number of birds in a flock, the times when the bird was detected and when last seen, predominant flight behavior, flight direction, distance to the nearest turbine, type of turbine, number of passes by a turbine, and flight height relative to the windswept zone, which is the height above ground from the lowest to the highest reaches of the turbine blades.

We considered two major bird behavior categories—flying and perching—but classified 18 flying activities (Table 3). The focus of the behavioral observations was to determine how close to a turbine each bird flew, and what types of behaviors it exhibited near the "zone of vulnerability." The zone of vulnerability in this study represents the reach of the rotating turbine blades or rotor swept area, within 50 m of the blades (Figure 3).

The estimation of the closest pass to the zone of vulnerability was vital to this study. Therefore, both field assistants practiced calibrations on height and depth measurements of known objects every six months.

A proximity value was assigned to each behavior in terms of how close that behavior was performed in relation to the turbine blades and according to the length of time birds spent doing that behavior near the blades. Proximity Level 1 involved behaviors performed within 1 – 50 m of the turbines. Proximity Level 2 involved behaviors seen within 51-100 m. Proximity Level 3 behaviors were performed farther from the turbine at 101-300 m.

Three hundred meters represented the farthest distance in which many flying birds could be clearly identified to species, their behavior followed, and their distance estimated, so only birds observed within that distance were recorded during the behavioral observations. If the biologists observed the bird perching, they recorded the time and specific perching structure. Perching was recorded on 21 structures within our study site (Table 4).

A bird's "utilization duration" was the amount of time it was observed during a 30-min observation session. We attempted to accurately quantify the amount of time spent flying and perching in order to determine the extent of both activities. After the observation period ended, the observer moved to the next sampling plot to complete another 30-min observation session.

Our biologists sampled all 20 plots at least once every week, stratified by morning and afternoon sessions. The morning session started at 07:00 and continued until 12:00. The afternoon session lasted from 12:01 until dusk. We observed behaviors throughout the year in nearly every weather condition, unless rain or fog reduced observer visibility to <60%, which was too poor to track bird activity accurately. We completed two sessions simultaneously, averaging 6-8 observation sessions per field day. We conducted all simultaneously occurring 30-min sessions on non-adjacent plots to ensure independence among observation sessions.

We calculated the mean minutes of flying and perching behaviors among the 30-min observation sessions for each bird species. Mean minutes of flying and perching behaviors were related to seasons, wind speed levels, topographic features, and wind turbine characteristics to determine whether these variables might affect mean flight time among raptor and non-raptor species. These factors were treated as independent variables in one-way analysis of variance (ANOVA) tests (Zar 1996) on the minutes of flying and perching activities per bird species.

When any of the ANOVA tests rejected the null hypothesis, we used the Tukey test (Zar 1996) to determine where differences existed. The mean minutes of each bird behavior were also considered in one-way ANOVA to identify significant differences for the raptor and non-raptor species among independent variables such as seasons, wind speeds, topographic characteristics, and turbine types.

Statistical tests were performed only for bird species observed in at least 10% of the sessions because the results of tests involving small sample sizes are unreliable and we had enough bird species with larger sample sizes to recognize general inter-specific patterns. In cases where subdivision of the data by years reduced the sample size substantially, we grouped data and analyzed them across both years. We performed Student t-tests (Zar 1996) to determine whether significant differences in flying and perching time occurred between years. The species included in our more rigorous analyses reported herein include American kestrel, red-tailed hawk, turkey vulture, golden eagle, burrowing owl, common raven, loggerhead shrike, and several other passerine species. We will provide analyses for the rarer species in the final report.

4.3.1 Observer Bias

To reduce the effects of observer bias in estimating and reporting distances and bird behaviors, paired observations were conducted for 1 month at the beginning of the study. At this time, we calibrated differences between observers in terms of distances, turbine and tower sizes, and depth perception. We also recorded bird behavior to become familiar with the data sheet and to standardize the names for all bird activities, behavior categories, and perching devices. Once the observers were achieving similar records and behavior interpretations, observers began conducting separate 30-min observation sessions. We completed the first calibration period in 18 observation sessions. We repeated these calibration sessions every 6 months in four observation sessions for a period of 1 to 2 days. The observers recorded the behavioral information simultaneously but independently on separate data sheets. At the end of each calibration session, we compared and discussed the information to help ensure consistency of the behavioral interpretations.

4.4 Landscape Features

We used a Trimble Pathfinder Pro-XR GPS to map the location of each wind tower with sub-meter accuracy. At each of these locations, we also recorded attributes of the tower/turbine and the landscape. These attributes were stored in a spatially explicit database (GIS). We recorded the type of turbine, whether it had an anemometer (in order to test whether its availability as a perching structure might relate to fatality rates), whether the turbine faced toward or away from the wind, the turbine's position within the string, the number of turbines in the string, and whether the turbine was part of a windwall, which is composed of turbines at two or more heights above the ground and which together extend the windswept zone. We recorded the physical relief, such as whether the tower/turbine was on a ridgeline, peak, slope, or swale. In addition, we recorded the slope aspect on which the tower/turbine occurs, the elevation in meters above sea level, and various notes about the site.

We mapped the location of each tower by using the offset function of the GPS because we wanted to avoid inaccuracies possibly caused by the electromagnetic field of operating wind turbines. We stood ≥5 m from each tower and input the distance, compass bearing to the tower, and degrees of inclination, if any.

We also mapped the locations of many of the fatalities. This data collection is ongoing and will allow us to complete this task later so that we can detect directional and distance patterns of where fatalities end up on the ground. Recognizing whether the locations of fatalities relate to local topographic and wind patterns might increase the efficiency of future fatality searches.

We mapped the perimeters of stock ponds and natural water bodies to test the effect of proximity to water body on the fatality rates. We mapped the perimeters of rock piles to test for any relationship between raptor fatality rates and proximity to cottontail denning habitat (rock piles). In some cases, pushing together rocks to clear space for the wind tower platforms had artificially created these features. We also mapped the distribution of fossorial rodents. We describe these maps below in more detail.

4.5 Burrowing Rodents

We mapped rodent burrows near 98 wind turbines composing nine turbine strings in the APWRA (see Figures 4 and 5). One string of 38 diagonal lattice turbines operated by ENRON is located on the south side of Altamont Pass Road. EnXco (formerly FORAS) operated eight of the turbine strings (60 tubular tower turbines) on the north side of Altamont Pass Road. These eight strings were selected to provide a wide range of fatality rates while at the same time to span the breadth of our EnXco sampling area. The ENRON string was selected due to its known high fatality rate. Our sampling scheme was intended to establish on a trial basis whether the distribution of rodent burrow systems around wind turbines might relate to fatality rates of raptors. Because of this trial, we have since expanded our sampling effort, but the results are not yet ready to present.

We mapped with GPS the approximate centers of pocket gopher, ground squirrel, and cottontail burrow systems. We located burrow systems based on freshly excavated soil or scats at the burrow entrance, which indicated the burrows were occupied. Although we easily recognized the boundaries of most individual pocket gopher and ground squirrel burrow systems, a pacing method (Smallwood and Erickson 1995) was used to separate burrows when continuity of sign rendered inter-burrow system distinctions difficult. This pacing method is worked out for pocket gophers, but not for ground squirrels, so the maps made of ground squirrel burrow systems are still preliminary. We mapped burrows used by cottontails and burrowing owls as we encountered them. The presence of scat at each burrow entrance helped identify them.

Our search for burrows began in the string of turbines. A 7.5-m-wide strip transect was walked from 15 m beyond the turbine at one end of the string to 15 m beyond the turbine at the other end. Then perimeter transects were walked at 15 m, 30 m, and 45 m away from the turbine string, thus covering increasingly larger areas around the turbine strings (Figure 4A). These 15-m intervals correspond with the distance across the largest burrow systems of male pocket gophers (Smallwood and Erickson 1995).

A laser rangefinder was used to maintain the intended distances away from the turbines while searching along perimeter transects. We estimated densities of gopher and ground squirrel burrow systems within each of the corresponding areas searched. Using least squares linear regression, densities of burrow systems were then regressed on the corresponding search areas and the steepness of the regression slope used as an indicator of contagion relative to the location of each turbine string. Also, we estimated the density of burrows within 55 m of each turbine string (Figure 4B) and compared these data to fatality rates of raptor mortality. The distance of 55 m was established by including 10 m of search area beyond the 45-m buffer described above.

We also measured the distance between the turbine and each burrow system, and we counted the burrow systems of each species occurring within 55 m of each turbine (e.g., Figure 4B). We aggregated these counts into zero, 1-2, and ≥ 3 burrow systems in order to facilitate χ^2 tests with adequate cell values. In addition, we classified red-tailed hawk fatalities as either zero or ≥ 1.

Since this preliminary study of animal burrow patterns around wind turbines, we have searched 43 additional turbine strings out to 80 m from each string. We have also begun monitoring the pattern of burrow systems across seasons of the year. The results of these studies are not included in this report.

5.0 PRELIMINARY RESULTS

5.1 Bird Use

We observed at least 36 bird species during the behavioral observations. Sightings averaged 3.2 birds per observation session. We observed no birds in 184 of the 1,958 observation sessions.

Sixty-nine percent of all bird sightings were raptors (n = 3,765), and 31% were non-raptors (n = 2,371). The most frequent raptor species sighted during the behavioral observation sessions was red-tailed hawk (n = 1,820, 48%), followed by turkey vulture (n = 801, 21%), American kestrel (n = 446, 12%), golden eagle (n = 424, 11%), and northern harrier (n = 117, 3%). The most common non-raptor bird species sighted was common raven (n = 837, 35%), gull species (n = 519, 22%), several blackbird species (combined; n = 396, 17%), and rock dove (n = 139, 6%). (These sightings consisted of individuals as well as flocks or small groups, so more birds were actually seen than the n-values reported herein.)

5.2 Bird Behaviors

We recorded 31,317 minutes of bird activity representing 6,146 behavioral sightings. The 13,725 minutes spent flying (44%) were nearly as many as the 17,592 minutes spent perching (56%) (Table 6).

For individual species, the total time spent flying versus perching (Table 7) varied considerably. Therefore, it is likely that there are considerable differences in the sensitivity of each species to turbine operations. For example, American kestrels, burrowing owls, western meadowlarks, and European starlings were usually observed perching, whereas turkey vultures, northern harriers, prairie falcons, mallards, and mourning doves were usually observed flying. One might conclude that the latter group of species would be more sensitive to turbine collisions if it were not for additional factors that influence fatality rates, such as exactly where these birds fly, when they fly there, and how much time they spend flying near turbine blades.

We recorded 6,377 observations of birds in flight, including multiple flights for the same bird. Fly-through behavior was the most common type of flight recorded for all bird species (27%, n = 1,726 sightings), followed by gliding (18%, n = 1,141) and soaring (16%, n = 1008). However, soaring lasted longest on average ($\bar{x}$ = 3.6, SD = 3.5), followed by gliding ($\bar{x}$ = 2.8, SD = 3.3) and fly-through ($\bar{x}$ = 1.22, SD = 0.54).

Raptor species flew more during medium and high wind speeds, with red-tailed hawks spending the greatest amount of time flying during these conditions (Figure 6). In general, larger bird species were seen in the air more often than smaller species. By examining each species' flight time within the species' range of flight times, species-specific use of wind patterns are evident (Figure 7). For example, flight time increases consistently with increasing wind speeds for northern harriers and American kestrels. This relationship plateaus after medium wind speeds for turkey vulture, golden eagle, and prairie falcon, and it drops substantially at medium wind speeds for burrowing owls. There is a noticeable peak for red-tailed hawks. Thus, species appear to differ in their sensitivity to turbine operations due to wind speeds.

Raptors performed 17 of the 19 behaviors observed for all species. Raptors differed significantly by mean flight time per proximity level (ANOVA, F = 105.60, P = 0.001, df = 2, 4,333) (Table 8). Raptors spent significantly more time flying at close proximity to turbine blades ($\bar{x}$ = 4.59 minutes, SD = 5.04) than 51-100 m away ($\bar{x}$ = 3.34, SD = 3.48) or >100 m away ($\bar{x}$ = 2.12, SD = 1.98) (Tukey's test, P < 0.05).

Among raptor species, red-tailed hawks performed 66% (n = 748) of the flight behaviors we thought made them most vulnerable to turbine collisions (i.e., flying within the height domain of the rotor plane and within 50 m of the turbines), golden eagles performed 15% (n = 170), and American kestrels performed 10% (n = 112) of them, respectively (Table 9).

American kestrels performed the highest percentage of flights within 50 m of the turbines (45% of 112 flights), followed by northern harriers (39% of 52 flights), and red-tailed hawks (38.6% of 748 flights). Turkey vulture and burrowing owl had the lowest frequency of flights within 50 m of the turbines (Table 10).

American kestrels differed by mean flight time within proximity levels (ANOVA, $F = 7.85$, $P < 0.001$, df = 2, 366), spending significantly less time per flight 101-300 m from the turbine blades compared to 0-50 or 51-100 m (Table 11, Fig. 8). Based on mean values, red-tailed hawks spent significantly more time per flight within proximity level 1 compared to farther away (ANOVA, $F = 57.89$, $P = 0.001$, df = 2, 2,146; Table 11, Fig. 8). Burrowing owls did not differ significantly by mean flying time among proximity levels (ANOVA, $P = 0.15$, $F = 2.07$, df = 2, 23), nor did golden eagles (ANOVA, $P = 0.460$, $F = 0.77$, df = 2, 577), northern harriers (ANOVA, $P = 0.15$, $F = 1.92$, df = 2, 130), and prairie falcons (ANOVA, $P = 0.15$, $F = 1.93$, df = 2, 79) (Table 11, Fig. 8). Turkey vultures did differ significantly by mean flight time within proximity levels (ANOVA, $P = 0.001$, $F = 74.03$, df = 2, 981), spending significantly more time flying per observation within proximity levels 1 and 2 (Table 11, Fig. 8).

Analysis of the mean flight time did not consider the number of times each species flew within proximity levels. Therefore, we examined the total number of minutes each species flew within each proximity level. Figure 8 illustrates the dramatic differences in interpretation when using total flight time rather than the mean flight time. Red-tailed hawks appear to spend the greatest average time per flight within proximity level 1, but considering the total minutes, this species spent more than four times the amount of time in proximity level 1 compared to other species. In proximity level 2, red-tailed hawks averaged no more time than did the other species, but they spent nearly twice as much time there than did turkey vultures and much more time than did the other species.

Total flight time by a species more closely indicates the differences in use of proximity levels than does the mean time per flight. Based on the mean time per flight, red-tailed hawks spent twice the time flying within proximity level 1 compared to proximity level 3, but based on the total time, red-tailed hawks spent more than four times the amount of time flying in proximity level 1 compared to proximity level 3. Factoring in the proportion of the APWRA occupied by these three proximity levels (by applying GIS coverages) will reveal the degree to which each species uses each proximity level relative to chance. This type of analysis will be forthcoming.

We approximated the proportion of the 2,780 ha of our study area composed of proximity levels 1, 2, and 3. Proximity levels 1, 2, and 3 occupy about 15%, 22%, and 63%, respectively, of the total area encompassed by all three proximity levels. Multiplying the total number of minutes of red-tailed hawk flight time by these proportions yields expected flight times of 1,241, 1,821, and 5,214 minutes in proximity Levels 1, 2, and 3, respectively. The observed flight times were 4,069, 3,598, and 609 minutes, respectively. Red-tailed hawks flew within 50 m of the turbine blades about 3.3 times longer than expected by chance, within 51-100 m of the blades 2.0 times longer than expected by chance, and within 101-300 m about 0.1 times the total flight time expected by chance.

Based on this preliminary analysis, it appears that red-tailed hawks are strongly attracted to lands within 50 m of wind turbines in the APWRA, and they seem to avoid lands located farther away from turbines. Analyzing the total number of minutes of flight time reveals that something about wind turbines may attract red-tailed hawks to fly near turbines and at dangerous heights.

Similarly, American kestrels flew in proximity level 1 nearly four times longer than expected by chance, golden eagles two times longer, and northern harriers three times longer. Burrowing owls flew in proximity level 1 only 0.67 times as long and turkey vultures only 0.2 times as long as expected by chance. Figure 9 shows the amount of time each of several raptor species flew within each proximity level relative to the availability (area) of each proximity level. All of these relationships were highly significant, based on the χ^2 test of association ($P < 0.0001$ for all of them).

This type of approach can also reveal important interaction effects, such as between wind levels and the number of passes made within 50 m and farther than 50 m of turbine strings. The proportion of the observation periods during a particular measured wind speed can be multiplied by the proportion of the area composed of proximity levels 1 or 2 to yield the proportion of the time that winds of that particular speed likely blew within that proximity level. This new proportion can then be multiplied by the total number of passes made by a species within each proximity level, and χ^2 analysis can be performed.

For example, Figure 10 illustrates the insight gained by deriving the observed ÷ expected number of passes made by red-tailed hawks during the behavioral observation sessions. Whereas the number of passes peaked during moderate wind levels at the APWRA, and whereas the number of passes was always greater within 50 m as compared to farther than 50 m for each wind speed level (Figure 10, left panel), the disparity in the number of passes between proximity levels is heightened when comparing the observed and expected values or the interaction effect (Figure 10, right panel).

Red-tailed hawks are strongly selecting to pass closely by the wind turbines during moderate wind speeds but are avoiding making passes >50 m from the wind turbines during all wind speeds, based on the availability of the area in proximity level 2 ($\chi^2 = 618$, d.f. = 15, $P < 0.0001$).

This result suggests that our distinction between sensitivity and vulnerability already has been contaminated by the placement of the turbines on the APWRA, meaning that any true observations of sensitivity, *per se*, would need to be made at one or more locations with similar environmental conditions but without the presence of the wind turbines. The placement of wind turbines in the APWRA has fundamentally changed the flight behavior of red-tailed hawks there. Specifically, 18% of the passes made by red-tailed hawks were closer to the turbine strings during winds of 1-34 kph than would be expected by chance based on areas and wind speed as the only factors. We expect that the clustering of prey species around wind turbines is the underlying reason for this altered raptor flight behavior. This same type of analysis remains to be performed for the other species in our study.

5.3 Fatality Searches

We found 439 dead birds and four dead mammals among 31 bird and one mammal species (Table 12). These fatalities included 226 (53%) raptors, 209 (49%) non-raptorial bird species, and 4 (1%) hoary bats. Of these bird carcasses, 372 (87%) were confirmed to be the result of turbine collisions, 11 (3%) we believe resulted from predation by other species, and the cause of death was undetermined for 43 (10%).

We did not find a raptor fatality at most of the turbines we sampled. Of the 1,110 turbine locations sampled from 12-30 months, only 272 (24%) have been recorded to cause one or more fatalities (Table 13). The left-skewed, leptokurtic distributions of mortality among turbines and turbine strings (Figure 11), coupled with the inter-specific correlations at turbines, pose the possibility that mortality among multiple avian species can be reduced by changing turbine and tower design, tower placement, and range management practices. That is, because multiple species are killed by the same subset of turbines, focusing on the factors common to that subset of turbines might benefit multiple species.

5.3.1 Scavenging Effects

Data from the fatality searches indicate that scavenging has little effect on the results, especially for medium to large birds. For example, three dead barn owls monitored for their duration of detectability remained visible in the field for 90, 120, and 150 days. For 17 freshly killed red-tailed hawks monitored for detectability, each remained visible for at least 180 days, with five visible for at least 360 days.

A comprehensive assessment of the role scavenging plays in carcass detection will be provided in the final report; however, at this point we have little reason to suspect that it affects the overall results of our fatality data.

5.4 Seasonal Use Patterns

5.4.1 Flight Time by Season

Mean flight time of raptor species combined varied throughout the seasons and years (Table 15). We found significant differences between years and seasons. These factors also strongly interacted (two-way ANOVA, season: F = 8.374, P = 0.001, df = 3; year: F = 18.789, P = 0.000, df = 1; season by year: F = 6.929, P = 0.001, df = 3, 2793).

The mean flight time of raptors differed by season during 1998-99 (ANOVA, F = 5.724, P = 0.001, df = 3, 865), averaging lowest during summer ($\bar{x}$ = 1.91, SD = 1.47, n = 255) and highest during fall ($\bar{x}$ = 2.75, SD = 3.03, n = 276). Mean flight time of raptors differed between summer and fall (Tukey's, P < 0.05), but not between summer and winter ($\bar{x}$ = 2.56, SD = 2.43, n = 257), nor spring ($\bar{x}$ = 2.63, SD = 3.10, n = 81), fall, and winter (Tukey's P > 0.5).

The highest mean flight time of raptors occurred during winter, 1999-00 ($\bar{x}$ = 4.05, SD = 5.42, n = 381) and lowest in fall ($\bar{x}$ = 2.73, SD = 3.36, n = 624). It differed by season during 1999-00 (ANOVA, F = 12.220, P = 0.001, df = 3, 1928), averaging the highest during winter (Tukey's, P < 0.05), but not differing in spring ($\bar{x}$ = 2.78, SD = 2.52, n = 325), summer ($\bar{x}$ = 2.88, SD = 2.52, n = 602), and fall.

Mean flight time of raptors did not differ significantly during spring (*t*-test, P = 0.644) and fall (*t*-test, P = 0.934), but it did during summer (*t*-test, P = 0.001) and winter (*t*-test, P = 0.001).

5.5 Physical Features

Certain avian species were clearly vulnerable to collisions with turbine rotor blades operating on a variety of tower types. In one instance, we observed a lone rock dove that flew upwind into a rotor and was struck by a rotor blade. We conclude that the majority of the dead birds we found would not have died where we located them had the wind turbines not been located there. Therefore, some aspect or combination of aspects of wind turbine operations resulted in these birds being vulnerable to injury or death.

Operation of these wind turbines also made certain avian species vulnerable to electrocution on electrical distribution poles because we found electrocuted raptors under distribution poles that otherwise would not be located on the APWRA in the absence of the wind turbines. The data presented below focus on various vulnerabilities that may contribute to bird fatalities caused by rotating turbine blades atop wind towers, plus rotations of vertical axis wind turbines.

The fatality rates of some species are correlated. The number of red-tailed hawk fatalities per string correlated with the number of fatalities of American kestrel (r_P = 0.455, P < 0.001), barn owl (r_P = 0.325, P < 0.05), burrowing owl (r_P = 0.210, P < 0.05), golden eagle (rP = 0.270, P < 0.05), and all non-raptor species combined

($r_P = 0.271$, $P < 0.05$). This indicates that patterns related to fatality rates observed for one can sometimes be used to represent the patterns expected of others, however weakly. Because fatality rates are correlated inter-specifically and because it appears that some turbine strings kill more individuals of multiple species, solutions to reduce the fatality rate of one species might be solutions for other species also.

5.5.1 String Size

The number of red-tailed hawk fatalities at a string correlated with the number of wind towers in the string ($r_P = 0.515$, $P < 0.001$), as did the number of fatalities of American kestrel ($r_P = 0.345$, $P < 0.001$), burrowing owl ($r_P = 0.219$, $P < 0.05$), and barn owl ($r_P = 0.353$, $P < 0.001$). These correlations might be significant simply because avian vulnerability to wind turbines increases with the number of wind towers present; that is, a string of 21 wind turbines poses a greater danger to birds than does a string of two wind turbines.

Table 16 includes regression coefficients around which residuals can be calculated and used to uncover relationships between fatality rates and other factors that otherwise may have been masked by the effect of the number of turbines composing a string (i.e., increased probability of fatalities occurring at a string because there are more opportunities for fatalities with more turbines present). If the size of the string is not factored into the analysis, then patterns of fatality rates related to other variables might be hidden and others might be spurious. We made use of these residuals in the analyses that follow.

5.5.2 Windswept Area

The number of fatalities at a turbine string increased with the total windswept area of the string (Table 17), where the windswept area included the sum of all windswept areas of only those wind towers that were operational spanning most of the period during our fatality searches. Windswept area of the string explained more of the variation and tended to be more significant than was the number of turbines in a string. This is evident by comparing the summary statistics provided in Tables 16, 17, and 18. In addition, the average windswept area generally increased with the number of fatalities of each taxonomic group (Figure 12), as well as with individual species (Figure 13).

This relationship indicates that other string-level analyses should also be adjusted by the string's windswept area, which appears to substantially increase vulnerability. We made this adjustment using unstandardized residuals that were calculated from the regression models in Table 17. We made use of these residuals in the analyses that follow.

5.5.3 Tower Type

Avian fatality rates associated non-randomly with tower types (Figure 14; Table 18). Bonus tubular towers killed 1.4 to 2.1 times more red-tailed hawks, golden eagles, burrowing owls, and barn owls than expected by chance. Vertical axis towers killed less than the expected number of red-tailed hawks, golden eagles, and American kestrels, ranging from none to 29% of the expected fatality rates. Diagonal lattice towers killed 1.4 times more American kestrels than expected by chance. Danwin tubular towers killed only one red-tailed hawk. These relationships appear to be closely linked to attributes of the towers, which are described below.

5.5.4 Rotor Diameter

Avian fatality rates associated non-randomly with rotor diameters (Figure 15; Table 18). The two largest diameter rotors killed 1.3 to 2.4 times more red-tailed hawks, golden eagles, burrowing owls, and barn owls than would be expected by chance. The smallest-diameter rotor killed about one-third of all red-tailed hawks but only because there were so many of these small rotors. Rotor diameter appeared not to affect American kestrel fatality rates.

At the string level of analysis, rotor diameter appears to slightly influence red-tailed hawk fatality rates (r^2 = 0.08, regression b = 0.23, df = 1, 107, P < 0.05), but factoring in string size revealed a stronger correlation, but still weak overall (r^2 = 0.17, regression b = 0.28, df = 1, 107, P < 0.001).

5.5.5 Rotor Speeds

Avian fatality rates associated non-randomly with turbine rotor speeds (Figure 16; Table 18). The faster turbines killed 1.2 to 2.1 times more red-tailed hawks, golden eagles, burrowing owls, and barn owls than would be expected by chance, given the frequency distributions of rotor speeds. Turbine rotor speed appears to be unassociated with the fatality rate of American kestrels, however. Interestingly, the average rate of the turbines correlated negatively with the number of turbines in the string (r_P = - 0.38, P < 0.001), indicating that some of the relationships with rotor speed may have been hidden by the strong positive correlations between fatality rates and number of turbines in the string (or windswept area). In addition, average rotor speed correlated positively with rotor diameter (r_P = 0.48, P < 0.01), turbine size (r_P = 0.35, P < 0.01), and tower height (r_P = 0.21, P < 0.05).

5.5.6 Tower Height

Avian fatality rates associated non-randomly with wind tower heights (Figure 17; Table 18). Towers with rotors that were centered 24 m above ground killed 1.1 to 1.3 times more red-tailed hawks, golden eagles, American kestrels, burrowing owls, and barn owls than would be expected by chance, given the frequency of each tower height in the sample. Although most of the wind towers were 24 m tall, these towers killed more than the expected number of each species compared to a random (uniform) distribution of kills. This attribute of wind towers might explain most of the relationship between Bonus tubular towers and their greater-than-chance fatality rates with several of the avian species we studied. Bonus tubular towers are 24 m tall.

However, tower height interacted with landscape features that are related to declivity winds for some species and with other landscape conditions for other species (see below).

5.5.7 Turbine Position in String

Avian fatality rates associated non-randomly with the position of the wind tower in the string (Figure 18; Table 18). Table 19 summarizes the frequency distribution of wind tower positions within the strings that we searched for fatalities in the APWRA.

At the turbine string level of analysis, a majority (68%) of red-tailed hawk fatalities occurred at 56% of the strings. In these strings, the end towers composed only 10%-50% of the string. It would appear, based on examination of the scatter plots (Figure 19), that red-tailed hawk fatalities were more frequent at turbine strings composed of fewer end and gap towers (i.e., edge towers; a gap within a string is defined as 25% greater distance between towers than the average inter-tower distance) and more interior towers. However, end towers composing 10%-50% of the string indicate that these strings were moderate in size because only two towers can be end towers on any given string. The string level of analysis was confounded by the effect of the number of wind towers composing the string and by the windswept area of the string.

Therefore, we calculated the unstandardized residuals from the regression models in Table 16 and then related these residuals to the position of the wind tower in the string (Figure 20). The residuals from the model in Table 16 did not regress significantly on turbine position in the string (Table 20). They increased, however, with increasing numbers of derelict turbines in the string among those strings that had derelict turbines (Figure 21), suggesting that an increasing proportion of derelict turbines in a string might confuse red-tailed hawks flying by them. It is even possible that derelict turbines are more visible because their rotor blades are not moving and so are not causing retinal smear. Red-tailed hawks might fly farther around them and into the rotor blades of adjacent turbines that *are* operating.

Similarly, American kestrels and barn owls appeared to be killed at an increasing rate with a smaller percentage of the string composed of end turbines and with a greater percentage of interior turbines, but these relationships vanished when adjusted by windswept area (Table 20). Golden eagle and burrowing owl fatality rates, however, demonstrated no relationships with turbine position in the string, except that the golden eagle fatality rate adjusted by windswept area increased with a greater percentage of end and gap turbines and with lower percentage of interior turbines (Table 20). However, even this latter relationship might have been influenced by a positive correlation between the percentage of the string composed of end and gap turbines and percentage of the string occurring within canyons ($r_P = 0.25$, $P < 0.01$).

Another inter-variable correlation to consider for future analysis of fatality rates includes the one between percentage of the string composed of end and gap towers and rotor speed ($r_P = 0.35$, $P < 0.01$). Apparently, turbine strings with more gaps and fewer interior turbines maintain higher rotor speeds, which might increase the vulnerability of avian species to turbine strikes. Furthermore, more of these strings also occur within canyons ($r_P = 0.25$, $P < 0.01$). More research is needed to fully understand the contribution of these relationships to fatality rates.

5.5.8 Type of Physical Relief

Avian fatality rates associated non-randomly with types of physical relief (Figure 22), but not significantly (Table 18). Compared to chance, wind towers on ridge tops and swales killed 1.2 and 2.9 times more red-tailed hawks than expected, respectively. Towers situated on slopes killed 1.4 times more golden eagles than expected due to chance. Otherwise, the physical relief appeared to not influence the fatality rates of the species we examined. However, whether the wind towers were located within one of three major canyons within our study area did relate to fatality rates (see Section 6.5.10).

5.5.9 Declivity Winds

Avian fatality rates associated non-randomly with whether the wind towers were placed to take advantage of the declivity winds (Figure 23), but not significantly for golden eagles, barn owls, and burrowing owls (Table 18). Red-tailed hawks were killed 1.3 to 2.1 times more often than expected by chance at 24-m towers placed on swales, ridgelines, and peaks, at 30-m towers on swales, and at 14-m towers on slopes. American kestrels collided with turbines 2.7 to 7.0 times more often than expected by chance at 24-m towers on ridgelines and at 24- and 30-m towers on swales. Thus, it appears that there is an interaction effect between physical relief and tower height for these species. Tall towers on swales or low spots along ridgelines often formed at the junction of two ridges appear to be especially troublesome for red-tailed hawks and American kestrels.

Obviously, the physical relief affects the declivity winds, so ultimately physical relief significantly affects turbine-caused mortality. To recognize the effect of physical relief, the analyst must factor in tower height in this case.

5.5.10 Canyon Effects

Avian fatality rates associated non-randomly with whether turbines were located in or out of canyons (Figure 24; Table 18). Wind towers located in one of the three major canyons in our study area killed 1.8-3.6 times the number of red-tailed hawks, golden eagles, burrowing owls, and barn owls that would be expected by chance given the frequencies of towers in or out of canyons. The rate of American kestrel fatalities did not relate to whether the towers were located in canyons. All the golden eagle fatalities we found occurred within canyons.

The percentage of the string occurring within the three major canyons within our study area also correlated positively with the average turbine-caused mortality ($r_P = 0.40$, $P < 0.001$), average rotor diameter ($r_P = 0.46$, $P < 0.001$), and negatively with average tower height ($r_P = -0.23$, $P < 0.05$). Thus, the relationships between raptor fatality rates and whether turbines occurred in canyons could instead be due to the relationships between fatality rates and these other tower/turbine attributes, or vice versa. More research is needed to isolate the contribution of each of these relationships.

5.5.11 Slope Aspect
Avian fatality rates associated non-randomly with slope aspect (Figure 25; Table 18). Wind turbines located on northwest-facing slopes killed more red-tailed hawks, golden eagles, and barn owls than would be expected by chance, given the proportion of turbines on these slopes. Towers on south-facing slopes killed more red-tailed hawks, American kestrels, and burrowing owls than would be expected by chance. Turbines located on southeast slopes killed more golden eagles than would be expected by chance.

5.5.12 Additional Features
At the time of this writing, at least three other related and important topics remain to be analyzed using GIS capabilities: percent slope, elevation, and complexity of relief. Data have been collected on these topics and the analyses will be completed for inclusion in the final project report.

5.6 Burrowing Rodents

As summarized in the introduction, ground squirrels have been thought to be the principal prey species of raptors at the APWRA. However, given the numbers of raptors killed on the south side of Altamont Pass Road, we suspected that ground squirrels might not be the species of principal interest to raptorial birds. Also, previous experience has led us to believe that pocket gophers are important prey of raptorial birds and that gopher burrow systems serve as habitat for various other prey species of raptorial birds. Pocket gophers appear to be abundant in the APWRA on both sides of Altamont Pass Road, whereas ground squirrels appear to be abundant only on the north side. During 2000 and 2001, we found 1,272 ground squirrel burrow systems within the 173.5 ha searched at EnXco for a density of 7.3 burrow systems per ha, which was 30.5 times more dense than the 18 ground squirrel burrow systems we found within the 74.2 ha searched at ENRON for a density of 0.24 burrow systems per ha (these are preliminary results only).

During a previous study we observed that raptorial birds spend a disproportionately large fraction of their flight time directly over pocket gopher burrow systems while capturing pocket gophers, voles, snakes, and black-tailed jackrabbits. Therefore, we decided to map the locations of pocket gopher and ground squirrel burrows in and around selected strings of wind turbines. Our objectives for this activity were to compare the mortality of raptorial birds to the densities and degree of contagion of burrow systems actively used by potential prey species around individual turbines and around turbine strings. Usually, pocket gophers clustered within close proximity to the wind turbines, whereas ground squirrels established colonies farther away from the turbines (Figure 5).

The results presented here are preliminary and therefore not conclusive. Our initial sample sizes were too small to lend much confidence to the results. Continued fieldwork will sufficiently increase the sample sizes of fatalities and turbine strings around which fossorial mammals are mapped, which will add considerable confidence to our results.

5.6.1 Intra-String Comparisons
Red-tailed hawk fatalities *tended* to occur at turbines with one-two gopher burrows more often than expected by chance, and less often at turbines without gopher burrows within 55 m ($\chi^2 = 5.28$, df = 2, P = 0.07). However, red-tailed hawk fatalities did not relate significantly to the occurrence of ground squirrel burrows at turbines ($\chi^2 = 2.88$, df = 2, P = 0.24).

Golden eagle fatalities occurred more often than expected by chance at turbines with ≥ 3 ground squirrel burrows within 55 m ($\chi^2 = 7.72$, df = 2, $P < 0.05$). However, half of the contingency table's expected cell values were less than 5, a condition that requires cautious interpretation of the test result.

Burrowing owl fatalities also occurred more often than expected at turbines with ≥ 3 ground squirrel burrows within 55 m ($\chi^2 = 13.35$, df = 2, $P < 0.001$). Burrowing owl fatalities occurred at the two turbines with the greatest numbers of burrowing owl burrows within 55 m (6 and 7 burrows, respectively; no statistical test performed). Golden eagle and burrowing owl fatalities did not relate significantly with the density of pocket gopher burrow systems around turbine strings. Pocket gophers are not considered a major prey item for either species.

These data suggest that red-tailed hawks and golden eagles, which differ in their foraging behavior and prey selection, were vulnerable to turbine collisions for different reasons. Moreover, the distribution of ground squirrels and pocket gophers near turbines may be used to predict risk for certain raptor species.

5.6.2 Inter-String Comparison

At the inter-string level of analysis, pocket gopher density consistently decreased as larger areas were searched around each turbine string (Figure 26). All turbine strings demonstrated a relationship between gopher burrow density and study area size that was similar to the pattern reported by Smallwood and Morrison (1999). Steeper regression slopes indicated greater clustering of gopher burrow systems in the immediate vicinity of the turbines. Ground squirrel burrows did not occur within 55 m of four of the nine turbine strings, and ground squirrel burrow density increased as larger areas were searched at another turbine string (Figure 27). At yet another string, the slope value of negative one between log ground squirrel burrow density and study area size was determined by only one burrow, which occurred along the interior transect. Dividing a constant number (one, in this case) by a variable area forces a slope value of negative one.

As was the case for pocket gophers, the density of burrow systems for all species declined as larger areas around the turbine strings were included it the search effort (Figure 28). This multi-species pattern was likely driven by the pocket gopher pattern, as many fossorial species take advantage of the burrows that are abandoned by gophers. Indeed, many gopher burrows were found near the 98 turbines that lacked ground squirrel burrows, but most ground squirrel burrows occurred near turbines that also had gopher burrows. By June 2001, we observed ground squirrels establishing new burrow systems where gopher burrows were previously mapped in the absence of ground squirrel burrows during 1999 and 2000. Pocket gophers are attracted to the vertical and lateral edge created by the access roads and tower laydown areas cut into the steep slopes.

Except for the turbine string at ENRON, which has a distinct assembly of rodent species compared to the EnXco turbine strings and is geographically separated, the number of red-tailed hawk fatalities per turbine string increased with an increasing slope of log gopher burrow density regressed on log study area size (Figure 29):

$$\text{Hawk fatalities} = -3.68-7.01 \times \text{Regression slope coefficient}$$

$r^2 = 0.58$, Root MSE = 0.97, df = 1,7, $P < 0.05$ (not including the ENRON string).

The number of fatalities did not correlate significantly with the intercept of log gopher burrow density regressed on log study area size, nor did it correlate with the overall density of gopher burrows within the areas searched, nor with the maximum density recorded within the interior 7.5-m strip transect.

The turbine string at ENRON, which is south of Altamont Pass Road, had accumulated the largest number of red-tailed hawk fatalities, although it only had one ground squirrel burrow. The larger area of the ENRON operations had very few additional ground squirrel burrows on the premises. Instead, the ENRON turbine strings were home to many cottontails, which live under the tower platforms. The ENRON turbine strings will need to be analyzed separately from the EnXco turbine strings when we search for relationships between raptor fatality rates and prey distributions based on our larger data set.

Of the remaining EnXco tubular turbine strings with ground squirrel burrows, the number of red-tailed hawk fatalities did not relate significantly with the regression slope of log ground squirrel burrow density and log study area size (Figure 30):

Hawk fatalities = 1.510-2.476 Regression slope coefficient

$r^2 = 0.48$, Root MSE = 2.54, df = 1,4, P = 0.20.

We note, however, that our original maps of gopher and ground squirrel burrow systems did not include cottontail burrows, which is a species we have since observed in abundance at this outlier ENRON turbine string and which lives in burrows excavated under the concrete platforms of the turbines. New data are being collected on this aspect of the analysis.

6.0 DISCUSSION

This report describes the progress to date of research designed to identify the factors responsible for avian fatality rates at Altamont Pass Wind Resources Area, and to establish the empirical basis for developing a predictive model. This project is ongoing. Therefore, readers should consider these findings as preliminary and subject to revision. A comprehensive final report is scheduled for completion in late 2003.

Based on 372 carcasses resulting from confirmed collisions with turbines, the combined average annual fatality rate was 0.19 fatalities/turbine/year. Table 14 presents the average annual fatality rates for each of eight individual tower/turbine configurations. These data indicate that collision rates vary considerably when compared based solely on facility configurations. However, other physical features, landscape characteristics, and biological factors may affect the comparative fatality rates.

Our fatality data were derived from only 24% of the turbine population in the APWRA. Nevertheless, assuming our sample is representative of the entire APWRA and applying the fatality rate of 0.19 fatalities/turbine/year to 5,400 active turbines in the APWRA, one may estimate that as many as 1,026 birds are killed per year in the APWRA. Of these, approximately 50% are expected to be raptors.

To date, golden eagles represent 2.4% of the total bird fatalities in our study. This percentage yields an estimated 24 golden eagle deaths per year in the APWRA. Our estimate is fewer than Orloff and Flannery's (1992, 1996) estimate of 39 golden eagle fatalities per year and Hunt’s (2002) estimate of 40 to 60 golden eagle fatalities per year.

Similarly, burrowing owls represent 9% of the fatalities in our study. Extrapolating this percentage across all wind towers in the APWRA yields an estimated 93 fatalities per year. Red-tailed hawks represent 24% of the fatalities in our study, suggesting fatalities number 244 per year in the APWRA. The APWRA has been in operation with more than 4,000 turbines since about 1984. The turbine population peaked in 1987-88 at some 7,000 operating turbines. During the past several years, 5,000-5,400 turbines have consistently remained in operation. These estimates of total annual fatalities for golden eagles, red-tailed hawks, and burrowing owls warrant continued research, monitoring, and management programs designed to reduce these rates.

Despite the higher mortality reported here, it is not possible to conclude that more bird fatalities per turbine occurred between 1998 and 2000 than in previous years. These data probably reveal, however, that historically the full extent of the bird fatality problem has been underestimated. In addition, the fatalities are continuing.

As expected, each species using the APWRA exhibits a somewhat different suite of behaviors. It appears, at least for raptors, that differences in their foraging behaviors and their selection of prey species are closely related to their relative vulnerability to turbines. Our data on gopher burrows indicate that gophers more frequently occur near turbine strings than they do away from turbine strings. Furthermore, the distribution and occurrence of gopher burrows is related to raptor fatalities at turbine strings. From these findings, we conclude that lack of prey availability on the slopes away form turbines encourages red-tailed hawks to hunt near the turbines, thereby increasing the vulnerability of this species to operating turbines.

The number of bird fatalities per turbine string increases in relation to the total rotor swept area of the strings. This factor tended to be more significant than was the relationship between fatality rates and the number of turbines in each string. From these data, it is reasonable to infer that reducing the number of turbines in a particular area will not result in a reduction in bird fatalities unless the total rotor swept area is also reduced. These results contradict the results of Howell (1997), who found that rotor swept area did not explain the difference in fatality rates between two turbine types with different rotor swept areas.

Each of the various turbine/tower configurations has been suspected of causing different bird fatality rates (Howell 1997; Orloff and Flannery 1992, 1996; Anderson et al., 1999). Our data confirm this suspicion, but it appears that these differences may be due to certain turbine attributes or other factors that associate with the distribution of each of these turbine types. It appears that factors other than tower type play more of a role in whether a particular turbine is associated with one or more fatalities, such as prey distribution about the tower's base, physical relief, and presence of declivity winds. Regardless, the number of fatalities at tubular towers was higher than at horizontal lattice towers. This is contrary to previous research results (Orloff and Flannery 1996, Howell and DiDonato 1991). The repowering Environmental Impact Report (EIR) (Alameda County 1998) concluded that replacing horizontal lattice towers with tubular towers to support the new, larger turbines would reduce the number of fatalities post-repowering. The results of the present study do not substantiate the findings of the repowering EIR regarding the likelihood that using tubular towers will significantly reduce bird fatalities.

Past researchers have reported that wind turbines located at the ends of strings kill most of the raptors (Orloff and Flannery 1992, 1996; Hunt 1994). Using a single factor approach, this observation appears correct, but factoring windswept area of the string eliminated the previously apparent effect of turbine position in the string. The exception was the number of derelict turbines in the string, which appeared to increase along with the number of red-tailed hawk fatalities in the string.

Red-tailed hawks fatalities occur more frequently than expected by chance at turbines located on ridgelines than on hillsides. The reverse appears to be true for golden eagles. This finding highlights the need for a species-specific approach to reducing bird fatalities in the APWRA and for a better understanding of the effects of multiple environmental and landscape factors on bird risk.

A relatively large number of burrowing owls were killed at wind turbines in the APWRA, at least in the areas that we have sampled thus far. This species is becoming increasingly rare throughout California. It is possible that the regional impact of turbine fatalities in the APWRA, especially in terms of maintaining a stable population size, will be more significant to this species than is reported for golden eagles nesting in the region. We observed that burrowing owls exhibit unique flight and foraging behaviors, and they nest in relatively large numbers in the immediate area of operating wind turbines. To address this unique circumstance, more research is needed on the effects of turbine kills on this local population of burrowing owls and possible emergency management options that will reduce those impacts.

The recent EIR prepared by Alameda County (Alameda County 1998) assessed the potential impacts of a partial repowering proposal in the APWRA. One of its conclusions was that replacing smaller turbines with larger ones at a 7:1 ratio was likely to result in substantially fewer bird fatalities. The EIR failed to address, however, that converting to fewer turbines would result in a slight net increase in the total rotor swept area. Based on data presented here, it is reasonable to expect that the number of bird fatalities at fewer post-repowering turbines should remain nearly equal to the number of kills reported at the more numerous pre-repowering turbines. This hypothesis remains to be tested as the repowering effort proceeds.

Overall, our results have broadened understanding of bird use, fatality rates, risk behaviors, and the interactions of a variety of landscape elements in relation to risk and fatalities. The results are promising, and we believe that they may eventually lead to a solution to the overall objective of reducing bird kills in the APWRA. For this to occur, however, additional research using comparable methods conducted over a larger percentage of the APWRA's operating turbines is needed.

Eventually we expect patterns to emerge that can be used to identify high risk factors. The distribution of most of these factors is uneven in the region. By quantifying and mapping them, it may be possible to predict where bird fatalities are most likely to occur or where placing new turbines might kill the fewest numbers of birds. Such a model would have wide applicability and might one day help to effectively reduce the number of fatalities well below those that have occurred virtually unabated since the mid-1980s.

6.1 Summary of Key Findings

The following are key findings derived form our results to date. They are provided in no particular order. We intend to discuss their importance in detail in the final report.

- The frequency of sightings of species on the APWRA did not correspond strongly with turbine-caused mortalities among species.

- American kestrels and red-tailed hawks made more flights and spent more time flying within 50 m of the turbines than 51-100 m or 101-300 m away.

- We found 426 dead birds (including 226 dead raptors) and four dead mammals at 685 turbines that were searched 8-16 times each over 12-30 months.

- Fatality rates of raptor species correlated positively with the number of turbines in the string and the windswept area of the string.

- Turbines with larger rotor diameters killed more than the expected number of birds based on turbine numbers alone.

- Turbines with faster rotor-tip speeds killed more than the expected number of birds based on turbine numbers alone.

- Turbines with rotors 24 m above ground killed more than the expected number of birds based on turbine numbers alone, and the majority of these were tubular towers.
- Turbines at the ends and gaps of strings killed more than the expected number of birds based on turbine numbers alone, but factoring in windswept area of the string eliminated this effect.
- Factoring in windswept area, the presence of derelict turbines in the string emerged as a significant associate of red-tailed hawk fatalities.
- Turbines on swales and ridge tops killed more than the expected number of birds based on turbine numbers alone, and tower heights of 24 m and 30 m increased the effect of these landscape features apparently due to the interactions of declivity winds with these tower heights.
- Red-tailed hawk fatalities increased in strings with greater degrees of clustering of pocket gopher burrows.
- Raptor fatalities did not correspond well with the distribution of California ground squirrels.

6.2 Tasks Remaining

We continue to collect data that we believe will eventually contribute a better understanding of avian fatality rates and fatality mechanisms. For example, we are extending the coverage of rodent burrow maps to 80 meters from the turbine string, and we have added maps of burrow systems at about 30-40 turbine strings. In addition, some of our data have yet to be tested analytically because they are still being processed. A good example is the collection of spatial data and our use of GIS to process it. Elevation contours are being estimated using a digital elevation model, against which some of our variables will be compared. We will use landscape complexity measurements from the spatial data we have collected and that we are obtaining from off-site sources. Finally, our results may change as the sample size for total fatalities increases, and as we rule out the contributions of possibly spurious relationships. The statistical power of our analyses will increase with sample size, as will the confidence in our conclusions.

6.3 Management Implications

The need exists for a better, more accurate method of monitoring bird fatalities than the Wildlife Response and Reporting System (WRRS), which is the one on which regulatory agencies currently rely. This is particularly true for the APWRA, where bird fatalities have been chronic and substantial. The WRRS is not a scientifically defensible sampling program. It includes no searches for bird carcasses, no regularity of visitation to turbines, and overall no resemblance to scientific monitoring methods. A partial analysis of data obtained using the WRRS compared to the results of the present study revealed that the WRRS underreports raptor fatalities by at least a factor of eight (Thelander and Smallwood 2002). The level of underreporting is much higher for non-raptors. This assessment is based on a comparison of this study's fatality survey results for May 1998 thru March 2000 (n = 213 non-raptor fatalities found at only 12% of APWRA turbines) to the additional fatalities (n = 166) reported to Alameda County and the USFWS by Green Ridge Services/AIC for the balance of the turbines where reporting is required (i.e., no reporting is required for turbines in adjacent Contra Costa County).

A systematic monitoring protocol, one based on a standardized and systematic sampling methodology with statistical validity, needs to be implemented throughout the APWRA. By doing so, documenting future fatality rates and long-term trends can be monitored with more accuracy than is currently being provided by the WRRS methodology. Also, the results of the various groups collecting fatality data in the APWRA would be comparable.

7.0 ACKNOWLEDGEMENTS

This project is funded by the National Renewable Energy Laboratory (NREL). We thank Karin Sinclair, NREL's Senior Project Leader, for her guidance and support. Michael L. Morrison, Ph.D., has consistently provided valuable insights and direction in all phases of the project.

