Results

Sixty-eight birds were found to collide with structures associated with the wind farms during this study, the majority of which (51) were from medium to large species. Large differences were found between the two wind farms in the frequency of casualties. The estimated number of bird losses and mortality rates per turbine were much lower at E3 than at PESUR (2 deaths and a 0.030 mortality rate vs. 68 deaths and a 0.360 mortality rate, respectively). Griffon vultures and common kestrels made up the most frequent fatalities (30 and 12, respectively); the highest concentration of fatalities occurred when species density was greatest (kestrels in summer, vultures in autumn/winter).

Vulture deaths were all found to occur between October and April (66.7% occurring between December and February), and more than half of the deaths occurred in two segments of PESUR (15% of turbines were responsible for 57% of collisions). Collisions rarely occurred in strong winds, and all deaths except one occurred on clear days. The absence of thermals in winter is believed to have forced vultures to use slopes for lift, the most likely mechanism influencing both their exposure to turbines and the risk of fatalities. Tower structure could be excluded as a factor, because the number of losses for each type of tower (85% lattice, 15% tubular) was not significantly different from their availability.

Common kestrel deaths were concentrated in the summer after the fledging period; 67% of fatalities occurred between July 15 and August 17, 1994. All common kestrel fatalities occurred at the PESUR wind farm. Fatalities were evenly distributed across the wind farm, and the distribution of collisions for lattice (75%) and tubular towers (25%) was not significant. The concentration of carcasses in open habitats around a single wind farm may indicate that risk is associated with hunting habitat preferences.

Of 14,524 bird passes near the wind farms, 4,809 (33%) were griffon vultures. Average annual sighting frequencies at PESUR (10 vultures/h) were higher than at E3 (6.5 vultures/h), as were the risk indices at the two locations (0.198 vs. 0.059, respectively). At wind speeds lower than 4.5 m/s, the turbine blades did not turn and there was no risk. When the turbine blades were rotating, the risk index was highest (0.343) at wind speeds from 4.6-8.5 m/s, and the risk decreased with increasing wind speed. The risk index was also higher when vultures circled (0.279) rather than when they were in straight or slope flights (0.131 and 0.032, respectively), as well as when the birds approached the turbines from below (0.259) rather than above (0.062).

Implications for Wind Development

This study indicates that avian vulnerability and fatalities at wind power facilities are the result of a combination of site-specific (wind-relief interactions), species-specific, and seasonal factors. Therefore, it is very important to conduct a detailed study of bird behavior at the precise location where construction is proposed in order to identify species that are particularly vulnerable, the sites that are used intensively, and thus the optimum turbine location. The results of this study lead the authors to believe that the most sensible approach to reducing avian mortality at PESUR and E3 would be to suspend operation of the small number of turbines that caused the most deaths during conditions that increase risk.

Case Study 4a

Alonso, J.C., J.A. Alonso, and R. Munoz-Pulido. (1994). "Mitigation of bird collisions with transmission lines through groundwire marking." *Biological Conservation* **67**: 129-134.

Introduction

Collisions with electric power transmission lines are known to cause fatalities among birds, and groundwires are especially problematic because they are thinner and more difficult for birds to see. While methods such as route planning, rerouting, and burying cables have proven effective in minimizing bird fatalities, these approaches are generally carried out before construction or are very expensive (e.g., burying cables). Removing or marking the groundwire can be done after lines have already been installed. The purpose of this study was to evaluate the effectiveness of groundwire marking as a method of reducing bird fatalities caused by collisions at a transmission line in southwestern Spain.

Techniques Used

Before the field study, the four most critical sectors of the power line were determined according to published or known information about local bird populations and collision data. The four sectors measured 4236 m, 7370 m, 8784 m, and 7811 m. Red-colored spirals made of polyvinyl chloride and measuring 1 m long and 30 cm diameter (maximum), were rolled around both groundwires at 10-m intervals in four sectors totaling 12,500 m.