BRC field biologists who have participated on the project include Lourdes Rugge (Field Team Leader), Stacia Hoover, James Cain, Cherilyn Burton, Elizabeth van Mantgen, Danika Tsao, Larry Lacunza, Tammy Lim, Julia Camp, Jessie Quinn, Natasha Tuatoo-Bartley, Cherilyn Burton, Adam Ballard, Laura Burkholder, Jennifer Phan, Caroline Szafranski, Erin Harrington, Marchel Munnecke, Angie Harbin, and Jeanette Weisman. Their dedication, positive attitudes, and willingness to work hard under demanding conditions have been an inspiration.

We especially thank the management and field personnel of ENRON, FORAS, EnXco, SeaWest, Green Ridge Services, and Altamont Wind Power for providing logistical support and permission to access wind energy generating facilities that they own, lease, manage, and/or maintain. Lastly, we thank the anonymous reviewers who provided thoughtful and valuable comments on an earlier draft. Where those comments were not addressed here, we plan to incorporate them into our final, comprehensive report on the project.

8.0 REFERENCES

Alameda County. (1998). *Repowering a Portion of the Altamont Wind Resource Area.* Final Environmental Impact Report. Community Development Agency. State Clearinghouse No. 98022024.

Anderson, R.; Morrison, M.; Sinclair, K.; Strickland, D. (1999). *Studying Wind Energy and Bird Interactions: a Guidance Document.* Washington, DC: National Wind Coordinating Committee.

Avery, W. L.; Springer, P.F.; Cassel, J.F. (1977). “Weather Influences on Nocturnal Bird Mortality at a North Dakota Tower.” *Wilson Bull.* (89); pp. 291-299.

Battaglin, W.A.; Goolsby, D.A. (1995). *Spatial Data in Geographic Information System Format on Agricultural Chemical Use, Land Use, and Cropping Practices in the United States.* Water Resources Investigations Report 94-4176. Denver, CO: U.S. Geological Survey.

Cairns Jr., J.; McCormick, P.V. (1992). “Developing an Ecosystem-Based Capability for Ecological Risk Assessments.” *The Environmental Professional* (14); pp. 186-196.

Carnie, S. K. (1954). “Food Habits of Nesting Golden Eagles in the Coast Ranges of California.” *Condor* (56): pp. 3-12.

Craighead, J. J.; Craighead Jr., F.C. (1956). *Hawks, Owls and Wildlife.* Harrisburg, PA: Stackpole Books.

Fitch, H. S.; Swenson, R.; Tillotson, D.F. (1946). “Behavior and Food Habits of the Red-Tailed Hawk.” *Condor* (48); pp. 205-237.

Gauthreaux, S. A. (1996). “Suggested Practices for Monitoring Bird Populations, Movements and Mortality in Wind Resource Areas. *Proceedings of National Avian-Wind Power Planning Meeting II.* Palm Springs, CA, 20-22 Sept. 1995. Prepared for the Avian Subcommittee of the National Wind Coordination Committee by RESOLVE Inc., Washington, DC, and LGL Ltd., King City, Ont.

Hodos, W.; Potocki, A.; Storm, T.; Gaffney, M. (2001). “Reduction of Motion Smear to Reduce Avian Collisions with Wind Turbines. *Proceedings of the National Avian-Wind Power Planning Meeting IV.* Carmel, CA, 16-17 May 2000. Prepared for the National Wind Coordinating Committee by RESOLVE Inc., Washington, DC.

Howell, J. A. (1997). “Avian Mortality at Rotor Swept Area Equivalents, Altamont Pass and Montezuma Hills, California.” *Transactions of the Western Section of the Wildlife Society 33:24-29.*

Howell, J. A.; DiDonato, J.E. (1991). *Assessment of Avian Use and Mortality Related to Wind Turbine Operations, Altamont Pass, Alameda and Contra Costa Counties, California, September 1988 through August 1989.* Final report prepared for U.S. Windpower, Inc., Livermore, CA.

Hunt, G. (1994). *A Pilot Golden Eagle Population Project in the Altamont Pass Wind Resource Area, California.* Prepared by the Predatory Bird Research Group, University of California, Santa Cruz, for the National Renewable Energy Laboratory, Golden CO.

Hunt, G. (1997). *A Population Study of Golden Eagles in the Altamont Pass Wind Resource Area: Population Trend Analysis 1997.* Prepared by Predatory Bird Research Group, Santa Cruz, California, for the National Renewable Energy Laboratory, Golden, CO.

Hunt, W. G. (2002). *Golden Eagles in a Perilous Landscape: Predicting the Effects of Mitigation for Energy-Related Mortality.* Report to the California Energy Commission, PIER Grant No. 500-97-4033 to the University of California, Santa Cruz, CA.

Hunt, W. G. Personal communication. University of California, Santa Cruz Predatory Bird Research Group/The Peregrine Fund, Inc., 17 May 2000.

Kerlinger, P.; Curry, R. *Analysis of Golden Eagle and Red-Tailed Hawk Fatalities at Kenetech Windpower’s Altamont Wind Resource Area (APWRA).* Unpublished status report on the Altamont Avian Plan to U.S. Fish and Wildlife Service and Kenetech, Inc., Livermore, CA, 1997.

Morrison, M.L. (1996). “Protocols for Evaluation of Existing Wind Developments and Determination of Bird Mortality.” *Proceedings of National Avian-Wind Power Planning Meeting II.* Palm Springs, CA, 20-22 Sept. 1995. Prepared for the Avian Subcommittee of the National Wind Coordination Committee by RESOLVE Inc., Washington, DC, and LGL Ltd., King City, Ont.

Munsters, C.J.M.; Noordervliet, M.A.W.; Ter Keurs, W.J. (1996). “Bird Casualties Caused by a Wind Energy Project in an Estuary.” *Bird Study* (43); pp. 124-126.

Olendorff, R.R. (1976). “The Food Habits of North American Golden Eagles.” *Amer. Midland Naturalist;* (95:3); pp. 231-236.

O'Neill R.V.; Jones, K.B.; Ritters, K.H.; Wickham, J.D.; Goodman, I.A. (1994). *Landscape Monitoring and Assessment Research Plan.* U.S. EPA 620/R-94/009, Environmental Protection Agency.

Orians, G. H.; Kuhlman, F. (1956). “Red-tailed Hawk and Horned Owl Populations in Wisconsin.” *Condor* (58); pp. 371-385.

Orloff, S.; Flannery, A. (1992). *Wind Turbine Effects on Avian Activity, Habitat Use, and Mortality in Altamont Pass and Solano County Wind Resource Areas.* Prepared by BioSystems Analysis, Inc., Tiburon, CA, for the California Energy Commission, Sacramento.

Orloff, S.; Flannery, A. (1996). *A Continued Examination of Avian Mortality in the Altamont Pass Wind Resource Area.* Prepared by BioSystems Analysis, Inc., California, for the California Energy Commission, Sacramento.

Pearson, S. Personal communication. U.S. Fish and Wildlife Service, Senior Resident Agent, Sacramento, CA, 2000.

Rapport D. J.; Reiger, H.A.; Hutchinson, T.C. (1985). “Ecosystem Behavior under Stress.” *American Naturalist* (125); pp. 617-640.

Reynolds, R. T.; Scott, J.M.; Nussbaum, R.A. (1980). “A Variable Circular-Plot Method for Estimating Bird Numbers.” *Condor* (82); pp. 309-313.

Rotmans, J.; van Asselt, M.B.A.; de Bruin, A.J.; den Elzen, M.G.J.; de Greef, J.; Hiderink, H.; Hoekstra, A.Y.; Janssen, M.A.; Koster, H.W.; Martens, W.J.M.; Niessen, L.W.; de Vries, H.J.M. (1994). *Global Change and Sustainable Development.* Global Dynamics & Sustainable Development Programme, GLOBO Report Series No. 4. RIVM, Bilthoven, The Netherlands.

Schulze I.; Colby, M.; Conomos, M.; Garetz, W.; Lacayo, H.; Stuart, T.; Wilkinson, P.; Solloway, C. (1994). *A Conceptual Framework to Support the Development and Use of Environmental Information.* Environmental Indicators Team, United States EPA, Office of Policy, Planning, and Evaluation. Washington, D.C.

Smallwood, K. S.; Erickson, W.A. (1995). “Estimating Gopher Populations and Their Abatement in Forest Plantations.” *Forest Science* (41) pp. 284-296.

Smallwood, K.S. (1993). “Understanding Ecological Pattern and Process by Association and Order.” *Acta Oecologica* 14(3); pp. 443-462.

Smallwood, K. S. (2002). “Habitat Models Based on Numerical Comparisons.” In *Predicting Species Occurrences: Issues of Scale and Accuracy.* Covello, CA: Island Press.

Smallwood, K. S.; Morrison, M.L. (1999). “Spatial Scaling of Pocket Gopher (*Geomyidae*) Density.” *Southwestern Naturalist* (44) pp. 73-82.

Taylor, W. K.; Kershner, M.A. (1986). “Migrant Birds Killed at the Vehicle Assembly Building (VAB), John F. Kennedy Space Center.” *J. Field Ornithol.* (57); pp. 142-154.

Thelander, C.G.; Smallwood, S. (2002). *The Altamont Pass Wind Resource Area's Effects on Birds: A Case History.* Manuela de Lucas, Guyonne Janss, and Miguel Ferrer, eds. Birds and Wind Power. In press.

University of California. *A Population Study of Golden Eagles in the Altamont Pass Wind Resource Area: Population Trend Analysis 1994-1997.* NREL/SR-500-26092. Work performed by Predatory Bird Research Group, Long Marine Laboratory, Santa Cruz, CA. Golden, CO: National Renewable Energy Laboratory, June 1999.

USDA. (1994). Agricultural resources and environmental indicators. U.S. Department of Agriculture, Economic Research Service, Natural Resources and Environment Division. Agricultural Handbook No. 705, Wash., D.C.

Watt, K.E.F. (1966). "Systems Ecology." *Systems Analysis in Ecology.* New York: Academic Press.

Watt, K.E.F. (1992). "Taming the Future." Davis, CA: The Contextured Web Press.

Zar, J. H. (1996). *Biostatistical Analysis.* Third edition. New Jersey: Prentice Hall.

Zhang, M.; Geng, S.; Smallwood, K.S. (1998). "Nitrate Contamination in Groundwater of Tulare County, California." *Ambio* (27:3); pp. 170-174.

9.0 TABLES

Table 1. Number of Individual Wind Turbines/Towers Sampled with Their Output and Physical Characteristics

Tower Type	Output (kW)	Rotor Diameter (m)	Tower Height (m)	No. Sampled	Percent
Vertical Axis	150	17	30	20	2
Vertical Axis	250	19	30	119	11
Tubular	110	19	24	25	2
Tubular	120	19	24	220	20
Tubular	150	23	24	100	9
Horizontal Lattice	100	17	18	367	33
Diagonal Lattice	100	17	43	38	3
Diagonal Lattice	300	33	42	16	1
Diagonal Lattice	100	17	24	169	15
Diagonal Lattice	100	17	24	6	1
Diagonal Lattice	100	17	14	30	3
Total				**1,110**	

Table 2. Plot Number, Plot Size, Tower Type, and Turbine Output Characteristics for 685 Non-AIC Turbines Included in Behavioral Observation Sessions (Turbines on Horizontal Lattice Towers Were Not Included in This Sample)

			TURBINE FREQUENCY						
			Tubular			Vertical Axis		Diagonal Lattice	
Plot No.	Area (Km^2)	Strings in Plot	120 kW	150 kW	110 kW	150 kW	250 kW	100 kW	Total
1	3.5	14	33	0	0	25	0	0	58
2	2.2	5	26	0	0	5	0	0	31
3	3.8	7	0	27	0	9	0	0	36
4	3.2	9	24	0	0	11	0	0	35
5	1.9	3	6	8	0	0	0	0	14
6	3.3	2	0	27	0	0	0	0	27
7	3.6	5	23	14	0	0	0	0	37
8	2.2	5	25	0	0	0	0	0	25
9	3.8	9	29	13	0	0	0	0	42
10	3.5	3	4	11	0	0	0	0	15
11	3.0	6	5	0	0	0	20	0	25
12	4.3	9	16	0	7	22	0	0	45
13	4.0	5	0	0	0	48	0	0	48
14	2.5	6	9	0	8	0	0	0	17
15	2.3	2	14	0	0	0	0	0	14
16	3.0	7	6	0	10	0	0	45	61
17	2.0	4	0	0	0	0	0	52	52
18	2.2	3	0	0	0	0	0	37	37
19	2.6	2	0	0	0	0	0	28	28
20	2.6	3	0	0	0	0	0	38	38
Total	**59.5**	**109**	**220**	**100**	**25**	**120**	**20**	**200**	**685**

Table 3. Flight Behavior Categories Used to Record Observations during 30-Min Observation Sessions in the Study Plots

Flight Behaviors	
1. Fly through	10. Being mobbed
2. Gliding	11. Column soaring
3. Soaring	12. Surfing
4. High soaring	13. Ground hopping
5. Contouring	14. Hawking insects
6. Circling	15. Fleeing
7. Kiting/Hovering	16. Interacting
8. Diving	17. Flocking
9. Mobbing	18. Flushed

Table 4. Possible Perching Structures Used during the 30-Min Observation Sessions

PERCHING STRUCTURES	
1. Tree	11. Vertical axis tower (inner framework)
2. Fence post	12. Vertical axis tower (guy wire)
3. Ground	13. Turbine motor (top)
4. Rock/vegetation	14. Turbine motor (inside)
5. Electrical distribution pole (top)	15. Turbine blade tip/side
6. Electrical distribution pole (wire)	16. Turbine propeller cone
7. Electrical distribution pole (crossarm)	17. Catwalk of wind tower
8. Anemometer tower	18. Side ladder of wind tower
9. Electrical tower	19. Diagonal lattice tower (top)
10. Vertical axis tower (top)	20. Diagonal lattice tower (mid-framework)
	21. Diagonal lattice lower (lower framework)

Table 5. Bird Species Composition and Frequency (*N* = 5,283 Sightings) of Sightings Recorded during the Behavioral Observation Sessions

Common Name	Scientific Name	Count	Common Name	Scientific Name	Count
Great blue heron	*Ardea herodias*	6	Mourning dove	*Zenaida macroura*	10
Mallard	*Anas platyrhynchos*	25	Burrowing owl	*Athene cunicularia*	56
Common goldeneye	*Bucephala clangula*	1	Northern flicker	*Colaptes auratus*	4
Turkey vulture	*Cathartes aura*	740	Say's phoebe	*Sayornis saya*	7
White-tailed kite	*Elanus leucurus*	6	Loggerhead shrike	*Lanius ludovicianus*	100
Northern harrier	*Circus cyaneus*	96	American crow	*Corvus brachyrhynchos*	39
Golden eagle	*Aquila chrysaetos*	381	Common raven	*Corvus corax*	667
Cooper's hawk	*Accipiter cooperii*	1	Horned lark	*Eremophila alpestris*	25
Red-tailed hawk	*Buteo jamaicensis*	1,519	Cliff swallow	*Petrochelidon pyrrhonota*	12
Rough-legged hawk	*Buteo lagopus*	4	Mountain bluebird	*Sialia currucoides*	24
Ferruginous hawk	*Buteo regalis*	10	European starling	*Sturnus vulgaris*	69
American kestrel	*Falco sparverius*	351	American pipit	*Anthus rubescens*	6
Prairie falcon	*Falco mexicanus*	59	Western meadowlark	*Sturnella neglecta*	55
Killdeer	*Charadrius vociferus*	7	Red-winged blackbird	*Agelaius phoeniceus*	81
American avocet	*Recurvirostra americana*	1	Tricolored blackbird	*Agelaius tricolor*	30
Long-billed curlew	*Numenius americanus*	4	Brewers blackbird	*Euphagus cyanocephalus*	40
Ring-billed gull	*Larus delawerensis*	111	House finch	*Carpodacus mexicanus*	19
California gull	*Larus califfornicus*	81	Unidentified Laridae		276
Band-tail pigeon	*Columba fasciata*	1	Unidentified raptor		44
Rock dove	*Columba livia*	134	Unidentified Icterid		85
			Unidentified passerine		28

Table 6. Summary of Time during Which Birds Were Observed Flying Versus Perching. More than One Perch or Flight Behavior May Be Recorded Per Bird Sighting. The Mean Refers to the Minutes of Activity Per Observation Session

	Total Minutes	Mean (Min)	SD
Flight Time	13,725	186.02	2428.45
Perch Time	17,592	11.87	135.86
Total Flying and Perching	31,317	235.53	2515.21

Table 7. Number of Minutes Flying and Perching for Species with 20 or More Sightings. Flying: *n* = 4,585 Sightings, 11,382 Minutes. Perching *n* = 1,520 Sightings, 13,189 Minutes. Total Sightings and Time: *n* = 5,161 Sightings in 24,556 Minutes

	Flying Activity				Perching Activity				Percent Time
Species	***n***	**Mean**	**SD**	**Sum**	***n***	**Mean**	**SD**	**Sum**	**in Flight**
Red-tailed hawk	1,254	3.47	4.03	4,351	600	11.16	9.07	6,696	39
Turkey vulture	737	2.21	2.48	1,629	15	5.00	6.13	75	96
Corvids	666	1.72	1.46	1,145	174	5.15	5.55	896	56
Gull species	468	2.42	3.89	1,133	0	0.00	0.00	0	100
Golden eagle	355	3.12	2.97	1,108	89	8.53	9.07	759	59
American kestrel	270	1.78	1.93	481	239	7.26	6.97	1,735	22
Generic blackbird	219	1.93	3.21	423	64	7.64	8.19	489	46
Rock dove	131	1.31	2.54	172	12	4.67	8.26	56	75
Generic passerine	101	1.71	2.18	173	74	5.01	5.94	371	32
Northern harrier	95	2.51	2.90	238	11	4.64	7.42	51	82
Prairie falcon	58	1.90	1.57	110	9	7.56	7.23	68	62
Loggerhead shrike	57	1.51	1.04	86	92	5.89	6.45	542	14
Swallow species	46	3.15	5.75	145	0	0.00	0.00	0	100
Western meadowlark	41	1.22	0.82	50	30	8.68	8.43	260	16
European starling	37	1.24	1.04	46	53	11.17	9.71	592	7
Mallard	25	1.04	0.20	26	0	0.00	0.00	0	100
Burrowing owl	24	2.46	4.36	59	54	12.61	9.92	681	8

Table 8. Raptor Flying Time (Minutes) According to Proximity Level. An Asterisk Indicates the Corresponding Mean Differed Statistically from the Others at α = 0.05

Proximity Level	*n*	Mean	SD	Total
0-50 m	1,112	4.59*	5.04	5,104
51-100 m	2,187	3.34	3.48	7,305
101-300 m	686	2.12	1.98	1,454

Table 9. Frequencies of Proximity Level 1 Flights by Raptor Species (AMKE = American Kestrel, BUOW = Burrowing Owl, GOEA = Golden Eagle, NOHA = Northern Harrier, PRFA = Prairie Falcon, RTHA = Red-Tailed Hawk, TUVU = Turkey Vulture). Data Are for Raptor Species with More than 20 Behavior Sightings (*n* = 3,985; March 1998 – March 2000)

	Frequency of Sightings													
	AMKE		BUOW		GOEA		NOHA		PRFA		RTHA		TUVU	
Flight Behavior	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*
Contouring	0.8	2	4.0	1	18.2	105	6.0	8	2.5	2	7	135	0.8	8
Kiting	4.8	12	0.0	0	1.6	9	1.5	2	0.0	0	15.3	296	0.0	0
Hover/Surfing	17.3	43	0.0	0	1.7	10	3.0	4	8.9	7	5.8	107	0.6	6
Diving	11.3	28	8.0	2	2.4	14	3.8	5	10.1	8	5.4	108	0.1	1
Mobbing	9.3	23	0.0	0	2.6	15	1.6	2	7.6	6	2.5	48	0.4	4
Interacting	0.8	2	0.0	0	0.5	3	2.3	3	0.0	0	2.3	44	0.0	0
Flushed	0.8	2	0.0	0	1.9	11	0.0	0	0.0	0	0.6	11	0.0	0
Fleeing	0.0	0	0.0	0	0.5	3	0.0	0	0.0	0	0.1	2	0.0	0
Gliding	9.7	24	16.0	4	23.1	133	12.8	17	17.7	14	17.8	345	33.3	328
Soaring	6.5	16	4.0	1	22.0	127	12.0	16	7.6	6	19.7	383	27.9	225
Circling	9.3	23	0.0	0	9.7	56	9.0	12	16.5	13	10.8	209	13.5	133
Hawking Insects	1.6	4	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Flocking	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Flying Through	25.8	64	48.0	12	6.3	36	20.3	27	22.8	18	7.7	150	15.0	148
High Soaring	0.8	2	0.0	0	9.2	53	6.0	8	5.1	4	5.4	104	8.0	79
Ground Hopping	1.2	3	20.0	5	0.2	1	0.8	1	0.0	0	0.1	1	0.2	2
Soaring in Column	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
TOTAL		**248**		**25**		**576**		**133**		**79**		**1,940**		**984**

Table 10. Frequencies of Proximity Level Flights by Raptor Species for March 1998 – March 2000

	Frequency of Sightings in Proximity Levels to Turbines					
	≤50 m		51-100 m		101-300 m	
Species	**%**	***n***	**%**	***n***	**%**	***n***
American kestrel	45	112	30.0	67	25.0	5
Burrowing owl	12.0	3	20.0	5	68.0	17
Golden eagle	29.5	170	54.9	316	15.6	90
Northern harrier	39.1	52	33.8	45	27.1	36
Prairie falcon	29.1	23	41.8	33	29.1	23
Red-tailed hawk	38.6	748	48.3	937	13.1	255
Turkey vulture	1.9	19	74.8	736	23.3	229
Total	**28.3**	**1,127**	**53.7**	**2,139**	**18.0**	**719**

Table 11. Mean Flying Time for Raptors by Proximity Level for March 1998 – March 2000.

Asterisk Indicates a Statistically Significant Difference between Means

	Flight Time (Minutes) per Observed Flight						
		≤50 m		51-100 m		101-300 m	
Species	***N***	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
American kestrel	369	2.11	1.88	2.55	3.22	1.39*	1.04
Burrowing owl	26	1.67	1.15	4.83	7.96	1.24	0.44
Golden eagle	580	3.75	3.89	3.67	3.19	3.23	2.82
Northern harrier	133	3.29	3.66	2.96	2.49	2.08	1.79
Prairie falcon	82	2.35	1.70	2.21	1.95	2.54	0.76
Red-tailed hawk	2,149	5.44*	5.61	3.84	3.95	2.39	2.15
Turkey vulture	984	3.74*	3.59	2.65*	2.74	1.83	1.64

Table 12. Summary of 439 Fatalities Divided between Raptors and Non-Raptors

Species/Group	Raptor Fatalities	Non-Raptor Fatalities
Red-tailed hawk	103	
Burrowing owl	51	
Barn owl	26	
American kestrel	24	
Golden eagle	11	
Great horned owl	6	
Northern harrier	2	
Prairie falcon	1	
White-tailed kite	1	
Buteo sp.	1	
Rock dove (pigeons)		60
Western meadowlark		49
European starling		19
Mallard		16
House finch		15
Horned lark		10
Passeridae sp. (sparrows)		8
Mourning doves		8
Icterinae sp. (blackbirds)		7
Laridae sp. (gulls)		5
Cliff swallow		4
Hoary bat		4
Black-crowned night herons		2
Common raven		2
Loggerhead shrike		2
Northern flicker		1
Wild turkey		1
Total	**226**	**213**

Table 13. Summary of Individual Tower/Turbine Configurations Involved in Bird Collisions

Type	Rotor Diameter (m)	Height (m)	Towers Sampled	Years Sampled	Towers with Collisions
Vertical Axis 150 kW	17	30	20	2.5	4
Vertical Axis 250 kW	19	30	119	2.5	27
Tubular 150 kW Bonus	23	24	100	2.7	43
Tubular 120 kW Bonus	19	24	220	2.7	78
Tubular 120 kW	19	24	25	2.5	1
Diagonal Lattice 100 kW	17	43	38	1.0	1
Diagonal Lattice 300 kW	33	42	16	1.0	5
Diagonal Lattice 100 kV	17	24	6	1.0	0
Diagonal Lattice 100 kW	17	24	169	2.5	52
Diagonal Lattice 100 kW	17	14	30	2.5	5
Horizontal Lattice 100 kW	17	18	367	1.0	6
			1,110		**272 (24%)**

Table 14. Summary of Bird Collisions Per Turbine Per Year by Tower and Turbine Type

Tower/Turbine/Output	No. Towers	No. Bird Collisions	Collisions/Tower/Year
Tubular Bonus 150	100	75	0.27
Tubular Bonus 120	220	109	0.18
Tubular Danwin 110	25	1	0.02
Vertical Axis 150	20	4	0.08
Vertical Axis 250	119	28	0.09
Diagonal Lattice 100	243	88	0.17
Diagonal Lattice KVS-33	16	5	0.31
Horizontal Lattice 56-100s	367	59	0.16

Table 15. Mean Flying Time (in Minutes) for Raptors by Season.

Asterisk Indicates a Statistically Significant Difference between Means

	1998-1999				1999-2000			
SEASON	***N***	***Mean***	***SD***	***Total***	***N***	***Mean***	***SD***	***Total***
Spring	81	2.63	3.10	213	325	2.78	2.52	904
Summer	255	1.91	1.47	487	602	2.88	2.94	1734
Fall	276	2.75	3.03	759	624	2.73	3.36	1704
Winter	257	2.56	2.43	658	381	4.05	5.42 *	1543

Table 16. Statistics Summarizing Fatality Rate Regressed on Number of Turbines in a String

Dependent Variable	a	b	r^2	RMSE	P
Red-tailed hawk	-0.0746	1.4100	0.27	1.23	0.001
Golden eagle	-0.0740	0.0059	0.01	0.34	0.36
American kestrel	-0.0058	0.0258	0.12	0.37	0.001
Burrowing owl	0.1070	0.0300	0.05	0.70	0.023
Barn owl	-0.0200	0.0339	0.13	0.47	0.001

Table 17. Raptor Fatalities per Turbine String Regressed on Windswept Area of Turbine String

Dependent Variable	a	b	r^2	RMSE	P
Red-tailed hawk	-0.27	0.00062	0.41	1.10	0.001
Golden eagle	0.015	0.00006	0.06	0.34	0.015
American kestrel	-0.006	0.00009	0.12	0.37	0.001
Burrowing owl	0.031	0.00015	0.10	0.68	0.001
Barn owl	-0.052	0.00014	0.17	0.46	0.001

Table 18. Chi-Square (χ^2) Test Results between Fatalities of Five Raptor Species and Attributes of the Wind Tower/Turbine

VARIABLE RELATED TO FATALITIES	χ^2 value	d.f.	P-value
Turbine/Tower Type (Fig. 14)			
Red-tailed hawk	22.0	3	$P < 0.01$
Golden eagle	13.6	3	$P < 0.01$
American kestrel	3.4	3	ns
Burrowing owl	15.3	3	$P < 0.01$
Barn owl	5.6	3	ns
Turbine Rate/Speed (Fig. 16)			
Red-tailed hawk	16.1	2	$P < 0.01$
Golden eagle	13.7	2	$P < 0.01$
American kestrel	2.3	2	ns
Burrowing owl	15.3	2	$P < 0.01$
Barn owl	5.4	2	ns
Turbine Orientation Relative to Wind			
Red-tailed hawk	17.9	1	$P < 0.01$
Golden eagle	3.0	1	ns
American kestrel	2.3	1	ns
Burrowing owl	0.1	1	ns
Barn owl	0.5	1	ns
Rotor Diameter (Fig. 15)			
Red-tailed hawk	29.3	4	$P < 0.01$
Golden eagle	13.8	4	$P < 0.01$
American kestrel	1.3	4	ns
Burrowing owl	13.9	4	$P < 0.01$
Barn owl	6.6	4	ns
Turbine Size (kW/h)			
Red-tailed hawk	3.4	4	ns
Golden eagle	8.6	4	ns
American kestrel	1.6	4	ns
Burrowing owl	15.8	4	$P < 0.01$
Barn owl	4.5	4	ns
Anemometer			
Red-tailed hawk		1	
Golden eagle		1	
American kestrel		1	
Burrowing owl		1	
Barn owl		1	

Tower Height (Fig. 17)			
Red-tailed hawk	18.2	2	$P < 0.01$
Golden eagle	4.0	2	ns
American kestrel	3.5	2	ns
Burrowing owl	1.7	2	ns
Barn owl	1.3	2	ns
Whether Part of a Windwall			
Red-tailed hawk		1	
Golden eagle		1	
American kestrel		1	
Burrowing owl		1	
Barn owl		1	
Position in String (Fig. 18)			
Red-tailed hawk	0.5	3	ns
Golden eagle	6.2	3	ns
American kestrel	3.1	3	ns
Burrowing owl	19.0	3	$P < 0.01$
Barn owl	1.4	3	ns
Whether in Canyon (Fig. 24)			
Red-tailed hawk	15.9	1	$P < 0.01$
Golden eagle	21.3	1	$P < 0.01$
American kestrel	0.1	1	ns
Burrowing owl	7.2	1	$P < 0.01$
Barn owl	20.5	1	$P < 0.01$
Slope Aspect (Fig. 25)			
Red-tailed hawk	11.8	8	ns
Golden eagle	9.5	8	ns
American kestrel	4.7	8	ns
Burrowing owl	10.0	8	ns
Barn owl	15.8	8	$P < 0.05$
Physical Relief (Fig. 22)			
Red-tailed hawk	4.2	4	ns
Golden eagle	2.5	4	ns
American kestrel	5.2	4	ns
Burrowing owl	1.5	4	ns
Barn owl	1.2	4	ns
Declivity (Fig. 23)			
Red-tailed hawk	24.6	14	
Golden eagle	6.9	14	ns
American kestrel	50.9	14	
Burrowing owl	3.8	14	ns
Barn owl	5.2	14	ns

Table 19. Frequency of Tower/Turbine Position within Strings of Turbines, where 2nd and 3rd Refer to Their Relative Locations from the End Turbines. These Frequencies Were Factored into the Chi-Square Tests as the Available Positions within the String, whereas the Frequencies in the Bottom Table Compose the Use, where Use Was Indicated by Fatalities

Position in String	Frequency	Percentage
End	183	26.8
2nd	129	18.9
3rd	82	12
Middle	176	25.8
Gap	97	14.2
Total	667	100

Simplified from Above:

Position in String	Frequency	Percentage
End	183	26.8
Gap	97	14.2
2nd	129	18.9
Middle	387	37.8
Total	667	100

Number of Fatalities:

Species	Total	End	Gap	2nd	3rd	Middle
Red-tailed hawk	88	24	15	16	9	24
American kestrel	17	4	4	1	3	5
Golden eagle	12	6	3	2	1	0
Burrowing owl	32	18	7	1	1	5
Barn owl	21	8	3	3	0	7

Table 20. Raptor Fatalities per Turbine String Regressed on the Percentage of Turbines Located at Particular Positions in the String. The Number of Raptor Fatalities Adjusted by Windswept Area Regressed on the Percentage of Turbines at Particular Positions in the String

	Dependent Variable: Fatalities per Turbine String					Fatalities per Turbine String Adjusted by Windswept Area of the String				
Predictor Variable: Percent of String	**a**	**b**	**r^2**	**RMSE**	**P**	**a**	**b**	**r^2**	**RMSE**	**P**
Red-tailed hawk										
End towers	1.332	-0.012	0.07	1.38	0.005	-0.057	0.0014	0.00	1.23	0.72
Gap towers	0.807	0.0005	0.00	1.43	0.920	-0.013	0.0009	0.00	1.23	0.84
Ends and gaps	1.654	-0.015	0.09	1.37	0.002	-0.225	0.004	0.01	1.10	0.29
Middle towers	0.152	0.016	0.11	1.36	0.001	0.017	-0.0004	0.00	1.23	0.92
Golden eagle										
End towers	0.143	-0.0008	0.01	0.34	0.475	-0.027	0.0007	0.00	0.34	0.527
Gap towers	0.079	0.0022	0.03	0.34	0.085	-0.030	0.0021	0.03	0.33	0.093
Ends and gaps	0.058	0.0009	0.01	0.34	0.429	-0.147	0.0026	0.05	0.33	0.023
Middle towers	0.134	-0.0006	0.00	0.35	0.629	0.092	-0.0022	0.04	0.33	0.045
American kestrel										
End towers	0.266	-0.0026	0.04	0.38	0.031	0.007	-0.0002	0.000	0.37	0.882
Gap towers	0.158	-0.00003	0.00	0.39	0.984	0.003	-0.0002	0.000	0.37	0.872
Ends and gaps	0.340	-0.0033	0.06	0.38	0.015	0.023	-0.0004	0.000	0.37	0.752
Middle towers	0.012	0.0035	0.07	0.38	0.006	-0.027	0.0007	0.000	0.37	0.589
Burrowing owl										
End towers	0.400	-0.0025	0.01	0.71	0.262	-0.061	0.0015	0.00	0.68	0.490
Gap towers	0.255	0.0028	0.01	0.71	0.289	-0.036	0.0025	0.01	0.68	0.320
Ends and gaps	0.333	-0.0007	0.00	0.72	0.792	-0.223	0.0004	0.03	0.67	0.089
Middle towers	0.260	0.0009	0.00	0.72	0.713	0.155	-0.0038	0.03	0.67	0.098
Barn owl										
End towers	0.366	-0.0041	0.07	0.49	0.008	0.018	-0.0004	0.00	0.46	0.756
Gap towers	0.169	0.0017	0.01	0.50	0.357	-0.021	0.0014	0.01	0.46	0.400
Ends and gaps	0.397	-0.0036	0.04	0.49	0.036	-0.039	0.0007	0.00	0.46	0.664
Middle towers	0.077	0.0029	0.03	0.50	0.089	0.060	-0.0015	0.01	0.46	0.342

10.0 FIGURES

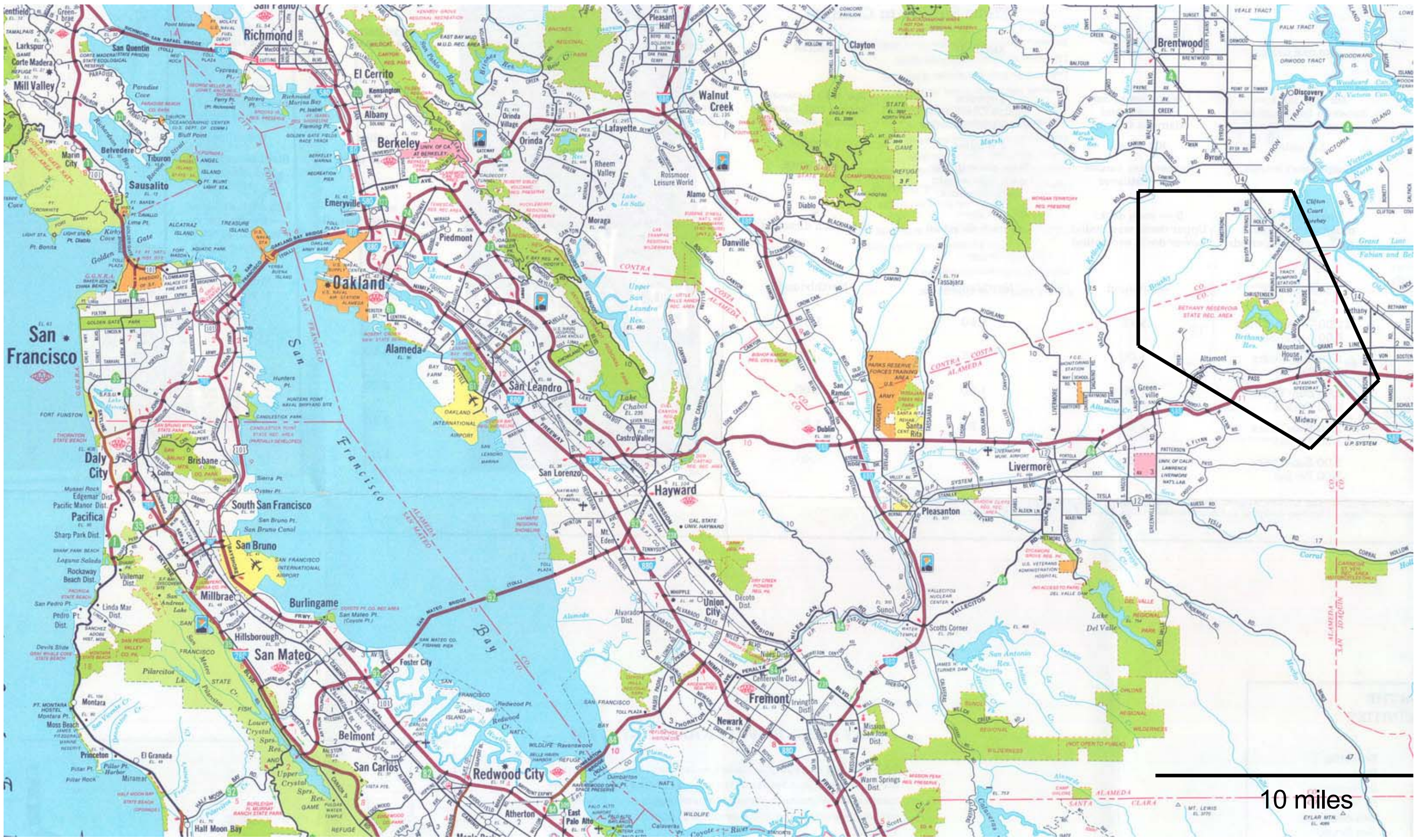


Figure 1. Approximate boundaries (outlined polygon) of the Altamont Wind Resource Area, located in Alameda and Contra Costa counties east of San Francisco, California.

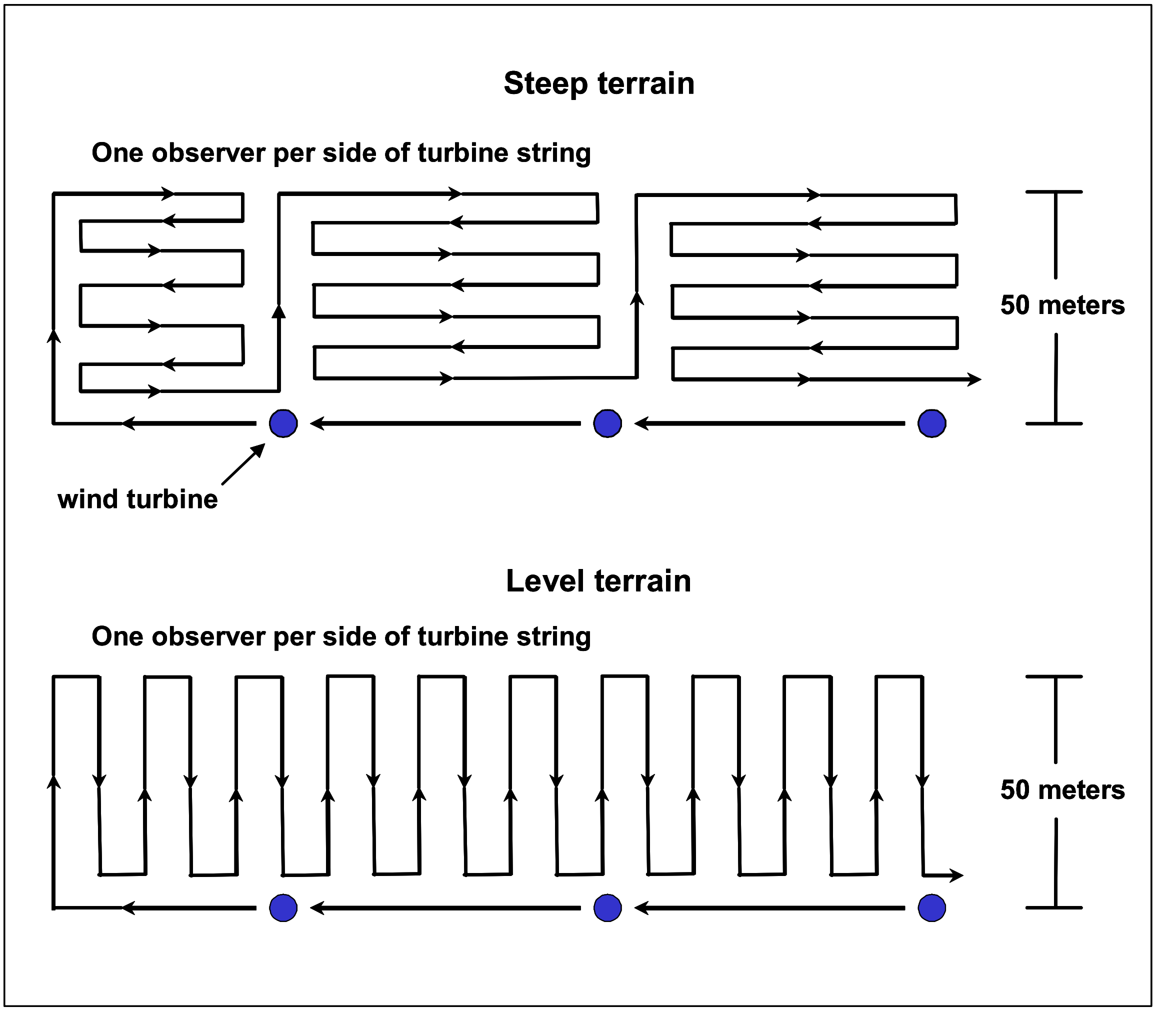


Figure 2. Searching pattern for the location of bird fatalities around wind turbines (search pattern is depicted for only one side of turbine string).

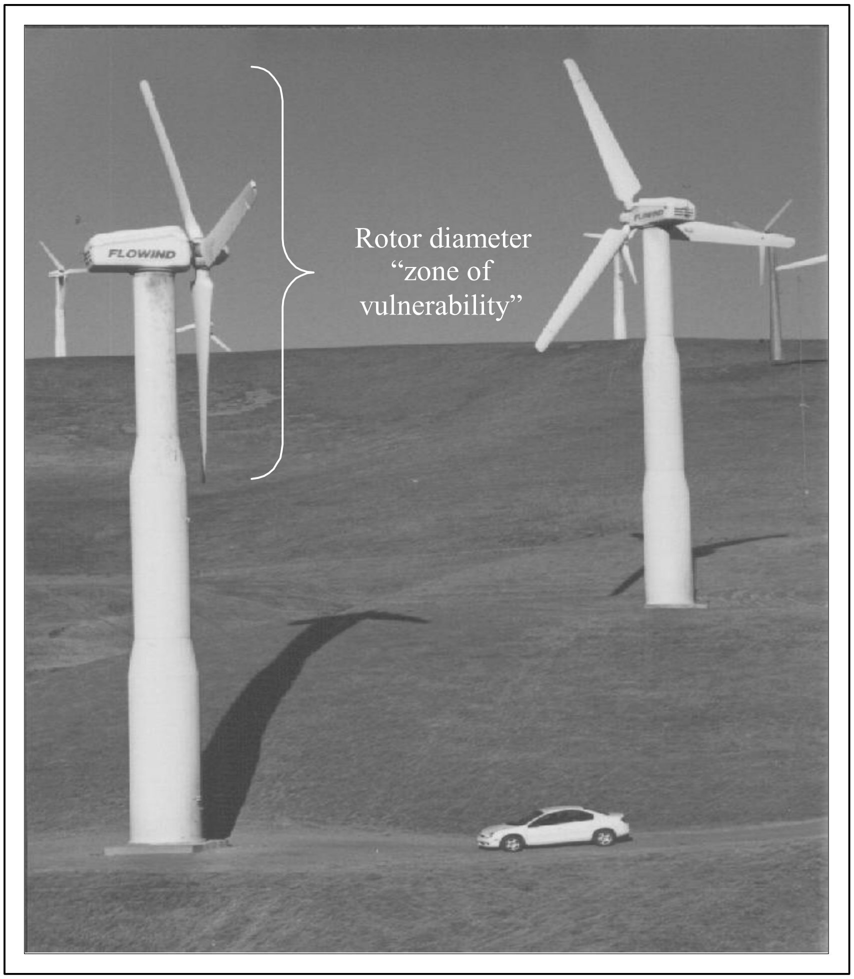


Figure 3. Wind turbine rotor diameter area or "zone of vulnerability."

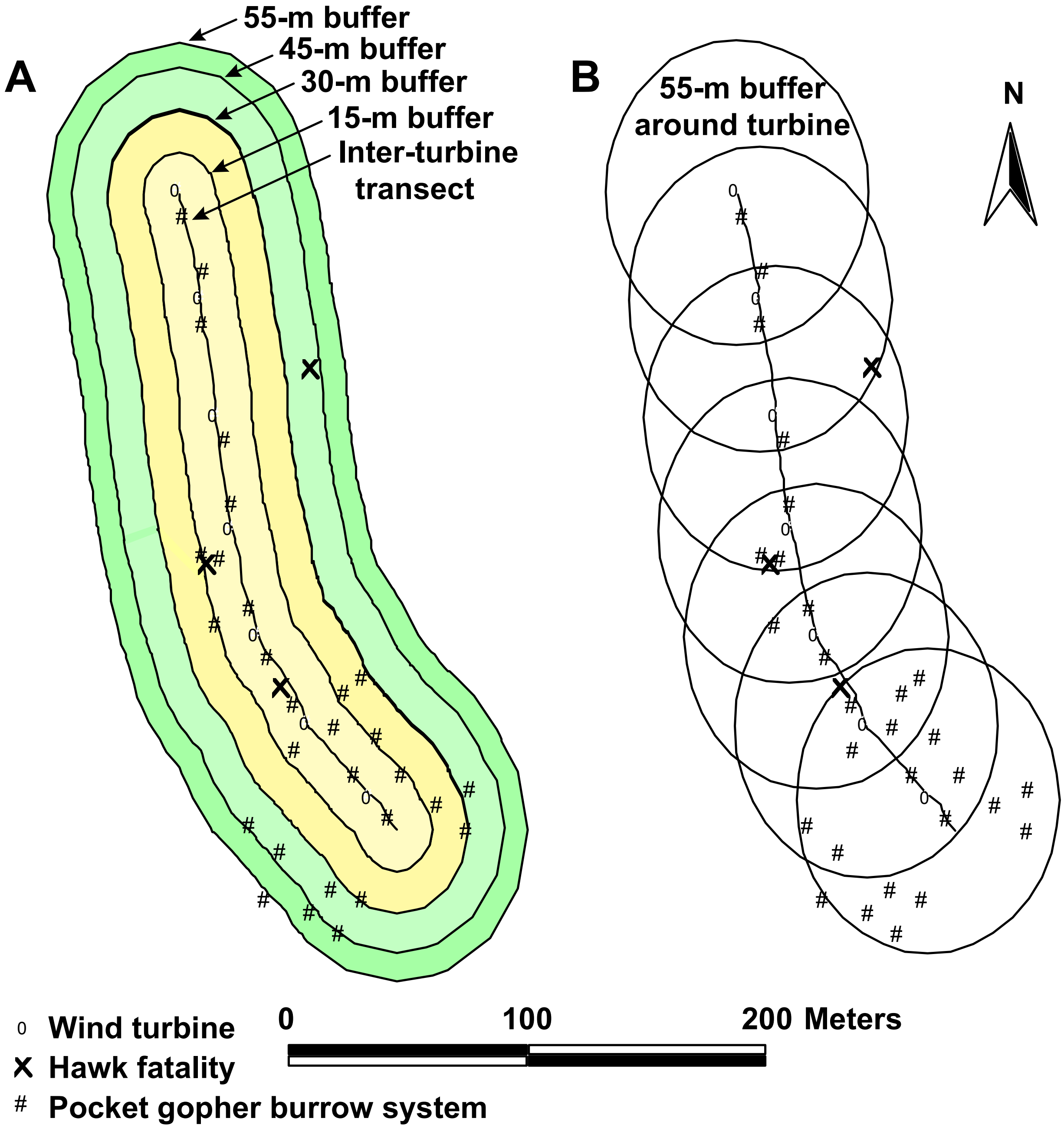


Figure 4. The density of pocket gopher burrow systems at Turbine String 9 (shown above) was calculated within each search area identified by the boundaries expanding away from the inter-turbine transect (A) and within 55 m of each turbine (B). Note that the gopher burrow systems are most strongly clustered near the wind turbines, and there is an additional cluster extending to the southwest of the turbine string.

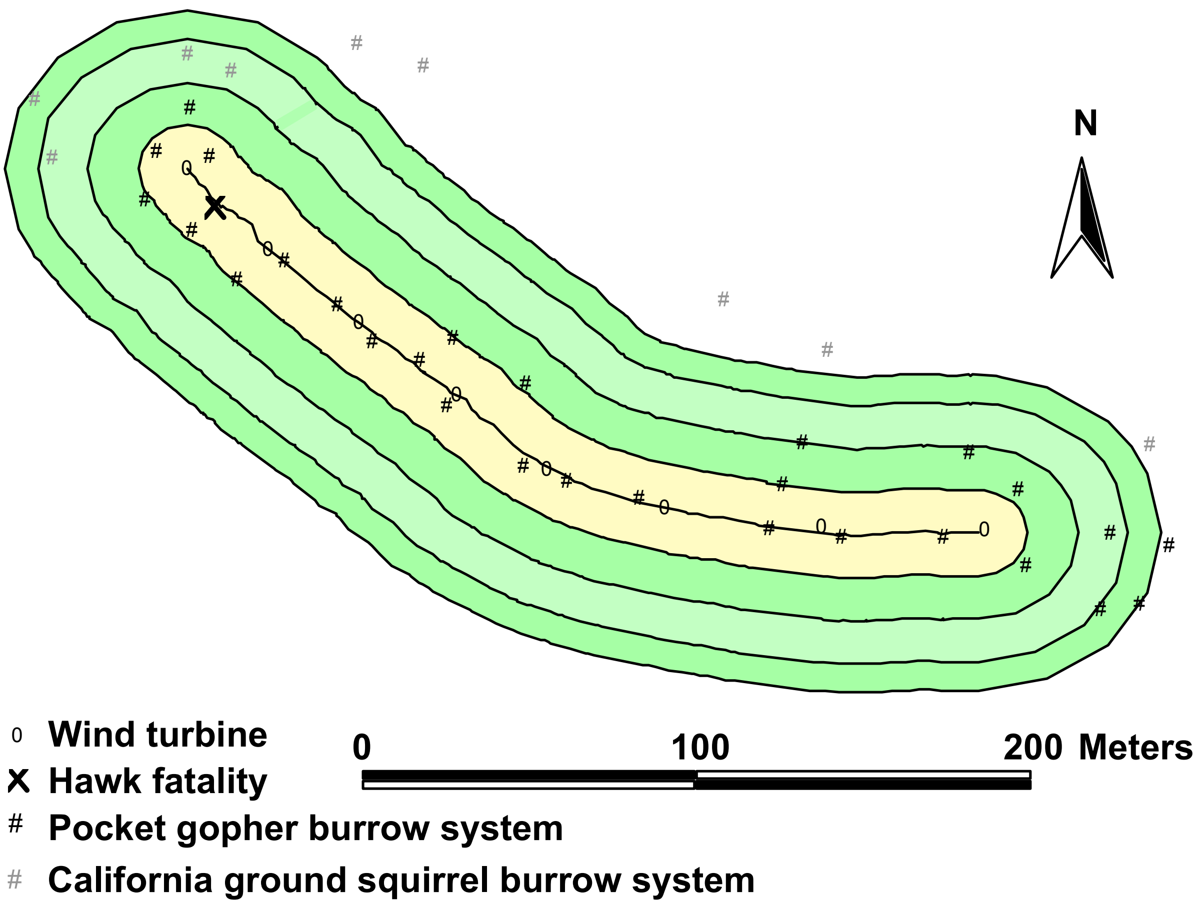


Figure 5. Gopher burrow systems are clustered within Turbine String 3 (shown here), whereas ground squirrel burrow systems are farther away. The largest portion of the ground squirrel colony is located north of this map beyond the search area.

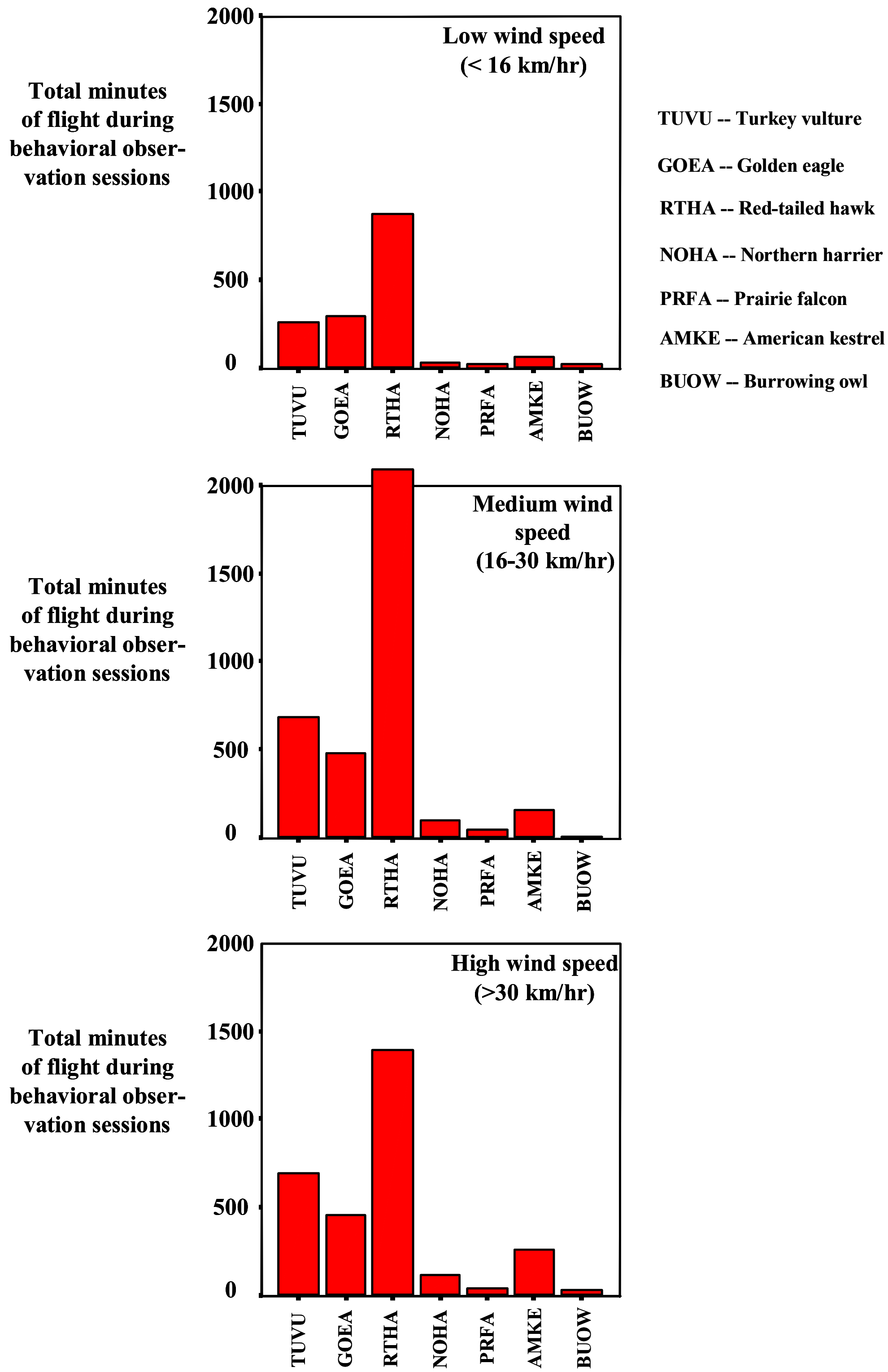


Figure 6. Comparisons of total flying time among raptor species during low (< 15 km/hr), medium (16-30 km/hr), and high (>31 km/hr) winds.

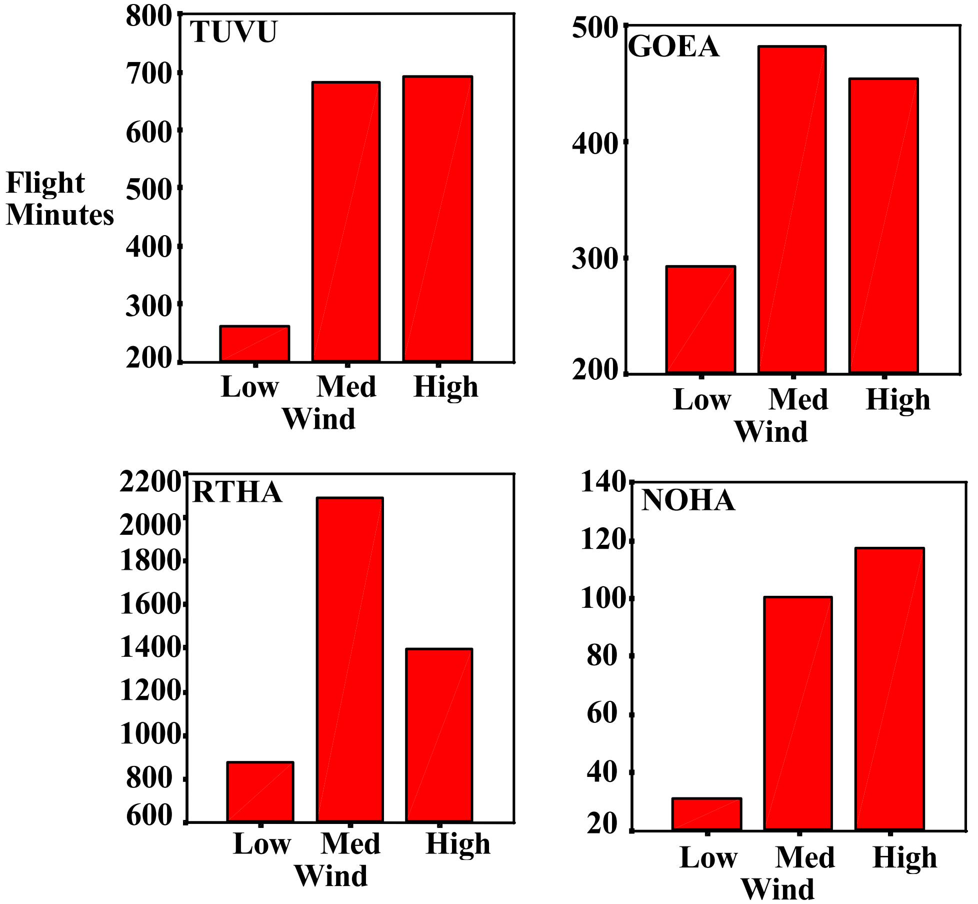


Figure 7. Total number of minutes flying in low, medium, and high winds for raptor species. TUVU = turkey vulture, GOEA = golden eagle, RTHA = red-tailed hawk, NOHA = northern harrier.

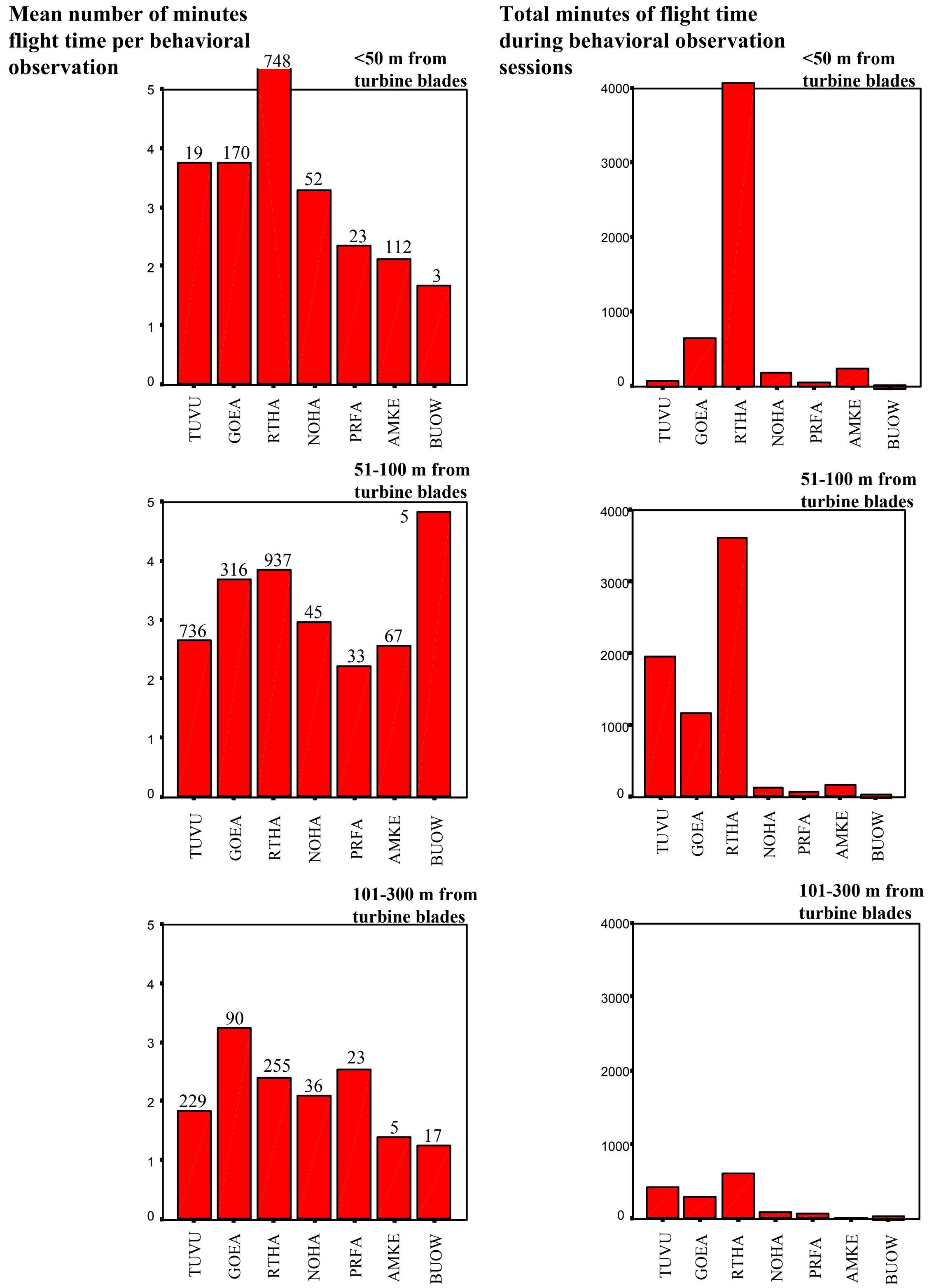


Figure 8. Differences between mean and total flight time of raptor species within proximity Level 1 (<50 m), Level 2 (51-100 m), and Level 3 (100-300 m). The species designations on the X-axis are American Ornithologist's Union acronyms: TUVU = turkey vulture, GOEA = golden eagle, RTHA = red-tailed hawk, NOHA = northern harrier, PRFA = prairie falcon, AMKE = American kestrel, and BUOW = burrowing owl.

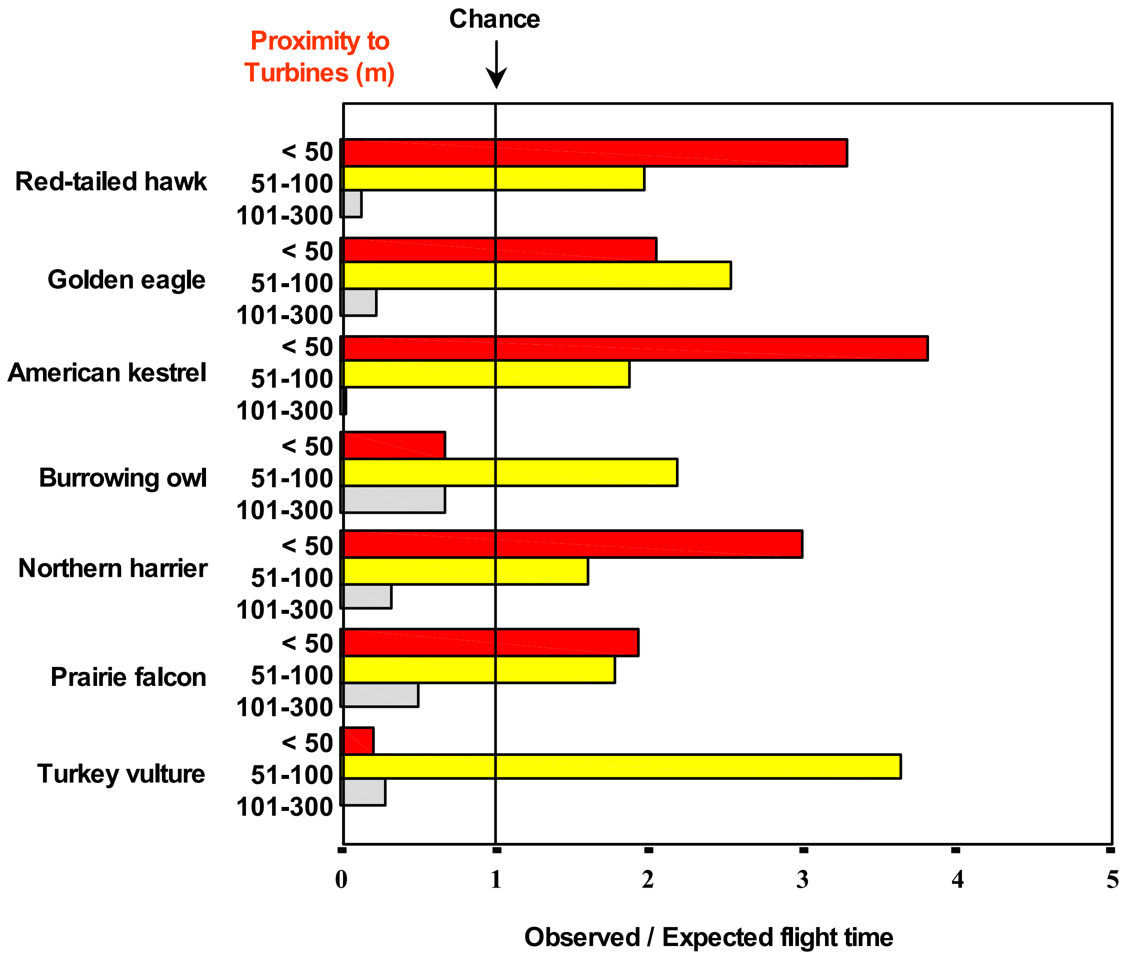


Figure 9. Associations between flight time and proximity to turbines among raptor species, where the total minutes of flying time within each proximity level was compared to the availability of the proximity level based on its approximate geographic area. Observed/expected values greater than 1 indicate the degree to which the observed value exceeds the expected value based on chance.

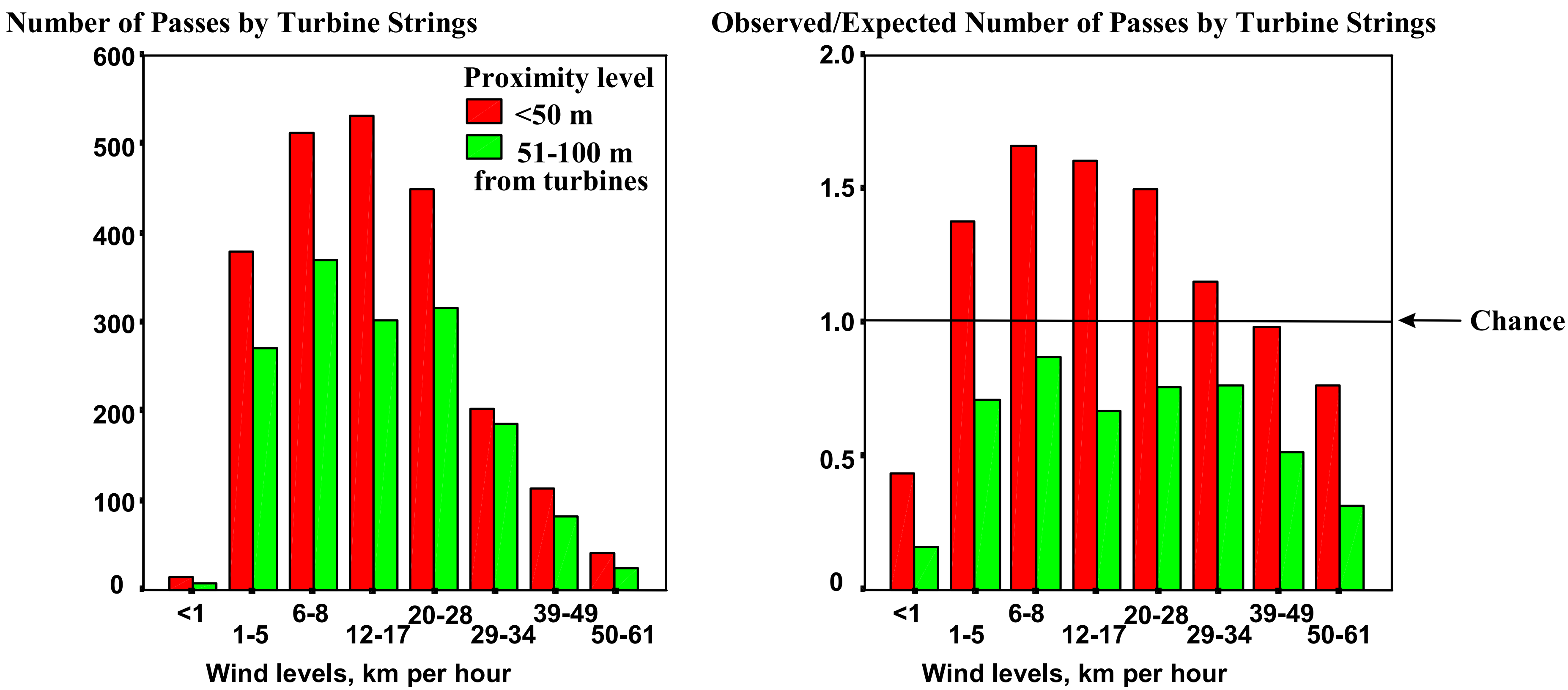


Figure 10. Left panel: Comparison of the number of passes by red-tailed hawk by turbine strings within and farther away than 50 m and at eight levels of wind speed. Right panel: A comparison of the observed and expected number of passes under these conditions, factoring in the proportion of observation sessions having a particular wind speed and the proportion of the area composed of proximity levels 1 and 2.

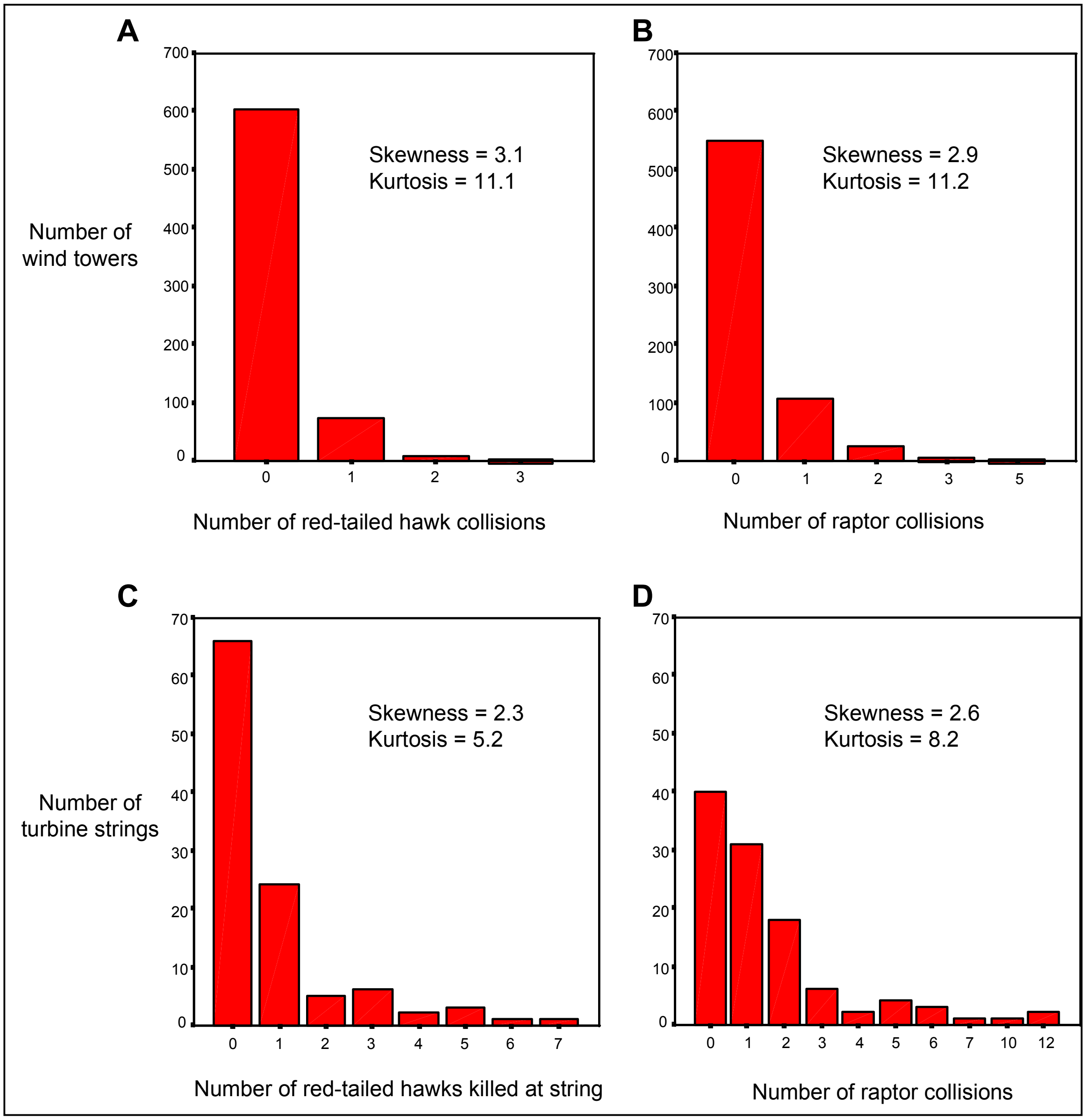


Figure 11. Frequency distributions of red-tailed hawk and all raptor fatalities among all wind towers (Graphs A and B, respectively) and among turbine strings (Graphs C and D, respectively).

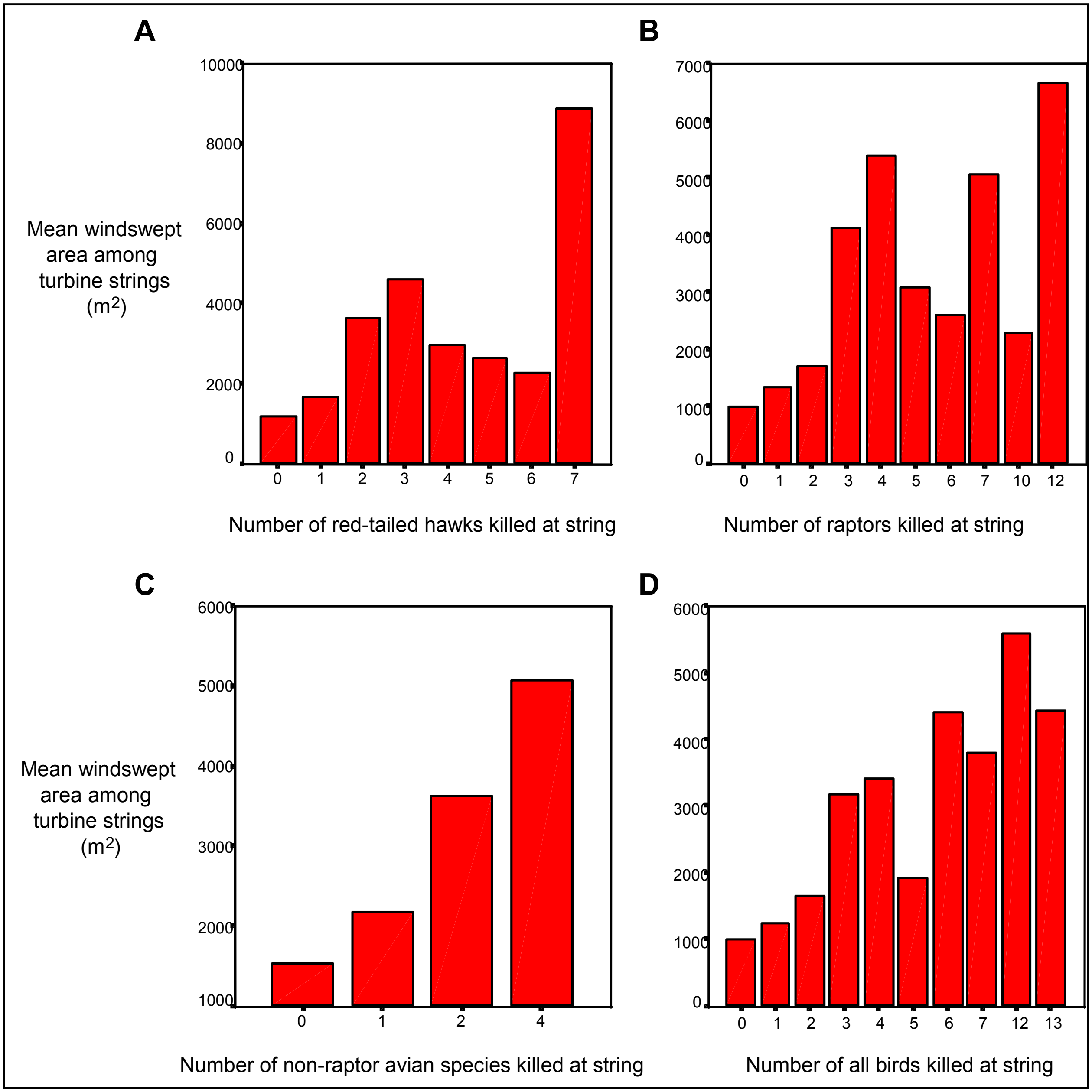


Figure 12. Mean windswept area per turbine strings associated with increasing numbers of fatalities of (A) red-tailed hawks, (B) all raptors, (C) non-raptor species, (D) all bird species.

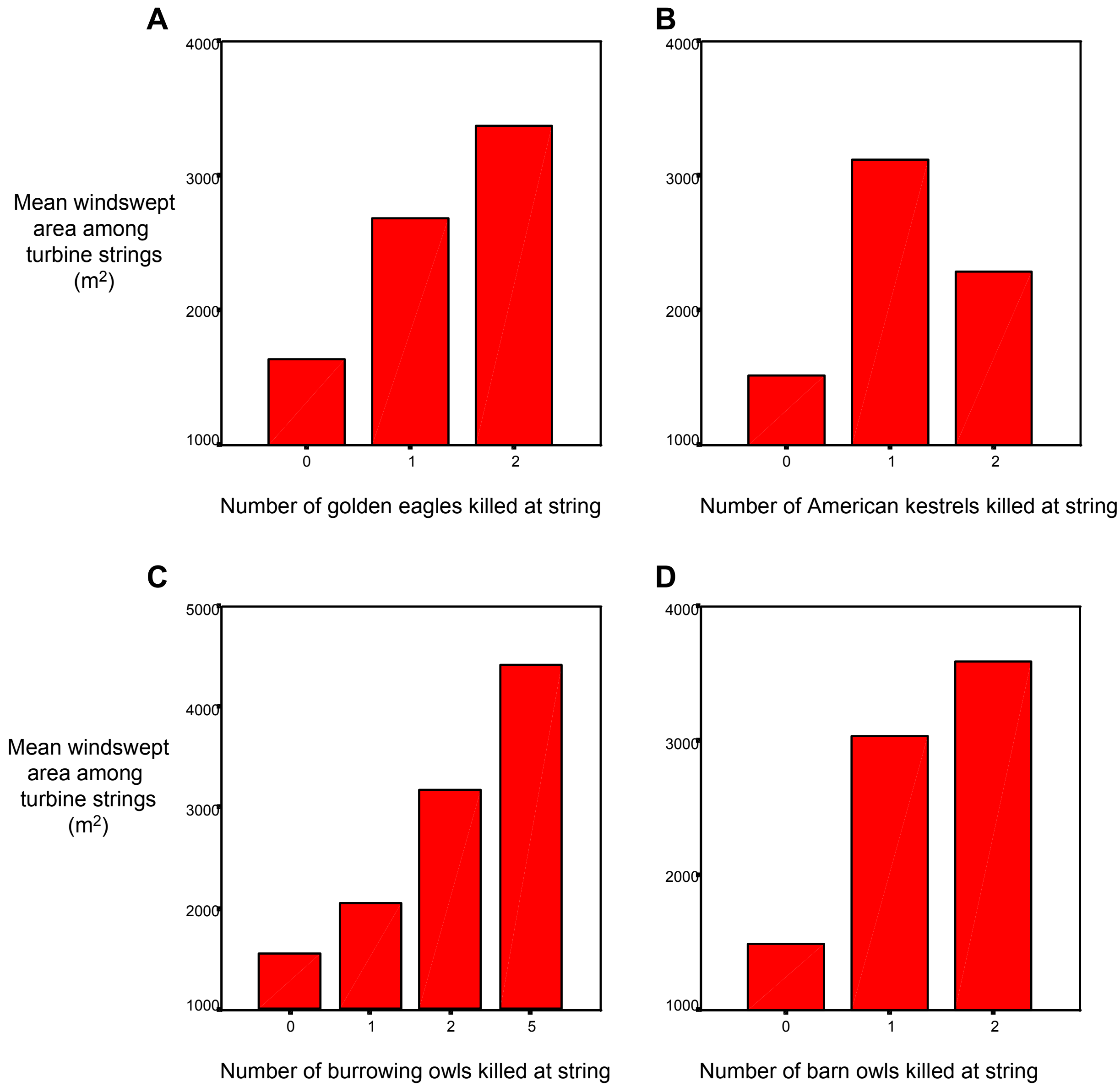


Figure 13. Mean windswept area per turbine strings associated with increasing numbers of fatalities for (A) golden eagles, (B) American kestrels, (C) burrowing owls, and (D) barn owls.

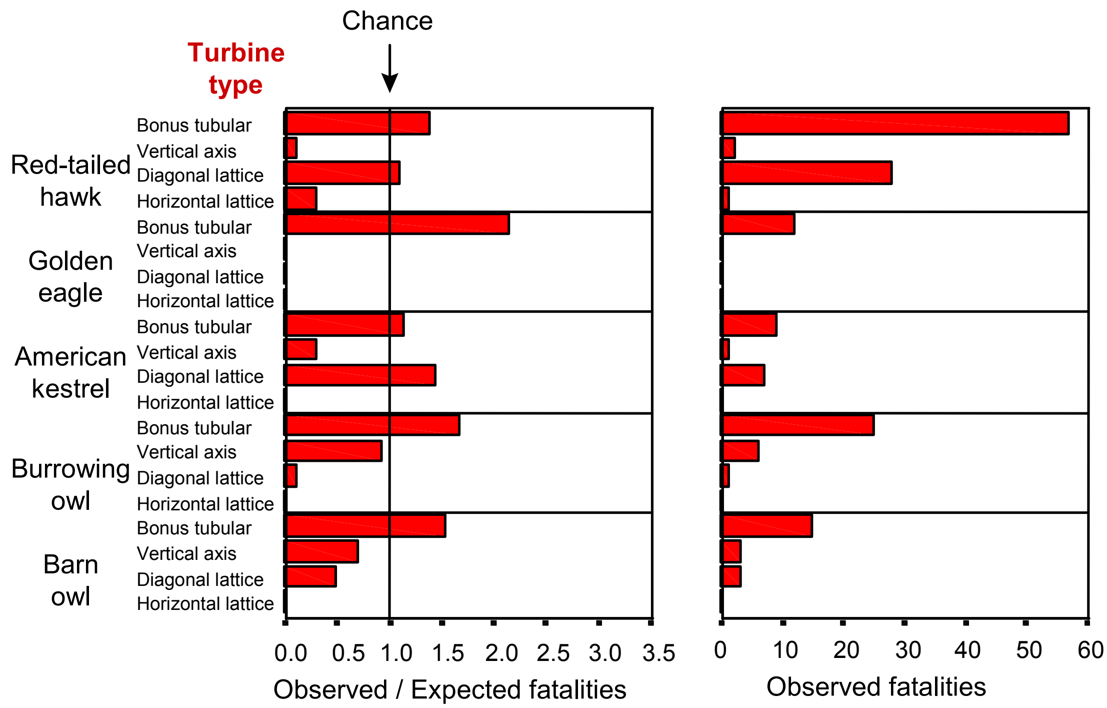


Figure 14. Associations between fatalities and tower/turbine type among raptor species. Observed/expected values greater than 1 indicate the degree to which the observed value exceeds the expected value based on chance.

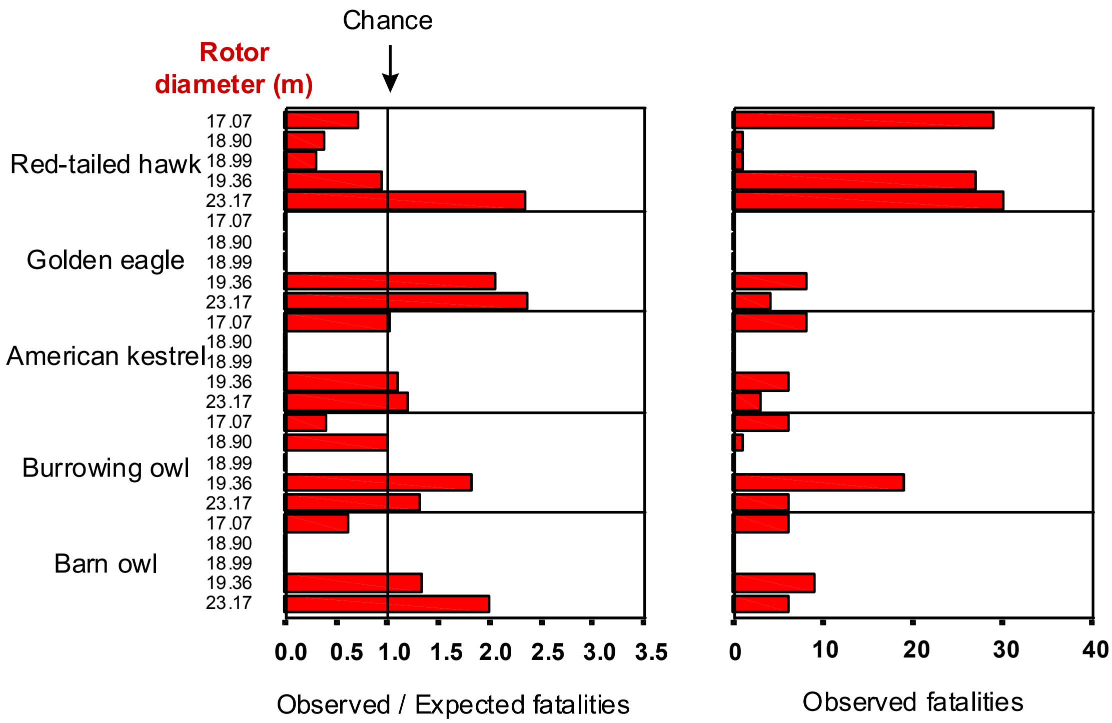


Figure 15. Associations between fatalities and rotor diameter among raptor species. Observed/expected values greater than 1 indicate the degree to which the observed value exceeds the expected value based on chance.

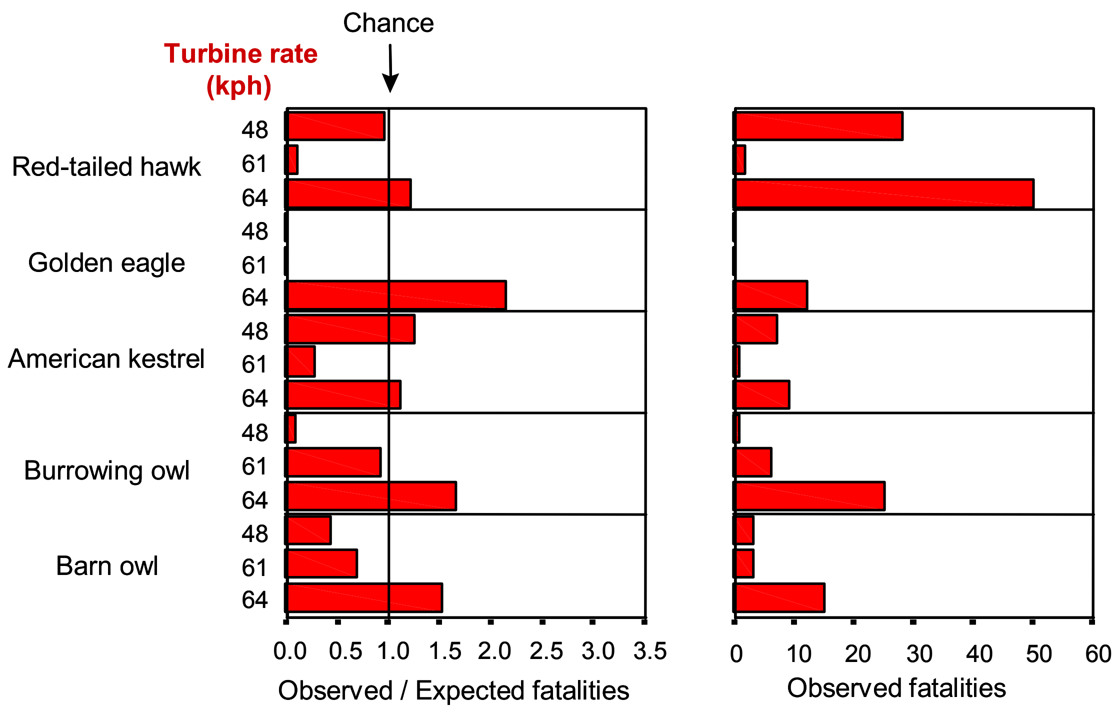


Figure 16. Associations between fatalities and rotor speed (kilometers per hour) among raptor species. Observed/expected values greater than 1 indicate the degree to which the observed value exceeds the expected value based on chance.

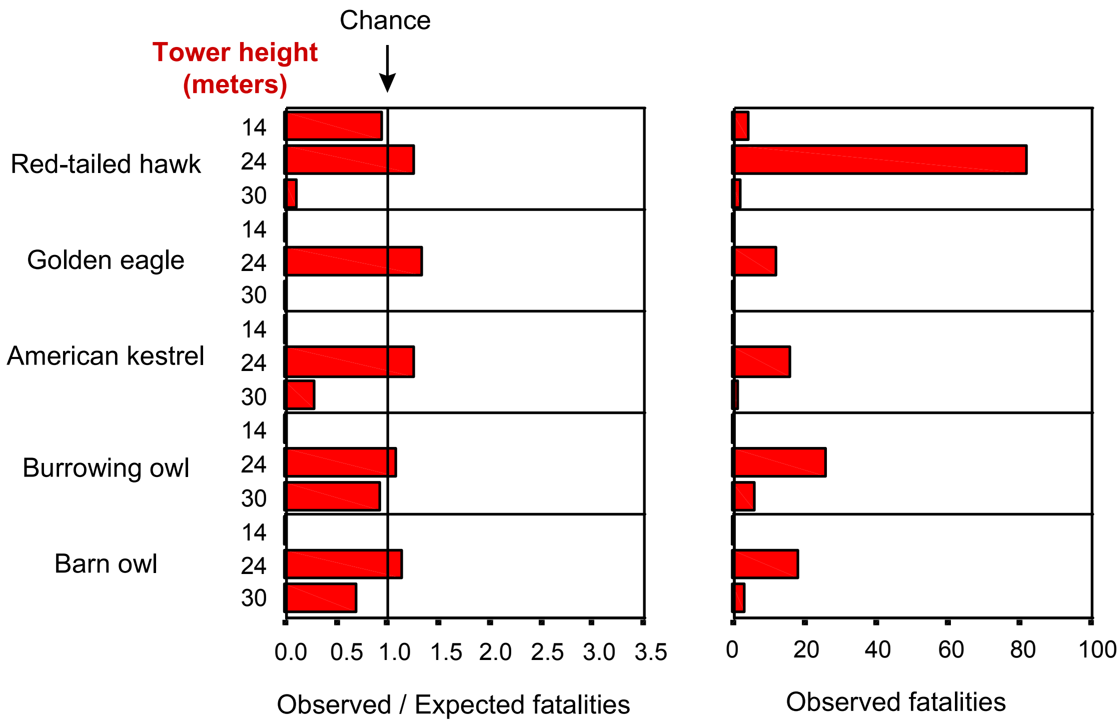


Figure 17. Associations between fatalities and tower height among raptor species. Observed/expected values greater than 1 indicate the degree to which the observed value exceeds the expected value based on chance.

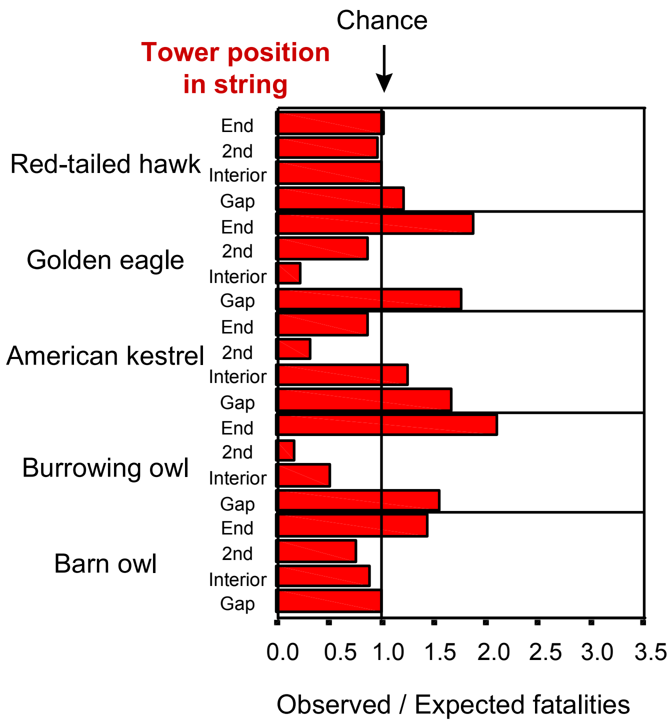


Figure 18. Associations between fatalities and tower position in the string among raptor species. Observed/expected values greater than 1 indicate the degree to which the observed value exceeds the expected value based on chance.

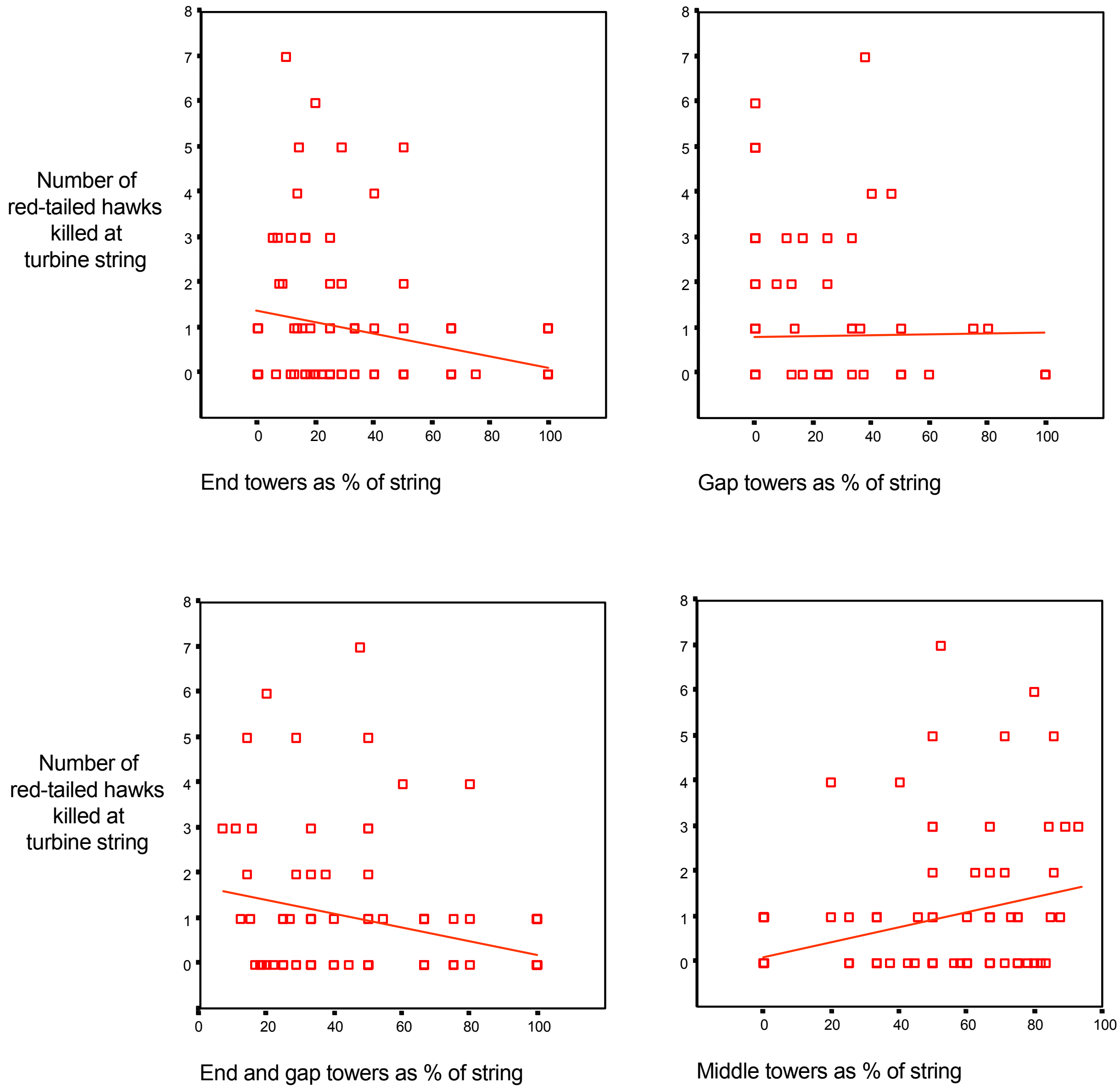


Figure 19. The number of red-tailed hawks plotted against the percentage of the string composed of end towers, gaps, ends and gaps, and interior towers.