Data Collection

Data were collected on line sectors from December 1989 to April 1990 and again during the same period in 1990 to 1991, before and after bird flight diverters were installed. Each power line sector was searched once weekly; observers walked in a zigzag pattern within the 50-m-wide search area. Full-day observations of bird flight intensity across two spans of the line (approximately 800 m) were conducted once monthly at each of the four line sections, for a total of 366 hours of observations. Flight intensity observations could not be made at unmarked spans during the second year, because the company decided to mark all spans previously selected for flight observation.

Fatality estimations did not take into account errors such as the disappearance of dead birds as a result of scavenging, birds undetected because of vegetation density, or birds seriously injured but not immediately killed by the collision. This is not believed to have affected the estimate of groundwire marking efficiency, however, as the possible bias in fatality estimates affected both study years, before and after the line was marked.

Results

A total of 7,456 individuals belonging to 59 species were observed during flight intensity observations; common cranes were the most numerous of the birds observed (33.6%). The mean daily numbers of birds observed flying across the power line decreased by 61% after the groundwire marking, and three of the four sectors exhibited significant decreases.

The mean number of individual birds of the same species seen flying across the power line decreased from 74.4 birds before groundwire marking to 29.3 birds after marking, but the difference was not significant. There were, however, significantly more species for which flight intensity decreased after groundwire marking than those for which flight intensity increased.

Fatality searches resulted in 107 dead birds belonging to 30 species; the most numerous species was wood pigeons (16.8%). The number and diversity of dead birds found in the marked sectors of the line significantly decreased, from 45 birds (19 species) to 18 birds (13 species) after groundwire marking. This increased from 19 birds (15 species) to 25 birds (15 species) in sectors left unmarked (not significant). The decrease in the number of dead birds found per span was significant in comparison to those found in the same span before marking. However, there was no significant change in the number of dead birds found in the sample of spans left unmarked (26/29 spans resulted in fewer or no change in dead birds).

Implications for Wind Development

This study illustrates the effectiveness of marking groundwires in order to reduce avian collisions with transmission lines. This technique may offer an appropriate solution for reducing avian impacts at wind farms where groundwires, transmission lines, and distribution lines are characterized by increased bird mortality rates.

Case Study 4b

Janss, G. F. E., and M. Ferrer (1997). "Rate of bird collision with power lines: Effects of conductor-marking and static wire-marking." *Journal of Field Ornithology* **69**(1): 8-17.

Introduction

Various marking schemes have been published over the years to address the issue of birds colliding with power lines. Although some studies have examined the effects of wire markers on distribution lines (Brown and Drewien 1995), there has been no comparison of fatalities at transmission lines to those at distribution lines. As a result, this study evaluated three different types of power lines in west-central Spain: one transmission line with static wires and two distribution lines without static wires. The purpose was to quantify the fatalities recorded for three different types of power lines and to evaluate the effect of three different types of markers.

Techniques Used

Line A was a 380-kV double-circuit transmission line with six duplex conductors forming three cable levels with two static wires overhead. Line A crossed a cultivated area in which 40-m-high towers were 500 m apart. Eight consecutive spans were studied (4.5 km) before and after white polypropylene spirals were rolled around the two static wires every 10 m and staggered between the static wires. The spirals were 1-m long with a maximum diameter of 30 cm.

Line B was a 132-kV simple-circuit distribution line without static wires, with three conductors on the same level. Line B crossed an extended cultivated area in which 20-m-high towers were 250 m apart. Fifteen consecutive spans were studied (3.9 km) before and after markers were installed every 20 m; the markers consisted of two neoprene black crossed bands (35 cm x 5 cm) and a phosphorescent stripe (5 cm x 4 cm) fixed on a plastic peg.

Line C was a 13-kV simple-circuit distribution line without static wires, with three conductors almost at the same level. Line C was located in a protected river delta, and consisted of 9-m towers placed 100 m apart. Ten consecutive spans (1.2 km) were examined before and after markers consisting of three thin plastic black stripes (70 cm x 0.8 cm) were hung every 12 m from the central conductor.