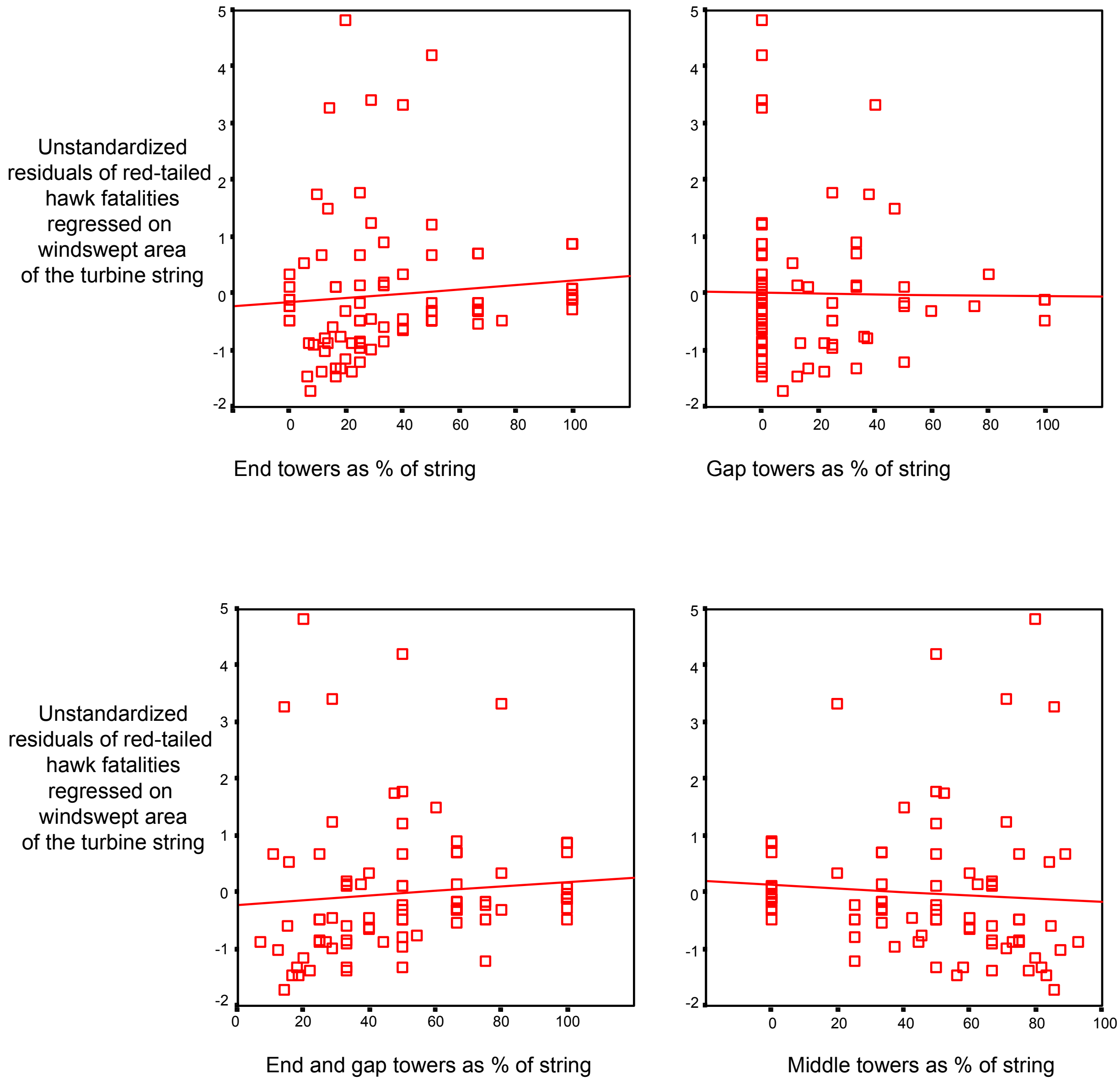


Figure 20. The residuals of number of red-tailed hawks regressed on windswept area, then plotted against the percentage of the string composed of end towers, gaps, ends and gaps, and interior towers. Note that strings with two towers are those with end towers composing 100% of the string.

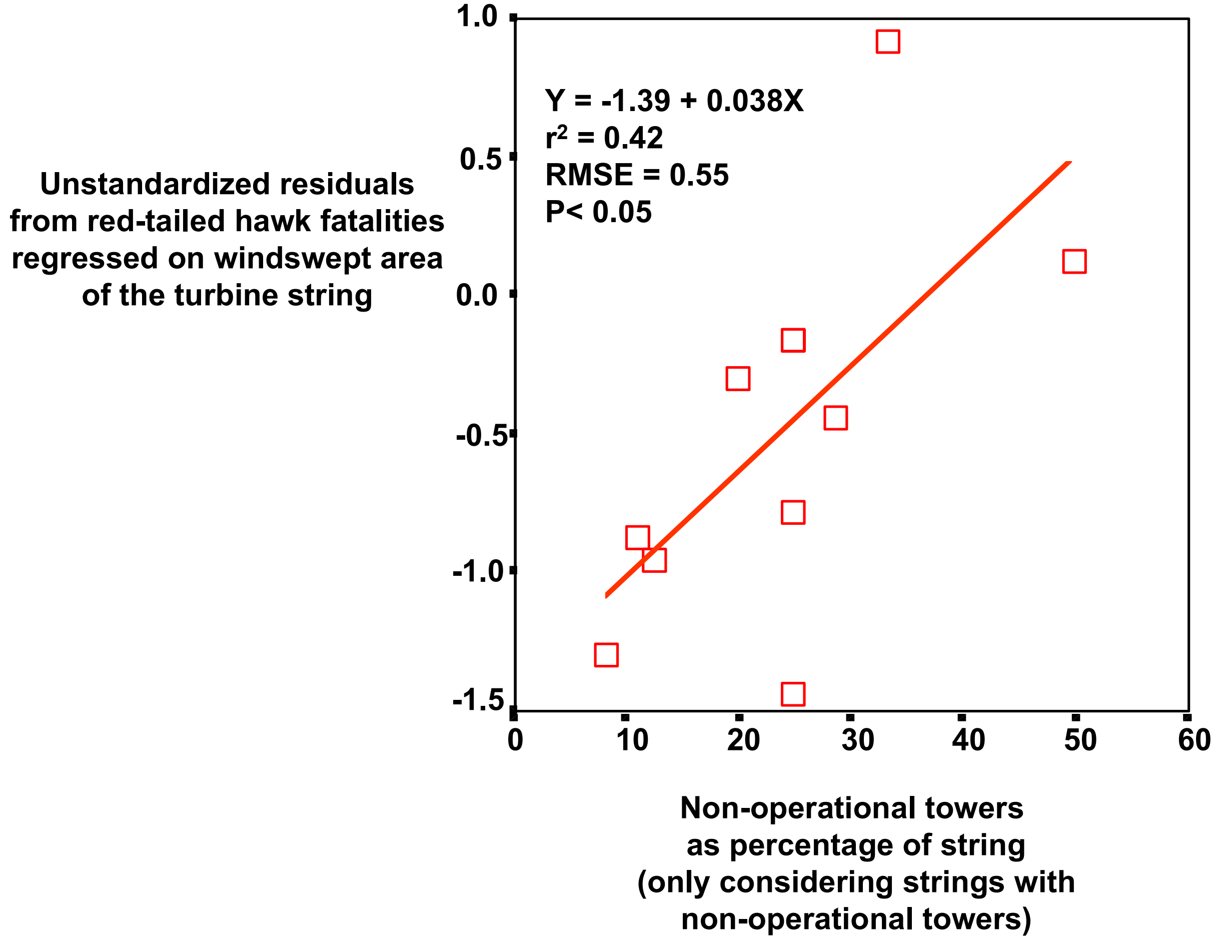


Figure 21. The residuals of number of red-tailed hawks regressed on windswept area, then plotted against the percentage of the string composed of non-operational towers.

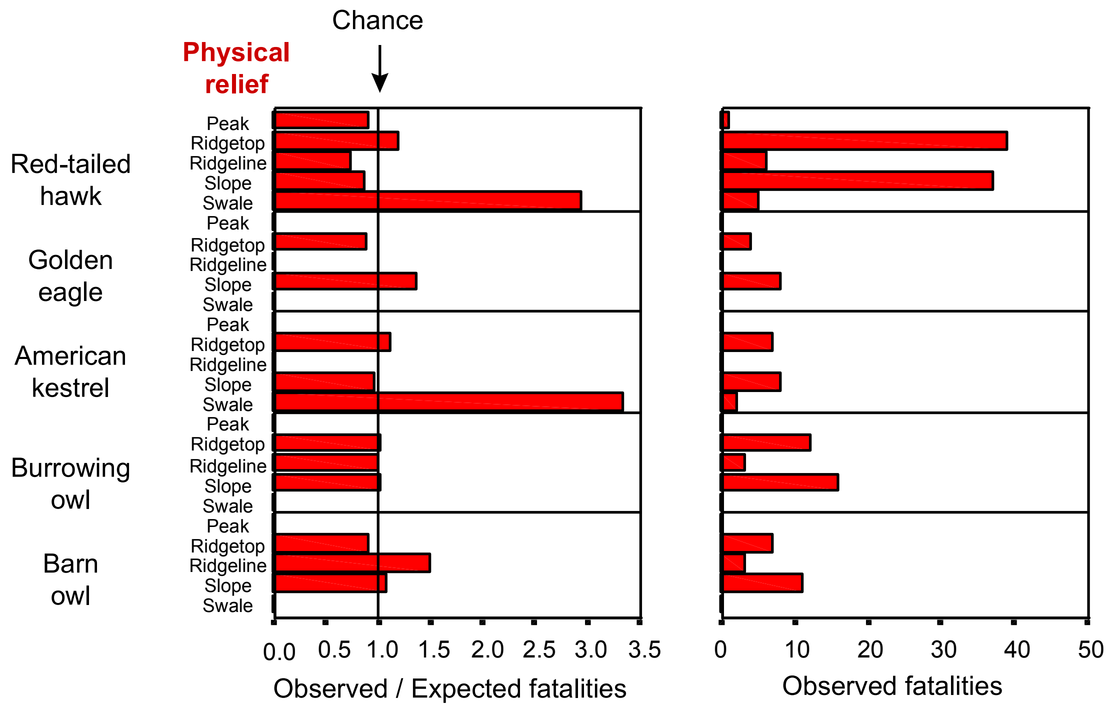


Figure 22. Associations between fatalities and physical relief among raptor species. Observed/expected values greater than 1 indicate the degree to which the observed value exceeds the expected value based on chance.

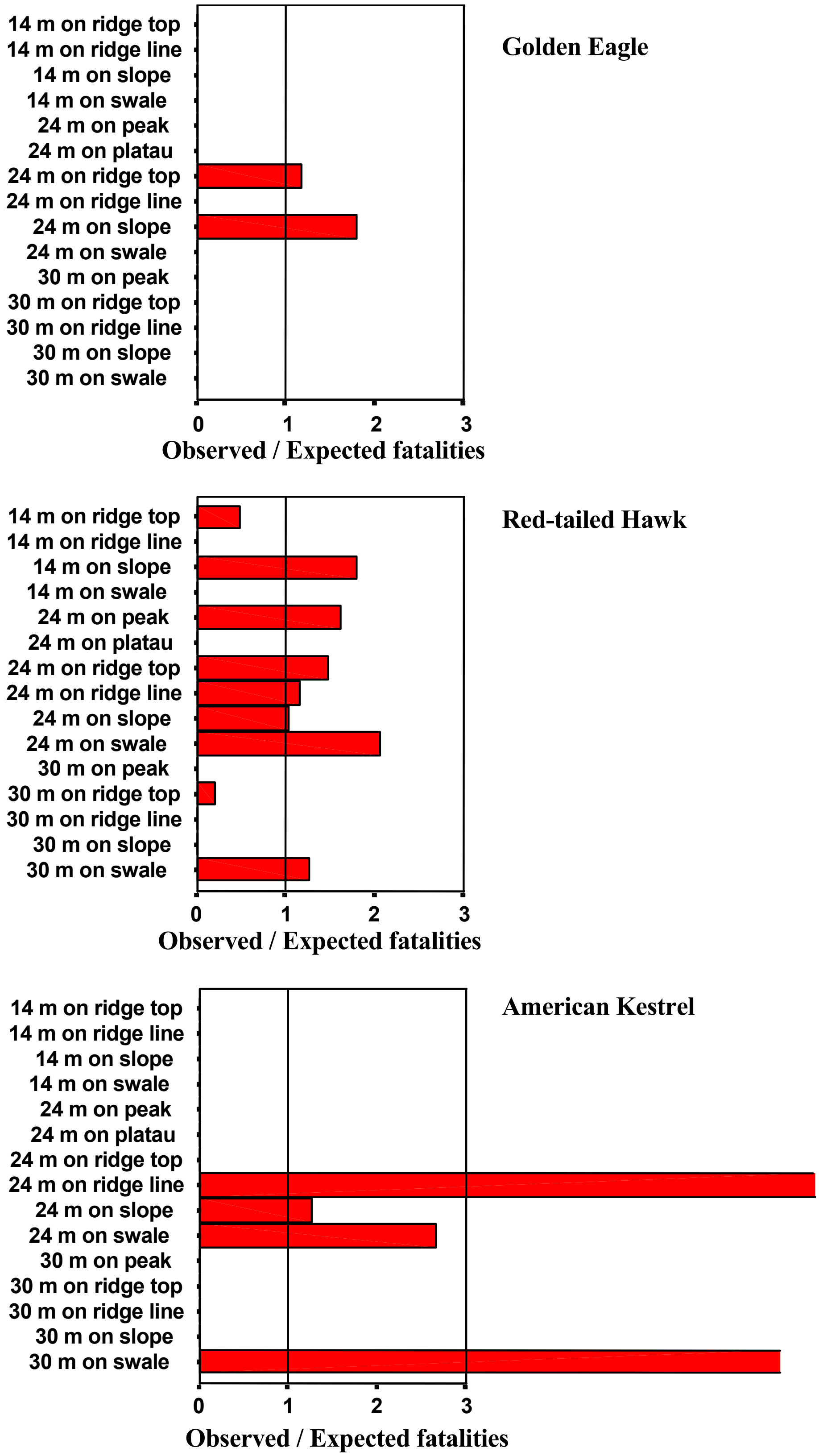


Figure 23. Associations between raptor fatalities and the interaction between physical relief and tower height.

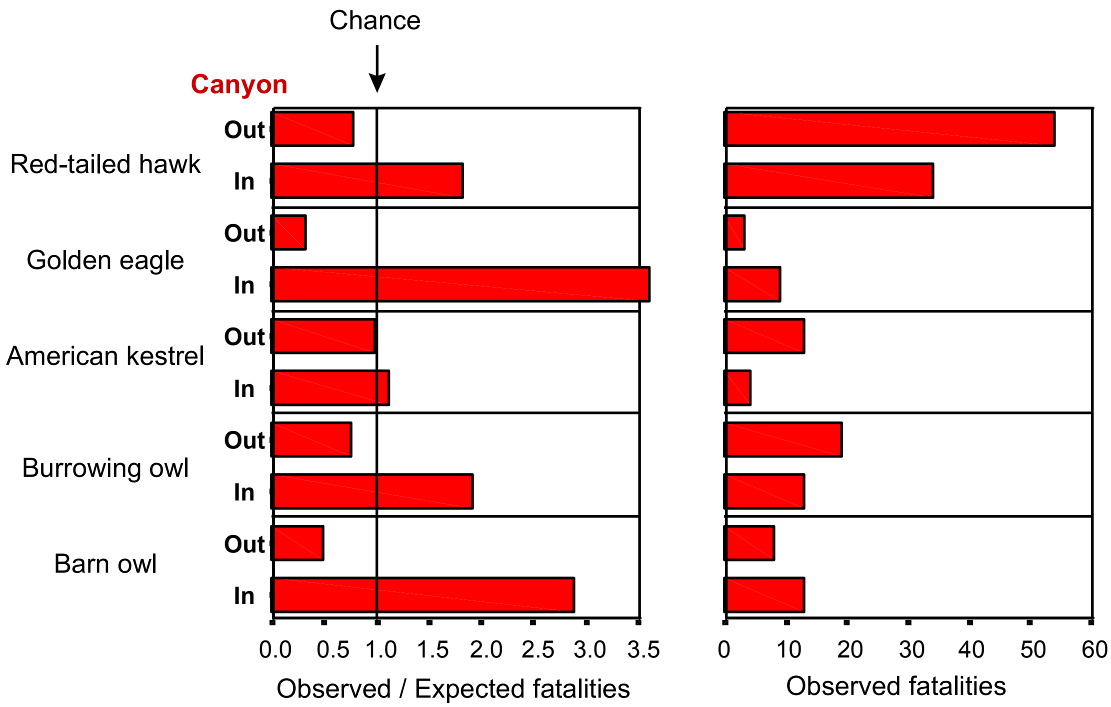


Figure 24. Associations between fatalities and whether in or out of canyons among raptor species. Observed/expected values greater than 1 indicate the degree to which the observed value exceeds the expected value based on chance.

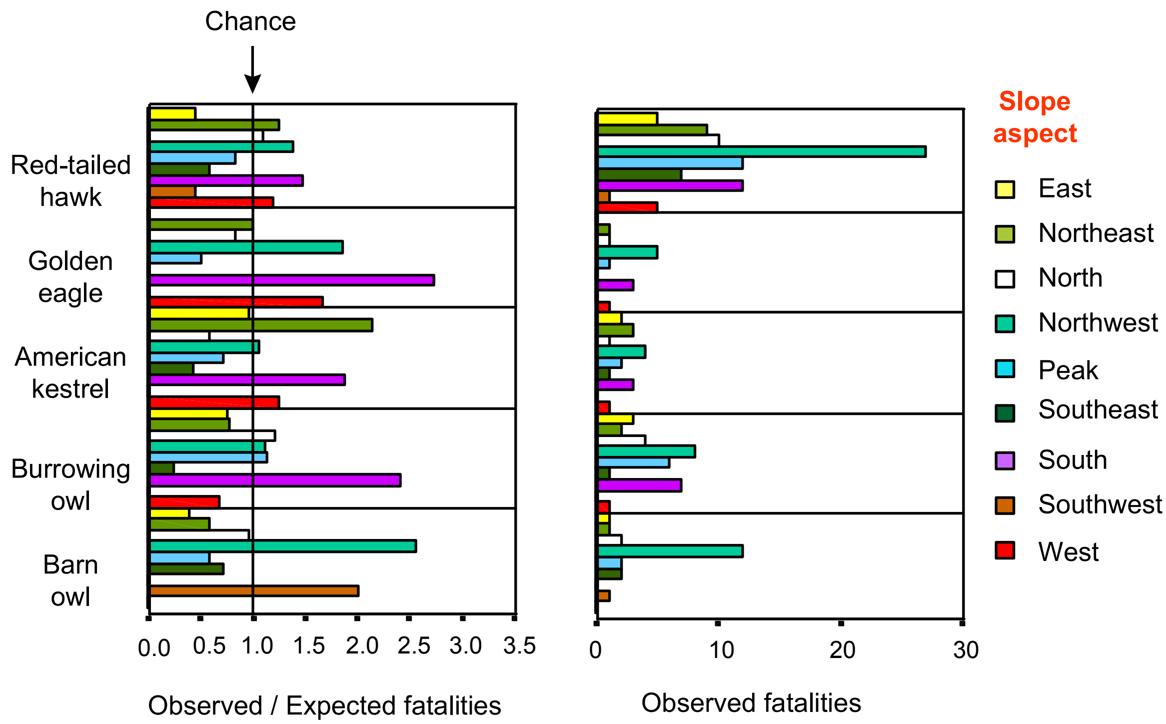


Figure 25. Associations between fatalities and slope aspect among raptor species. Observed/expected values greater than 1 indicate the degree to which the observed value exceeds the expected value based on chance.

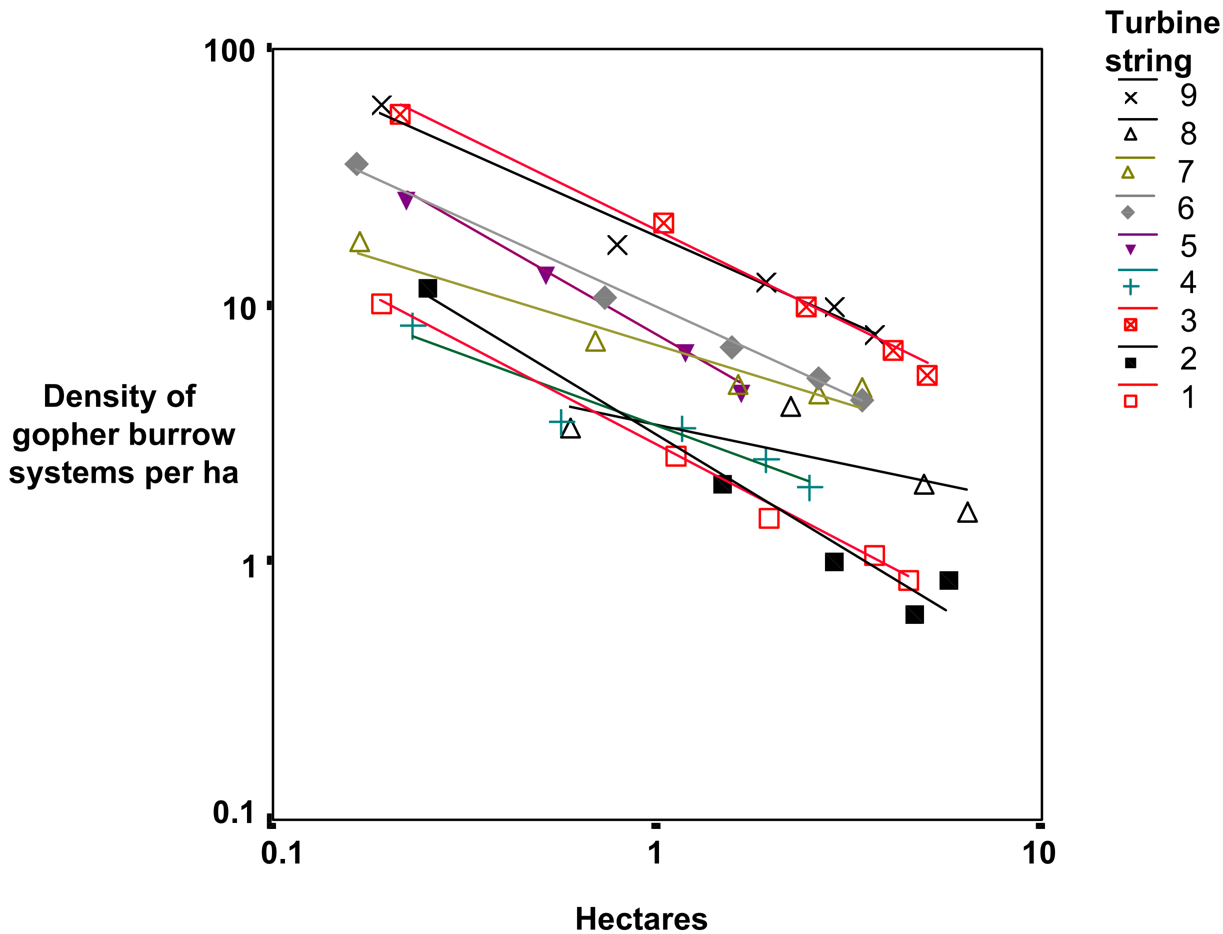


Figure 26. Pocket gopher burrow density displays an inverse power relationship to the search area surrounding each turbine string.

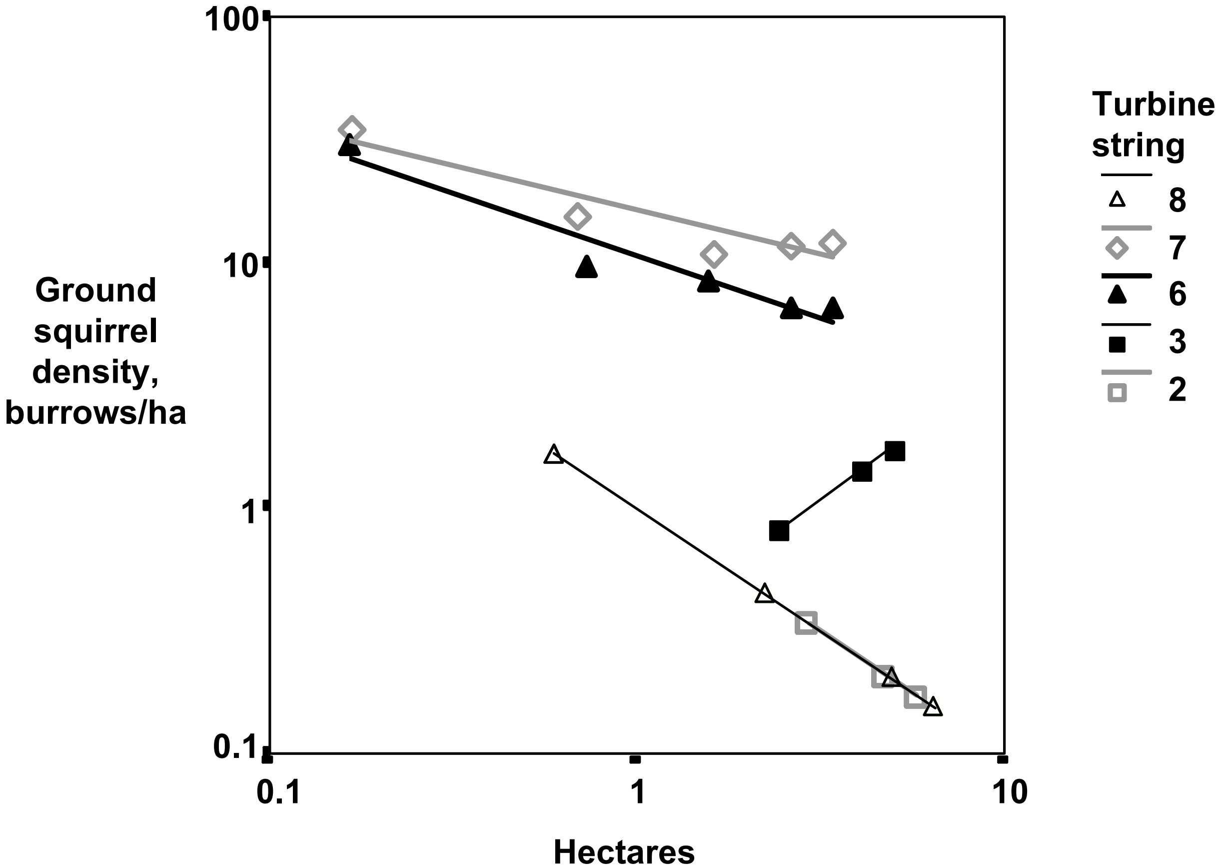


Figure 27. Ground squirrel burrow density displays two well-founded inverse power relationships to the search area surrounding the turbine string, but two others are based on one burrow system, and ground squirrels were absent at the other four turbine strings.

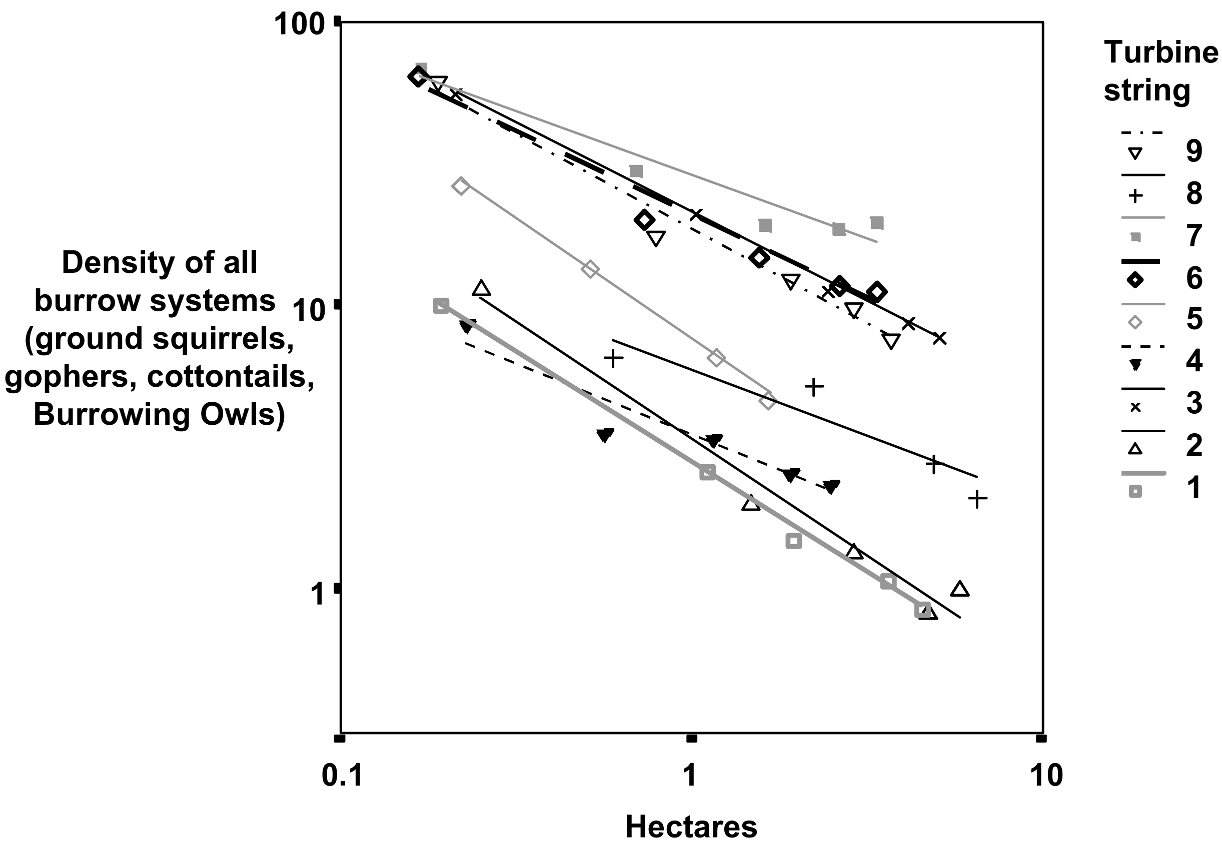


Figure 28. The density of all animal burrow systems displays an inverse power relationship to the search area surrounding each turbine string, but is likely driven mostly by the clustering of pocket gophers around the turbines.

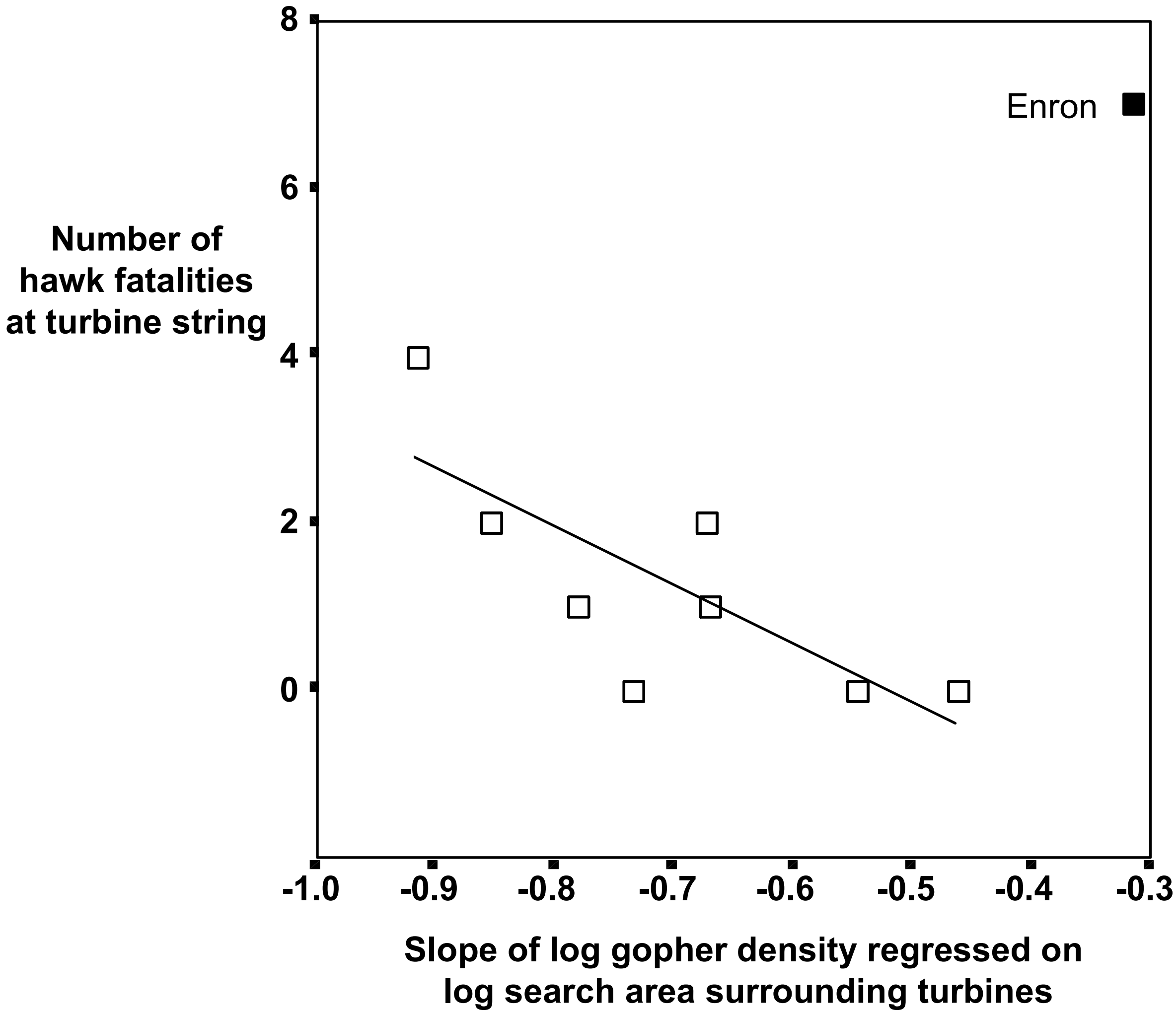


Figure 29. The number of hawk fatalities decreased with shallower slopes of log density of pocket gopher burrow systems regressed on log study area size.

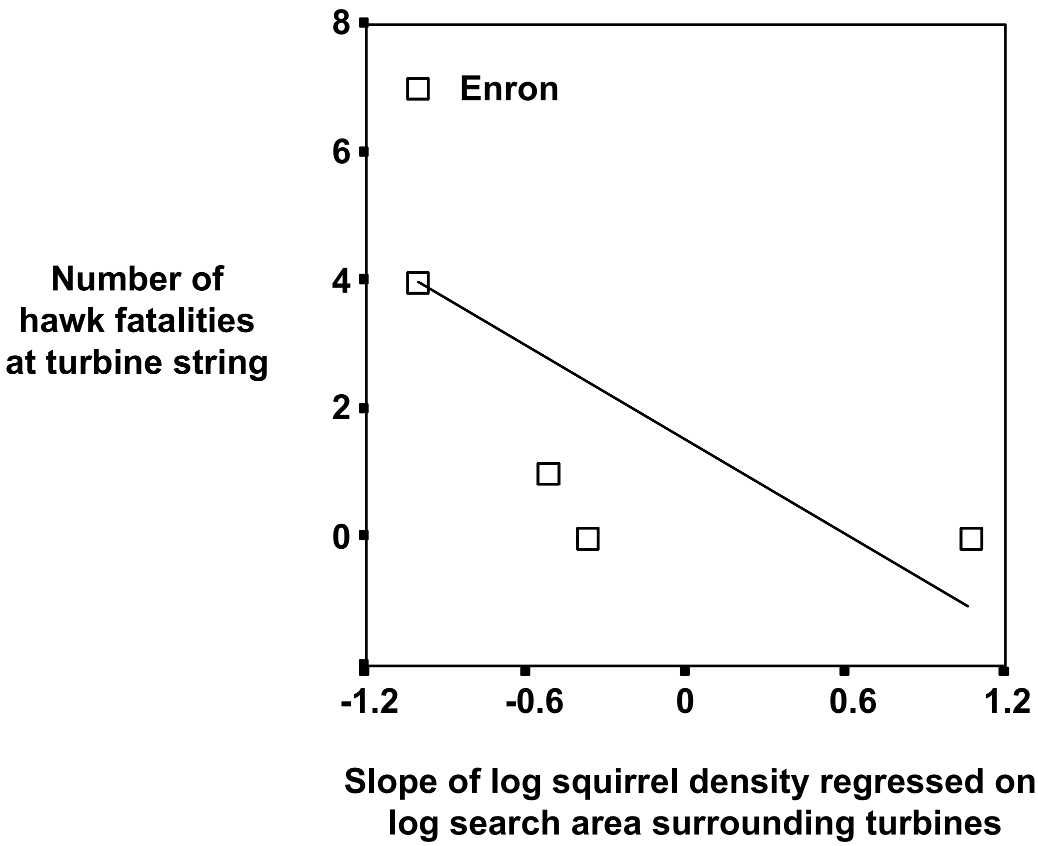


Figure 30. The number of hawk fatalities decreased with shallower slopes of log density of ground squirrel burrow systems regressed on log study area size, although the regression was not statistically significant.

APPENDIX: DATA DICTIONARY

```
"Altamont", Dictionary, "Turbines and fatalities @ Altamont Pass"
"Turbine", point
  "Type", menu,
    "Tubular Bonus"
    "Tubular Danwin"
    "Vertical Axis"
    "Diagonal Lattice"
    "Horizontal lattice", default
  "Row", numeric, 0, 0, 1000, 1
  "Number", numeric, 0, 0, 10000, 1
  "String", numeric, 0, 1, 100, 1, "Number of turbines in string"
  "Anemometer?", menu,
    "yes"
    "no", default
  "Location", menu,
    "Edge"
    "Interior", default
  "Height", menu,, "Relative height of turbine"
    "Tall"
    "Short", default
  "Topography", menu,
    "Ridge top", default
    "ridgeline"
    "Peak"
    "Slope, convex"
    "slope, concave"
    "slope, convex break"
    "slope, concave break"
    "swale"
    "plateau"
    "Ravine"
  "Aspect", menu,, "Direction faced by slope"
    "Peak", default
    "north"
    "northeast"
    "east"
    "southeast"
    "south"
    "southwest"
    "west"
    "northwest"
  "Notes", text, 30
  "Photo 1", filename
  "Photo 2", filename


"Fatality", point, "Attributes of killed bird"
  "Number", numeric, 0, 1, 1000, 1, "corresponding with data base key"
```

```
  "Species", text, 30
  "Type", menu,
    "Turbine collision", default
    "Electrocution"
    "Old bones"
    "Undetermined"
    "Predation"
    "Other"
  "Date", date, auto, dmy, "Date carcass was located"
  "Associated structure", menu,
    "Turbine"
    "Utility pole"
  "Notes", text, 30
  "Topography", menu,
    "Ridge top", default
    "Ridgeline"
    "Slope"
    "Slope Convex"
    "Slope concave"
    "Slope break, convex"
    "Slope break, concave"
    "Peak"
    "Ravine"
    "Stream"
    "Swale"
    "Plateau"
  "Aspect", menu,, "Direction faced by slope"
    "Peak", default
    "north"
    "northeast"
    "east"
    "southeast"
    "south"
    "southwest"
    "west"
    "northwest"
  "Photo 1", filename
  "Photo 2", filename
  "Photo 3", filename
  "Photo 4", filename

"Pond", area
  "Inundation", menu,
    "Perennial", default
    "Seasonal"
  "Photo 1", filename
  "Photo 2", filename

"Tree", point
  "Species", text, 30
```

```
  "Height", numeric, 0, 1, 100, 9, "in meters"
  "Photo", filename

"Plot number", point
  "Number", numeric, 0, 1, 20, 1
  "Notes", text, 30

"Topography", line
  "Topography", menu,
    "Ridgetop", default
    "Ridgeline"
    "Slope, Convex"
    "Slope, concave"
    "Slope break, convex"
    "Slope break, concave"
    "Swale"
    "Plateau"
    "Stream"
    "Ravine"
    "Ravine bottom"
    "Pond"
  "Aspect", menu,
    "Peak"
    "North"
    "Northeast"
    "East", default
    "Southeast"
    "South"
    "Southwest"
    "West"
    "Northwest"
  "Transect width", numeric, 0, 1, 30, 15, "Distance observable to either side"

"Burrow", point
  "Species", menu,
    "Pocket gopher", default
    "Ground squirrel"
    "Rabbit"
    "Badger"
    "Coyote"
    "Fox"
    "Burrowing Owl"
  "Notes", text, 30
  "Photo", filename


"Turbine count area", area, "for burrow counts"
  "Notes", text, 30
  "Photo 1", filename
  "Photo 2", filename
```

"Gopher burrow", point

"Gr squirrel burrow", point

"Burrowing owl", point

REPORT DOCUMENTATION PAGE

Form Approved
OMB NO. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
December 2003

3. REPORT TYPE AND DATES COVERED
Subcontractor Report
Period of Performance: March 1998-December 2000

4. TITLE AND SUBTITLE
Bird Risk Behaviors and Fatalities at the Altamont Pass Wind Resource Area

5. FUNDING NUMBERS
WER4 7202

6. AUTHOR(S)
C.G. Thelander, K.S. Smallwood, and L. Rugge

PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
BioResource Consultants
PO Box 1539
Ojai, CA 93024

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NREL/SR-500-33829

11. SUPPLEMENTARY NOTES
NREL Technical Monitor: K. Sinclair

12a. DISTRIBUTION/AVAILABILITY STATEMENT
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

It has been documented that wind turbine operations at the Altamont Pass Wind Resource Area kill large numbers of birds of multiple species, including raptors. We initiated a study that integrates research on bird behaviors, raptor prey availability, turbine design, inter-turbine distribution, landscape attributes, and range management practices to explain the variation in avian mortality at two levels of analysis: the turbine and the string of turbines. We found that inter-specific differences in intensities of use of airspace within close proximity did not explain the variation in mortality among species.

Unique suites of attributes relate to mortality of each species, so species-specific analyses are required to understand the factors that underlie turbine-caused fatalities. We found that golden eagles are killed by turbines located in the canyons and that rock piles produced during preparation of the wind tower laydown areas related positively to eagle mortality, perhaps due to the use of these rock piles as cover by desert cottontails. Other similar relationships between fatalities and environmental factors are identified and discussed. The tasks remaining to complete the project are summarized.

14. SUBJECT TERMS
wind energy; wind turbines; birds; avian issues; Altamont Pass Wind Resource Area; California.

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT
Unclassified

20. LIMITATION OF ABSTRACT
UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

Influence of Behavior on Bird Mortality in Wind Energy Developments

K. SHAWN SMALLWOOD,[1] *3108 Finch Street, Davis, CA 95616, USA*

LOURDES RUGGE,[2] *California State University, Sacramento, Department of Biological Sciences, 6000 J Street, Sacramento, CA 95819, USA*

MICHAEL L. MORRISON, *Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843, USA*

ABSTRACT As wind power generation is rapidly expanding worldwide, there is a need to understand whether and how preconstruction surveys can be used to predict impacts and to place turbines to minimize impacts to birds. Wind turbines in the 165-km^2 Altamont Pass Wind Resource Area (APWRA), California, USA, cause thousands of bird fatalities annually, including hundreds of raptors. To test whether avian fatality rates related to rates of utilization and specific behaviors within the APWRA, from March 1998 to April 2000 we performed 1,959 30-minute behavior observation sessions (360° visual scans using binoculars) among 28 nonoverlapping plots varying from 23 ha to 165 ha in area and including 10–67 turbines per plot, totaling 1,165 turbines. Activity levels were highly seasonal and species specific. Only 1% of perch time was on towers of operating turbines, but 22% was on towers of turbines broken, missing, or not operating. Of those species that most often flew through the rotor zone, fatality rates were high for some (e.g., 0.357 deaths/megawatt of rated capacity [MW]/yr for red-tailed hawk [*Buteo jamaicensis*] and 0.522 deaths/MW/yr for American kestrel [*Falco sparverius*]) and low for others (e.g., 0.060 deaths/MW/yr for common raven [*Corvus corax*] and 0.012 deaths/MW/yr for turkey vulture [*Cathartes aura*]), indicating specific behaviors or visual acuity differentiated these species by susceptibility to collision. Fatality rates did not correlate with utilization rates measured among wind turbine rows or plots for any species except burrowing owl (*Athene cunicularia*) and mallard (*Anas platyrhynchos*). However, mean monthly fatality rates of red-tailed hawks increased with mean monthly utilization rates ($r^2 = 0.67$) and especially with mean monthly flights through turbine rows ($r^2 = 0.92$). Fatality rates increased linearly with rates of utilization ($r^2 = 0.99$) and flights near rotor zones ($r^2 = 1.00$) for large raptor species and with rates of perching ($r^2 = 0.13$) and close flights ($r^2 = 0.77$) for small non-raptor species. Fatalities could be minimized or reduced by shutting down turbines during ≥ 1 season or in very strong winds or by leaving sufficiently large areas within a wind farm free of wind turbines to enable safer foraging and travel by birds. (JOURNAL OF WILDLIFE MANAGEMENT 73(7):1082–1098; 2009)

DOI: 10.2193/2008-555

KEY WORDS Altamont Pass, behavior, birds, fatality rate, utilization, wind turbine.

The Altamont Pass Wind Resource Area (APWRA) has caused numerous bird fatalities due to collisions with wind turbines, electrocutions on electric distribution poles, and other causes related to the wind farm (Howell et al. 1991; Orloff and Flannery 1992, 1996; Smallwood and Thelander 2008). Wind turbine–caused fatality rates were recently estimated at 2,710 (SE = 11.848) birds per year in the APWRA, including 1,127 (SE = 1.547) raptors per year (Smallwood and Thelander 2008). As a result of these high fatality rates, bird mortality has been investigated at other wind farms throughout North America, and bird behaviors and activity levels have been investigated at some of these (Janss and Clave 2000; Kerlinger 2000; Anderson et al. 2004, 2005; Hoover and Morrison 2005). These investigations attest to the importance attributed to bird behaviors and activity levels in relation to bird collisions with wind turbines.

Investigators have often monitored live birds at wind farms pre- and postconstruction, usually due to operating permit requirements but sometimes for research purposes. Bird monitoring has been directed toward measuring site utilization and identifying behaviors that are more hazardous and which might be exploited to mitigate wind turbine collisions. At wind farms these objectives are usually pursued simultaneously using visual scans over timed sessions to not only count birds using the area, but also to identify flight paths and frequencies of behaviors that might help guide wind turbine placement and tower height, inter-turbine arrangement, timing of operations, and land management practices.

During the last 2 decades, it has been hypothesized that specific behaviors predispose certain species to more likely collide with operating wind turbines (e.g., Orloff and Flannery 1992; Erickson et al. 1999; Strickland et al. 2001*b*; Smallwood and Thelander 2004, 2005). It has been hypothesized that the amount of time a species uses a wind farm, referred to as utilization rate, also contributes to wind turbine collision rates (Morrison 1998, Anderson et al. 2001, Strickland et al. 2001*a*, Hunt 2002). We related wind turbine–caused fatality rates to rates of utilization and specific behaviors. We also related bird behaviors and activity levels that were associated with wind turbines to environmental conditions in the APWRA. We hypothesized that birds lose track of wind turbines while focused on diving for prey items, fly-catching, and hovering.

STUDY AREA

The APWRA occupied about 16,450 ha of mostly annual grassland in eastern Alameda County and southeastern Contra Costa County, California, USA. It ranged from 78 m to 470 m above mean sea level, composed of hills, ridges, and valleys, and including stock ponds, small seasonal ponds, and marshes. Most ridges were oriented northwest to southeast, bisected by seasonal streams. Other

[1] *E-mail: puma@yolo.com*
[2] *Present address: ECORP Consulting, Inc., 2525 Warren Drive, Rocklin, CA 95677, USA*

physiographic elements included alkali meadow, emergent marsh, riparian woodland and scrub, and rock outcrops. Landowners principally grazed livestock but also leased land to wind turbine owners.

When our study began, the APWRA included about 5,400 wind turbines of various models with a total rated capacity of about 580 megawatts (MW). These wind turbines were owned by multiple companies and were mounted on 3 tower types with rotor hubs of vertical-axis turbines ranging from 14 m to 43 m above ground. Many were on ridge crests or ridgelines descending into ravines from the ridge crests. Smallwood et al. (2007) and Smallwood and Thelander (2008) provided additional details on APWRA land uses, wind turbines, and other aspects of the study area.

METHODS

Field Methods

Two biologists collected bird behavior data in 28 study plots from 26 March 1998 through 18 April 2000. Study plots were nonoverlapping and ranged from 23 ha to 165 ha ($\bar{x}$ = 94 ha) in area due to complex terrain and the irregular arrangement of wind turbines. Plots contained 10–67 turbines each, totaling 1,165 turbines, or all of the turbines accessible to us in 1998–2000. All the turbines in each plot were visible from a fixed observation point. Twelve plots included wind turbines on lattice towers only, 8 included turbines on tubular towers only, 7 included both tubular towers and vertical-axis turbines, and one included tubular and lattice towers. Observers carried plot maps to identify each turbine and to link it to recorded bird activities. Each observer performed circular visual scans (360°), also called variable distance circular point observations (Reynolds et al. 1980), using 8 × 40 binoculars out to 300 m from the wind turbines in the plot or shorter if the plot boundary was defined by topography (i.e., visibility) or where distances were equal between turbines in the plot under observation and those in the adjacent plot. Observation sessions lasted 30 minutes, and we often performed 2 sessions simultaneously on nonadjacent plots to improve our degree of independence between sessions. We typically completed 6–8 sessions per day.

We sampled all 28 plots once per 10–20 days on average, stratified by morning (0700 hr to 1200 hr) and afternoon (1201 hr to dusk), but most sessions started between 0900 hours and 1700 hours. We visited 20 plots 60–120 times each, and we added another 8 in October 1999 and visited them >20 times each. To represent behaviors in all weather conditions, we observed behaviors throughout the year, unless rain or fog reduced observer visibility to <50% of the turbines in the plot. Sessions were infrequent during January and May but were otherwise distributed evenly among seasons. Most occurred during moderate temperatures, from 10° C to 27° C.

We identified each bird entering the study plot and continuously followed it until it left the plot. We recorded species, number of birds in a flock, times of first and last detection, predominant flight behavior, and number of passes by a turbine. While the bird made its closest pass to the rotor zone, we recorded flight direction, distance to nearest wind turbine, type of wind turbine, and flight height relative to the rotor plane, which was the height above ground from the lowest to highest reaches of the turbine blades. We classified flight behaviors as fly-through, gliding, soaring, high soaring, contouring, circling, kiting–hovering, diving, mobbing, being mobbed, column soaring, surfing, ground hopping, hawking insects, fleeing, interacting with conspecifics, flocking, and flushed. We classified 21 perch structures, including ground, rock–vegetation, tree, fence post, the top, cross-arm, or wire of electric distribution poles, anemometer tower, electric transmission tower, top inner framework or guy wire of vertical-axis wind turbines, top or inside of wind turbine motors, turbine blade, turbine propeller cone, catwalk of wind tower, side ladder of wind tower, and top, lower, or middle framework of diagonal lattice wind turbine towers.

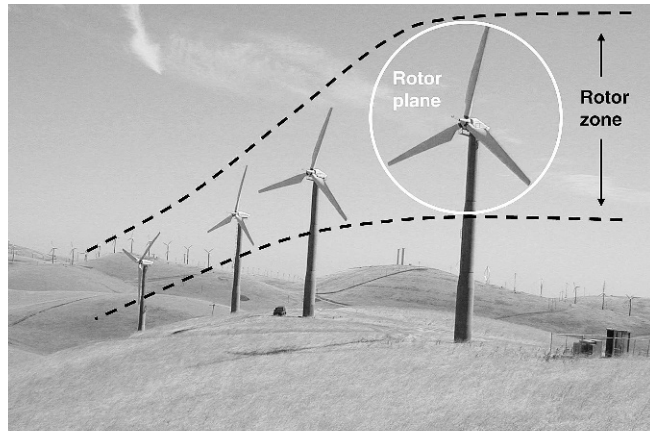


Figure 1. Rotor plane of a Bonus 150-kilowatt wind turbine (Bonus Wind Turbines, Inc., Brande, Denmark) in the Altamont Pass Wind Resource Area, California, USA, 1998–2003, and the upper and lower reaches of the rotor zone of the turbine row, where the rotor zone also extends 50 m laterally in all directions.

Of particular interest were behaviors and distances of flights from the rotor zone, which was where we assumed birds were most vulnerable to collisions. The rotor zone was the reach of the rotating turbine blades or rotor-swept area within 50 m of the blades, which was a 50-m extension of the rotor plane (Fig. 1). To improve accuracy and consistency in recording the closest pass to the rotor zone, both field assistants calibrated height and depth measurements of known objects every 6 months. To minimize observer bias in distance estimates and behavior reporting, we made paired observations over 18 sessions in the study's first month. Observers recorded behavioral information simultaneously but independently on separate data sheets. At the end of each calibration session, we compared information to help ensure consistency of behavior interpretations. Once observers achieved similar distance estimates and behavior records, they began conducting separate 30-minute observation sessions. Four calibration sessions were repeated over 1–2 days every 6 months.

We recorded specific behaviors with alphanumeric codes onto a standardized data sheet, along with session start time, temperature, wind speed, wind direction (its origin), number of turbines operating, and cloud cover at the beginning of each session. For analysis, we lumped actual start times into representative times of the day, so 0800 hours represented 0700–0859 hours, 1000 hours was for 0900–1059 hours, 1200 hours for 1100–1259 hours, 1400 hours for 1300–1459 hours, 1600 hours for 1500–1659 hours, and 1800 hours for 1700–2059 hours. We measured temperature with a handheld thermometer, and we aggregated temperatures across spans of 2.8° C (5° F) for analysis. We measured wind force on the Beaufort scale, where 0 was <0.3 m/second, 1 was 0.3–1.5 m/second, 2 was 1.6–3.3 m/second, 3 was 3.4–5.4 m/second, 4 was 5.5–7.9 m/second, 5 was 8–10.7 m/second, 6 was 10.8–13.8 m/second, and 7 was >13.8 m/second. When wind speed exceeded 15 m/second (near gale winds), we left the field for safety reasons (i.e., parts of wind turbines can become dislodged).

On fatality searches, biologists searched out to 50 m from all rows of wind turbines that were made available to us by the wind companies in the APWRA (Smallwood and Thelander 2008). Search intervals varied from weekly to greater than monthly and spanned 1.5–4.5 years or longer than the behavior observation study at most turbine rows. Fatalities considered herein, along with resulting fatality rate estimates, corresponded with turbine rows and plots included in this behavior study.

Analytical Methods

We expressed utilization rates as number of birds seen per session or per hour when we compared them by month of the year. We expressed utilization rates as mean number of observations per session per hectare when we compared them among plots or turbine rows. Turbine rows were bounded by the line equidistant between adjacent turbine rows and extended to the 300-m plot boundary nearest the turbine row. We used a Geographic Information System to delineate plot and turbine row boundaries and to calculate areas.

We also compared number occurrences of specific behaviors per session, per hour, and per hectare in the same manner we compared utilization rates. We related behavior rates to session start time, temperature during the session, month and season of the year, wind speed, wind direction, and distance from wind turbines.

To estimate fatality rates, we used only fatalities estimated to have been caused ≤90 days before discovery, found within 125 m of wind turbines, and not determined to have died by causes other than wind turbines. Even though 50 m was the search radius, searchers recorded all carcasses, no matter how far from turbines. We included carcasses seen out to 125 m because the hills under turbine rows were steep, permitting carcasses thrown from turbines 50 m laterally to fall down the slope farther than 50 m away as measured by rangefinder. Also, many of these carcasses were visible from within the search radius due to short-stature vegetation, though we undoubtedly missed carcasses beyond 50 m more often than within 50 m of turbines. We established our inclusion threshold of 125 m after the study, using our experience in the study area to judge how far searchers could reasonably scan the ground for carcasses from the 50-m search radius.

Within each turbine row, we expressed the fatality rate as number of fatalities per MW per year, where MW was the sum of the MW of rated power outputs for all of the wind turbines in the row searched. Although individual turbines killed birds, we used wind turbine row as our study unit because we sometimes could not determine which turbine within the row killed a bird. To the number of years used in the fatality rate estimate, we added the number of days equal to the average search interval used at each turbine row to represent the time period when carcasses could have accumulated before our first search. We adjusted fatality rates for searcher detection error and scavenger removal rates using the approach of Smallwood (2007), and we used fatality rate estimates in Smallwood and Thelander (2008), but in this case we used estimates specific to each wind turbine row and to behavior plots instead of the entire wind farm.

We compared fatality rates to utilization rates and behavior rates among the 28 observation plots and to turbine rows within the plots using Pearson's correlation tests and least squares regression analysis. We also tested for correlations between fatality and utilization rates by month of the year. We estimated fatality rate by month of the year by multiplying the mean annual fatality rate estimate by the proportion of fatalities backdated to each month, where we based backdating on the field biologists' estimate of number of days since death.

RESULTS

Characteristics of Observation Sessions

During observation sessions, we recorded wind direction most often from the southwest (41%), followed by northeast (17%), west (13%), and northwest (13%). Winds measured on the Beaufort scale were 0 for 1.8% of sessions, 1 for 17.4%, 2–4 for 58.9%, 5 for 11.3%, 6 for 7.4%, and 7 for 3.2% of sessions. Wind speeds measured on the Beaufort scale averaged fastest from the southwest ($\bar{x} = 3.94$, SD = 1.52), followed by the west ($\bar{x} = 3.45$, SD = 1.68), northwest ($\bar{x} = 3.13$, SD = 1.63), south ($\bar{x} = 2.76$, SD = 1.58), north ($\bar{x} = 2.24$, SD = 1.51), northeast ($\bar{x} = 2.14$, SD = 1.08), southeast ($\bar{x} = 2.08$, SD = 1.04), and east ($\bar{x} = 1.97$, SD = 1.09). Average monthly proportion of turbines operating during the session correlated strongly with average monthly wind speed measured on the Beaufort scale ($r_P = 0.98$, $n = 12$, $P < 0.001$), and both variables peaked during summer.

We observed 36 bird species during 1,959 behavior observation sessions spanning 979.5 hours. We recorded 48,396 individuals, or 24.7 individuals per session and 49.4 per hour. Factoring in the number of minutes of observations of tracked individuals, recorded bird activity totaled 460,520 minutes, 67% of which were of gulls (*Larus* spp.) making daily flights to a landfill located west of the

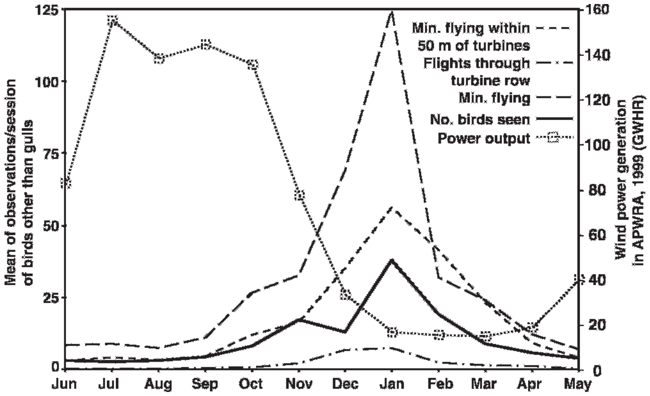


Figure 2. Middle of winter was when we observed avian species to peak in mean flying time, flight time within 50 m of wind turbines, number of passes through the turbine row, and number of birds seen in the plot, but winter was also the nadir of wind power generation in the Altamont Pass Wind Resource Area, California, USA, in 1999–2000.

central aspect of the APWRA. We observed no birds in 184 (9.4%) of the sessions.

Utilization rates (birds/session) were highly seasonal (Figs. 2, 3). Whereas power output peaked over summer, bird activity peaked over winter (Fig. 2). Flights through turbine rows and flights within 50 m of turbines peaked during winter, when wind turbine operations were lowest (Fig. 2). By species, red-tailed hawk and American kestrel (*Falco sparverius*) utilization of the APWRA peaked in late fall, whereas golden eagle (*Aquila chrysaetos*) utilization peaked in summer (Fig. 3). Turkey vulture (*Cathartes aura*) activity peaked in late summer and late winter, and common raven (*Corvus corax*) and gull activity peaked over winter and early spring. Western meadowlark (*Sturnella neglecta*), horned lark (*Eremophila alpestris*), and house finch (*Carpodacus mexicanus*) activity peaked in winter, but mourning dove (*Zenaida macroura*) activity peaked in early spring. Loggerhead shrike (*Lanius ludovicianus*) utilization was even throughout the year. Burrowing owl (*Athene cunicularia*)

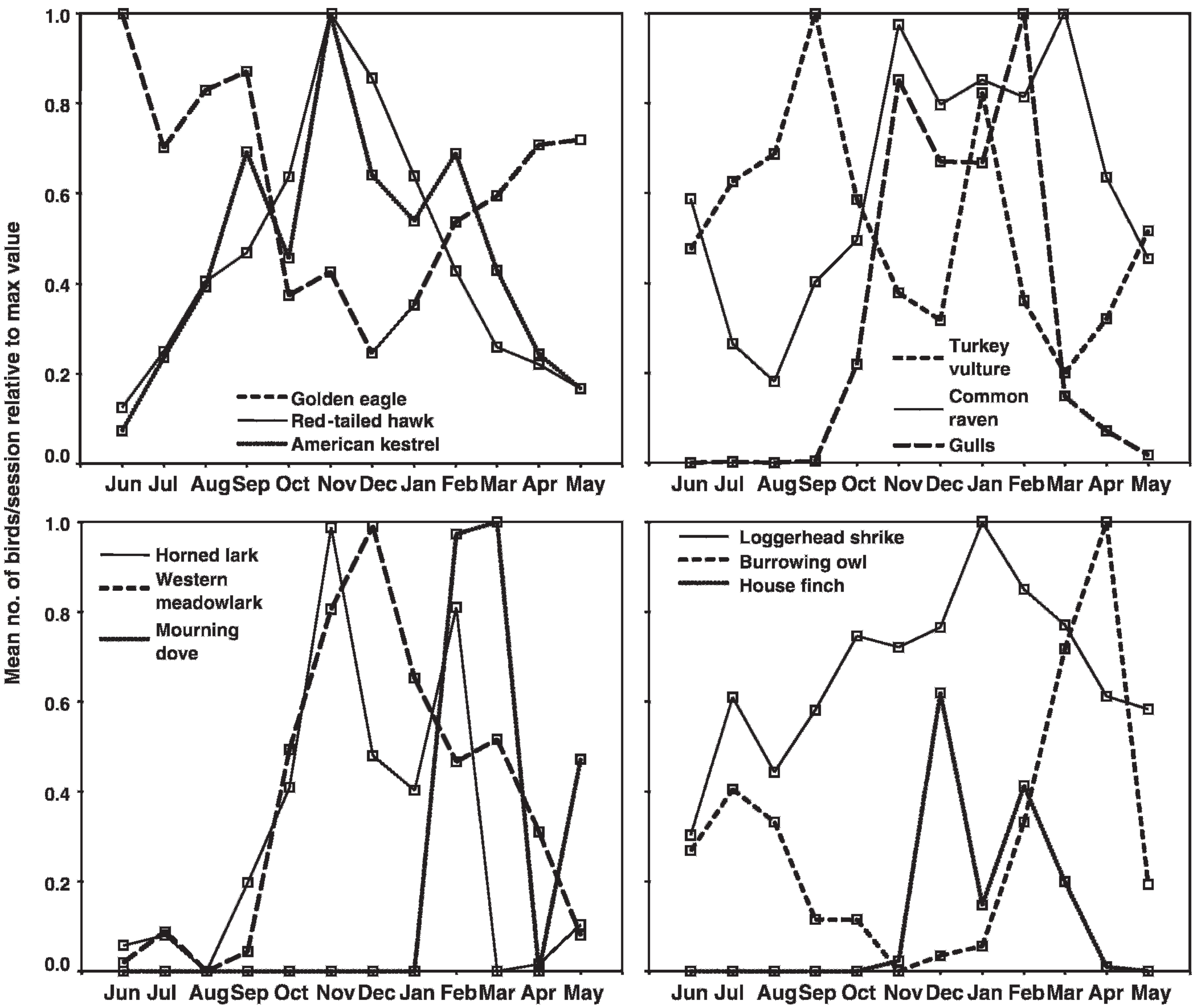


Figure 3. Relative seasonal abundance of various select avian species observed in the Altamont Pass Wind Resource Area, California, USA, during 1998–2000.

Table 1. Behavioral activities by species in the Altamont Pass Wind Resource Area, California, USA, 1998–2000.

Species	Scientific name	No. of birds seen	Total min	Min (%)		Distance (m) to closest turbine		No. of flights	
				Flying	Perching	$\bar{x}$	SD	Through rotor zone	<50 m to turbine
Mallard	*Anas platyrhynchos*	79	83	100	0	85	52	0	16
Common goldeneye	*Bucephala clangula*	1	1	100	0	10		0	2
Great blue heron	*Ardea herodias*	3	3	100	0	60	46	2	5
Turkey vulture	*Cathartes aura*	980	2,542	96	4	72	69	51	1,047
White-tailed kite	*Elanus leucurus*	1	2	100	0	100		0	0
Northern harrier	*Circus cyaneus*	126	389	76	24	76	82	21	162
Cooper's hawk	*Accipiter cooperii*	2	3	100	0	35	7	0	6
Red-tailed hawk	*Buteo jamaicensis*	2,005	15,680	43	57	65	81	270	2,682
Ferruginous hawk	*Buteo regalis*	12	74	59	41	53	41	0	38
Rough-legged hawk	*Buteo lagopus*	6	27	100	0	125	95	0	5
Golden eagle	*Aquila chrysaetos*	465	2,374	58	42	82	73	32	450
American kestrel	*Falco sparverius*	462	3,033	25	75	48	71	102	583
Prairie falcon	*Falco mexicanus*	66	199	58	42	62	60	4	84
Killdeer	*Charadrius vociferus*	2	2	100	0	20		0	1
Long-billed curlew	*Numenius americanus*	7	19	53	47	58	37	0	1
Ring-billed gull	*Larus delawerensis*	503	9,823	100	0	39	27	0	12
California gull	*Larus califfornicus*	36	36	100	0	50	42	0	5
Gull spp.		28,750	299,517	100	0	67	60	14	552
Rock pigeon	*Columba livia*	526	834	85	15	57	71	10	160
Band-tailed pigeon	*Columba fasciata*	30	30	100	0	5		1	1
Mourning dove	*Zenaida macroura*	7	88	8	92	45	38	0	5
Burrowing owl	*Athene cunicularia*	100	1,631	12	88	117	69	0	31
Say's phoebe	*Sayornis saya*	2	6	50	50	50	28	0	1
Loggerhead shrike	*Lanius ludovicianus*	139	846	16	84	49	56	11	98
American crow	*Corvus brachyrhynchos*	25	145	23	77	6	6	8	31
Common raven	*Corvus corax*	1,313	4,280	55	45	42	59	176	1,787
Horned lark	*Eremophila alpestris*	213	676	39	61	36	37	3	45
Cliff swallow	*Petrochelidon pyrrhonota*	23	52	100	0	22	10	0	14
Mountain bluebird	*Sialia currucoides*	118	291	79	21	52	37	0	6
European starling	*Sturnus vulgaris*	259	2,373	10	90	16	58	10	106
Red-winged blackbird	*Agelaius phoeniceus*	470	6,569	12	88	25	29	8	34
Tricolored blackbird	*Agelaius tricolor*	78	298	100	0	88	62	0	0
Western meadowlark	*Sturnella neglecta*	207	721	37	63	31	46	16	72
Brewer's blackbird	*Euphagus cyanocephalus*	337	1,744	40	60	35	66	7	41
Brown-headed cowbird	*Molothrus ater*	2	2	100	0	70		0	2
Blackbird spp.		7,924	67,425	39	61	38	56	45	329
House finch	*Carpodacus mexicanus*	1,024	15,620	13	87	25	48	6	61
Passerine spp.		1,974	23,076	33	67	38	68	25	141

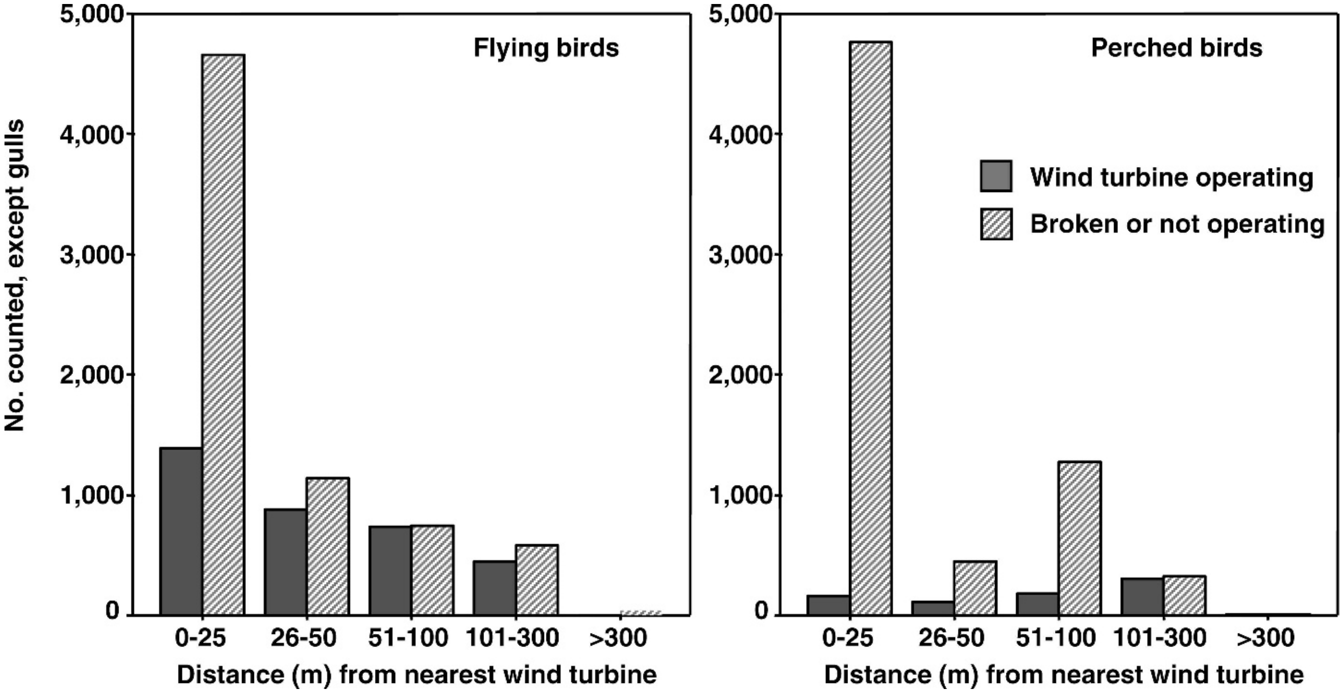


Figure 4. Counts of birds flying (left) and perched (right) by ranges of the distance to nearest turbine and whether the turbine operated at the time of the observation in the Altamont Pass Wind Resource Area, California, USA, 1998–2000.

activity peaked in spring, with a secondary peak in July and August (Fig. 3).

Behavior Patterns Around Wind Turbines

Of species observed $\geq$25 times, those observed usually flying included gulls, tricolored blackbird (*Agelaius tricolor*), turkey vulture, northern harrier (*Circus cyaneus*), rock pigeon (*Columba livia*), band-tailed pigeon (*Columba fasciata*), and mountain bluebird (*Sialia currucoides*; Table 1). Species observed usually perching included American kestrel, American crow (*Corvus brachyrhynchos*), European starling (*Sturnus vulgaris*), red-winged blackbird (*Agelaius phoeniceus*), and house finch. The species that averaged the closest distance to wind turbines included American crow, band-tailed pigeon, European starling, house finch, cliff swallow (*Petrochelidon pyrrhonota*), red-winged blackbird, and western meadowlark. We observed most (90%) birds other than gulls $\leq$100 m from wind turbines, and we observed 60% $\leq$25 m from turbines, but 82% of these close distances corresponded with times when the nearest turbine was either not operating or broken (Fig. 4). We recorded 8,618 flights that passed $\leq$50 m from turbines at blade height and 824 flights through the rotor zone; these 2 behaviors were highly correlated with each other while wind turbines were operating ($r_P = 0.96$, $n = 39$, $P < 0.001$).

Number of passes $\leq$50 m from turbines ($F_{<50}$) decreased with increasing proportion of turbines that operated during the observation session, T_{op} ($r^2 = 0.74$, SE $= 0.89$, $P < 0.001$):

$$F_{<50} = 7.98 - 6.41 \times T_{\mathrm{op}}.$$

This same pattern was reflected in number of flights per bird within 50 m of turbines by month of the year (Fig. 5). As the proportion of turbines operating peaked during summer, number of flights per bird within 50 m of turbines was fewest, and when the proportion of turbines operating was smallest during winter, number of flights/bird within 50 m of turbines was greatest.

As the percentage of turbines that were operating increased with wind speed, mean number of birds observed during the session decreased, but mean number of flights per bird within 50 m of turbines increased (Fig. 6). In other words, birds were increasingly out of sight as wind increased

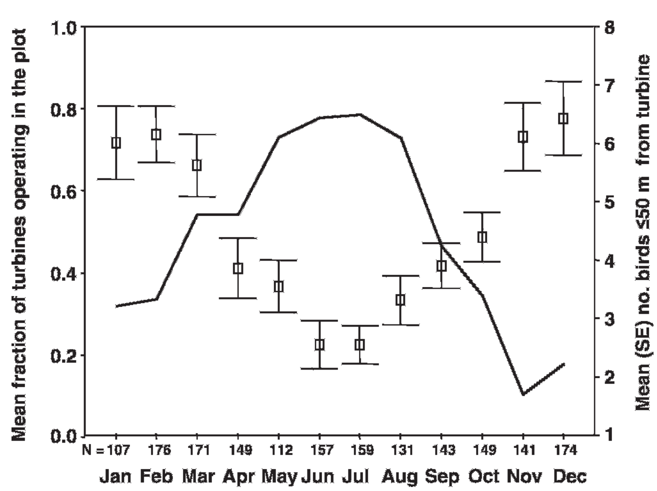


Figure 5. Mean fraction of turbines operating during behavior observation sessions (solid line) peaked over summer and was least during winter, whereas mean number of flights/bird within 50 m of turbines peaked in winter and was least during summer in the Altamont Pass Wind Resource Area, California, USA, 1998–2000.

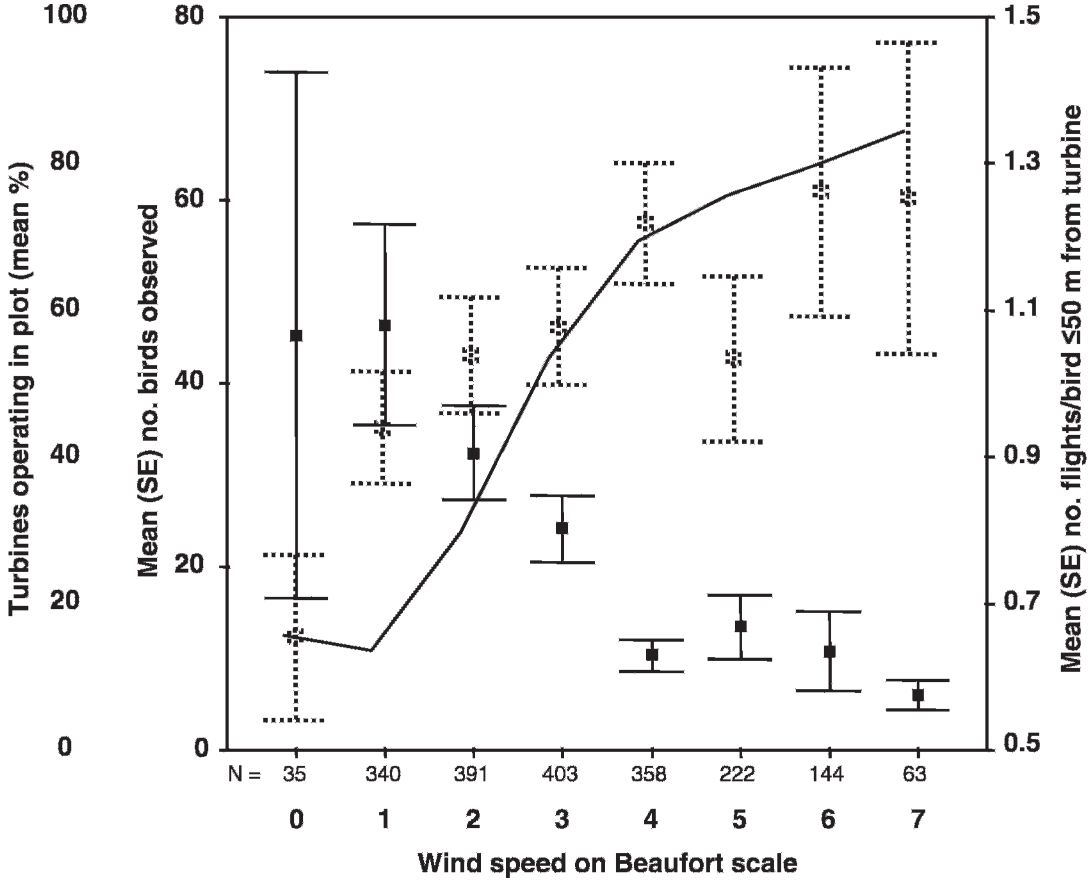


Figure 6. As wind increased in speed, the percentage of wind turbines operating within the behavior observation plot increased (solid line), mean number of birds observed decreased (solid squares and solid error bars), and mean number of flights per bird within 50 m of turbines increased (open squares and dashed error bars) in the Altamont Pass Wind Resource Area, California, USA, 1998–2000.

in strength, but flights by birds that remained observable were more frequently close to turbines. Each species responded to wind speeds in their own way, peaking in number and flights per session through the turbine row at particular wind speeds (Fig. 7).

Red-tailed hawk (*Buteo jamaicensis*) was among the most often observed species in the APWRA and the most often performing what we assumed to be more dangerous behaviors (Table 1). Gulls were by far the most commonly observed birds in the APWRA during our study, accounting for nearly 300,000 minutes of observations (we multiplied min/flock by no. of birds/flock). We did not identify most (98%) gulls to species, and of those we identified 93% were ring-billed gull (*Larus delawerensis*) and 7% were California gull (*Larus califfornicus*). Blackbirds were also common, accounting for >70,000 minutes of observation. We did not identify most (90%) blackbirds to species, but red-winged blackbird was 53% of blackbirds we identified. House finch was common and so were unidentified passerine species.

We assumed that dangerous behaviors included flights through turbine rows within the height domain of the blades, and we referred to these flights as through the rotor zone (rather than the rotor plane, which is specifically through the area swept by the blades). We also considered closer distances to turbines or number of flights ≤ 50 m from turbines to be more dangerous. Flights within 50 m were performed most often by red-tailed hawk (31.1%), common raven (20.7%), turkey vulture (12.2%), American kestrel (6.8%), gulls (6.6%), golden eagle (5.2%), and blackbirds (4.7%), followed by northern harrier (1.9%), rock pigeon (1.9%), and loggerhead shrike (1.1%) and most infrequently by burrowing owl (0.4%), swallows (0.2%), and rough-legged hawk (*Buteo lagopus*; 0.1%), among others (Table 1).

Among species we observed ≥ 10 times, the ratio of flights ≤ 50 m from turbines to number of birds observed per session was greatest for ferruginous hawk (*Buteo regalis*; 3.17), followed by common raven (1.36), red-tailed hawk (1.33), northern harrier (1.29), prairie falcon (*Falco mexicanus*; 1.27), American kestrel (1.26), turkey vulture (1.07), and golden eagle (0.97). Bird species with the smallest ratios included tricolored blackbird (0.00), gulls (0.02), band-tailed pigeon (0.03), blackbirds (0.04), mountain bluebird (0.05), and house finch (0.06).

The most commonly recorded flight behaviors included flying through the plot (61%), soaring (16%), and gliding (2%), followed by ground-hopping, flocking, and circling–searching (Table 2). Contouring, diving, fleeing while being mobbed, and being flushed were the rarest behaviors (<1% each). Considering total flight time per observation, the

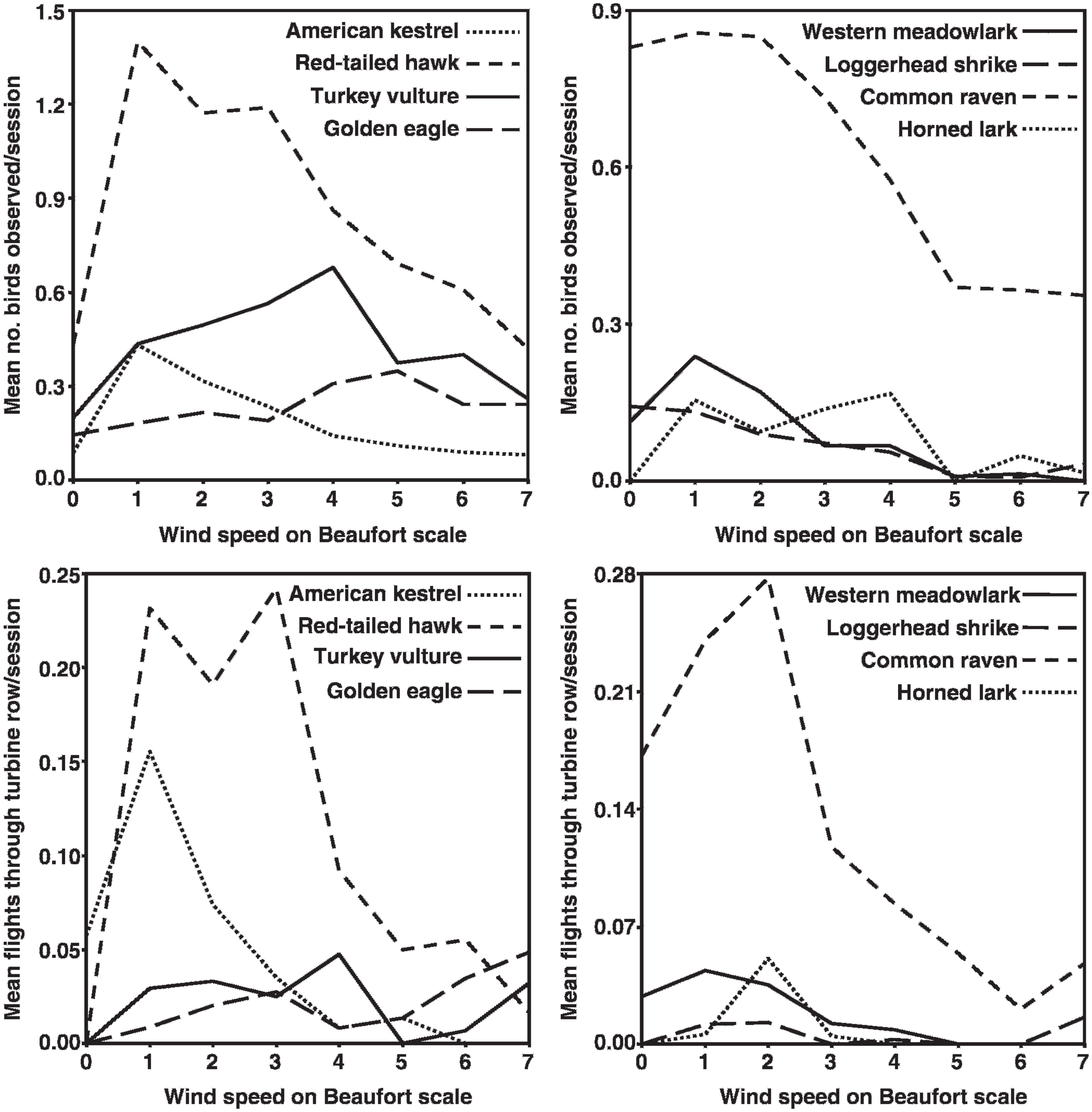


Figure 7. Mean number of birds observed and mean number of passes through the turbine row in relation to wind speed for various select species of birds in the Altamont Pass Wind Resource Area, California, USA, from 1998–2000.

most common behaviors were flying through (77%), column soaring (9%), flocking, and ground-hopping, and the rarest behaviors were diving, fleeing while being mobbed, and being flushed (Table 3).

For some species, operational status of the nearest turbine roughly corresponded with time spent flying to travel, forage, or interact with other birds while within the turbine rotor zone (Table 4). For example, golden eagles were traveling during almost 75% of total recorded time, but 9% of their time was shifted to foraging behaviors (i.e., hovering and contouring) while within the rotor zone, and we saw them interacting with other birds when the nearest turbine was operating. We observed substantial increases in time spent foraging (i.e., hovering, kiting, and diving) of red-tailed hawk (40%), prairie falcon (28%), and American kestrel (25%) while within the rotor zone of operating turbines (Table 4), likely because winds were stronger while turbines operated. Northern harriers spent 29% more of their flight time traveling (i.e., from low contour flights to straight fly-through) while moving through the rotor zone, no matter whether turbines were on.

Table 2. Flight behaviors recorded per bird observation during 1,958 sessions in the Altamont Pass Wind Resource Area, California, USA, 1998–2000.

Flight behaviors	% of observations[a]													
	All birds	GOEA	RTHA	NOHA	PRFA	AMKE	BUOW	TUVU	CORA	MALL	LOSH	WEME	HOLA	ROPI
Soar	4	38	28	24	9	3	3	27	7	0	0	0	0	<1
Column soar	12	<1	<1	0	2	0	0	0	0	0	0	0	0	0
Fly through	61	12	18	35	42	40	41	23	60	97	54	74	71	96
Glide	2	24	15	12	16	4	3	35	10	0	1	3	0	0
Surf	2	2	1	1	2	1	0	<1	3	0	3	0	11	0
Contour	<1	7	<1	17	0	0	0	<1	<1	0	0	0	0	0
Circle–search	3	10	13	8	13	6	0	14	10	0	0	0	0	2
Kite–hover	1	1	19	3	5	18	0	0	1	0	5	0	0	0
Fly-catch	<1	0	0	0	0	2	0	0	<1	0	1	0	0	0
Dive	<1	1	1	0	6	6	3	<1	<1	0	10	0	0	0
Ground hop	7	<1	1	0	2	1	19	<1	2	0	9	17	8	<1
Short flights	2	0	1	0	0	9	32	<1	5	1	11	6	5	2
Display	1	<1	1	0	2	2	0	0	1	0	4	0	5	0
Flocking	6	0	0	0	0	0	0	0	0	0	0	0	0	0
Mob	<1	<1	1	0	2	6	0	0	1	0	0	0	0	0
Mobbed–flee	<1	1	1	0	2	1	0	0	<1	0	1	0	0	0
Flushed	<1	3	1	0	0	1	0	0	<1	1	1	0	0	0
Total no.	46,568	426	1,642	124	64	358	37	971	1,240	79	80	178	205	514

[a] AMKE = American kestrel, BUOW = burrowing owl, CORA = common raven, GOEA = golden eagle, HOLA = horned lark, LOSH = loggerhead shrike, MALL = mallard, NOHA = northern harrier, PRFA = prairie falcon, ROPI = rock pigeon, RTHA = red-tailed hawk, TUVU = turkey vulture, and WEME = western meadowlark.

Table 3. Total minutes of flight behaviors recorded during 1,958 observation sessions in the Altamont Pass Wind Resource Area, California, USA, 1998–2000.

Flight behaviors	% of flight activity[a]													
	All birds	GOEA	RTHA	NOHA	PRFA	AMKE	BUOW	TUVU	CORA	MALL	LOSH	WEME	HOLA	ROPI
Soar	2	45	23	32	11	2	2	31	8	0	0	0	0	<1
Column soar	9	<1	0	0	2	0	0	0	0	0	0	0	0	0
Fly through	77	6	8	20	39	27	9	13	51	98	47	57	56	74
Glide	1	23	11	7	17	8	1	29	14	0	1	2	0	0
Surf	<1	2	<1	<1	3	1	0	<1	2	0	4	0	18	0
Contour	<1	9	<1	28	0	0	0	0	0	0	0	0	0	0
Circle–search	1	9	13	9	12	11	0	26	13	0	0	0	0	3
Kite–hover	1	1	37	3	4	28	0	0	1	0	4	0	0	0
Fly-catch	<1	0	0	0	0	5	0	0	0	0	1	0	0	0
Dive	0	1	1	0	6	5	1	0	<1	0	7	0	0	0
Ground hop	3	<1	4	0	2	1	4	<1	1	0	23	37	19	<1
Short flights	<1	0	1	0	0	5	83	<1	5	1	8	4	4	23
Display	1	1	1	0	1	1	0	0	1	0	3	0	4	0
Flocking	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Mob	0	<1	1	0	2	5	0	0	2	0	0	0	0	0
Mobbed–flee	0	1	1	0	2	1	0	0	<1	0	1	0	0	0
Flushed	0	1	<1	0	0	1	0	0	0	1	1	0	0	0
Total no.	363,186	1,366	6,724	293	116	746	183	2,420	2,318	83	137	258	262	694

[a] AMKE = American kestrel, BUOW = burrowing owl, CORA = common raven, GOEA = golden eagle, HOLA = horned lark, LOSH = loggerhead shrike, MALL = mallard, NOHA = northern harrier, PRFA = prairie falcon, ROPI = rock pigeon, RTHA = red-tailed hawk, TUVU = turkey vulture, and WEME = western meadowlark.

Table 4. Distribution of percentage of time we observed species performing flights typical of traveling or foraging (i.e., soaring, column soaring, flying through, gliding), foraging (i.e., surfing, contouring, circling–searching, kiting, hovering, fly-catching, diving, ground hopping), and interacting with other birds in a non-predatory manner (i.e., short flights, display, flocking, mobbing, being mobbed, fleeing, flushed) in the Altamont Pass Wind Resource Area, California, USA, 1998–2000.

	Total flight min (%)			Flight time in rotor zone of nonmoving turbine (%)			Flight time in rotor zone of operating turbine (%)		
Species	**Travel**	**Forage**	**Interact**	**Travel**	**Forage**	**Interact**	**Travel**	**Forage**	**Interact**
Golden eagle	74.7	22.7	2.6	68.3	31.7	0.0	60.0	32.7	7.3
Red-tailed hawk	44.2	52.3	3.5	59.4	38.7	1.9	18.1	79.6	2.3
Northern harrier	59.7	40.3	0.0	88.2	11.8	0.0	88.9	10.1	0.0
Prairie falcon	69.0	26.7	4.3	70.6	17.6	11.8	54.5	45.5	0.0
American kestrel	38.2	49.9	11.9	36.1	51.0	13.0	15.2	75.8	9.1
Burrowing owl	12.0	4.9	83.1	0.0	0.0	100.0	0.0	0.0	0.0
Turkey vulture	72.9	27.0	0.1	79.3	20.7	0.0	71.7	28.3	0.0
Common raven	73.3	17.8	8.9	66.6	23.2	10.2	82.8	4.6	12.6
Mallard	97.6	0.0	2.4	100.0	0.0	0.0	0.0	0.0	0.0
Loggerhead shrike	47.4	40.1	12.4	16.7	41.7	41.7	0.0	0.0	0.0
Western meadowlark	58.9	37.2	3.9	100.0	0.0	0.0	100.0	0.0	0.0
Horned lark	55.7	36.6	7.6	100.0	0.0	0.0	0.0	0.0	0.0
Rock pigeon	74.2	2.9	22.9	72.2	5.6	22.2	86.4	6.8	6.8

We recorded most (83%) burrowing owl flights as interacting with other birds (Table 4), but probably included short foraging flights in addition to interactions with conspecifics. However, we recorded no burrowing owl flights within the rotor zone while the nearest turbine was operating. Both turkey vulture and common raven demonstrated no substantial shifts in flight behaviors within rotor zones (Table 4), but it was also difficult to discern when either of these species was foraging rather than traveling. Mallards (*Anas platyrhynchos*) traveled through study plots 98% of the time, but we did not see them flying through the rotor zone of operating turbines. Loggerhead shrike and horned lark also avoided the rotor zone of operating turbines, but loggerhead shrikes were much more interactive with other birds while within the rotor zone of nonoperating turbines. Western meadowlarks flew through rotor zones, but their flights typified traveling behavior. Rock pigeons were 15% less interactive with other birds while in the rotor zone of operating turbines (Table 4).

Eight species spent $\geq 25\%$ of their perching time on wind turbines and their towers when turbines were broken or not operating (Table 5). Some birds, including golden eagle, prairie falcon, burrowing owl, and house finch, never perched on operating wind turbines, whereas they did perch on nonoperating turbines (Table 5). Red-tailed hawk, American kestrel, common raven, loggerhead shrike, and western meadowlark perched on operating turbines 1–3% of the time but perched on nonoperating turbines 26–52% of the time. Overall, observations of birds perched on turbines were 22 times more common while the turbines were not operating than when operating (Table 5), though this difference did not factor in the

Table 5. Distribution of perch time among select species observed in the Altamont Pass Wind Resource Area, California, USA, 1998–2000.

		Time perching (%)						
Species	**Total min**	**Operating wind turbine[a]**	**Nonoperating wind turbine[b]**	**Power pole**	**Landscape element**	**Transmission tower**	**Electric distribution line**	**Ancillary structure**
Golden eagle	1,003	0	3	26	41	23	4	4
Turkey vulture	96	0	0	0	89	0	11	0
Red-tailed hawk	8,799	1	47	15	18	4	12	3
Northern harrier	86	0	1	0	99	0	0	0
Prairie falcon	83	0	17	12	28	13	30	0
American kestrel	2,239	2	42	5	6	1	39	4
Burrowing owl	1,438	0	4	2	86	8	0	0
Common raven	1,904	3	52	9	20	1	12	2
European starling	2,140	11	76	0	0	0	9	3
House finch	13,525	0	54	0	0	0	45	1
Loggerhead shrike	698	1	26	8	9	0	50	6
Rock pigeon	128	20	65	1	0	0	1	13
Western meadowlark	450	2	50	1	15	0	28	4
Horned lark	409	0	0	0	100	0	0	0
Total	93,366	1	22	2	45	1	13	17

[a] Includes tower structure and all other components of turbine.
[b] Includes towers supporting turbines that are broken, missing, or functional but not operating.

Table 6. We fit models to average number of birds per session per 100 ha within 100-m intervals of distances between the observation point and turbine rows in the Altamont Pass Wind Resource Area, California, USA, 1998–2000.

Species or group	Regression model	*P*	r^2	SE	*a*	*b*	Distance from observer before detections at 100 m can be predicted to be fewer by 25%	75%
Turkey vulture	Inverse	<0.001	0.97	6.96	−3.373	13,200.123	132	372
Golden eagle	Inverse	<0.001	0.95	3.34	0.485	4,981.640	134	412
Red-tailed hawk	Linear	<0.001	0.93	10.63	122.970	−0.118	332	807
Northern harrier	Linear	<0.050	0.83	1.26	8.541	−0.009	316	738
Prairie falcon	Inverse	<0.001	0.95	1.08	−1.508	1,580.734	109	271
American kestrel	Logarithmic	<0.001	0.98	2.17	127.902	−18.509	178	563
Burrowing owl[a]	Power	<0.050	0.52	0.70	776.740	−0.927	136	446
Common raven	Linear	<0.001	0.85	14.19	103.251	−0.103	325	777
Gull spp.	Inverse	<0.001	0.98	377.92	−954.093	811,838.861	105	252
Mallard	Logarithmic	<0.050	0.70	2.28	29.740	−4.454	168	473
Medium-sized birds	Logarithmic	<0.001	0.96	4.51	194.431	−28.399	175	537
Non-gull spp.	Linear	<0.050	0.66	327.20	1,405.766	−1.421	322	767
Rock pigeon	Logarithmic	<0.001	0.90	5.85	153.008	−22.600	172	507
Mourning dove	Logarithmic	<0.050	0.58	0.60	6.048	−0.916	165	447
Loggerhead shrike	Inverse	<0.001	0.96	1.50	−2.266	2,549.385	130	316
Horned lark	Inverse	<0.001	0.90	2.82	−2.998	2,858.643	129	304
Western meadowlark	Inverse	<0.001	0.84	9.88	−10.973	7,648.279	127	280
Small-bodied birds[b]	logarithmic	<0.050	0.88	127.89	2,957.651	−427.548	178	567

[a] We added the value 1 to number of burrowing owls to prevent taking the log of 0.
[b] We held out record at 600 m as an outlier.

percentage of time during sessions when turbines were not operating.

Rates of Utilization and Fatalities Compared Spatially

Among all species, the largest correlation coefficient was 0.35 between fatality rates at turbine rows and utilization rates (i.e., no. of individuals observed/session/100 ha), so we did not report statistical test results. However, utilization rates among turbine rows declined with increasing distance between the observer and turbine row, indicating a substantial bias (Table 6; Fig. 8). Using models that best fit the data (i.e., homoscedastic pattern in the residuals, smallest root mean square error, and largest r^2 value), distances were much shorter at which predicted utilization rates declined to 25% and 75% of the observed rates at 0–100 m among small-bodied species, for the most part. Utilization rates declined rapidly with distance from observer for gulls, and steeply for golden eagles, turkey vultures, and prairie falcons, whereas rates for northern harriers and common ravens were less responsive to distance from the observer (Table 6).

We saved the unstandardized residuals from utilization rates regressed on distance of turbine row from observer (models in Table 6), and we related these residuals to fatality rates. However, the residuals did not explain variation in fatality rates among turbine rows for any bird species (all $r^2 < 0.1$, $P > 0.25$).

At the plot scale, utilization rate declined with increasing plot size (ha) for turkey vulture ($r = -0.70$, $P < 0.001$), red-tailed hawk ($r = -0.65$, $P < 0.001$), common raven ($r = -0.55$, $P < 0.001$), and American kestrel ($r = -0.44$, $P < 0.05$), but not for any other species. For these 4 species with significant correlations with plot size, we fit regression models and tested unstandardized residuals for a correlation with fatality rate among plots (Table 7). Fatality rate correlated with utilization rate only for all birds as a group ($r = 0.46$, $P < 0.05$), burrowing owl ($r = 0.54$, $P < 0.001$), and mallard ($r = 0.60$, $P < 0.001$). Fatality rate did not change with residuals from models fit for turkey vulture, red-tailed hawk, common raven, and American kestrel.

Behaviors and Fatality Rates

Mean monthly fatality rate of birds as a group increased with increasing flights/session through turbine rows (Fig. 9):

$$F_1 = 0.527 + 0.0876 \times U_T$$

and

$$F_2 = 0.911 + 0.631 \times U_T,$$

where F_1 represented October through April ($r^2 = 0.88$, root mean square error [RMSE] = 0.102, df = 1, 6, $P < 0.05$), F_2 represented May through September ($r^2 = 0.77$, RMSE = 0.041, df = 1, 4, $P < 0.05$), and U_T was utilization of turbine rows, or number of flights/session through the turbine row.