Markers were placed on alternating study spans, so that each marked span had an adjacent unmarked span.

Data Collection

Fatality searches were conducted over 4 years and consisted of two study periods. The first study period (1991-1993) took place before the installation of the markers. Surveys were conducted as follows: Line A – seven surveys from February 1992-February 1993, every 2 months; Line B – four surveys from August 1992-March 1993, every 2 months, and four surveys conducted monthly from July-October 1993; Line C – seven surveys conducted from August 1991-August 1992, every 2 months.

The second study period (1993-1995) took place after the line markers were installed in some of the study spans. Fatality searches were conducted monthly for at least 13 months at each line: Line A – February 1994-February 1995, 3 marked, 4 unmarked; Line B – December 1993-

December 1994, 7 marked, 8 unmarked; Line C – August 1993-November 1995, 4 marked, 4 unmarked.

Results

One hundred and fifty casualties of 26 species were found during this study, 64 during the first study period and 86 during the second period. Avian mortality was not found to differ between the three power lines studied. Gruiformes were the most common victims, with great bustards and little bustards representing 15.3% and 17.3%, respectively, of all bird remains.

The greatest frequency of collisions (2.95 birds/km) occurred at Line C, followed by Line A (0.96) and B (0.84). No statistical differences were detected between the three power lines in collision frequency per survey. The reductions in mortality for all birds when the white spirals were used (Line A) was 81%. The total number of birds under spans marks with crossed bands (Line B) was significantly smaller than those under unmarked spans (a 71% reduction); however, when the great bustard was included in the analysis, the markers were found to have no effect. There was no significant reduction in mortality as a result of using the black striped marker (Line C).

Implications for Wind Development

Although overall mortality rates were reduced by more than 75% using both the spiral and crossed-band markers, it is important to note that this excludes the great bustard, for which no effective marker could be found. This suggests that markers for transmission or distribution lines near wind farms, while effective overall, may not be effective for all species and should not be assumed to be an adequate mitigation strategy for some birds. This study also illustrates (through research and reference) that various markers can be effective in reducing avian mortality so that other factors, such as price and durability, should be considered. The effectiveness of these markers on wind turbines and meteorological towers supported by guyed wires has not yet been tested.

Case Study 5

Earnst, S.L., J.A. Ballard, and D.S. Dobkin. (2004). *Riparian Songbird Abundance a Decade after Cattle Removal on Hart Mountain and Sheldon National Wildlife Refuges*. U.S. Department of Agriculture Forest Service Gen. Rep. PSW-GTR-191.

Introduction

Concern has been growing about the health of riparian habitats in the arid West, because they support a higher diversity of breeding songbirds than any other habitat type but comprise only 1% of the landscape. In addition, they are being severely affected by agriculture, recreation, timber harvesting, water diversion, and, in particular, livestock grazing. Previous studies have indicated that ground or near-ground nesting species and shrub nesting species are more affected by cattle grazing than habitat generalists, canopy nesters, and cavity nesters because cattle have a greater effect on lower vegetation strata.

Within the Sheldon-Hart Mountain National Wildlife Refuge Complex in Oregon and Nevada, there are currently 26 riparian species of concern. They are defined in this study as riparian associates that had either (1) a significant declining trend on North American Breeding Bird Survey (BBS) routes within USFWS Region 1 (comprising Calif., Ore., Wash. State, Nev., Idaho); (2) a significant declining trend on BBS routes in the Columbia Plateau physiographic area; (3) a Partners in Flight score for the Columbia Basin of >20; or (4) an Oregon Management Index score of >10. The objectives of this study were to compare the abundance of riparian birds 1-3 years and 11-12 years after livestock removal occurred at the Sheldon and Hart Mountain National Wildlife Refuges.

Techniques Used

Survey data collected during this study was compared with survey data collected during May 7-July 11 from 1991 to 1993 (three times annually). Mean detections per visit were averaged among visits within a year and among years within a phase (i.e., 1991-1993 and 2000-2001). The mean difference across all plots was calculated for each species and a paired t-test was used to determine whether the difference for each species was significantly different from 0. Comparisons were limited to passerines, doves, woodpeckers, and shorebirds that either nested or foraged primarily in riparian habitat within the Hart-Sheldon landscape and that had an average of $\geq$ 0.02 detections per plot visit (n = 51 species). Species were assigned to primary habitats (aspen, willow, meadow), nesting guilds (ground/low cup, high cup, cavity) and foraging guilds (ground/understory, overstory, aerial, bark). Binomial tests, t-tests, and one-way analyses of variance within groups were used to test for differences among guilds over time (based on detections/km^2).

Data Collection

Data were collected from 69 permanent study plots within six different cover types (meadow, riparian aspen, snow pocket aspen, willow, nonriparian shrub, and mixed deciduous): five cover types in five drainages in Hart Mountain (n = 47) and four cover types in six drainages in Sheldon (n = 2). Each plot was 150 m long by 100 m wide, and most plots were at least 250 m apart. Each study plot was surveyed three times from May 8-June 24, 2000, and May 17-June 25, 2001, by an observer walking slowly along the center-line of the plot and recording the first occurrence of each individual seen or heard within the plot.

Results

Preliminary results one decade after cattle removal indicated that 71% (36/51) of riparian species exhibited positive trends and 76% (16/21) of species increased that had exhibited a significant change (either positive or negative). Species associated with aspen and willow habitats exhibited a significant increase in detections/km^2, but species associated with meadows did not exhibit this change. Ground/low cup nesting species were found to increase more than either high cup or cavity nesting species, and ground/understory foraging species increased significantly more than overstory or bark foraging species and marginally more than aerial foragers. Only meadow associates, cavity nesters, and bark gleaners did not increase significantly.

Of the 26 riparian species of concern for which there were sufficient detections, seven exhibited significant increases on original plots since the removal of cattle (yellow warbler, white-crowned sparrow, dusky flycatcher, warbling vireo, MacGillivray's warbler, orange-crowned warbler, and mourning dove) and three exhibited significant declines (Bullock's oriole, ruby-crowned kinglet, and Wilson's warbler). For the 16 significantly increasing species found within this study, patterns of change on BBS routes from 1980-1999 suggested that the changes found in this study were not merely a reflection of regional patterns.

Implications for Wind Development

Removing cattle from riparian habitats has been shown to significantly increase the abundance of certain species, specifically those that are open nesting, insectivorous, or neotropical migrants. Purchasing riparian habitat and enhancing it, or protecting riparian habitat near a wind farm, may prove to be a viable mitigation option. Wind development that occurs near riparian areas where livestock are located should consider installing fences to prevent cattle from decimating the habitat.

Case Study 6

Roby, D., K. Collins, et al. (2002). "Effects of colony relocation on diet and productivity of Caspian terns." *Journal of Wildlife Management* **66**(3): 662-673.

Introduction

This study addresses salmon fishery managers' concerns that colonial waterbirds were inhibiting the recovery of certain endangered and threatened salmon species in the Columbia River Basin. Initial research indicated that Caspian terns relied heavily on juvenile salmonids as a food source, especially the Rice Island colony, which is the largest of its kind in North America. Previous attempts to reduce avian predation of fish stocks along the Columbia River included lethal control, oiling eggs, harassing fish-eating birds, protecting fish, and changing rearing practices in hatcheries. While a number of these techniques had proven effective, the public often considered them unacceptable.

The objectives of this study, therefore, were to monitor and evaluate efforts to relocate the Caspian tern colony from Rice Island to East Sand Island (based on colony size and nest productivity). The study also aimed to test the efficacy of this approach for reducing the reliance of terns on juvenile salmonids as a food source (based on diet composition analyses). This approach was based on studies indicating the successful restoration of historical breeding colonies of terns along the northeastern shore of the United States and Canada, although these studies did not attempt to relocate an entire colony.