Mean monthly fatality rate of red-tailed hawks increased with increasing utilization rate, or the flights/session (Fig. 10):

$$F_3 = 0.033 + 0.029 \times \ln U,$$

where F_3 was mean monthly fatality rate of red-tailed hawks and U was utilization rate of the APWRA ($r^2 = 0.67$,

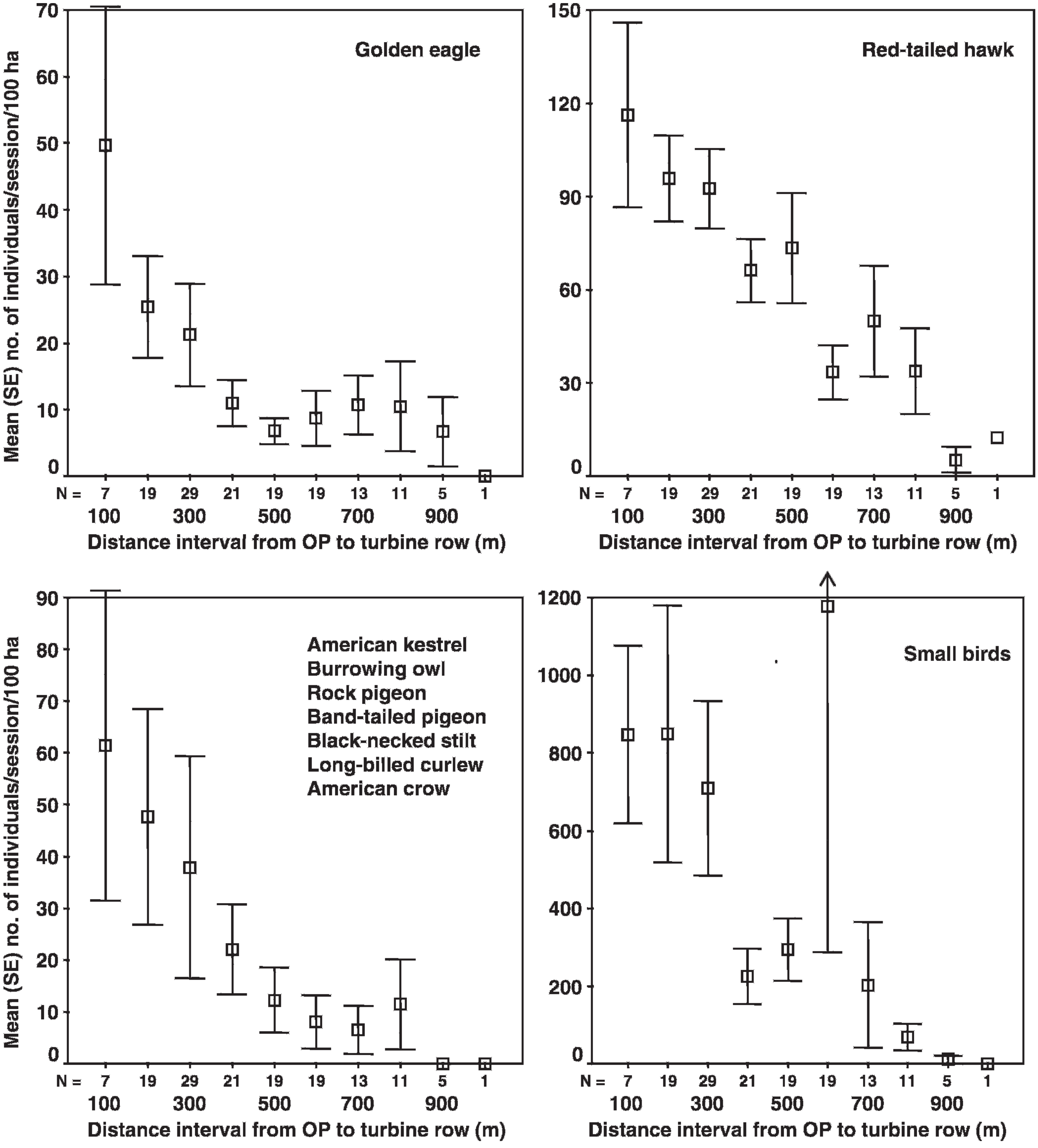


Figure 8. Utilization rates declined with increasing distance between wind turbine row and observer for golden eagles (top left), red-tailed hawks (top right), medium-sized birds (lower left), and small birds (bottom right), where distances were average distances to wind turbines in the row and aggregated to 100-m intervals in the Altamont Pass Wind Resource Area, California, USA, 1998–2000.

RMSE = 0.011, df = 1, 10, $P < 0.01$). Mean monthly fatality rate increased with number of flights per session through turbine rows (Fig. 10):

$$F_4 = 0.0512 - \frac{0.0017}{U_T}$$

and

$$F_5 = -0.0474 + 1.3010 \times U_T,$$

where F_4 represented October through April ($r^2 = 0.92$, RMSE = 0.006, df = 1, 6, $P < 0.001$), F_5 represented May through September ($r^2 = 0.92$, RMSE = 0.007, df = 1, 4, $P < 0.01$), and U_T was utilization of turbine rows, or number of flights/session through the turbine row.

Table 7. We fit models fit to average number of birds per session per 100 ha compared to plot size (ha) in the Altamont Pass Wind Resource Area, California, 1998–2000.

Species	Regression model	P	r^2	SE	a	b	Plot size (ha) before detections in 23 ha can be predicted to be fewer by	
							25%	75%
Turkey vulture	Logarithmic	<0.001	0.52	20.24	219.567	−40.970	40	122
Red-tailed hawk	Logarithmic	<0.001	0.45	32.34	323.057	−56.939	43	154
American kestrel	Logarithmic	<0.001	0.21	12.13	70.513	−12.018	46	178
Common raven	Linear	<0.001	0.23	29.09	93.943	−0.455	69	161

Mean monthly fatality rate of American kestrels correlated positively with rate of flights within 50 m of wind turbines ($r = 0.68$, $n = 12$, $P < 0.05$) and with number of flights/session through the turbine row ($r = 0.61$, $n = 12$, $P < 0.05$). Mean monthly fatality rates of golden eagles and burrowing owls did not correlate with rates of particular behaviors. Mean monthly fatality rate of western meadowlarks correlated with number of flights/session within 50 m of turbines while at rotor height ($r = 0.60$, $n = 12$, $P < 0.05$).

Fatality rate among plots correlated weakly with frequency of close flights per session per hectare for all birds as a group ($r = 0.38$, $P < 0.05$) but not for any individual species. Fatality rate did not correlate with frequency of hazardous flights made by any species or species group.

Fatality rate increased linearly with rates of utilization (i.e., birds/hr) and specific flight behaviors (i.e., flights/hr) of large raptors and small birds other than raptors within plots where we monitored behaviors (Fig. 11; Table 8). These increases in fatality rate were much faster among small birds than among large raptors, including 3.6 times faster for utilization, 5 times faster for flight time, 37 times faster for flights within 50 m of turbines, and 29 times faster for flights that cross the turbine row (Table 8). Relating fatality rate to rates of utilization and behaviors while birds were at blade height resulted in nonsignificant linear regression models for small birds but increased fatality rates among large raptors. Regressing fatality rate of large raptors on rates of behaviors performed at the heights of the turbine blades resulted in slope coefficients that were 3.5 times larger for utilization, 2.6 times larger for flight time, 7 times larger for flights within 50 m of turbines, and 0.7 times larger for flights through the turbine rows (Table 8).

Large-raptor fatality rate increased fastest with increasing number of flights/hour made by the species at blade height through turbine rows, followed by flights/hour at blade height within 50 m of turbines, and by number of birds/hour counted at blade height (Table 8). Small-bird fatality rate increased with increasing flights/hour made by species through turbine rows, followed by flights/hour within 50 m of turbines. Fatality rates of both large raptors and small birds were least responsive to amount of time species were observed perching/hour.

Whereas utilization (i.e., birds/hr) and recorded behaviors/hour explained nearly all variation in large-raptor fatality rate ($r^2 = 0.99–1.00$), they explained much less of the variation in small-bird fatality rate (Table 8). Number of flights close to turbines was the best predictor of small-bird fatality rate. Three species of small birds were consistent outliers in regressions of fatality rate on behaviors, and we therefore held them out of regression models. These consistent outliers were western meadowlark, mourning dove, and European starling and, compared with the other species of small birds, they died at wind turbines at rates much higher than we observed them during behavior monitoring. American kestrel and burrowing owl also fit none of the patterns observed for small birds and large raptors, and neither did medium- and large-sized species other than raptors, including mallard, gulls, and common raven.

Among species recorded diving toward the ground (i.e., foraging), fatality rate correlated with diving behavior in terms of number of minutes ($r = 0.85$, $n = 7$, $P < 0.05$) and number of individuals ($r = 0.98$, $n = 7$, $P < 0.001$) per hour. Among species observed fly-catching (i.e., foraging), fatality rate correlated with fly-catching in terms of number of minutes ($r = 0.93$, $n = 5$, $P < 0.05$) and number of individuals ($r = 0.88$, $n = 5$, $P < 0.05$) per hour. Among

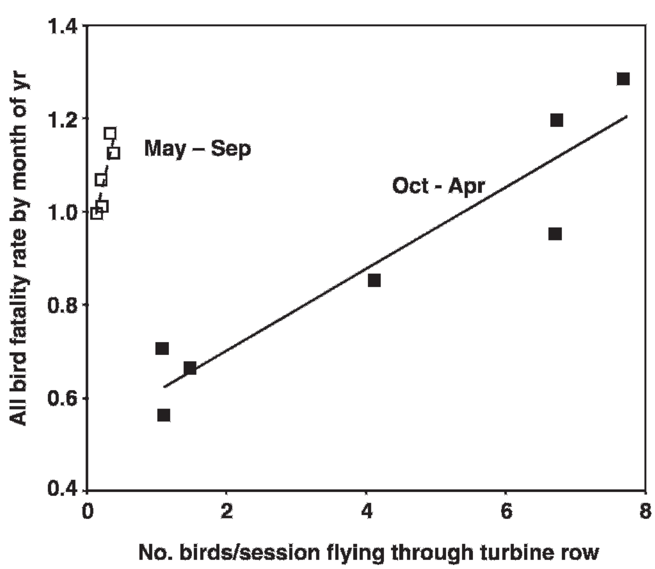


Figure 9. Adjusted fatality rate estimates of all birds increased with number of birds observed flying through turbine rows during observation sessions in the Altamont Pass Wind Resource Area, California, USA, 1998–2000.

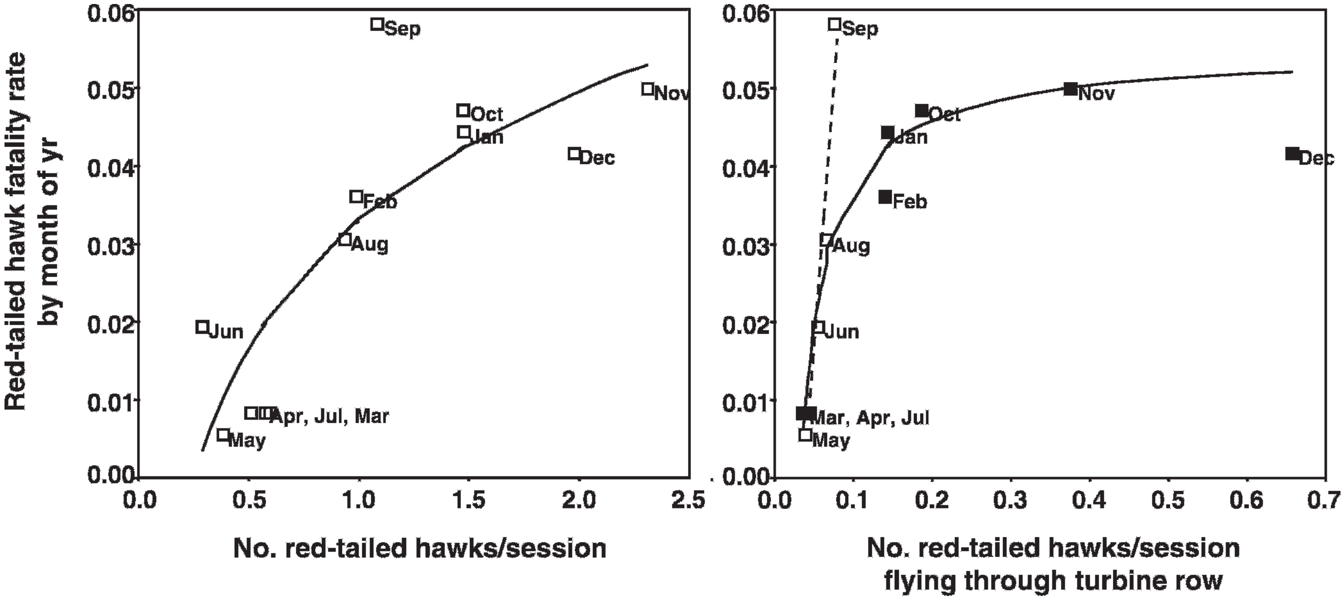


Figure 10. Mean monthly fatality rate estimates of red-tailed hawks increased with utilization rate (left) and rate of flights through turbine rows (right) during observation sessions in the Altamont Pass Wind Resource Area, California, USA, 1998–2000.

species observed hovering, fatality rate correlated with number of birds per hour that were hovering ($r = 0.71$, $n = 9$, $P < 0.05$).

DISCUSSION

Our results did not refute our hypothesis that birds lose track of wind turbines while focused on diving for prey items, fly-catching, and hovering. Those species more often expressing these directed foraging behaviors appeared to be more susceptible to wind turbine collisions. Periods of focused foraging comprised lapses in what otherwise appeared to be nearly constant caution of operating wind turbines by birds in the APWRA. Caution was demonstrated by birds rarely perching on towers of operating turbines and spending less time flying within 50 m of turbines as turbine operations increased through the observation session or seasonally. Northern harrier showed particular caution around wind turbines, switching to traveling flights only while flying within 50 m of turbines or crossing turbine rows, regardless of whether turbines were operating. However, the greater time golden eagle, red-tailed hawk, American kestrel, and prairie falcon spent foraging within the rotor zone of operating turbines probably countered the caution they exercised most of the time.

Another suite of behaviors that corresponded with higher fatality rates was interactions with other birds while in the rotor zone. Golden eagles often displayed territorial behaviors towards younger conspecifics and other raptors while in the rotor zone of operating turbines. Burrowing owls, loggerhead shrikes, rock pigeons, and American kestrels experienced high fatality rates, and we observed these species interacting with other birds while in the rotor zone nearest nonoperating turbines or vacant towers. Interaction behaviors are also distracting, and could lead to collisions with turbines operating adjacent to the nonoperating turbines or with the blades of nonoperating turbines that are allowed to move in the wind (termed feathering).

At wind speeds >1.5 m/sec, birds generally spent increasingly less time in the air with increasing wind speeds. However, of the birds that were flying in these winds, more flew within 50 m of turbines as wind speed increased. In strong winds, the proportion of birds flying within 50 m of wind turbines peaked, and this is when most wind turbines can be seen operating and when birds typically experience the most trouble controlling their flights. We hypothesize that collision risk increases for birds flying in high winds within the APWRA.

As previously hypothesized, collision rates corresponded with utilization rates, especially among small-bodied, non-raptor species and among large raptors flying at blade height. Outliers among interspecific comparisons between fatality rates and rates of utilization and specific flight behaviors included burrowing owl, American kestrel, western meadowlark, European starling, mourning dove, and medium- and large-sized birds other than raptors. For these species, we may have missed the rates of utilization and flight behaviors that matter most, such as nocturnal utilization and behaviors, which would matter if these species were killed mostly at night. This was certainly true of strictly nocturnal species, such as barn owl (*Tyto alba*) and great horned owl (*Bubo virginianus*), which we found dead, but that were unobserved during surveys.

We found that fatality rate precisely related to seasonal utilization of the APWRA by red-tailed hawk and that it related to frequency of flights through turbine rows by red-tailed hawks and all birds as a group. Flights through turbine rows during late spring and summer appeared especially deadly, resulting in steep slopes between fatality rate and flights through turbine rows. Also, mean monthly

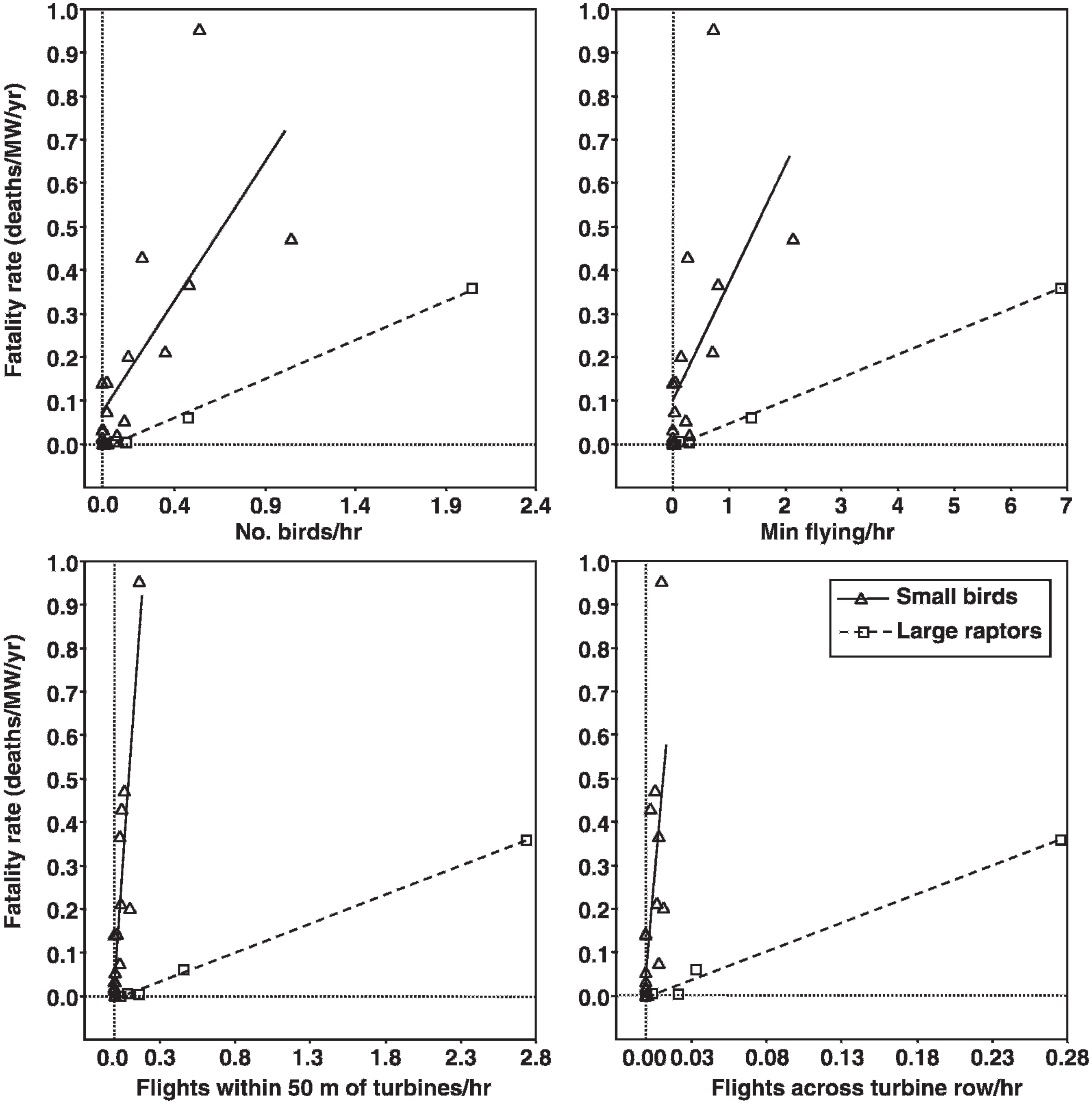


Figure 11. Response of mean adjusted fatality rate at wind turbines to rates of utilization and flight behaviors in the Altamont Pass Wind Resource Area, California, USA, 1998–2002 (fatality rate) and 1998–2000 (behavior).

fatality rates of American kestrels correlated with flights in the rotor zone, and those of western meadowlark did so while flights were at rotor height.

Contrary to correlations we observed between fatality and utilization rates both inter-specifically and seasonally, we failed to find strong correlations when we compared these rates spatially. Spatial comparisons of these rates were likely confounded by variable plot sizes and the strong decreases in utilization rates with increasing distance from the observer of the turbine rows. However, even after accounting for the effect of distance from the observer, fatality rates still did not correlate with utilization rates among turbine rows. Among observation plots, fatality and utilization rates correlated only for burrowing owl, mallard, and all birds as a group.

Orloff and Flannery (1992) found no relationship between fatality and utilization rates among their observation plots in the APWRA, which was consistent with our finding for most species examined. Perhaps these fatality and utilization rates do not correlate spatially, but we suspect the correlation eluded us and Orloff and Flannery (1992) due to the strong, species-specific effect of distance from the observer on estimating utilization rates. We failed to record small-bodied bird species beyond 400 m or 500 m, whereas

Table 8. Models of mean adjusted fatality rate (deaths/megawatt/yr) regressed on rates of utilization and bird flights and perching among observation plots in the Altamont Pass Wind Resource Area, California, USA, during 1998–2002 (fatality rate) and 1998–2000 (behavior).

Fatality rate	Observation records/hr	r^2	SE	*P*	*a*	*b*
Large raptors	No. birds	1.00	0.01	<0.001	−0.0081	0.1770
	Flight time	1.00	0.01	<0.001	−0.0046	0.0524
	Perch time	1.00	0.01	<0.001	0.0032	0.0390
	Close flights	1.00	0.01	<0.001	−0.0052	0.1330
	No. birds at blade ht	1.00	0.01	<0.001	−0.0006	0.6220
	Flight time at blade ht	0.99	0.01	<0.001	0.0044	0.1360
	Close flights at blade ht	0.99	0.01	<0.001	0.0025	0.9330
	Crossing turbines at blade ht	0.99	0.02	<0.001	0.0022	2.4270
Small birds	No. birds	0.52	0.18	<0.01	0.0734	0.6370
	Flight time	0.35	0.21	<0.05	0.1030	0.2680
	Perch time	0.13	0.25	>0.05	0.1600	0.0254
	Close flights	0.77	0.13	<0.001	0.0400	4.9120
	Crossing turbines	0.42	0.20	<0.01	0.0624	38.4240

we often recorded some conspicuous birds 800 m to 1,000 m distant. Due to this strong effect of distance from the observer, we also suggest that past comparisons of fatality and utilization rates among wind farms were of dubious value (Erickson et al. 2001, Young et al. 2003, Smallwood and Thelander 2004, Johnson et al. 2006, Whitfield and Madders 2006). Comparisons of fatality and utilization rates between sites will probably yield no useful patterns until methods are standardized to account for how the size of the area surveyed affects utilization rates.

On the other hand, temporal comparisons of fatality and utilization rates were often significant, likely because comparing utilization in the same plot through time cancels the effect of distance between birds and observer. High seasonal variation in flight activity among species suggested to us that pre- and postconstruction utilization monitoring needs to span all seasons and probably should do so for several years to account for interannual variation in relative abundance of species. Erickson et al. (W. Erickson, Western Ecosystems Technology, Inc., unpublished report) concluded that bird observations are not needed beyond one season of the year, but we disagree. Had we restricted our observations to summer, for example, we would have grossly mischaracterized utilization of the APWRA by red-tailed hawk, golden eagle, burrowing owl, etc. Utilization and behavior surveys also need to be extended into the night to detect nocturnal species and diurnal species that sometimes may be active at night.

MANAGEMENT IMPLICATIONS

Managers can now use the relationships we reported between fatality and utilization rates to forecast avian fatality rates at proposed wind farms, so long as adequate preconstruction utilization surveys are performed and adjustments made for differences in local conditions and wind turbine model and size. For example, if a large-bodied raptor species was seen flying at blade height within a proposed wind farm at the rate of 10 birds/hour, then the appropriate model (Table 8) would predict a fatality rate of 6.2 birds/MW/year, assuming no effect of differences in turbine size between the APWRA and the proposed wind farm.

A seasonal shutdown of wind turbines would reduce fatality rates of some but not all species due to considerable interspecific variation in seasonal activity patterns. However, a seasonal shutdown, such as a winter shutdown in the APWRA, can make sense as a tradeoff measure, balancing bird fatality reductions with minimizing loss of power generation in the wind farm. Shutting down wind turbines during high wind speeds also might reduce fatality rates, but unknown effects of this measure would warrant an experimental implementation.

Because birds almost never perch on operating turbines, perching on them did not relate to fatality rates. However, some species with high fatality rates often interacted among defunct turbines and vacant towers, so removing vacant towers, repairing broken turbines, and synchronizing turbine operations within a row might help reduce hazardous use of the rotor zone, thereby reducing collisions. Another measure to minimize or reduce fatality rates would be to leave sufficiently large gaps between groups of turbines to allow birds to travel and forage without having to necessarily fly close to wind turbines.

ACKNOWLEDGMENTS

Our project was funded by the National Renewable Energy Laboratory (NREL). We thank K. Sinclair (NREL) for her guidance and support. We thank the field biologists who participated on the project, including S. Hoover, L. Burkholder, C. Burton, E. van Mantgen, T. Lim, J. Camp, L. Lacunza, D. Tsao, A. Harbin, A. Ballard, J. Phan, C. Szafranski, E. Harrington, M. Munnecke, J. Cain, J. Quinn, N. Tuatoo-Bartley, and J. Weisman. We thank S. Sutherland for his Geographic Information System and Global Positioning System support. Finally, we thank the management and field personnel of ENRON, FORAS, EnXco, SeaWest, Green Ridge Services, and Altamont Wind Power for providing logistical support and permission to access wind turbines that they owned, leased, managed, or maintained. We also thank Associate Editor L. Brennan and 2 anonymous reviewers for helpful comments on the manuscript.

LITERATURE CITED

Anderson, R., W. Erickson, D. Strickland, M. Bourassa, J. Tom, and N. Neumann. 2001. Avian monitoring and risk assessment at Tehachapi

Pass and San Gorgonio Pass Wind Resource Areas, California. Pages 31–46 *in* Proceedings of National Avian–Wind Power Planning Meeting III, San Diego, California, May 1998. Prepared for the Avian Subcommittee of the National Wind Coordinating Committee. LGL, King City, Ontario, Canada.

Anderson, R., N. Neumann, J. Tom, W. P. Erickson, M. D. Strickland, M. Bourassa, K. J. Bay, and K. J. Sernka. 2004. Avian monitoring and risk assessment at the Tehachapi Pass Wind Resource Area: period of performance: October 2, 1996–May 27, 1998. NREL/SR-500-36416, National Renewable Energy Laboratory, Golden, Colorado, USA.

Anderson, R., J. Tom, N. Neumann, W. Erickson, D. Strickland, M. Bourassa, K. J. Bay, and K. J. Sernka. 2005. Avian monitoring and risk assessment at the San Gorgonio Wind Resource Area. NREL/SR-500-38054, National Renewable Energy Laboratory, Golden, Colorado, USA.

Erickson, W. P., G. D. Johnson, M. D. Strickland, K. Kronner, P. S. Becker, and S. Orloff. 1999. Baseline avian use and behavior at the CARES Wind Plant Site, Klickitat County, Washington. Final report. NREL/SR-500-26902, National Renewable Energy Laboratory, Golden, Colorado, USA.

Erickson, W. P., G. D. Johnson, M. D. Strickland, D. P. Young, Jr., K. J. Sernka, and R. E. Good. 2001. Avian collisions with wind turbines: a summary of existing studies and comparisons to other sources of avian collision mortality in the United States. National Wind Coordinating Committee, c/o RESOLVE, Washington, D.C., USA.

Hoover, S. L., and M. L. Morrison. 2005. Behavior of red-tailed hawks in a wind turbine development. Journal of Wildlife Management 69:150–159.

Howell, J. A., J. Noone, and C. Wardner. 1991. Visual experiment to reduce avian mortality related to wind turbine operations, Altamont Pass, Alameda and Contra Costa counties, California, April 1990 through March 1991. Final report. Prepared for U.S. Windpower, Livermore, California, USA.

Hunt, W. G. 2002. Golden eagles in a perilous landscape: predicting the effects of mitigation for wind turbine blade-strike mortality. 500-02-043F. Consultant report to California Energy Commission, Sacramento, USA.

Janss, G., and A. T. Clave. 2000. Bird behavior in and near a wind farm at Tarifa, Spain: management considerations. Pages 110–114 *in* Proceedings of National Avian–Wind Power Planning Meeting III, San Diego, California, May 1998. Prepared for the Avian Subcommittee of the National Wind Coordinating Committee. LGL, King City, Ontario, Canada.

Johnson, G., W. P. Erickson, and J. D. Jeffrey. 2006. Analysis of potential wildlife impacts from the Windy Point Wind Energy Project, Klickitat County, Washington. Prepared for Energy and Environment, Portland, Oregon, USA.

Kerlinger, P. 2000. An assessment of the impacts of Green Mountain Power Corporation's Searsburg, Vermont, wind power facility on breeding and migrating birds. Pages 90–96 *in* Proceedings of National Avian–Wind Power Planning Meeting III, San Diego, California, May 1998. Prepared for the Avian Subcommittee of the National Wind Coordinating Committee. LGL, King City, Ontario, Canada.

Morrison, M. L. 1998. Avian risk and fatality protocol. NREL/SR-500-24997, National Renewable Energy Laboratory, Golden, Colorado, USA.

Orloff, S., and A. Flannery. 1992. Wind turbine effects on avian activity, habitat use, and mortality in Altamont Pass and Solano County Wind Resource Areas: 1989–1991. Report to California Energy Commission, Sacramento, USA.

Orloff, S., and A. Flannery. 1996. A continued examination of avian mortality in the Altamont Pass Wind Resource Area. Report to California Energy Commission, Sacramento, USA.

Reynolds, R. T., J. M. Scott, and R. A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. Condor 82:309–313.

Smallwood, K. S. 2007. Estimating wind turbine-caused bird mortality. Journal of Wildlife Management 71:2781–2791.

Smallwood, K. S., and C. Thelander. 2004. Developing methods to reduce bird mortality in the Altamont Pass Wind Resource Area. Final report to the California Energy Commission, Public Interest Energy Research–Environmental Area, Contract 500-01-019, Sacramento, USA.

Smallwood, K. S., and C. Thelander. 2005. Bird mortality at the Altamont Pass Wind Resource Area, March 1998–September 2001. Final report. NREL/SR-500-36973, National Renewable Energy Laboratory, Golden, Colorado, USA.

Smallwood, K. S., and C. G. Thelander. 2008. Bird mortality in the Altamont Pass Wind Resource Area, California. Journal of Wildlife Management 72:215–223.

Smallwood, K. S., C. G. Thelander, M. L. Morrison, and L. M. Rugge. 2007. Burrowing owl mortality in the Altamont Pass Wind Resource Area. Journal of Wildlife Management 71:1513–1524.

Strickland, M. D., W. P. Erickson, G. Johnson, D. Young, and R. Good. 2001*a*. Risk reduction avian studies at the Foote Creek Rim Wind Plant in Wyoming. Pages 107–114 *in* S. S. Schwartz, editor. Proceedings of the National Avian–Wind Power Planning Meeting IV. Avian Subcommittee of the National Wind Coordinating Committee, c/o RESOLVE, Inc., Washington, D.C., USA.

Strickland, M. D., G. Johnson, W. P. Erickson, and K. Kronner. 2001*b*. Avian studies at wind plants located at Buffalo Ridge, Minnesota and Vansycle Ridge, Oregon. Pages 38–52 *in* S. S. Schwartz, editor. Proceedings of the National Avian–Wind Power Planning Meeting IV. Avian Subcommittee of the National Wind Coordinating Committee, c/o RESOLVE, Inc., Washington, D.C., USA.

Whitfield, D. P., and M. Madders. 2006. A review of the impacts of wind farms on hen harriers *Circus cyaneus* and an estimation of collision avoidance rates. Natural Research Information Note 1 (revised), Natural Research, Banchory, United Kingdom.

Young, D. P., Jr., W. P. Erickson, M. D. Strickland, R. E. Good, and K. J. Sernka. 2003. Comparison of avian responses to UV-light-reflective paint on wind turbines. Subcontract report July 1999–December 2000. NREL/SR-500-32840, National Renewable Energy Laboratory, Golden, Colorado, USA.

Associate Editor: Brennan.

Rulemaking Petition to the U.S. Fish & Wildlife Service for Regulating the Impacts of Wind Energy Projects on Migratory Birds

Petitioner: AMERICAN BIRD CONSERVANCY

December 14, 2011

TABLE OF CONTENTS

GLOSSARY

ABC	American Bird Conservancy
ABPP	Avian and Bat Protection Plan
APA	Administrative Procedure Act, 5 U.S.C. § 500 et seq.
AWEA	American Wind Energy Association
AWWI	American Wind Wildlife Institute
BCC	Birds of Conservation Concern
BGEPA	Bald and Golden Eagle Protection Act, 16 U.S.C. §§ 668-668c
BMPs	Best Management Practices
BOEM	U.S. Bureau of Ocean Energy Management
BLM	U.S. Bureau of Land Management
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
ESA	Endangered Species Act, 16 U.S.C. § 1531 et seq.
FAA	Federal Aviation Administration
FACA	Federal Advisory Committee Act, 5 U.S.C. App. 2 §§1-16
FOIA	Freedom of Information Act, 5 U.S.C. § 552
FWS or Service	U.S. Fish and Wildlife Service
GAO	U.S. Government Accountability Office
GW	Gigawatt
HCP	Habitat Conservation Plan
ITP	Incidental Take Permit
MBTA	Migratory Bird Treaty Act, 16 U.S.C. § 703 et seq.
MOU	Memorandum of Understanding
MW	Megawatt
OCS	Outer Continental Shelf
Corps	U.S. Army Corps of Engineers

EXECUTIVE SUMMARY

Pursuant to the Administrative Procedure Act ("APA"), 5 U.S.C. § 553(e), and the implementing regulations of the U.S. Department of the Interior ("DOI"), 43 C.F.R. Pt. 14, American Bird Conservancy ("ABC"), hereby submits this Petition for Rulemaking to the U.S. Fish and Wildlife Service ("FWS" or "Service"), requesting the agency to promulgate regulations governing the impacts of wind energy projects on migratory birds. In particular, ABC petitions FWS to establish a permitting scheme that would regulate the impacts of wind power projects on migratory birds. As discussed in this Petition, such a scheme is clearly authorized by the Migratory Bird Treaty Act ("MBTA"), 16 U.S.C. § 703 et seq., would significantly improve the protection of birds covered by the MBTA, and would afford the wind power industry a degree of regulatory and legal certainty that cannot be provided in the absence of such a scheme.

ABC recognizes that properly sited and operated wind energy projects may be an important part of the solution to climate change, a phenomenon that indisputably poses an unprecedented threat to species and ecosystems. However, such projects also pose a serious threat to various species of birds, including large birds of prey and raptors such as the Bald Eagle, Golden Eagle, Ferruginous Hawk, Swainson's Hawk, American Peregrine Falcon, Short-eared Owl, and Flammulated Owl; endangered and threatened species such as the California Condor, Whooping Crane, Snail Kite, Marbled Murrelet, Hawaiian Goose, and Hawaiian Petrel; and other species of special conservation concern such as the Bicknell's Thrush, Sprague's Pipit, Cerulean Warbler, Oak Titmouse, Lewis's Woodpecker, Brewer's Sparrow, Long-billed Curlew, Bay-breasted Warbler, and Blue-winged Warbler. These species are impacted by existing wind energy projects and threatened by potential projects primarily through collision with wind turbines and associated power lines, and through loss or modification of essential habitat.

Based on the operation of approximately 22,000 turbines, FWS estimated in 2009 that at least 440,000 birds were killed each year by wind turbines. By 2020, there are expected to be more than 100,000 wind turbines in the United States and these are expected to kill at least one million birds each year, an estimate that ABC believes will be exceeded significantly. Further, wind energy projects are also expected to impact almost 20,000 square miles of terrestrial habitat, and another 4,000 square miles of marine habitat.

The MBTA, Endangered Species Act ("ESA"), 16 U.S.C. § 1531 et seq., and the Bald and Golden Eagle Protection Act ("BGEPA"), 16 U.S.C. §§ 668-668c, prohibit "take" of migratory birds, endangered and threatened species, and Bald and Golden Eagles. 50 C.F.R. § 10.12 (implementing regulations defining the term "take" to include to wound or kill, or to attempt to wound or kill). Bald and Golden Eagles are protected under both MBTA and BGEPA, and many species listed under the ESA are also protected under the MBTA, such as Whooping Cranes, California Condors, Least Terns, Kirtland's Warblers, Northern Aplomado Falcons, Roseate Terns, and Piping Plovers. While the ESA and BGEPA provide mechanisms for FWS to regulate, and in some instances authorize, take of endangered and threatened species and Bald and Golden Eagles respectively, at present no such comparable mechanism exists under the MBTA to authorize incidental take by wind power projects.

This reality is particularly significant for the wind industry because wind energy projects will inevitably take birds protected under the MBTA. In fact, because it is virtually impossible to operate a wind energy project without killing or injuring at least some migratory birds, most wind energy projects that are already in operation are in ongoing violation of the take prohibition of the MBTA. In addition, FWS itself is aware of other projects that are being planned that will also take migratory birds in violation of federal law.

FWS has prepared "voluntary" Guidelines in an attempt to address the impacts of wind energy projects on migratory birds instead of imposing mandatory regulatory obligations on wind energy projects to anticipate and avoid such impacts before they occur. By allowing the industry itself to make siting decisions in this manner, FWS has permitted widespread disregard for legal mandates the Service is entrusted to enforce. Further, while the Guidelines essentially treat the agency as a quasi-permitting authority requiring it to evaluate extensive information and provide advice to the developers, unlike a formal permitting system, FWS neither obtains appropriate permit fees (which typically provide some amount of resources and revenue to the agency), nor does the wind industry obtain unequivocal regulatory certainty for incidental take of migratory birds.

Thus, as explained in this Petition, ABC supports "bird-smart" wind energy that employs careful siting, operation, construction, mitigation, bird monitoring, and compensation criteria, designed to reduce and redress any unavoidable bird mortality and habitat loss. ABC recognizes the need for renewable energy development and will support the wind industry in its efforts to extend the federal tax grant and production tax credit for wind energy production, if FWS puts in place a system that ensures ongoing compliance with the MBTA along with other wildlife protection laws.

In this Petition, ABC urges FWS to promulgate regulations establishing a mandatory permitting system for siting, constructing, and operating wind energy projects and mitigating of their impacts on migratory birds. The Petition first sets forth the factual basis establishing the need for such a system, i.e., the proliferation of wind energy projects and the significant adverse effects this development is having and will increasingly have on migratory birds, particularly those of conservation concern. Then the Petition describes the legal framework under which FWS has more than sufficient authority to promulgate MBTA regulations specifically aimed at encouraging the development of wind power in a manner that ameliorates, to the extent practicable, the adverse effects on migratory birds. Further, the Petition examines in detail the several benefits of the proposed permitting system. Finally, ABC offers specific regulatory language that would accomplish the objectives identified in this Petition.

A. PETITIONER: AMERICAN BIRD CONSERVANCY

This Petition for Rulemaking is submitted on behalf of ABC by Meyer Glitzenstein & Crystal, a Washington D.C.-based public interest law firm specializing in environmental and wildlife laws.[1]

Petitioner ABC is a 501(c)(3) non-profit organization whose mission is to conserve native birds and their habitats throughout the Americas. It achieves this by safeguarding the rarest bird species, restoring habitats, and reducing threats to bird species. ABC is the only U.S.-based group with a major focus on bird habitat conservation throughout the entire Americas. ABC has more than 8,000 individual members and 30,000 constituents. ABC's members, supporters, and activists enjoy viewing, studying, and photographing migratory birds. Some of its members and activists routinely observe migratory birds in states such as California, New York, Texas, Pennsylvania, Washington and Oregon, where rapid wind energy development poses a serious threat to such birds.

ABC is a leading organization working to reduce threats to birds from habitat destruction; from collisions with buildings, towers, and wind turbines; and from toxins such as hazardous pesticides and lead. ABC uses a variety of mechanisms to achieve these objectives including scientific research and analysis; advocating for bird conservation at the local, state, regional, and federal levels; forming bird conservation partnerships; and pressing for meaningful regulatory changes to address such threats effectively through various means, including rulemaking petitions and litigation. See, e.g., ABC v Fed. Commc'ns Comm'n, 516 F.3d 1027 (D.C. Cir. 2008) (in response to ABC's review petition seeking protection of migratory birds from collisions with communications towers, the court vacated a part of the order for violation of the National Environmental Policy Act ("NEPA"), 42 U.S.C. § 4321 et seq.). ABC's staff includes more than 20 scientists with expertise in migratory birds, over a dozen of whom have doctoral degrees. ABC's scientists have published in many reputed journals.[2]

---

[1] More information about Meyer Glitzenstein & Crystal is available at http://www.meyerglitz.com/.

[2] These journals include the Antarctic Journal of the United States, The Auk, Biodiversity Conservation, Biological Invasions, Biological Sciences, Bird Conservation International, Boletin SAO, Canadian Field Naturalist, Chelonion Research Monographs, Colonial Waterbirds, Condor, Cotinga, Ecological Applications, Ecology, Emu, Florida Field Naturalist, International Zoo Yearbook, Journal of Avian Medicine and Surgery, Journal of Field Ornithology, Journal of Raptor Research, Journal of Wildlife Diseases, Journal of Wildlife Management, Molecular Ecology, Neotropical Birding, North American Bird Bander, Oecologia, Ornitologiá Columbiana, Ornitologiá Neotropical, Oryx, Pacific Conservation Biology, Proceedings of the National Academy of Science, Proceedings of the Western Foundation of Vertebrate Zoology, Wilson Bulletin, Wilson Journal of Ornithology, and Zoo Biology.

ABC launched its "Bird-Smart Wind Program" to address the threats to birds and their habitats from wind energy development. ABC's Wind Program works to eliminate threats to birds and conserve habitat through the implementation of "Bird-Smart Wind Principles."[3] These Principles recognize that "bird-smart" wind energy is an important part of the solution to climate change. Bird-smart wind energy employs careful siting, operation, construction, mitigation, bird monitoring, and compensation criteria, designed to reduce and redress any unavoidable bird mortality and habitat loss. A key element of ABC's Bird-Smart Wind Principles is to work with FWS to establish appropriate mandatory federal standards for the siting, construction and operation of wind facilities. Thus, ABC believes that birds and wind power can co-exist, and that wind power can be "bird-smart," if the wind industry is held to mandatory standards that protect birds. More than 60 conservation groups, scientific societies, and businesses have endorsed ABC's Bird-Smart Wind Principles.[4]

ABC's experts have been extensively involved in studying and analyzing the impacts of wind energy, and its involvement in this issue predates the formation of the Wind Turbines Guidelines Federal Advisory Committee ("Wind FAC" or "Committee") established by DOI in 2007. For example, in 2005 ABC submitted comments on the Interim Guidance on Avoiding and Minimizing Impacts from Wind Energy prepared by FWS. In 2007, ABC's former Director of Conservation Advocacy, Dr. Michael Fry, testified before a Congressional subcommittee on the wildlife impacts of improperly sited wind energy projects.

Most recently, ABC has been actively involved in analyzing the ongoing preparation by FWS of voluntary guidelines for land-based wind energy projects. In this regard, ABC has attended every Wind FAC meeting, and has commented on each draft of the guidelines and the Wind FAC's recommendations.[5] ABC has also submitted comments during federal regulatory processes applicable to wind energy projects, including the FWS Draft Eagle Conservation Plan Guidance, the Great Plains Wind Energy Habitat Conservation Plan (scoping), the Desert Renewable Energy Conservation Plan (scoping), and the Mid-Atlantic Regional Environmental Assessment for Wind Leasing Areas (Delaware, Maryland, New Jersey, Virginia). ABC has also commented on

---

[3] ABC's "Bird-smart Wind Principles" are available at http://www.abcbirds.org/abcprograms/policy/collisions/wind_policy.html

[4] A list of these organizations is available at http://www.abcbirds.org/abcprograms/policy/collisions/wind_letters.html

[5] ABC's comments on all iterations of the Wind Guidelines and the Eagle Guidance are available here: http://www.abcbirds.org/abcprograms/policy/collisions/wind_letters.html

individual wind projects, such as Kaheawa Wind II (Maui), Kawailoa Wind (Oahu), and Baryonyx (offshore Texas).[6]

ABC submits this Petition for Rulemaking to FWS pursuant to the APA, 5 U.S.C. § 553(e), and implementing regulations of the DOI, 43 C.F.R. Pt. 14, requesting the agency to expeditiously promulgate regulations establishing a permitting scheme for proper siting, construction, and operation of wind energy projects to reduce and redress bird mortality and habitat loss. Pursuant to 43 C.F.R. § 14.2, this Petition for Rulemaking provides the text of the proposed rule as well as detailed reasons in support of the Petition. ABC requests that the Petition be given prompt consideration as required by applicable regulations. 43 C.F.R. § 14.3. As an initial step, ABC requests that notice of this Petition be published in the Federal Register for public comment. 43 C.F.R. § 14.4.

B. SPECIES INFORMATION

Migratory birds protected under the MBTA, 16 U.S.C. § 703 et seq., are facing serious threats and many are in rapid decline. About 30% of the birds protected by the MBTA are officially recognized by FWS as being in need of particular protection, including approximately 75 endangered and threatened species, and more than 240 species that are listed by FWS as Birds of Conservation Concern ("BCC"). See FWS, Birds of Conservation Concern (2008);[7] see also FWS, Summary of Listed Species Listed Populations and Recovery Plans (Nov. 21, 2011).[8] FWS is statutorily required to designate and maintain the BCC list pursuant to a 1998 amendment to the Fish and Wildlife Conservation Act of 1980, 16 U.S.C. § 2901 et seq., which requires the agency to "identify species, subspecies, and populations of all migratory nongame birds that, without additional conservation actions, are likely to become candidates for listing under the Endangered Species Act of 1973." Id. § 2912(a)(3). Only a handful of birds designated as BCC are not protected by the MBTA. Thus, nearly 1/3 of the birds protected by the MBTA are either listed under the ESA, 16 U.S.C. § 1531 et seq., or designated as in danger of being listed if action to prevent listing is not taken.

---

[6] ABC's comment letters are available here: http://www.abcbirds.org/abcprograms/policy/collisions/wind_letters.html

[7] Available at http://www.fws.gov/migratorybirds/NewReportsPublications/SpecialTopics/BCC2008/BCC2008.pdf. (last visited Nov. 20, 2011).

[8] Available at http://ecos.fws.gov/tess_public/pub/boxScore.jsp. (last visited Nov. 20, 2011).

Further, some common migratory birds that have not been officially designated as being of conservation concern are experiencing sharp population declines. According to the National Audubon Society, "[s]ince 1967 the average population of the common birds in steepest decline has fallen by 68 percent; some individual species nose-dived as much as 80 percent. All 20 birds on the national Common Birds in Decline list lost at least half their populations in just four decades." Nat'l Audubon Soc'y, Common Birds in Decline.[9] These declines indicate that birds in the United States are facing serious threats and potential extinction. For example, the fate of the Passenger Pigeon – once the most abundant bird in North America, with a population estimated in the billions, which was driven to extinction in fewer than 100 years – illustrates that even common birds can become extinct. T. D. Rich et al., Partners in Flight North American Landbird Conservation Plan: Part 1 The Continental Plan 4 (2004) ("N.A. Landbird Conservation Plan Part 1").[10]

Migratory birds face many threats including habitat loss, degradation and fragmentation; excessive logging and inappropriately managed forests; inappropriately or inadequately managed fires; hydrologic change to wetlands; exotic and invasive species; resource extraction and energy industry operations; overgrazing; climate change; contaminants and pesticides; prey resource depredation; human disturbance; long line and gill net fisheries; collisions with human-created structures; and intentional illegal killing. T. D. Rich et al., Partners in Flight North American Landbird Conservation Plan: Part 2 Conservation Issues 39 (2004) ("N.A. Landbird Conservation Plan Part 2");[11] see also Stephen Brown et al., United States Shorebird Conservation Plan 5 (2001) ("2001 U.S. Shorebird Conservation Plan");[12] Waterbird Conservation for the Americas, Waterbirds at Risk (Mar. 20, 2007).[13] Because there are serious threats to birds and such threats cumulatively pose even larger risks to their survival and conservation, it is important that action be taken to reduce each one.

ABC believes that threats to birds from wind energy development pose particular concern, especially because the industry is growing rapidly and projects are being frequently sited in important bird habitats. Wind energy is also recognized as a serious bird conservation issue in the North American Landbird Conservation Plan, which is an important conservation plan that has wide support throughout the bird conservation community. N.A. Landbird Conservation Plan Part 2 at 39,

---

[9] Available at http://web4.audubon.org/bird/stateofthebirds/cbid/ (last visited Nov. 20, 2011).

[10] Available at http://www.pwrc.usgs.gov/pif/cont_plan/PIF2_Part1WEB.pdf (last visited Nov. 25, 2011).

[11] Available at http://www.pwrc.usgs.gov/pif/cont_plan/PIF3_Part2WEB.pdf (last visited Nov. 20, 2011).

[12] Available at http://www.fws.gov/shorebirdplan/USShorebird/PlanDocuments.htm (last visited Nov. 20, 2011).

[13] Available at http://www.waterbirdconservation.org/atrisk.html (last visited Nov. 20, 2011).

62. The plan was created by Partners in Flight, an international coalition of government agencies (including FWS), conservation groups, and scientific researchers. It identifies two types of native birds that are of high conservation importance, "those that show some combination of population declines, small ranges, or distinct threats to habitat, and those that are restricted to distinct geographical areas, but otherwise not currently at risk." N.A. Landbird Conservation Plan Part 1 at 5. Inclusion of the impacts of wind energy as a conservation issue in the plan indicates that there is widespread recognition among major bird conservation groups, government agencies, and scientists of the grave threats posed by wind energy projects to migratory birds. In addition, wind energy is described as a form of energy development that can have significant negative impacts on birds in the 2009 State of the Birds report, which is a document collectively drafted by government agencies (including FWS), bird conservation coalitions, conservation groups, and scientific researchers. N. Am. Bird Conservation Initiative, U.S. Comm., The State of the Birds, United States of America (2009) 9, 30, 31 ("2009 State of the Birds Report").[14]

Set out below is a brief discussion of certain bird species that are facing risks from wind energy development. The list of birds discussed below is merely illustrative and not a complete or exhaustive listing of birds that ABC believes are at serious risk due to wind energy development.[15]

Hawaiian birds

Hawaiian birds face special risks from wind energy. Unfortunately, Hawaii is now cited as "the bird extinction capital of the world," where more bird species are vulnerable to extinction than anywhere else in the world. 2009 State of the Birds Report at 26. Almost any imaginable site for a wind energy project in Hawaii has the potential to impact federally listed threatened and endangered species, as well as other birds of conservation concern. The state has adopted an aggressive mandate to produce 40% of its electricity from renewable energy by 2030, and consequently several wind energy projects are being developed at sites that seriously impact species of conservation concern. See Am. Wind Energy Ass'n ("AWEA"), Wind Energy Facts: Hawaii (Aug. 2011).[16]

[14] Available at http://www.stateofthebirds.org/2009/pdf_files/State_of_the_Birds_2009.pdf (last visited Nov. 25, 2011).