Techniques Used

To encourage the relocation of the tern colony, East Sand Island was altered to create a bare sand habitat similar to the one found on Rice Island. Caspian tern decoys and audio playback systems (recorded at the Rice Island colony) were installed throughout the bare sand area on East Sand Island and a limited number of glaucous-winged gulls were removed to encourage prospecting terns to settle and nest on the new island. Site treatments were undertaken again in 2000 and 2001 to reduce encroaching vegetation, and two 20- to 30-m-wide buffer strips were added on either end of the core colony area in 2001 to provide additional protection to the terns by discouraging nesting by glaucous-winged gulls. On Rice Island, suitable nesting habitat was reduced through plantings, silt fencing, and the placement of streamers and wire across the previous colony site. An area of 0.65 ha was left unaltered in the core of the colony in 1999 and was subsequently reduced each year after that to encourage the relocation of terns.

Data Collection

Colony size and productivity data were collected from aerial photographs and ground counts from observation blinds on both islands. Further details on the aerial photo census methods utilized are described in Collis et al. 2002. Diet composition data were collected through direct observation of adults as they returned to the colony with fish (bill-load observations). Prey items were identified as salmonid/nonsalmonid, and researchers were able to further distinguish nonsalmonid taxa, but not salmonid. In order to assess the relative proportion of various salmonid species in tern diets, an additional 10 bill-load fish/week were collected through shooting at each site when that activity was determined to not have a negative impact on the colony. Data on colony numbers, diet composition, and causes of nesting failure were collected daily.

Results

All nesting Caspian terns elected to move from the Rice Island colony to the East Sand Island colony during the 1999-2001 study period. In May 1999, about 550 of the 8,300 pairs of terns were nesting on East Sand Island, and by July 1999 this had more than doubled to 1,400 pairs. By 2000, 94% of the Caspian terns that nested in the Columbia River estuary were located on East Sand Island.

Nest productivity was found to be consistently higher for Caspian terns nesting on East Sand Island than for those nesting on Rice Island, reaching 1.4 young per pair in 2001. This was the highest productivity observed at either tern colony after 1996. Terns nesting on East Sand Island were also found to have significantly fewer salmonids in their diets than those nesting on Rice Island (42% to 83%, respectively); anchovies, herrings, and sardines were becoming the most prevalent prey types found in the East Sand Island terns' diets.

Implications for Wind Development

Although this study does not apply to wind development sites, it does show definitively that it is possible to relocate an entire colony of birds. The study focused on terns, but it may be a useful approach for other colonial nesting bird species, such as double-crested cormorants or great blue herons, which nest near freshwater lakes and wetlands. As wind development grows, there may be some interest in developing near inland water bodies. Thus, this approach may prove useful in minimizing or eliminating the risk to colonial nesting birds. In addition, this study was based on other efforts that successfully restored historical tern colonies along the eastern shore; this suggests that it may prove useful in the future as wind development expands to coastal areas.

Future Case Studies

McNew, L.B., et al. (In progress) Effects of Wind Power Development on the Demography of the Greater Prairie Chicken.

> This study is examining the impacts of wind development on lek attendance, mating behavior, habitat use, dispersal, and demographic performance of Greater Prairie Chickens. A before-after control-impact, or BACI, design with three replicates of paired study sites will be used to assess potential impacts of wind development on prairie-chicken demography. Focal population studies will occur at the Elk River II site in Butler County, Kansas, in Year 1 and expand to three sites in Years 2-4. Birds will be captured and radio-marked at leks during the 2006-2009 breeding seasons for this study. Treatment and reference sites will be monitored simultaneously during three phases of wind power development: predevelopment, construction, and operation.