[15] It is pertinent to note that some of the birds discussed in this Section are also listed by the American Wind Wildlife Institute ("AWWI") (which includes wind industry members) as potentially being adversely impacted by wind energy development. AWWI, Wind and Wildlife Landscape Assessment Tool: Wind and Wildife Species List (2011), http://wind.tnc.org/awwi/#app=515d&7843-selectedIndex=0&fefa-selectedIndex=3 (last visited Dec. 7, 2011). This list includes many, but not all, of the birds ABC has identified as being at special risk from wind energy development (for example, the AWWI list is mainland focused and thus misses many Hawaiian birds. Another species not identified by AWWI's list is the Ferruginous Hawk, which has demonstrated mortality at U.S. wind projects.).

[16] Available at http://www.awea.org/learnabout/publications/upload/Hawaii.pdf (last visited Nov. 20, 2011).

Bird species of conservation concern that have already been killed at one Hawaiian wind project include the Hawaiian Goose (federally endangered, Red WatchList), Hawaiian Petrel (federally endangered, Red WatchList) and (Hawaiian) Short-eared Owl (BCC, Yellow WatchList).[17] See Kaheawa Wind Power II, LLC, Kaheawa Wind Power II Draft Habitat Conservation Plan 52 (2010).[18] Other imperiled birds present in Hawaii where wind energy development and its associated infrastructure currently exist, or are in the process of development, include the Newell's Shearwater (federally threatened, Red WatchList), Hawaiian Common Moorhen (federally endangered), Hawaiian Coot (federally endangered, Red WatchList), Hawaiian Duck (federally endangered, Red WatchList), Hawaiian Hawk (federally endangered, Red WatchList), Hawaiian Stilt (federally endangered), Band-rumped Storm-Petrel (BCC, Red WatchList), and Pacific Golden-Plover (U.S. Shorebird Conservation Plan, high concern).[19] See 2001 U.S. Shorebird Conservation Plan at 57.[20] Also of concern are MBTA-protected birds that have not yet been listed as endangered or threatened, such as frigatebirds, shearwaters, boobies, terns, noddies, and albatrosses.

Although in recent years certain wind energy developers have applied under the ESA for incidental take permits ("ITPs") for federally listed birds at proposed Hawaiian wind projects, see 16 U.S.C. § 1539 (authorizing FWS to issue ITPs allowing limited take of endangered and threatened species if prescribed criteria are satisfied), such applications have not been filed by all developers and some existing projects that may impact federally listed birds continue to operate without an ITP.

---

[17] The United States WatchList, a joint project between ABC and the National Audubon Society, reflects a comprehensive scientific survey and study of all the bird species in the United States. It identifies those bird species in greatest need of immediate conservation attention. Red WatchList species are those of greatest conservation concern. Yellow WatchList species are still of concern but not to as extreme a degree as Red WatchList species.

[18] Available at http://www.fws.gov/pacificislands/Publications/DRAFT%20KWP%20II%20HCP.pdf (last visited Nov. 27, 2011).

[19] As of November 17, 2011, draft or final incidental take permits issued under the ESA have already been prepared for various federally listed species, including, Hawaiian Common Moorhen, Hawaiian Coot, Hawaiian Duck, Hawaiian Goose, Hawaiian Petrel, Hawaiian Stilt, and Newell's Shearwater.

[20] The U.S. Shorebird Conservation Plan is a partnership effort of state and federal agencies (including FWS), non-governmental conservation organizations, academic institutions, and individuals from across the country committed to restoring and maintaining stable and self-sustaining populations of shorebirds in the United States and throughout the Western Hemisphere. The plan provides a scientific framework to determine species, sites, and habitats that most urgently need conservation action. Available at http://www.fws.gov/shorebirdplan/USShorebird/downloads/USShorebirdPlan2Ed.pdf (last visited Nov. 27, 2011).

Further, such ITPs do not apply to BCC species (which by definition are not federally listed under the ESA), unless the developer agrees to include them in a Habitat Conservation Plan ("HCP").[21]

Grassland birds

The birds of America's grasslands are also in trouble, and unless properly regulated, wind energy development will add to the impacts that are already causing these birds' numbers to dwindle. "Grassland birds are among the fastest and most consistently declining birds in North America." 2009 State of the Birds Report at 4. Of the 46 grassland-breeding bird species, 48% are of particular conservation concern and 55% are declining significantly. Four are already federally listed as endangered. Id. at 8. MBTA-protected birds such as the Mountain Plover (BCC, Red WatchList), Sprague's Pipit (federal listing candidate, Yellow WatchList), Lark Bunting (BCC, Yellow WatchList), Baird's Sparrow (BCC, Red WatchList), Chestnut-collared Longspur (BCC, Yellow WatchList), and McCown's Longspur (BCC) show steep population declines of 68–91%. Id. at 8.

All the above-mentioned birds (except the Baird's Sparrow) engage in aerial displays – a behavior that makes them more vulnerable to turbine strikes. During aerial displays, males may not be paying attention fully to the structures around them. Grassland birds that engage in aerial displays during courtship, such as the Long-billed Curlew, Upland Sandpiper, Vesper Sparrow, Horned Lark, Chestnut-collared Longspur, and McCown's Longspur, have a greater risk of colliding with wind turbine rotor blades that occur within a male's territory. See Wyo. Game and Fish Dep't, Wildlife Protection Recommendations for Wind Energy Development in Wyoming 5 (Apr. 23, 2010).[22] Thus, birds that engage in aerial displays face a greater threat from wind energy turbines as they are particularly prone to collisions. Other grassland species of conservation concern that are especially vulnerable to harm from wind energy development include the Long-billed Curlew (BCC, Yellow WatchList), Grasshopper Sparrow, and Lesser Prairie-Chicken (federal listing candidate, BCC, Red WatchList).

Sprague's Pipit is protected under the MBTA and is an ESA candidate species. It is also a BCC species and on the Yellow WatchList. The species is typically found in open plains, especially shortgrass prairies. Sprague's Pipit is one of the few species endemic to the North American

[21] For example, the Hawaiian Short-eared Owl, which is not ESA-listed, will receive some protection under the proposed HCP for the Kaheawa Wind II facility. This happened because a conservation group worked to have protections for the species included in the HCP. Thus, it should not be assumed that all BCC species will be covered by HCPs for federally listed species at Hawaiian wind projects.

[22] Available at http://gf.state.wy.us/downloads/pdf/April%2023%202010%20Commission%20Approved%20Wind%20Recommendations.pdf (last visited Nov. 26, 2011).

grasslands. Like many grassland species, Sprague's Pipits are semi-nomadic, seeking suitable grassland conditions within their range for nesting in any particular year. They are associated with unbroken tracts of native grassland. In addition to the potential of losing additional habitat to wind energy development, Sprague's Pipit faces extra risk of being killed by collision with wind turbines because its behavior includes the longest periods of aerial display of any passerine species, and its display heights place the Pipit within the rotor-swept zone of modern wind turbines. Aerial displays lasting as long as three hours at display heights of 50 meters to over 100 meters above the ground have been documented. Mark B. Robbins, Display Behavior of Male Sprague's Pipits, 110 Wilson Bull. of Ornithology 435-438, 435 (1998).[23] The Government of Alberta identifies Sprague's Pipit as a species with potential for collisions with wind turbines due to its aerial display behavior. Gov't of Alta., Wildlife Guidelines for Wind Energy Projects 3 (Sept. 19, 2011) ("Alberta Wildlife Guidelines").[24] In addition, wind farms can cause Sprague's Pipits, like other grassland birds, to abandon otherwise suitable habitats. There is no reliable population estimate for Sprague's Pipit – according to the FWS Sprague's Pipit Conservation Plan, the global species population has been estimated at 870,000, but the plan also cautions that that number relies on standard assumptions and calculations that are "unverified with the existing data." FWS, Sprague's Pipit (Anthus spragueii) Conservation Plan 15 (2010).[25] The plan describes the estimate as a "rough" estimate with "unknown, but potentially large, error." Id.

Chestnut-collared Longspur is a shortgrass prairie species that is protected under the MBTA and has also been designated by FWS as a BCC species. It is on the Yellow WatchList. "The primary factor suspected to be limiting nesting populations of this species is the availability of native grasslands as they will not nest in croplands. Conversion of native grasslands to croplands and habitat loss to urbanization and industrialization have caused a contraction in this species' breeding range and range wide population declines." Wyo. Game and Fish Dep't, Chestnut-Collared Longspur 1 (2010).[26] In addition, "[w]ind power development in nesting areas can be problematic due to the courtship displays this species exhibits during the breeding season." Id. at 20. The 2004 N.A. Landbird Conservation Plan estimated the U.S and Canadian population of the Chestnut-collared Longspur at 5,600,000. N.A. Landbird Conservation Plan Part 1 at 21.

---

[23] Available at http://elibrary.unm.edu/sora/Wilson/v110n03/p0435-p0438.pdf (last visited Nov. 20, 2011).

[24] Available at http://srd.alberta.ca/FishWildlife/WildlifeLandUseGuidelines/documents/WildlifeGuidelines-AlbertaWindEnergyProjects-Sep19-2011.pdf (last visited Nov. 20, 2011).

[25] Available at http://www.fws.gov/mountain-prairie/species/birds/spraguespipit/SpraguesJS2010r4.pdf. (last visited Nov. 20, 2011).

[26] Available at http://gf.state.wy.us/downloads/pdf/swap/birds/ChestnutcollarLongspur.pdf (last visited Nov. 20, 2011).

McCown's Longspur is a rare grassland bird which is protected under the MBTA and is also on the FWS BCC list. This species has suffered dramatic declines in the northern part of its range. Habitat loss and fragmentation due to loss of native prairie and conversion to agriculture are major threats to McCown's Longspur. If the ongoing population declines continue, McCown's Longspur could be petitioned for listing as a federally endangered species. The species engages in aerial display, putting the birds at heightened risk of collision with wind turbines. In addition, wind energy development in the plains will likely further decrease habitat availability for McCown's Longspur, potentially accelerating the population decline. The 2004 North American Landbird Conservation Plan estimated the U.S and Canadian population of the Chestnut-collared Longspur at 1,100,000. U.S. Landbird Conservation Plan Part 1 at 19.

The Long-billed Curlew is the largest North American shorebird. It is protected under the MBTA and is also listed as a FWS BCC species, a Species of Special Concern in Canada, and Highly Imperiled in both the U.S. and Canadian shorebird conservation plans. Additionally, it is listed on the Yellow WatchList. Its population has been estimated at only 20,000 birds. 2001 U.S. Shorebird Conservation Plan at 52. As the FWS Status Assessment and Conservation Action Plan for the Long-billed Curlew explains, "[t]he high levels of concern are due to the loss of the eastern third of their historical breeding range and apparent population declines, particularly in the shortgrass and mixed-grass prairies of the western Great Plains." FWS, Status Assessment and Conservation Action Plan for the Long-Billed Curlew (Numenius americanus) vii (2009).[27] The Conservation Plan further states that Long-billed Curlews are vulnerable to direct mortality due to strikes from wind power rotor blades, increased predation associated with additional wind farm structures and incursion into grasslands, disruption of aerial breeding displays, disturbance caused by increased human activity during both the development stage and during general maintenance of the wind farm, and habitat fragmentation. Id. at 12. The Long-billed Curlew relies primarily on native grasslands for nesting and overwintering. The conversion of these grasslands to agriculture is the primary ongoing threat to the species, and wind energy development will likely further decrease habitat availability. Long-billed Curlews also spend much time in flight defending their territories, thereby increasing their risk of colliding with wind turbines. The Government of Alberta identifies the Long-billed Curlew as a species with heightened potential for collisions with wind turbines due to its aerial display. Alberta Wildlife Guidelines at 3. A Long-billed Curlew fatality attributed to wind energy development has been recorded in the Pacific Northwest. See Gregory D. Johnson & Wallace P. Erickson, Avian, Bat And Habitat Cumulative Impacts Associated with Wind Energy Development in the Columbia Plateau Ecoregion of Eastern Washington and Oregon 12 (2010).[28]

---

[27] Available at http://library.fws.gov/BTP/long-billedcurlew.pdf (last visited Nov. 20, 2011).

[28] The wind facility where the Long-billed Curlew was killed is not identified in the report. Nor did the report indicate whether the mortality searches took place during the times of Long-billed Curlew courtship, when the risk of turbine collision would be highest. Available at

Some grassland species may avoid areas with wind turbines, leading to reduced densities of birds in locations of highest quality habitat and with potentially adverse long-term impacts. Research to determine which grassland bird species are most susceptible to displacement from wind power development is still in its early stages. However, preliminary research by the U.S. Geological Survey has already demonstrated that displacement occurs with Grasshopper Sparrows and Clay-colored Sparrows, which are both listed as BCC species. See Partners in Flight, Landbird Population Estimates Database (2004) ("2004 PIF Population Estimates Database").[29] The North American Grasshopper Sparrow population is estimated at 14,000,000 and the North American Clay-colored Sparrow population is estimated at 23,000,000. Density of these birds decreased near wind turbines at study sites in Minnesota, North Dakota, and South Dakota. Jill A. Shaffer & Douglas H. Johnson, Displacement Effects of Wind Developments on Grassland Birds in the Northern Great Plains 51 (2010).[30] Some grassland birds have also been found to avoid important habitats near wind turbines and roads at other locations in Minnesota, Oregon, and Washington. Wallace Erickson et al., Protocol for Investigating Displacement Effects of Wind Facilities on Grassland Songbirds 2-3 (2007).[31]

Sagebrush-dependent songbirds

In addition to grassland songbirds, sagebrush-dependent songbirds also face threats from wind energy development in their habitat. One species known to have experienced mortality at U.S. wind energy facilities is the Brewer's Sparrow. Although no comprehensive study of Brewer's Sparrow mortality at wind energy facilities has been conducted, Brewer's Sparrow fatalities have been documented in Washington and Wyoming at the Tuolumne Wind and Foote Creek Rim facilities.[32] Brewer's Sparrow is a FWS BCC species and on the Yellow WatchList. Brewer's Sparrow breeds in sagebrush across the western United States and adjacent southern Canada, wintering from the southwestern United States to central Mexico. Threats it faces include

---

http://www.whitmancounty.org/download/App%20F%20CPE%20Cumulative%20Impacts%20Report.pdf (last visited Nov. 26, 2011).

[29] Available at http://rmbo.org/pif_db/laped/ (last visited Nov. 20, 2011).

[30] Available at https://www.nationalwind.org/assets/research_meetings/Research_Meeting_VII_Shaffer.pdf. (last visited Nov. 20, 2011).

[31] Available at http://digitalcommons.unl.edu/usgsnpwrc/131/ (last visited Nov. 20, 2011).

[32] See, e.g., Tamara Enz & Kimberly Bay, Post-Construction Avian and Bat Fatality Monitoring Study, Tuolumne Wind Project, Klickitat County, Washington, Final Report, April 20, 2009 to April 7, 2010 19 (July 6, 2010), Attachment B; see also West, Inc., Avian and Bat Mortality Associated with the Initial Phase of the Foote Creek Rim Windpower Project, Carbon County, Wyoming November 1998 - June 2002 8 (Jan. 10, 2003), http://west-inc.com/reports/fcr_final_mortality.pdf (last visited Dec. 9, 2011).

destruction and fragmentation of sagebrush caused by agricultural expansion, over-grazing, altered fire regimes, invasive plants, and energy development. Daniel J. Lebbin et al., ABC, The North American Bird Conservancy Guide to Bird Conservation 108 (2010) ("ABC Guide to Bird Conservation "), Attachment A. Brewer's Sparrow population was estimated in 2004 at 16,000,000. The Landbird Conservation Plan recommends that the Brewer's Sparrow population be increased by 100% in order to protect the species. N.A. Landbird Conservation Plan Part 1 at 19.

Raptors

Many raptors are known to have been killed at U.S. wind energy facilities, with several on both the FWS BCC list and the U.S. WatchList. They include Swainson's Hawk (BCC, Yellow WatchList), American Peregrine Falcon (BCC), Ferruginous Hawk (BCC), Short-eared Owl (BCC, Yellow WatchList), Flammulated Owl (BCC, Yellow WatchList), Golden Eagle (BCC), and Bald Eagle (BCC).[33]

Swainson's Hawks breed in open grassland, shrub-land and agricultural land from Alaska through the Canadian prairies, then south through the western United States to northern Mexico. The California population has declined by 90%, and declines have been observed in Canada, but populations are believed to be stable elsewhere. See ABC Guide to Bird Conservation at 44, Attachment A. In 2004, the U.S. and Canadian population of the Swainson's Hawk was estimated at 460,000. N.A. Landbird Conservation Plan Part I at 18. Swainson's Hawks migrate in flocks through Central America to winter in the grasslands of Argentina, and this migration places the species at special additional risk of collision with wind turbines. More than 90% of the global population of Swainson's Hawk passes through the south of the Isthmus of Tehuantepec, where wind energy is being developed rapidly. According to Friends of the Swainson's Hawk, a California conservation group, 5,000 wind turbines are planned in the Isthmus of Tehuantepec. See Friends of the Swainson's Hawk, Energy Projects Challenge Wildlife and Habitat.[34] These proposed Mexican projects will add to the cumulative effects of wind energy development in the United States that Swainson's Hawks face.

---

[33] Examples of wind energy facilities and regions where these raptors are known to have been killed include Shiloh I Wind, CA (Swainson's Hawk); Tehachapi Pass Wind Resource Area, CA (Flammulated Owl); Jersey-Atlantic Wind Farm, NJ (Peregrine Falcon); Stateline Wind Energy Center, OR-WA (Swainson's Hawk); Juniper Canyon Wind, WA (Ferruginous Hawk); Nine Canyon Wind, WA (Short-eared Owl); Big Horn Wind, WA (Short-eared Owl, Ferruginous Hawk); Harvest Wind, WA (Swainson's Hawk); and Foote Creek Rim Wind, WY (Short-Eared Owl). It should be noted that these examples are a fragmentary sampling of actual mortality, not a full accounting. Mortality data is not collected at all U.S. wind energy facilities, and even when data is collected, it is not collected during all operating hours, nor is it usually collected for all wind turbines in a facility. In addition, mortality data is very often not made publicly available.

[34] Available at http://www.swainsonshawk.org/story2.html (last visited Nov. 27, 2011).

The American Peregrine Falcon was removed from the federal endangered species list in 1999 but will continue to be monitored by FWS through 2015. See FWS, Proposed Information Collection; Monitoring Recovered Species After Delisting-American Peregrine Falcon, 76 Fed. Reg. 17147, 17148 (Mar. 28, 2011). Peregrine Falcons are most associated with mountain ranges, river valleys, and coastlines. FWS estimated their population in 2003 at 3,000 breeding pairs in Mexico, the United States, and Canada. Although the species has made a remarkable recovery, the pesticide best known for the falcon's decline, DDT, is still found in some parts of its environment within and outside the United States. See FWS, Peregrine Falcon (Falco peregrinus) Fact sheet (2006).[35] Wind energy development in Peregrine Falcon habitat adds to the cumulative impacts the species faces.

Another species potentially at risk from wind energy development is the Ferruginous Hawk, designated by FWS as a BCC species. The Ferruginous Hawk is the largest hawk in North America, inhabiting arid and open grassland, shrub steppe, and desert in the United States, Canada, and Mexico. It was petitioned for but denied endangered species status in the early 1990s. The 2004 estimate of the Ferruginous Hawk population was only 20,000. 2004 PIF Population Estimates Database. Ferruginous Hawks are known to have been killed at U.S. wind energy facilities in the West, for instance at the Big Horn Wind Energy Project in Washington. See, e.g., K. Shawn Smallwood, Avian and Bat Mortality at the Big Horn Wind Energy Project, Klickitat County, Washington 6 (Oct. 18, 2008).[36] Risk to Ferruginous Hawks from wind energy development has been acknowledged by FWS itself. See Patricia Y. Sweanor, FWS, Best Management Practices for Wind Energy in Areas with Golden Eagles (Aquila chrysaetos) in Wyoming 58 (abstract of paper submitted at the 2010 Raptor Research Foundation Conference).[37]

The Short-eared Owl nests in open habitats (tundra, grasslands, marshes, agricultural lands, and coastal dunes) throughout Eurasia and North America, with a Hawaiian subspecies that is also known to have been killed at a wind energy facility. In addition to the threat of collision with wind turbines and habitat loss and fragmentation posed by wind energy development, the Short-eared Owl also is threatened by loss and fragmentation of grassland, marsh, and coastal habitats due to agriculture, over-grazing and urban and coastal development, as well as invasive predators, potentially West Nile Virus, and pesticides. See ABC Guide to Bird Conservation at 74, Attachment A. In 2004, the U.S. and Canadian population of Short-eared Owls was estimated at 710,000. N.A. Landbird Conservation Plan Part 1 at 18.

---

[35] Available at http://library.fws.gov/ES/peregrine06.pdf (last visited Nov. 27, 2011).

[36] Available at http://www.efsec.wa.gov/Whistling%20Ridge/Adjudication/Intervenor's%20pre-filed%20testimony/Ex%2022.03.pdf (last visited Dec. 12, 2011).

[37] Available at http://www.rmrp.info/pdf/2010_printed_program-9_091210_LAK.pdf (last visited Nov. 20, 2011).

The Flammulated Owl nests in cavities of dead and dying trees in open, montane ponderosa pine forest and is patchily distributed from southern British Columbia through the western United States to central Mexico. In addition to the threat of collision with wind turbines and habitat loss and degradation posed by wind energy development, the Flammulated Owl is threatened by degradation and loss of habitat, reduction of cavities available for nesting due to cutting of dead trees, declines in populations of woodpeckers that create the cavities in which the owls nest, and reductions in insect prey due to pesticide use in forests. Its global population is estimated at only 37,000. See ABC Guide to Bird Conservation at 73, Attachment A. In 2004, the Flammulated Owl population was estimated at only 29,000 in the United States and Canada. See N.A. Landbird Conservation Plan Part 1 at 19.

The American birds most emblematic of the need to properly regulate the wildlife impacts of wind energy are probably the Golden Eagle and Bald Eagle, both of which are protected under the MBTA. The Golden Eagle is a FWS BCC species; its population is difficult to state with certainty due to limited data. In 2011, FWS estimated the Golden Eagle population at perhaps only 30,000 in the United States. See FWS, Golden Eagles Status Fact Sheet (2011).[38] The 2004 Partners in Flight estimate of Golden Eagle population in North America was 80,000. 2004 PIF Population Estimates Database. Golden Eagles occur across much of the United States, utilizing habitats that include tundra, grasslands, forested habitat, woodlands, brush lands, and deserts. This broad range of habitats exposes Golden Eagles to a multitude of threats such as habitat loss, electrocution by and collision with energy infrastructure (including power lines and wind turbines), lead and rodenticide poisoning, human disturbance, climate change, disease, stock tank drowning, vehicle collisions, and illegal intentional killing. FWS, Minutes and Notes from the North American Golden Eagle Science Meeting (Sept. 21, 2010).[39] Scientific experts have ranked wind energy as the third greatest direct mortality threat to Golden Eagles (behind electric infrastructure, i.e., electrocutions from and collisions with power lines, which will also be expected from wind power expansion, and lead poisoning). Id. at 22.

The risk that wind power facilities pose to Golden Eagles has been known for some time due to the well-documented fatalities at Altamont Pass in California, where a 2010 study estimated that 55-94 Golden Eagles annually were killed by wind turbines since 1998. K. Shawn Smallwood, Fatality Rates in the Altamont Pass Wind Resource Area 1998-2009 (2010) at 25.[40] In fact,

---

[38] Available at http://www.fws.gov/habitatconservation/Golden_Eagle_Status_Fact_Sheet.pdf (last visited Nov. 20, 2011).

[39] Available at http://www.dfg.ca.gov/wildlife/nongame/raptors/goldeneagle/docs/NAGoldenEagleScienceMeeting-2010-09-21.pdf (last visited Nov. 20, 2011).

[40] Available at http://altamontsrc.org/alt_doc/p145_smallwood_fatality_monitoring_results_12_31_09.pdf. (last visited Nov. 20, 2011).

Altamont Pass has not only been a death trap for the species, but has also been found to be a population sink, where turbine blade strikes kill more eagles than are produced within the area surveyed, thereby demanding a flow of recruits from outside the area to fill breeding vacancies as they occur. See Grainger Hunt & Teresa Hunt, The Trend of Golden Eagle Territory Occupancy in the Vicinity of the Altamont Pass Wind Resource Area: 2005 Survey 2 (2006).[41]

Further, FWS has been lax in providing information to the public regarding Golden Eagle deaths at wind energy projects through the Freedom of Information Act ("FOIA"), 5 U.S.C. § 552, or other mechanisms.[42] Indeed, the fragmentary picture of Golden Eagle mortality at wind farms that does emerge from the scattered bits of information made public is not encouraging.

For example, in 2011, the Los Angeles Times reported that at least six Golden Eagles had been killed at the Pine Tree wind project in California. Louis Sahagun, Federal Officials Investigate Eagle Deaths At DWP Wind Farm (L.A. Times, Aug. 3, 2011).[43] The Associated Press wrote about the death of a Golden Eagle at the Goodnoe Hills Wind Project in Washington in 2009. Associated Press, Golden Eagle killed by Wash. Wind turbines (Aug. 15, 2009).[44] In addition, Golden Eagle mortality at wind projects in Wyoming also appears serious. See Sophie Osborn, Wyo. Outdoor Council, Wind turbines killing more golden eagles in Wyoming than expected (June 21, 2011) (discussing Golden Eagle mortality at wind projects in Wyoming based on FWS data).[45] According to a FWS staff paper submitted at a 2010 conference of scientific experts specializing in raptor conservation, at one geographic region in Wyoming the mortality rate is one Golden Eagle death per 13 wind turbines per year; at another it is one Golden Eagle death per 39 wind turbines per year. Patricia Y. Sweanor, FWS, Best Management Practices for Wind Energy in Areas with Golden Eagles (Aquila chrysaetos) in Wyoming 58 (abstract of paper submitted at the 2010 Raptor Research Foundation Conference).

---

[41] Available at http://www.energy.ca.gov/2006publications/CEC-500-2006-056/CEC-500-2006-056.PDF (last visited Dec. 11, 2011).

[42] It should be noted that information concerning wildlife fatalities, particularly Golden Eagle mortalities, at wind energy facilities is often known to FWS but such information is not easily accessible to the public, in part due to the increasingly long time that it takes the agency to respond to FOIA requests for wind project mortality data, typically extending well beyond the statutorily prescribed durations. For example, as of the beginning of December 2011, ABC is still waiting for FWS to send complete wind farm mortality data in response to a FOIA request that was made in April 2011.

[43] Available at http://articles.latimes.com/2011/aug/03/local/la-me-wind-eagles-20110803 (last visited Nov. 16, 2011).

[44] Available at http://www.nwcn.com/archive/62395757.html (last visited Nov. 16, 2011).

[45] Available at http://wyomingoutdoorcouncil.org/blog/2011/06/21/wind-turbines-killing-more-golden-eagles-in-wyoming-than-expected/ (last visited Nov. 16, 2011).

This means there are likely to be equivalents of the Pine Tree facility, or possibly worse, in Wyoming, where FWS staff has stated approximately 1,000 wind turbines were operating by September 2010 and another 1,000 are expected to be constructed in the following two years. Id. Unless steps are taken to better address these impacts – such as those proposed in this Petition – the number of Golden Eagles killed at wind power facilities will become even worse over time and will likely result in efforts to list the species as endangered or threatened under the ESA.

The Bald Eagle is another iconic American bird species that illustrates the need for effective regulation of wildlife impacts to wind energy. The FWS National Bald Eagle Management Guidelines state that there are breeding populations of Bald Eagles in each of the lower 48 states. The Guidelines also assert that, "[t]he largest North American breeding populations are in Alaska and Canada, but there are also significant bald eagle populations in Florida, the Pacific Northwest, the Greater Yellowstone area, the Great Lakes states, and the Chesapeake Bay region." FWS, National Bald Eagle Management Guidelines 3 (2007).[46] The Bald Eagle was removed from the endangered species list in 2007, but remains a FWS BCC species, and is undergoing post-delisting monitoring. The 2004 North American Landbird Conservation Plan estimated 330,000 Bald Eagles in the United States and Canada. N.A. Landbird Conservation Plan Part 1 at 20. At delisting, FWS estimated 9,789 Bald Eagle breeding pairs in the lower 48 states. FWS, Endangered and Threatened Wildlife and Plants; Removing the Bald Eagle in the Lower 48 States From the List of Endangered and Threatened Wildlife, 42 Fed. Reg. 37346, 37350 50 CFR Pt. 17 (July 9, 2007). Threats to the Bald Eagle include collisions with power lines, vehicles, and other obstacles; electrocution; disease; lead and pesticide poisoning; and shooting. See FWS, Post-delisting Monitoring Plan for the Bald Eagle (Haliaeetus leucocephalus) in the Contiguous 48 States 18 (2010).[47]

Wind energy development in Bald Eagle habitat is expanding and therefore Bald Eagles will over time have greater potential for collisions with wind turbines. A 2004 Bald Eagle species assessment prepared for the U.S. Bureau of Land Management ("BLM") states, "[i]t is assumed that an increase in the number and type of wind-power turbines will generally increase the number of bald eagle deaths by aerial collisions, especially if such turbines are positioned with little consideration of bald eagle habitat." Amber Travsky & Gary P. Beauvais, Species Assessment for Bald Eagle (Haliaeetus Leucocephalus) in Wyoming (prepared for BLM, 2004) at 25.[48] In fact, Bald Eagle deaths at wind facilities in Wyoming and Ontario, Canada have been reported in scattered

---

[46] Available at http://www.fws.gov/pacific/eagle/NationalBaldEagleManagementGuidelines.pdf (last visited Nov. 20, 2011).

[47] Available at http://www.fws.gov/midwest/eagle/protect/FINAL_BEPDM11May2010.pdf (last visited Nov. 20, 2011).

[48] Available at http://www.blm.gov/pgdata/etc/medialib/blm/wy/wildlife/animal-assessmnts.Par.41209.File.dat/BaldEagle.pdf (last visited Dec. 6, 2011).

outlets. DecorahNews.com, Ask Mr. Answer Person about the Luther Wind Turbine (Nov. 16, 2011);[49] see also U.S. Dep't of Energy ("DOE"), South Dakota PrairieWinds Project, Final Environmental Impact Statement 180 (2010).[50]

While publicly reported Bald Eagle mortality at wind projects so far appears low, Bald Eagle mortality is also likely to increase as more wind facilities are built in Bald Eagle habitat, especially if those projects are inappropriately sited. There has been some speculation that Bald Eagles might be more likely than Golden Eagles to avoid wind turbines. Lynn Sharp, Comparison of Pre- and Post-construction Bald Eagle Use at the Pillar Mountain Wind Project, Kodiak, Alaska, Spring 2007 & 2010 66-68 (2010).[51]

Eastern forest and woodland birds

Although raptors such as eagles have been known for some time to be at risk from wind energy development on western ridgelines, as the industry spreads into new habitats the impacts of wind power on new groups of birds, such as Eastern forest and woodland birds, need to be addressed. These include the Bicknell's Thrush, Cerulean Warbler, Bay-breasted Warbler, and Blue-winged Warbler.

The Bicknell's Thrush is a rare forest bird with a fragmented and limited breeding range in montane and maritime forest habitats in the Catskills and Adirondacks of New York and the higher peaks of northern New England and Quebec, New Brunswick, and Nova Scotia. Wind energy has already been developed in Bicknell's Thrush habitat in New Hampshire, was proposed in Bicknell's Thrush habitat in Maine, and more projects are likely in its U.S. range, which could lead to further habitat loss and fragmentation. Bicknell's Thrush is an ESA candidate species, FWS BCC species and on the Red WatchList. The 2004 estimate of the Bicknell's Thrush population was only 40,000 in the United States and Canada; the International Bicknell's Thrush Conservation Group estimated 95,000 to 126,000 globally. U.S. Landbird Conservation Plan Part 1 at 18.

Another eastern forest bird of great concern is the Cerulean Warbler. It is protected under the MBTA, listed as a FWS BCC species and has been petitioned for ESA listing. (The listing petition was rejected in 2006). It is also on the Yellow WatchList, and is a Species of Continental

[49] Available at http://www.decorahnews.com/news-stories/2011/11/1237.html (last visited Nov. 20, 2011).

[50] Available at http://www.rurdev.usda.gov/SupportDocuments/DOE-EIS-0418_Ch8_Use-Productivity.pdf (last visited Nov. 20, 2011).

[51] Available at http://www.nationalwind.org/assets/research_meetings/Research_Meeting_VIII_Proceedings1.pdf. (last visited Nov. 20, 2011).

Importance in the North American Landbird Conservation Plan. It has had the steepest rate of decline of any North American warbler that is monitored by North American Breeding Bird Surveys; Cerulean Warbler populations have been declining at more than 3% annually for the last 40 years. FWS, A Conservation Action Plan for the Cerulean Warbler (Dendroica cerulea) 3-4 (2007).[52] According to FWS, factors that limit the bird's population are not well understood, "[h]owever, it is widely assumed that loss of habitat quantity and degradation of habitat quality on the non-breeding and breeding habitats are critical factors that have contributed to the observed declines." Id. at 4. The Cerulean Warbler's U.S. breeding habitat is located in mature deciduous forests in the East, much of it in the Appalachian region, where wind power is developing rapidly. Id. at 3. Threats to the species' habitat include mountaintop removal coal mining and unregulated wind energy development. No comprehensive study of Cerulean Warbler mortality at wind facilities has been conducted, but a Cerulean Warbler mortality was reported in a one-year mortality study at a wind project in Tennessee. See J. K. Fiedler et al., Results of Bat and Bird Mortality Monitoring at the Expanded Buffalo Mountain Windfarm, 2005 21 (June 28, 2007), Attachment C.

The Bay-breasted Warbler migrates through the eastern United States and winters in forested habitats and shade coffee plantations in Central and South America; 90% of the population breeds in mature boreal forest in Canada. ABC Guide to Bird Conservation at 102, Attachment A. The Bay-breasted Warbler is a FWS BCC species and on the Yellow WatchList. Its population was estimated at 3,100,000 in 2004. N.A. Landbird Conservation Plan Part 1 at 18. It is threatened by forestry practices that favor young even-aged forests or trees resistant to budworm over older forests, as well as pesticide spraying for budworms, winter habitat loss and collisions during migration. ABC Guide to Bird Conservation supra at 102. No comprehensive study of Bay-breasted Warbler mortality at wind facilities has been conducted, but Bay-breasted Warbler fatalities were reported in 2011 at the NedPower Mt. Storm wind power project in West Virginia. David P. Young, Jr. & Zapata Courage, Avian/Bat Monitoring September 25, 2011 Memo 2 (Sept. 30, 2011), Attachment D.

The Blue-winged Warbler breeds in early successional habitats, ranging from the Midwest, east to New England and the Appalachians, and north to Ontario, Canada. It winters in tropical forests from Mexico to Panama. It is threatened by loss of breeding and wintering habitat; hybridization with Golden-winged Warblers; predation by feral cats; nest parasitism; and collisions with manmade structures. ABC Guide to Bird Conservation supra at 97. The Blue-winged Warbler is a FWS BCC species and on the Yellow WatchList. Its population was estimated in 2004 at 390,000 in the United States and Canada. N.A. Landbird Conservation Plan Part 1 at 19. No comprehensive study of Blue-winged Warbler mortality at wind facilities has been conducted, but Blue-winged Warbler fatality was reported between 2007 and 2009 at an unidentified Pennsylvania

---

[52] Available at http://www.fws.gov/migratorybirds/CurrentBirdIssues/Management/FocalSpecies/Plans/CeruleanWarbler.pdf (last visited Nov. 20, 2011).

wind energy facility or facilities. Tracey Librandi Mumma & William Capouillez, Pa. Game Comm'n, Wind Energy Voluntary Cooperation Agreement: Second Summary Report 31 (rev. Mar. 16, 2011).[53]

Western forest and woodland birds

The Oak Titmouse nests in oak and pine-oak woodlands from southern Oregon south through California to Baja California, Mexico. It is threatened by loss and degradation of habitat for urban development, pasture, and agriculture, as well as fire suppression, over-grazing, fuel-wood harvesting, and West Nile virus. ABC Guide to Bird Conservation at 89, Attachment A. It is a FWS BCC species and on the Yellow WatchList. Its population was estimated in 2004 at 900,000 in the United States and Canada. N.A. Landbird Conservation Plan Part 1 at 18. No comprehensive study of Oak Titmouse mortality at wind facilities has been conducted, but an Oak Titmouse mortality was reported in 2010 at the Pine Tree wind project in California. BioResource Consultants Inc., 2009/2010 Annual Report Bird and Bat Mortality Monitoring, Pine Tree Wind Farm, Kern County, California 8 (Oct. 14, 2010), Attachment E.

Lewis's Woodpeckers occur locally in the western United States and southern British Columbia, Canada, breeding mainly in open ponderosa pine forests in mountains (especially burned forests), but also using open cottonwoods, aspen and oak woodlands, and pinyon-juniper forest. Northern populations migrate south during winter, sometimes as far as northern Baja California, Mexico. Lewis's Woodpecker is threatened by habitat loss and degradation, over-grazing, and pesticides. ABC Guide to Bird Conservation supra at 78. It is a FWS BCC species and on the Red WatchList (highest concern). Its population was estimated in 2004 at 130,000 in the United States and Canada. No comprehensive study of Lewis's Woodpecker mortality at wind facilities has been conducted, but Lewis's Woodpecker fatality was reported as early as 1999 at the Vansycle Wind, Oregon wind facility. Wallace P. Erickson et al., Avian and Bat Mortality Associated with the Vansycle Wind Project, Umatilla County, Oregon 1999 Study Year 9 (Feb. 7, 2000).[54]

Birds at risk from offshore wind development

With the development of the U.S. offshore wind industry in the oceans and the Great Lakes, additional birds of conservation concern protected under the MBTA are at risk of collision with turbines or displacement from important habitat, such as traditional feeding areas. Because offshore

---

[53] The Pennsylvania Game Commission publishes wind energy mortality data in summary form, without the exact date or name of facility where it occurred. Available at http://www.scribd.com/doc/52395539/Wind-Energy-Voluntary-Cooperation-Agreement-Second-Summary-Report (last visited Nov. 27, 2011).

[54] Available at http://www.west-inc.com/reports/vansyclereportnet.pdf (last visited Nov. 27, 2011).

wind power is not currently installed in the United States, there is no existing U.S. track record to indicate which species will likely be killed. In addition, knowledge of offshore bird presence and migration routes is not as well developed as for birds onshore, so there may be species at risk from offshore wind development that have not yet been flagged as such.

Government agencies, academics, and conservation groups have already identified a number of birds of conservation concern believed to be at risk from offshore wind development in the United States. A sampling of these species includes federally threatened and endangered species such as the Piping Plover (also Red WatchList), Roseate Tern (also Yellow WatchList), Whooping Crane (also Red WatchList), and Kirtland's Warbler (also Red WatchList); candidate species for ESA listing such as the Red Knot (BCC, Yellow WatchList); and others such as the Black-Capped Petrel (BCC, Yellow WatchList), Wilson's Plover (BCC, Yellow WatchList), Gull-billed Tern (BCC, Yellow WatchList) and Audubon's Shearwater (BCC, Yellow WatchList), and landbirds that can fly through nearshore areas such as Bald and Golden Eagles (both BCC) and Peregrine Falcons (BCC). See, e.g., Doug Forsell, FWS, Waterbirds and Offshore Wind Energy Development, A Biologists [sic] Perspective On Regulation 2 (2010);[55] see also Sarah M. Karpanty, Virginia Tech, Virginia Coastal Energy Research Consortium: Potential Effects of Virginia Offshore Wind Power on Birds 4 (2011) ("Virginia Coastal Energy Research");[56] David N. Ewert et al., The Nature Conservancy, Wind Energy: Great Lakes Regional Guidelines 11 (2011).[57]

Other birds potentially at risk from U.S. offshore wind development include sea ducks (such as Long-tailed Ducks, mergansers, scoters, eiders), Redheads, loons, gannets, shorebirds, terns, and migratory songbirds. See Virginia Coastal Energy Research at 4; see also Albert Manville, FWS, Presentation on Shoreline, Near-shore, and Offshore Wind Energy Development in Texas State Waters: Tools to Help Avoid or Minimize "Take" of Waterbirds and Other Avifauna 14 (2011), Attachment F.

In sum, more than one-third of the migratory birds protected under the MBTA are facing several serious threats that are leading to declines in or uncertainty about their population numbers. In the absence of any regulations for avoiding and minimizing the impacts of wind energy projects through an appropriate permitting scheme – such as those proposed in this Petition – rapid wind energy development poses a grave threat to many migratory birds protected under the MBTA. As

---

[55] Available at http://web2.uconn.edu/seagrantnybight/documents/Energy%20Docs/Forsell_NY%20Bight%20Energy%20Oct%207%202010_Seabirds.pdf (last visited Nov. 27, 2011).

[56] Available at http://vasierraclub.org/Karpanty.pdf (last visited Nov. 27, 2011).

[57] Available at http://www.glc.org/energy/wind/pdf/TNC-Great-Lakes-Regional-Guidelines.pdf (last visited Nov. 27, 2011).

described infra, see Section C.3, FWS's approach to these impacts, i.e., through voluntary inadequate guidelines in lieu of mandatory regulations, will likely exacerbate the decline of many species protected under the MBTA, potentially leading to the need to list such species as endangered or threatened under the ESA.[58]

C. FACTUAL BACKGROUND

C.1. Thousands of wind turbines are already in operation and thousands more are being planned.

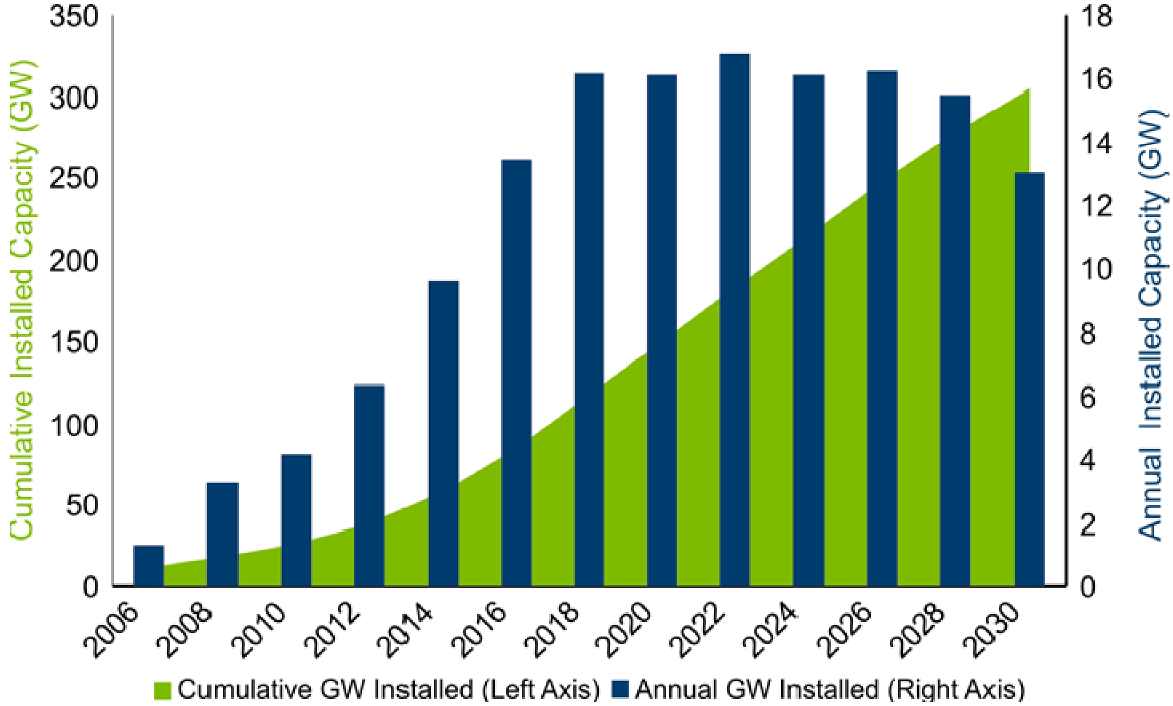
Growth in the wind industry

"[T]he U.S. wind industry is growing rapidly," driven by several policy incentives such as federal production tax credits, and renewable portfolio standards in roughly 50% of the states. See DOE, 20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply 1 (July 2008) ("DOE 20% Wind Report").[59] The DOE has announced a collaborative effort in which wind power is expected to provide 20% of U.S. electricity by 2030. Id. The 20% wind U.S. scenario would require an installation rate of 16 GW per year after 2018. See Figure 1: Cumulative and Annual Wind Installations By 2030.

[58] An upsurge in ESA listings will have serious consequences particularly for the industry, which will then be required to comply with comprehensive ESA requirements and may also be required to shut down projects due to potential ESA violations. For example, in response to a citizen suit, a federal court recently issued an injunction against the Beech Ridge wind energy project in West Virginia for potential take of the endangered Indiana bat without an incidental take permit. See Animal Welfare Inst. v. Beech Ridge Energy LLC, 675 F. Supp. 2d 540, 545 (D. Md. 2009). Accordingly, the industry has an enormous incentive to avoid additional ESA listings of species affected by wind power projects.

[59] Available at http://www.nrel.gov/docs/fy08osti/41869.pdf (last visited Dec. 11, 2011).

Figure 1: Cumulative and Annual Wind Installations By 2030[60]



The number of operating wind turbines is estimated at 30,000 in 2009 and will likely increase to over 70,000 turbines by end of 2011.[61] See Figure 2: Wind Turbines in the United States (2003-2011); Table: 1: Increase in Proposed and Existing Wind Turbines in the United States (2003-2011).

---

[60] Source: DOE 20% Wind Report at 7.

[61] These figures are estimates based on the data submitted to the FAA for proposed wind projects.

Figure 2: Estimate of Wind Turbines in the United States (2003-2011)

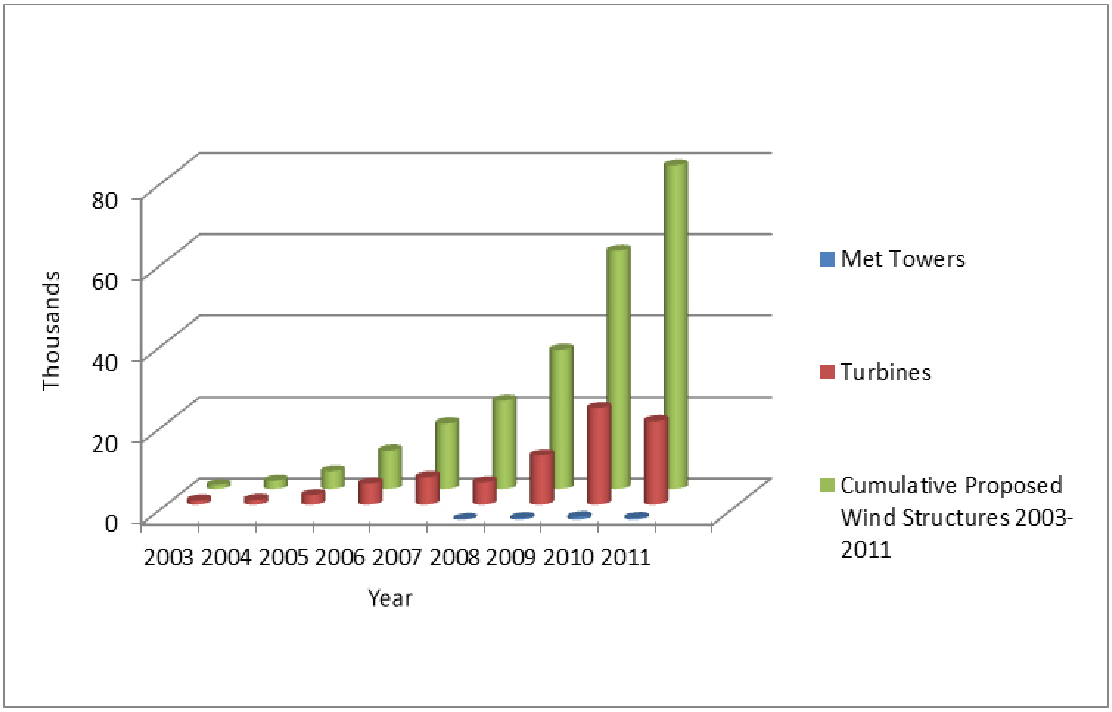


Figure 2 (above) is based on all unique wind turbines and associated meteorological tower proposals submitted to the Federal Aviation Administration/Obstruction Evaluation/Airport Airspace Analysis offices ("FAA - OE/AAA"). Wind turbines that were already proposed or existing prior to 2003 are not included in this analysis. Although meteorological towers were proposed during 2003-2007, they are not included in this data set due to data compilation and processing issues.

Table 1: Estimated Increase in Wind Turbines in the United States (2003-2011)

Year	# Wind Turbines	# Meteorological Towers[62]	Total Wind Related Structures	# Cumulative Proposed Wind Structures 2003-2011
2003	950	n/a	950	**950**
2004	1114	n/a	1114	**2064**
2005	2253	n/a	2253	**4317**
2006	5124	n/a	5124	**9441**
2007	6700	n/a	6700	**16141**
2008	5446	179	5625	**21766**
2009	12063	398	12461	**34227**

[62] Although meteorological towers were proposed during 2003-2007, they are not included in this data set due to data compilation and processing issues.

Year	# Wind Turbines	# Meteorological Towers[62]	Total Wind Related Structures	# Cumulative Proposed Wind Structures 2003-2011
2010	23714	661	24375	**58602**
2011 (through 11-1-11)	20460	451	20911	**79513**

The cumulative wind power capacity in the United States grew by a healthy 15% in 2010. DOE, 2010 Wind Technologies Market Report 1 (June 2011) ("2010 DOE Wind Market Report").[63] In fact, according to AWEA's most recent third quarter report published in October 2011, the wind industry had more than 1,200 MW installed in the third quarter, and more than 8,400 MW under construction – the most in any quarter since 2008. AWEA, U.S. Wind Industry Third Quarter Market Report (Oct. 2011) ("AWEA Third Quarter Report");[64] see also Meg Cichon, Meanwhile, Wind Industry Sees Big Gains – Will it Last? (RenewableEnergyWorld.com Nov. 17, 2011).[65]

Further, around 50% of U.S. states have adopted binding "renewable portfolio standards," i.e., state policies that require electricity providers to obtain a minimum percentage of their power from renewable energy resources by a certain date. See Table 2: State Renewable Portfolio Standards.

63 Available at http://eetd.lbl.gov/ea/ems/reports/lbnl-4820e.pdf (last visited Nov. 17, 2011).

64 Available at http://www.awea.org/learnabout/publications/reports/upload/3Q-2011-AWEA-Market-Report-for-Public-2.pdf (last visited Nov. 14, 2011).

65 Available at http://www.renewableenergyworld.com/rea/news/article/2011/11/meanwhile-wind-industry-sees-big-gains-will-it-last (last visited Nov. 17, 2011).

Table 2: State Renewable Portfolio Standards[66]

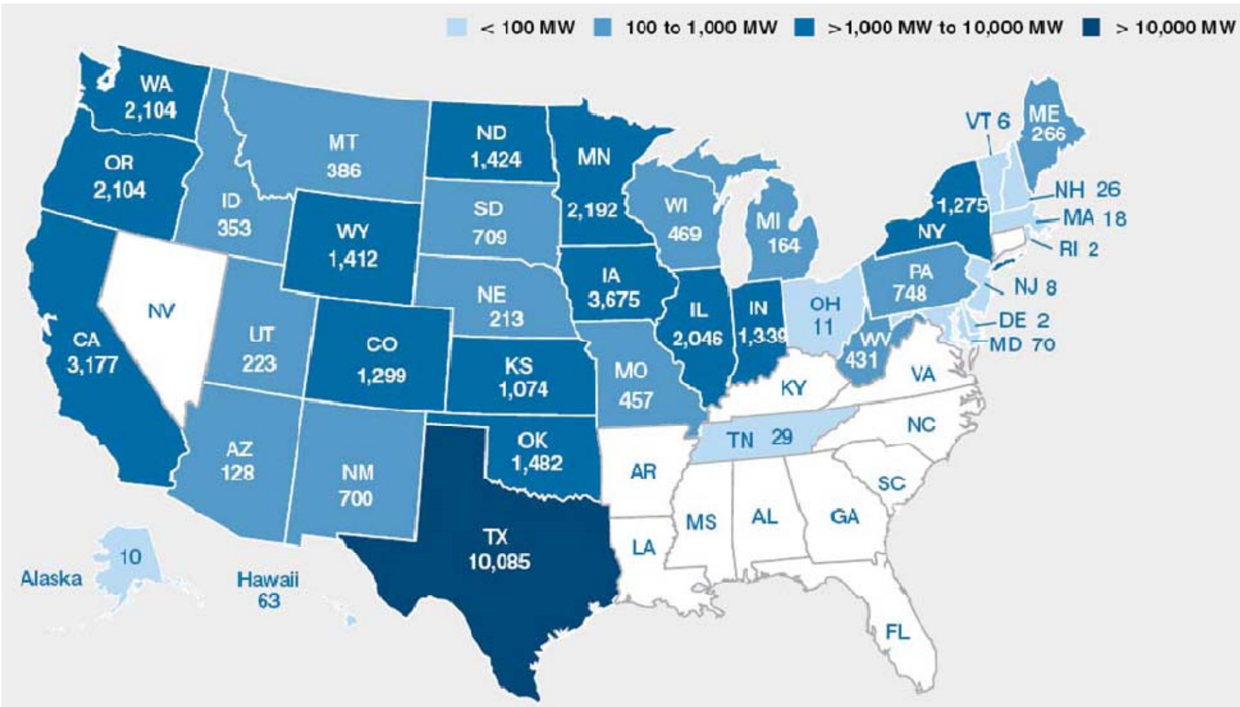
	State	Renewable Energy Amount	Year
1.	Arizona	15%	2025
2.	California	33%	2030
3.	Colorado	20%	2020
4.	Connecticut	23%	2020
5.	District of Columbia	20%	2020
6.	Delaware	20%	2019
7.	Hawaii	20%	2020
8.	Iowa	105 MW	-
9.	Illinois	25%	2025
10.	Massachusetts	15%	2020
11.	Maryland	20%	2022
12.	Maine	40%	2017
13.	Michigan	10%	2015
14.	Minnesota	25%	2025
15.	Missouri	15%	2021
16.	Montana	15%	2015
17.	New Hampshire	23.8%	2025
18.	New Jersey	22.5%	2021
19.	New Mexico	20%	2020
20.	Nevada	20%	2015
21.	New York	24%	2013
22.	North Carolina	12.5%	2021
23.	North Dakota*	10%	2015
24.	Oregon	25%	2025
25.	Pennsylvania	8%	2020
26.	Rhode Island	16%	2019
27.	South Dakota*	10%	2015
28.	Texas	5,880 MW	2015
29.	Utah*	20%	2025
30.	Vermont*	10%	2013
31.	Virginia*	12%	2022
32.	Washington	15%	2020
33.	Wisconsin	10%	2015

Thirty-eight states have utility-scale wind installations. See Figure 3: 2010 State Wind Installed Capacity. Texas has the largest installed wind capacity followed by Iowa and California.

[66] Source: DOE, State Renewable Portfolio Standards, http://apps1.eere.energy.gov/states/maps/renewable_portfolio_states.cfm (last visited Nov. 17, 2011). Percentages refer to a portion of electricity sales and megawatts (MW) to absolute capacity requirements. *Five states, North Dakota, South Dakota, Utah, Virginia, and Vermont, have set voluntary goals for adopting renewable energy instead of portfolio standards with binding targets.

AWEA, Wind Energy Facts: California (Aug. 2011).[67] Seven of the nation's ten largest wind farms are in Texas, including all of the top five. AWEA, Wind Energy Facts: Texas (Aug. 2011).[68]

Figure 3: 2010 State Wind Installed Capacity[69]



Further, the maps provided below (Maps 1.1 – 2.3) illustrate the actual locations of many of the wind projects in the United States – showing that this is an industry that is growing rapidly across the nation. The point maps and heat maps provided below are based on all unique wind turbine and associated meteorological tower proposals submitted to the FAA - OE/AAA between 2003 (the year when voluntary guidelines were established for wind energy projects by FWS) to 2011. Wind turbines that were already proposed or existing prior to 2003 are not shown. Meteorological towers represent 2.12% of the structures on the map.

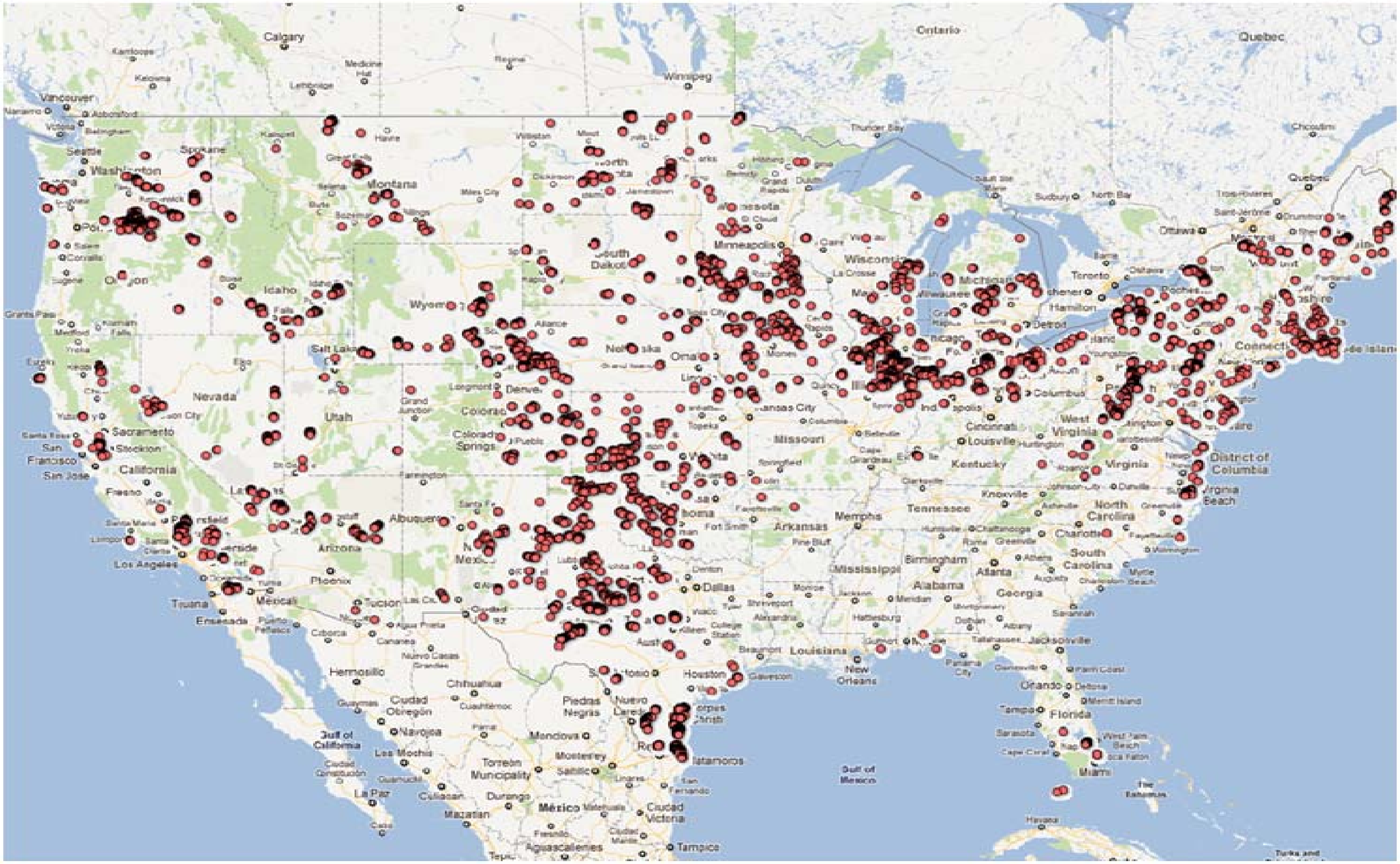
---

[67] Available at http://www.awea.org/learnabout/publications/upload/California.pdf (last visited Nov. 14, 2011).

[68] Available at http://www.awea.org/learnabout/publications/upload/Texas.pdf (last visited Nov. 14, 2011).

[69] Source: AWEA, 2010 U.S. Wind Industry Market Update, available at http://www.awea.org/learnabout/publications/factsheets/upload/Market-Update-Factsheet-Final_April-2011.pdf (last visited Nov. 14, 2011).

MAP 1.1: Estimated Wind Turbines in the Lower 48 States (2003 – 2011)[70]

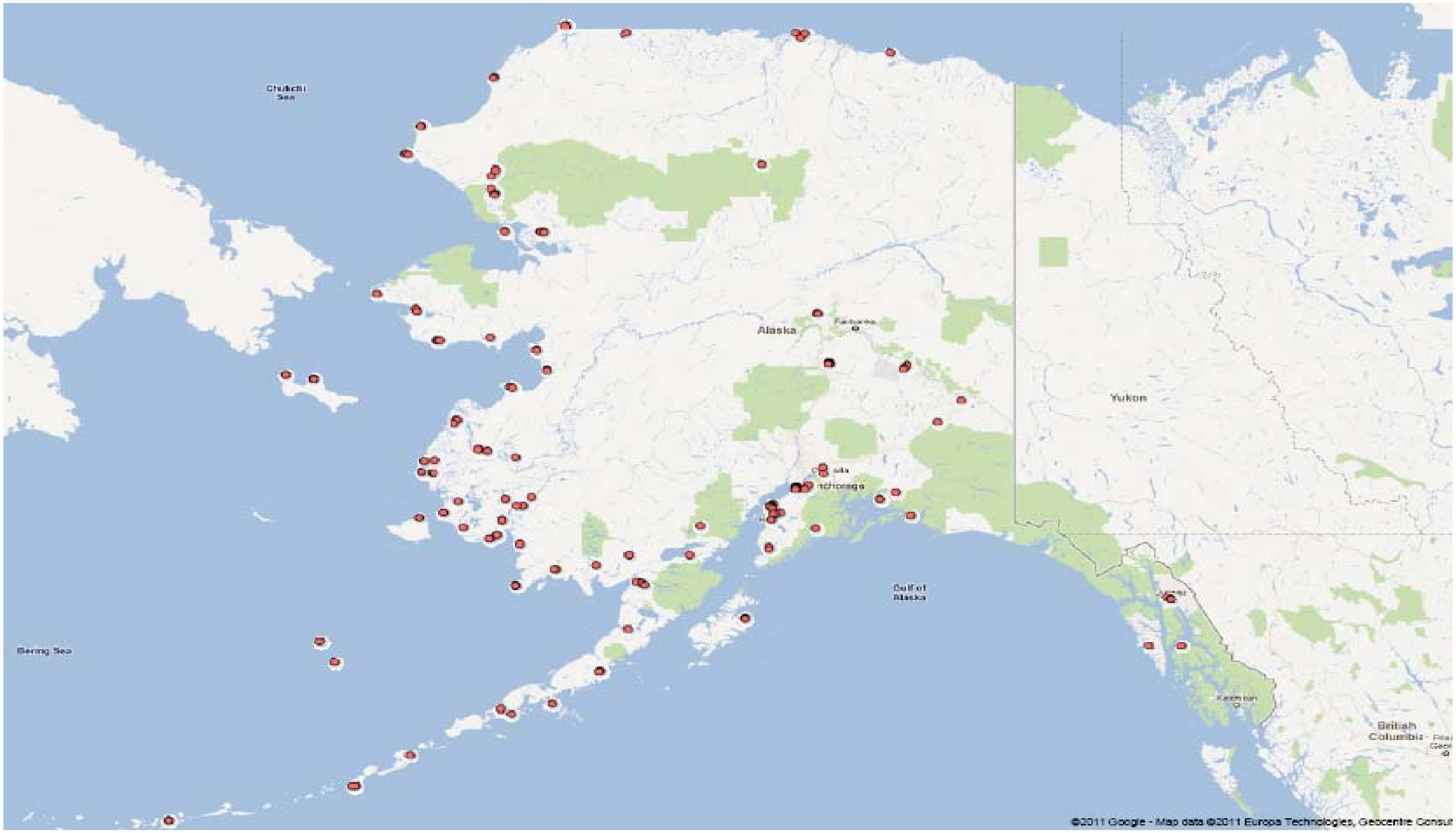


[70] Point map illustrating the location of wind turbines in 48 states in the United States that were logged with the FAA between 2003 and 2011. These are a mix of both existing and proposed wind turbines, as well as meteorological towers. Meteorological towers make up 2.12% of the logged structures on the overall U.S. map. All maps provided in this Petition are based on data available on the FAA website.

MAP 1.2: Estimated Wind Turbines in Hawaii (2003 – 2011)[71]

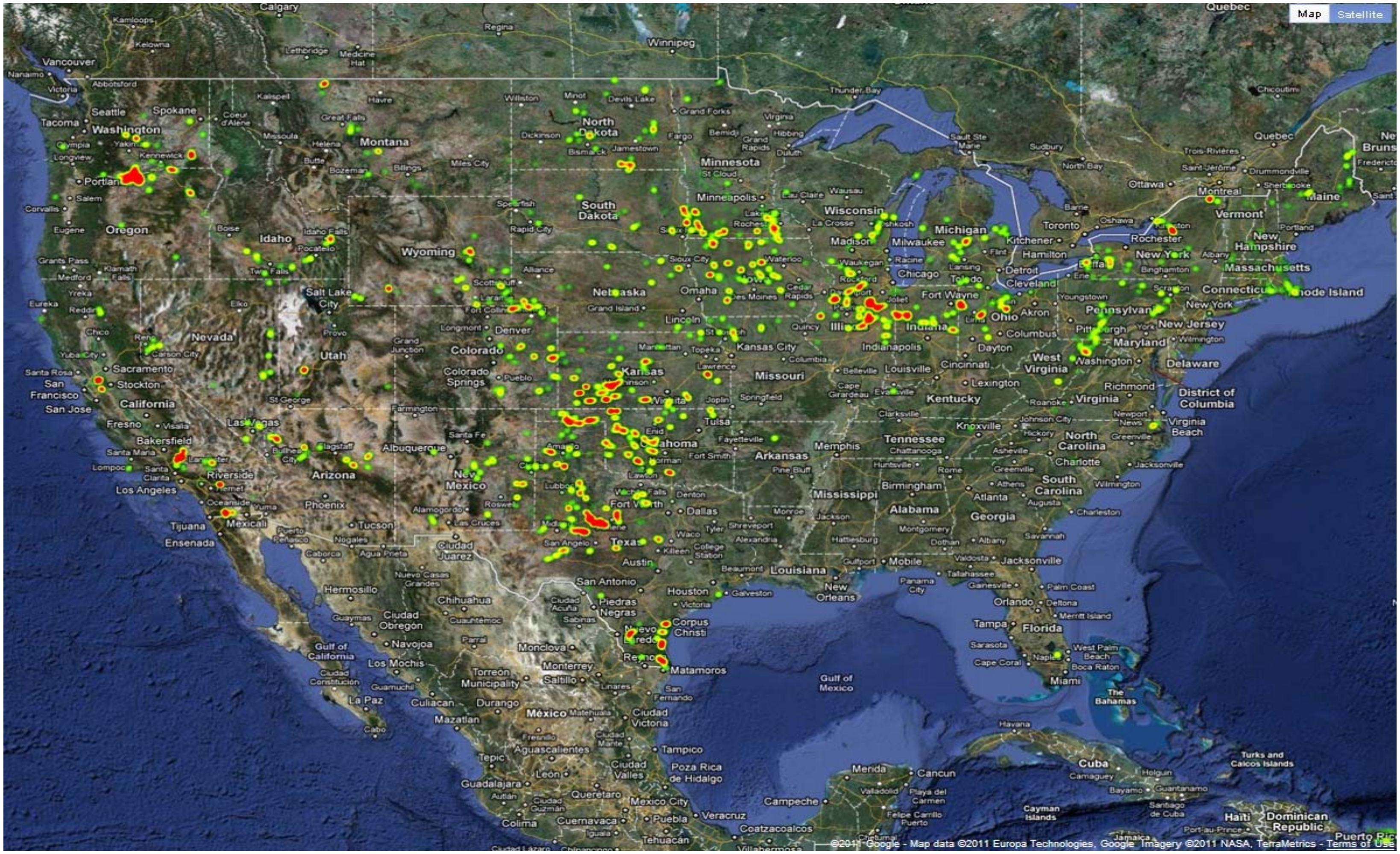
[71] Point map illustrating the location of wind turbines in Hawaii that were logged with the FAA between 2003 and 2011. These are a mix of both existing and proposed wind turbines, as well as meteorological towers. Meteorological towers make up 2.12% of the logged structures on the overall U.S. map. All maps provided in this Petition are based on data available on the FAA website.

MAP 1.3: Estimated Wind Turbines in Alaska (2003 – 2011)[72]



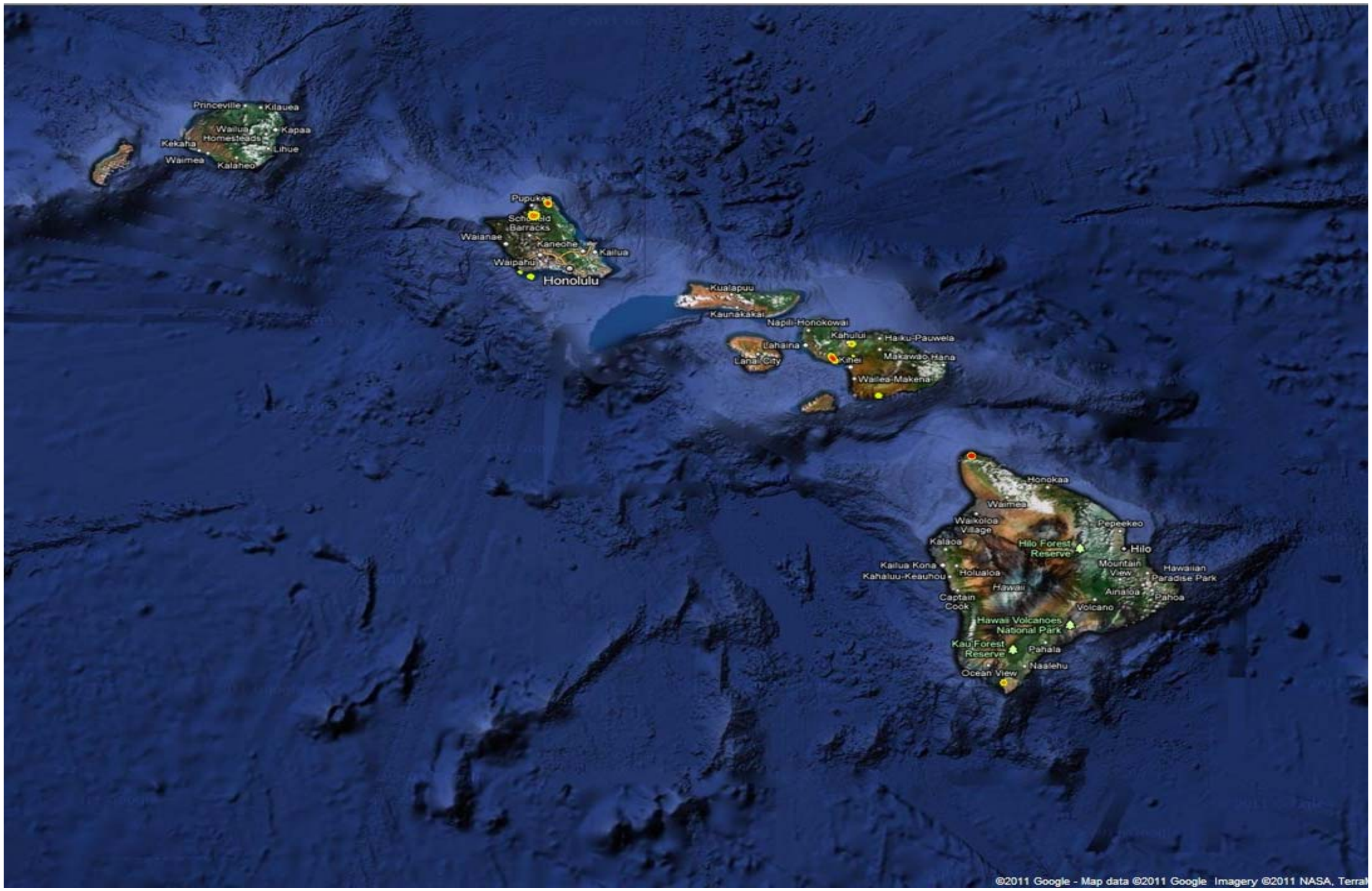
[72] Point map illustrating the location of wind turbines in Alaska that were logged with the FAA between 2003 and 2011. These are a mix of both existing and proposed wind turbines, as well as meteorological towers. Meteorological towers make up 2.12% of the logged structures on the overall U.S. map. All maps provided in this Petition are based on data available on the FAA website.

MAP 2.1: Estimated Wind Turbines in the Lower 48 States (2003 – 2011)[73]



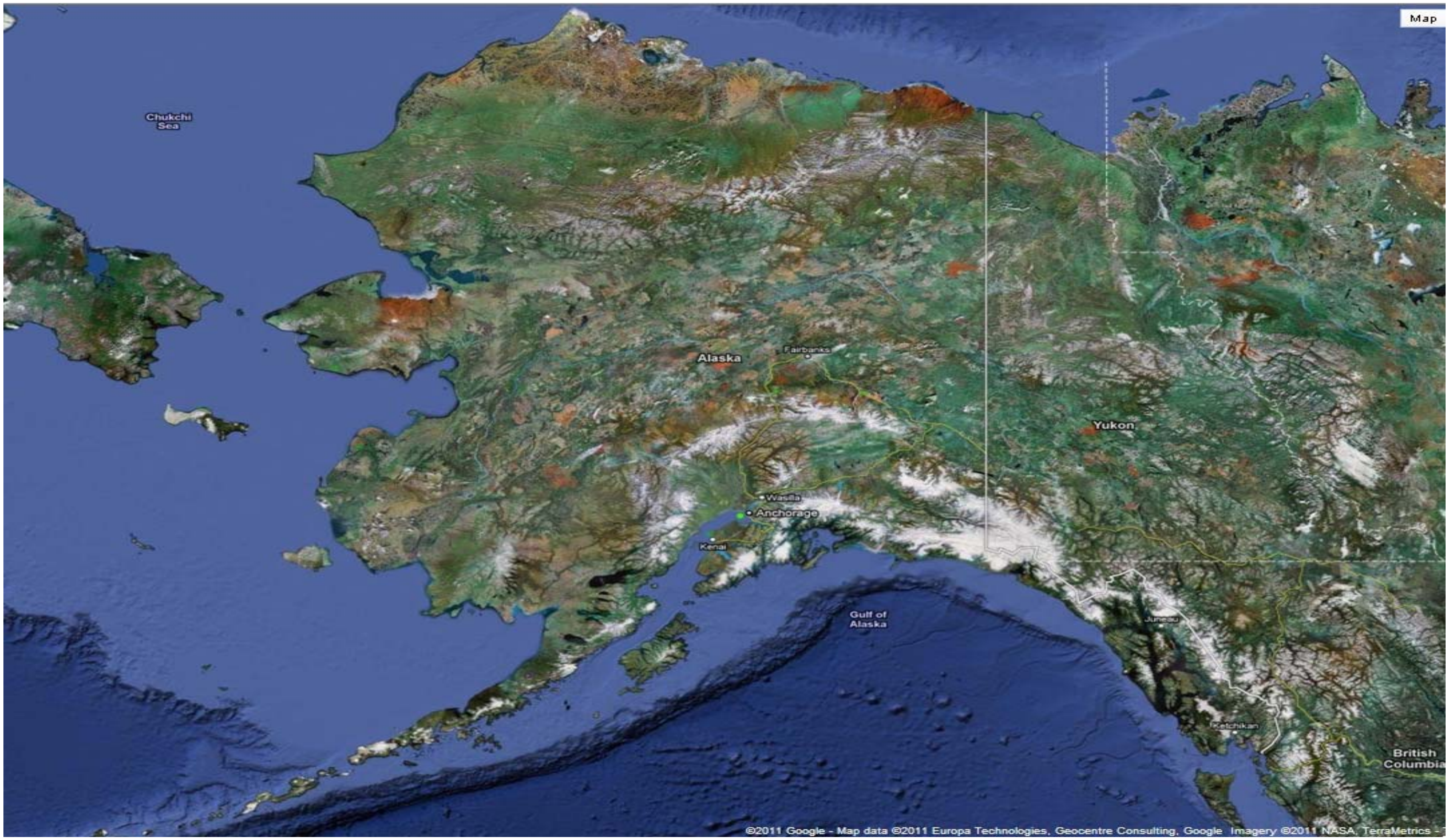
[73] Heat map indicating location of wind turbines in 48 states in the United States that were logged with the FAA between 2003 and 2011. These are a mix of both existing and proposed wind turbines, as well as meteorological towers. Meteorological towers make up 2.12% of the logged structures on the overall U.S. map. The darker orange and red dots represent areas with a relatively higher density of proposed wind structures than areas with green, yellow or no color dots. All maps provided in this Petition are based on data available on the FAA website.

MAP 2.2: Estimated Wind Turbines in Hawaii (2003 – 2011)[74]



[74] Heat map indicating location of wind turbines in Hawaii that were logged with the FAA between 2003 and 2011. These are a mix of both existing and proposed wind turbines, as well as meteorological towers. Meteorological towers make up 2.12% of the logged structures on the overall U.S. map. The darker orange and red dots represent areas with a relatively higher density of proposed wind structures than areas with green, yellow or no color dots. All maps provided in this Petition are based on data available on the FAA website.

MAP 2.3: Estimated Wind Turbines in Alaska (2003 – 2011)[75]



---

[75] Heat map indicating location of wind turbines in Alaska that were logged with the FAA between 2003 and 2011. These are a mix of both existing and proposed wind turbines, as well as meteorological towers. Meteorological towers make up 2.12% of the logged structures on the overall U.S. map. Because there are relatively few wind turbines in Alaska, they appear as small, light green dots on the map and might not be visible to some readers without magnification. All maps provided in this Petition are based on data available on the FAA website.

In addition to projects that have completed construction, there are over 90 separate projects totaling 8,400 MW of capacity currently under construction in 29 states. AWEA Third Quarter Report.

Along with land-based wind development, offshore wind energy is also poised to develop rapidly. See, e.g., DOI Press Release, Salazar, Chu Announce Major Offshore Wind Initiatives (Feb. 7, 2011)[76] (unveiling a coordinated strategic plan which pursues the deployment of 10 GW of offshore wind capacity by 2020 and 54 GW by 2030 and announcing $50.5 million in funding for offshore wind energy deployment). The Energy Policy Act of 2005 authorized the Secretary of the Interior to grant leases on the Outer Continental Shelf ("OCS") for alternative energy projects, including offshore wind energy projects. Pub. L. No. 109-58, 119 Stat. 594, § 388. The Secretary delegated this authority to the Director of the U.S. Bureau of Ocean Energy Management ("BOEM"), which subsequently approved the nation's first commercial offshore wind energy project with around 130 turbines – the Cape Wind project – in federal waters off the coast of Massachusetts. Many other projects are being planned for construction in federal waters off the coast of Delaware, New Jersey, Florida and Georgia. See BOEM, Offshore Renewable Energy: Interim Policy Projects.[77] In addition, several projects are also being planned for state waters, such as Baryonyx Corporation's proposal to construct 500 wind turbines off the Texas Gulf Coast. DOI has also announced a 'Smart from the Start Initiative' to facilitate siting, leasing and construction of new projects in the Atlantic Outer Continental Shelf. See DOI Press Release, Salazar Launches 'Smart from the Start' Initiative to Speed Offshore Wind Energy Development off the Atlantic Coast (Nov. 23, 2010).[78]

The leading wind energy developers in the United States include developers that have extensive past experience with renewable energy sources, such as Iberdrola Renewables and Horizon Wind Energy, as well as subsidiaries of large oil companies such as BP and Shell. See, e.g., BP Alternative Energy, Our Business: Wind Power;[79] Shell, Wind Energy Operations.[80]

---

[76] Available at http://www.doi.gov/news/pressreleases/Salazar-Chu-Announce-Major-Offshore-Wind-Initiatives.cfm (last visited Nov. 15, 2011)

[77] Available at http://www.boemre.gov/offshore/RenewableEnergy/Projects.htm (last visited Nov. 15, 2010).

[78] Available at http://www.doi.gov/news/pressreleases/Salazar-Launches-Smart-from-the-Start-Initiative-to-Speed-Offshore-Wind-Energy-Development-off-the-Atlantic-Coast.cfm (last visited Nov. 15, 2010).

[79] Available at http://www.bp.com/sectiongenericarticle.do?categoryId=9024940&contentId=7046497 (last visited Nov. 11, 2011)

[80] Available at http://www.shell.us/home/content/usa/innovation/wind/projects/ (last visited Nov. 17, 2011).

Increase in size of wind turbines in order to produce more energy

The growth in the industry has been paralleled by an expansion in the size of the turbines. "Modern wind turbines are giant structures" and may vary from 200 to 400 short tons in weight. AWEA et al., Winds of Change: A Manufacturing Blueprint for the Wind Industry (June 2010) at 6, 20. The blade tip speed of the turbines is typically around 180 mph. See Albert Manville, FWS, Presentation on Framing the Issues Dealing with Migratory Birds, Commercial Land-based Wind Energy Development, USFWS, and the MBTA (Oct. 21, 2011) 5 ("FWS 2011 MBTA Conference Presentation") (explaining that the combination of large turbine blades and high speed increases the potential for bird collisions), Attachment G. Further, offshore wind energy projects use turbines much larger than those typically installed onshore. Id. at 16.

Larger turbines produce more energy. See DOE, Wind Power Today (May 2007) ("DOE Wind Power Today")[81] (explaining that DOE has been working with the wind industry to develop larger machines that are more efficient and that capture more energy from the wind). To meet the growing demand, in 2006 alone, average turbine size increased by more than 11% over the 2005 level. See DOE 20% Wind Report at 5; see also Global Energy Concepts, Wind Turbine Technology: Overview (Oct. 2005)[82] ("The rotor diameters and rated capacities of wind turbines have continually increased in the past 10 years"). The average turbine installed in 2006 (at 1.5 MW) was almost as tall as the Statue of Liberty and had a rotor large enough to sweep a football field. DOE Wind Power Today at 2. By 2010, the size of wind turbines had increased with the rotor diameter of the blades exceeding 364 feet (111 meters) (a space that could provide parking for 24 average-sized cars end to end across the diameter of its rotor). Id. at 3.

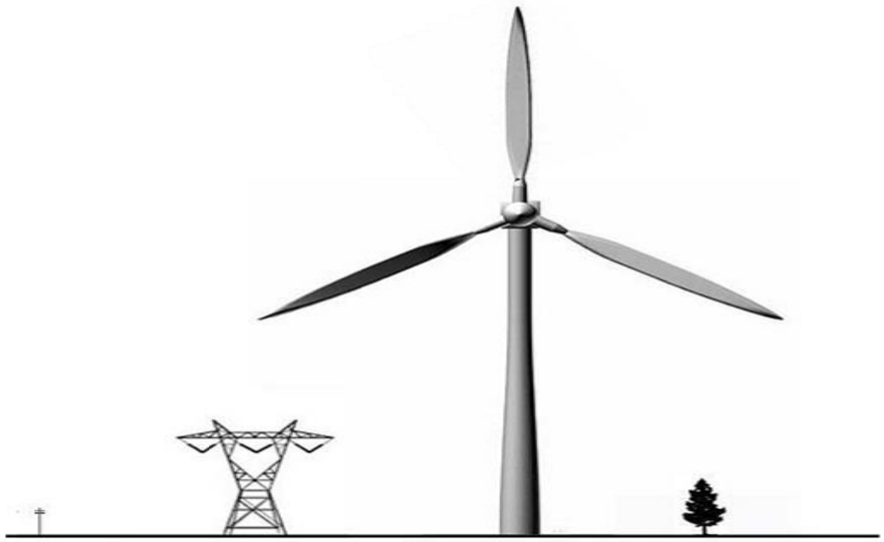
Significant increase in the size of wind turbines is expected in the near term. By 2015, the average turbine size is expected to exceed 700 feet (213 meters) in height. DOE Wind Power Today at 3; see also Figure 4: Comparison Of The Height Of A Large Wind Turbine With Other Tall Structures. A recent DOE study on trends in the wind industry found that: "[a]verage hub heights and rotor diameters have also scaled with time, to 79.8 and 84.3 meters, respectively, in 2010. Since 1998-99, the average turbine hub height has increased by 43%, while the average rotor diameter has increased by 76%. Industry expectations as well new turbine announcements (especially to serve lower-wind-speed sites) suggest that significant further scaling, especially in rotor diameter, is anticipated in the near term." 2010 DOE Wind Market Report at v; DOE Wind Power Today at 29-31.

---

[81] Available at http://www.nrel.gov/docs/fy07osti/41330.pdf (last visited Nov. 16, 2011).

[82] Available at http://www.powernaturally.org/programs/wind/toolkit/9_windturbinetech.pdf (last visited Nov. 16, 2011).

Figure 4: Comparison Of The Height Of A Large Wind Turbine With Other Tall Structures[83]



In sum, the wind industry has developed rapidly over this decade and has great potential to continue to grow. Further, larger and more efficient turbines are generating greater amounts of wind power at lower costs. However, the industry has been concerned about the expiration of a federal production tax credit by the end of 2012. ABC recognizes the need for renewable energy development and will support the industry in its efforts to extend the tax credit for wind energy production, if FWS puts in place a system that ensures ongoing compliance with the MBTA along with other wildlife protection laws.

C.2. Unregulated wind energy projects pose a serious threat to migratory birds protected under federal wildlife laws.

Rapid development of the wind industry and proliferation of massive wind turbines pose a serious threat to migratory bird species if they take place without meaningful regulation and appropriate mandatory federal standards. Indeed, the wind power industry has two essential attributes that render it particularly suitable to development of a permitting system for regulating take of migratory birds.

First, it is an industry that is inherently risky to birds because it entails placing huge turbines and associated power lines and other infrastructure in areas where killing of migratory birds (and hence violations of the MBTA) are virtually inevitable. See Letter from Laury Zicari, FWS to Jennifer McCarthy, U.S. Army Corps of Engineers ("Corps") (May 11, 2011), Attachment H (in providing recommendations in relation to the wildlife impacts of the Saddleback Ridge wind project,

[83] Source: Virginia Wind, Turbine Size, http://www.vawind.org/#javascript (last visited Nov. 17, 2011).

FWS observed that, "[a]ll wind power projects will take birds and bats."); Nat'l Wind Coordinating Collaborative, Wind Wildlife Research Meeting VIII: Presentation and Poster Abstracts 45-46 (Oct. 2010)[84] ("The rapid development of the wind industry in the US has resulted in situations in which wind sites without environmental constraints are becoming increasingly rare. Therefore, more sites with potential conflicts with endangered species and their habitats are under consideration for development… Locations with threatened or endangered species issues are becoming more common as the industry becomes more competitive. Although the species may differ, consistent problems with special status species exist nationwide.").

Indeed, most birds impacted by wind energy projects are protected under the MBTA. See, e.g., Thomas Kunz et al., Assessing Impacts of Wind-Energy Development on Nocturnally Active Birds and Bats: A Guidance Document, 71(8) J. Wildlife Mgmt. 2449, 2450 (2007)[85] ("In a review of bird collisions reported from 31 studies at utility-scale wind energy facilities in the United States, Erickson et al. (2001) showed that 78% of carcasses found at wind-energy facilities outside of California were songbirds protected by the Migratory Bird Treaty Act.").[86]

Second, the environmentally responsible development of wind power is generally recognized to be of benefit to society, particularly because it may be able to play a long-term role in alleviating the effects of climate change on ecosystems. A permitting system – such as that proposed in this Petition – is essential to such development.

Collision with wind turbines and related infrastructure

Wind energy projects adversely impact migratory birds in multiple ways. First, migratory birds are routinely killed by collisions with wind turbines or the infrastructure needed to support wind energy facilities. FWS estimated in 2009 that 440,000 birds were being killed annually by wind turbines in the United States. This mortality estimate is likely an underestimate based on the operation of approximately 22,000 turbines in 2009. See Albert Manville, FWS, Towers, Turbines, Power Lines, and Buildings – Steps Being Taken By the U.S. Fish and Wildlife Service to Avoid or Minimize Take of Migratory Birds at These Structures 6 (July 17 2009) ("Manville 2009 Paper"), Attachment I. By 2020, more than 100,000 turbines are projected to be operating, and it is expected that such an exponential increase of wind turbines will kill at least one million birds each year, and it

---

[84] Available at http://www.nationalwind.org/assets/research_meetings/Research_ Meeting_ VIII_ Abstracts.pdf (last visited Nov. 16, 2011).

[85] Available at http://www.batsandwind.org/pdf/jwm_m&m.pdf (last visited Nov. 16, 2011).

[86] Poorly sited and operated wind power projects may also have very detrimental effects on other wildlife, particularly bats. As discussed infra, see Section E.4, although this Petition is directed at migratory bird impacts, the permitting scheme that it advocates would have collateral benefits for other wildlife as well.

is likely that the actual mortality will significantly exceed this estimate. See ABC Bird-Smart Wind Principles.

Further, while there are no well-established estimates for the numbers of birds killed by wind energy infrastructure (other than turbines) such as power lines, substations, and meteorological towers, three examples demonstrate why this infrastructure is also of serious concern. See Manville 2009 Paper at 7.

First, power lines are known to be the greatest source of anthropogenic mortality for fledged Whooping Cranes, whose Aransas-Wood Buffalo migration corridor traverses the Great Plains, where a large build out of wind power is expected. See FWS Regions 2 and 6, Whooping Cranes and Wind Development – an Issue Paper 2-3 (2009).[87] Golden Eagle and hawk mortality at power lines are also well documented.

Second, substations associated with wind energy facilities can be another source of mortality, especially when steady-burning lights are left on in low-visibility conditions during migration, as happened during October 1-2, 2011 at the Laurel Mountain wind project and around May 23, 2003 at the Mountaineer wind facility, both in West Virginia. See Memo from Stantec Consulting (consultants for developer) to Laura Hill, FWS, Bird Mortality at Laurel Mountain Substation Memo (Oct. 25, 2011) at 1, Attachment J; Curry & Kerlinger, LLC, A Study of Bird and Bat Collision Fatalities at the Mountaineer Wind Energy Center, Tucker County, West Virginia: Annual Report for 2003 (Feb. 14, 2004) at 5.[88] 484 birds killed by the Laurel Mountain wind energy project, mostly MBTA-protected songbirds, were found at a substation and battery energy storage station on the site; at Mountaineer, 33 birds were found dead at a substation and three wind turbines.

Third, meteorological towers are documented to kill birds. For example, at the Shiloh II Wind Power Project in California, more than 52 birds were found dead at ten meteorological towers over a two-year period (these are unadjusted mortality numbers and actual mortality at the sites would have been higher). See Curry & Kerlinger LLC, Meteorological Tower Fatality Study at the

---

[87] Available at ftp://wiley.kars.ku.edu/windresource/Whooping_Crane_and_Wind_Development_FWS_%20April%202009.pdf (last visited Nov. 17, 2011).

[88] Available at http://www.wvhighlands.org/Birds/MountaineerFinalAvianRpt-%203-15-04PKJK.pdf (last visited Nov. 17, 2011).

Shiloh II Wind Project, Solano County, California (Apr. 2008) at 6.[89] According to the Shiloh II study, 85% of the dead birds were legally protected.[90] Id. at 14.

Habitat loss and degradation

Development of wind energy projects can harm birds through long-term habitat loss, alteration, degradation, and fragmentation. Wind energy projects are expected to impact almost 20,000 square miles of terrestrial habitat, and another 4,000 square miles of marine habitat. See DOE 20% Wind Report at 110-11. A U.S. Government Accountability Office ("GAO") report on wind energy found that, "[a]ccording to FWS, the loss of habitat quantity and quality is the primary cause of declines in most assessed bird populations and many other wildlife species." GAO, Wind Power: Impacts on Wildlife and Government Responsibilities for Regulating Development and Protecting Wildlife 15 (2005) ("GAO Wind Power Report");[91] see also Ill. Dep't of Natural Res., The Possible Effects of Wind Energy on Illinois Birds and Bats 2 (2007).[92]

FWS itself has raised concerns about both direct and indirect effects of various wind energy projects. See, e.g., Letter from FWS to Amber Zuhlke, Wind Capital Group, Big Lake Wind Facility in Palm Beach, Florida (July 1, 2011), Attachment K (regarding construction of a project in the Everglades Agricultural Area, FWS stated that the site "supports a host of sensitive trust resources including federally protected migratory birds… The Service has significant concerns on the effects of the proposed project on our trust resources and their habitats. These include both the direct effects of "take" (i.e., mortality and injury through collision) and the indirect effects of habitat fragmentation, site avoidance, disturbance, habitat degradation, barriers, and creation of marginal/suboptimal adjacent wetlands habitats, among others.").

Wind energy facilities require not only wind turbines but also access roads and other infrastructure such as power lines, substations, and outbuildings, resulting in habitat impacts. Furthermore, another form of habitat that is lost due to wind energy development is the airspace that birds formerly used in flight, which can disrupt migrations and other essential behavioral patterns. See FWS 2011 MBTA Conference Presentation at 2.

---

[89] Available at http://www.co.solano.ca.us/civicax/filebank/blobdload.aspx?blobid=8916 (last visited Nov. 17, 2011).

[90] The study states that 15% of the dead birds found at the met towers were legally unprotected. It is likely that the remaining 85% of the birds killed by the project were protected under the MBTA because almost all of the species that were listed as fatalities found during the study were those protected under the MBTA.

[91] Available at http://www.gao.gov/new.items/d05906.pdf (last visited Dec. 11, 2011).

[92] Available at http://dnr.state.il.us/publications/pdf/00000544.pdf (last visited Dec. 11, 2011).

In addition to the habitat lost to the cumulative footprint of wind facilities, habitat that remains but is fragmented by the facility can lose its value for some bird species. Examples of species sensitive to habitat fragmentation include the Lesser Prairie-Chicken and Grasshopper Sparrow. See Lesser Prairie-Chicken Interstate Working Group, Assessment and Conservation Strategy for the Lesser Prairie-Chicken (Tympanuchus pallidicinictus) 10 (1999).[93] For instance, the Grasshopper Sparrow has been found by the U.S. Geological Survey to avoid habitat near wind turbines. See Jill A. Shaffer & Douglas H. Johnson, U.S. Geological Survey, Displacement Effects of Wind Developments on Grassland Birds in the Northern Great Plains 51 (2010).[94]

Habitat fragmentation results in an increase of "edges" – areas where habitat is interrupted by human-created features such as access roads and substations. According to FWS, "an increase in edge may result in greater nest parasitism and nest predation." FWS, Revised Draft Land-Based Wind Energy Guidelines 86 (Sept. 13, 2011) ("Wind Guidelines Third Draft").[95] Moreover, some bird species are sensitive to tall structures and will abandon important habitat when tall structures are added. For example, Greater Sage-Grouse abandoned key habitat at an Idaho site after meteorological towers for wind testing were installed. See Biodiversity Conservation Alliance, Wind Power in Wyoming: Doing It Smart from the Start 21 (2008).

Barrier effects

In addition to collision with wind turbines and displacement from habitat, there are other serious threats posed by wind energy development to migratory birds. "Barrier effects," i.e., the energetic impacts to birds of avoiding wind energy facilities rather than flying through them, will become of increasing importance as the size of wind facilities increases and as migration pathways or regional use areas fill with wind turbines. See FWS, Barrier Effect (2011) (providing an overview of barrier effects).[96]

For example, more than 2,000 wind turbines have been proposed at a project in the Whooping Crane's Aransas-Wood Buffalo migration corridor in South Dakota (Titan Wind project). Clipper Wind Power, Clipper Windpower And BP Alternative Energy Form Joint Venture To Develop Up To 5,050 MW: Project to be World's Largest (2008).[97] Further, 1,000 wind turbines

---

[93] Available at http://bsi.montana.edu/prairiemap/files/LesserChicken.pdf (last visited Dec. 11, 2011).

[94] Available at https://www.nationalwind.org/assets/research_meetings/Research_Meeting_VII_Shaffer.pdf (last visited Dec. 12, 2011).

[95] Available at http://www.fws.gov/windenergy/ (last visited Dec. 11, 2011).

[96] Available at http://www.fws.gov/windenergy/docs/Barrier_Effect.pdf. (last visited Nov. 15, 2011).

[97] Available at http://www.clipperwind.com/pr_073008.html (last visited Nov. 15, 2011).

have been proposed for a project in Golden Eagle use areas in Wyoming (Chokecherry-Sierra Madre project). See BLM, Chokecherry and Sierra Madre Draft Environmental Impact Statement (2011).[98]

According to FWS, barrier effects have been observed at both land-based and offshore wind projects. In addition, FWS has said that energetic impacts caused by birds avoiding wind turbines may lead to population impacts over time. Barrier Effect supra (2011).

Noise effects

The effects of noise produced by wind turbines can also have adverse impacts on bird species. For instance, utility-scale wind turbines have been demonstrated to produce noise within the range that can reduce densities in some grassland and woodland birds. Noise can also mask the calls birds use to communicate. See FWS, The Effects of Noise on Wildlife (2011) (providing an overview of noise impacts).[99]

Mapping of Estimated Wind Turbines in Key Bird Use Areas

The maps provided below, see Maps 3.1 – 3.3, demonstrate that many wind energy projects have already likely been constructed in areas that are extremely important for birds. These maps have been created by ABC based on data submitted to the FAA - OE/AAA between 2003 (the year when voluntary guidelines were established for wind energy projects by FWS) to 2011. They include all unique wind turbine and associated meteorological tower proposals submitted to the FAA during that time. Wind turbines that were already proposed or existing prior to 2003 are not shown. Meteorological towers represent 2.12% of the structures on the map. These FAA-documented proposed wind turbines and metrological towers are overlaid on the ABC Wind Development Bird Risk Map.[100]

On the maps provided below, red indicates critically important areas for birds where wind energy should not be developed. These areas include important habitat for endangered birds, for concentrations of 500,000 or more migratory birds, for concentrations of the rarest WatchList bird, or those that have special habitat requirements and/or are especially likely to be vulnerable to wind-

---

[98] Available at http://www.blm.gov/wy/st/en/info/NEPA/documents/rfo/Chokecherry.html (last visited Nov. 15, 2011).

[99] Available at http://www.fws.gov/windenergy/docs/Noise.pdf (last visited Nov. 15, 2011).

[100] The data presented on the maps provided below are derived from a variety of sources. Examples of primary sources include ABC's list of the 500 most Important Bird Areas in the United States, data on Sage-Grouse core areas from the BLM, and data on the migration corridor of the Whooping Crane from The Nature Conservancy/AWWI. Boundaries of sites are either provided by existing federal or other Geographic Information System layers, or produced by ABC using the best available maps and expert staff opinion. The boundaries of these areas are set on the map based on ABC's best expert judgment as to where the greatest concentration of birds will be present during most migration periods.