PIER Energy-Related Environmental Research. (In progress) Range Management Practices to Reduce Wind Turbine Impacts on Burrowing Owls and Other Raptors in the East Bay Regional Parks. For information, see http://www.energy.ca.gov/pier/environmental/project_summaries/PS_500-01-032_DIDONATO.PDF.

> This study is investigating land management practices in relation to raptor behavior and prey distributions, as well as raptor flight behavior and spatial distribution over land with and without wind turbines at the Altamont Pass Wind Resource Area (APWRA). The study seeks to understand how vegetation management practices (e.g., sheep grazing) in the APWRA can modify raptor foraging patterns by changing the distribution of prey. Three-dimensional global information system models will be used to characterize the influence of range management practices on raptor flight patterns, small mammal burrow distributions, burrowing owl nesting patterns, and turbine-induced avian mortality. A progress report detailing preliminary results is expected in late 2007.

Schroeder, M.A., et al. (In progress) Effects of Wind Power Development on Sage Grouse.

> This study is examining the effect of wind power generation on sagebrush steppe habitat, specifically that of the sage grouse. The hypothesis is that the 'footprint' of wind power generation in the sagebrush steppe is far larger than previously believed because of the spread of noxious weeds and exotic plants, habitat loss and fragmentation, and fatality risk due to predation and collision with turbines, powerlines, fences and vehicles. Additional disturbance and noise caused by wind farms is also of concern in relation to sage grouse populations.

Sherwell, J. (In progress) Developing a Mitigation Strategy for Bat Impacts from Windpower Development in Maryland.

> This study presents a model that has been established to aid in the development of mitigation strategies for bats at wind farms in Maryland along the Appalachian Mountains. Two mitigation scenarios were investigated: one in which suboptimum tip speed ratios is explored, the other in which rotation rate is managed from a low value up to a threshold value, above which the optimum tip speed ratio is established. Results suggest that low wind speed curtailment can significantly reduce the risk of bat collisions. This study has been conducted, but results have not yet been published and economic consequences have not yet been explored.

Szewczak, J., and E.B. Arnett. (In progress) Evaluation of Acoustic Deterrents to Reduce Bat Fatality at Wind Facilities.

This study was based on earlier observations that bats avoided areas featuring high-intensity ultrasounds; it sought to determine whether high-intensity ultrasounds deterred bats from wind turbines. The hypothesis is that, above some threshold, bats will show avoidance because they can't hear anything but the sound emitting from the deterrence device. Only preliminary results from laboratory and field tests are currently available.

United States Fish and Wildlife Service (In progress; contact: Ron Reynolds [9/2006])

This study is being conducted to examine the effectiveness of a mitigation strategy to remedy problems for ruddy ducks on their wintering grounds resulting from an oil spill in the Patauxent River in Maryland. A Board of Trustees decided that mitigation for the spill required the organization to introduce new ruddy ducks into the population to make up for the ones that were lost. In order to do this, the USFSW Habitat and Population Evaluation Team is helping to restore or create new habitat on the breeding grounds in North Dakota. Evaluations of mitigation will begin as soon as the mitigation treatments are completed, and they will last for 10 years. Mitigation includes restoring the function of degraded wetlands or replacing drained wetlands, largely through conservation easements on agricultural lands. They are currently targeting areas with high ruddy duck breeding populations because they are already supportive landscapes.

Villegas-Patraca, Rafael et al. (In progress) Impact and Potential Conflicts of Wind Power Generation on Raptor Migration in Tehuantepec Isthmus, Mexico.

Several companies will be developing the largest wind-farm facilities in Latin-American over the next five years in the Isthmus of Tehuantepec in Oaxaca, Mexico. During three field work seasons, more than four million migratory raptors were found around the potential sites for the wind-farm. The majority of these birds were Turkey Vultures, Swainson Hawks and Broadwing Hawks flying at heights less than 120m. There is a potential high risk that birds will collide with the wind turbines within a range of 72-130m high in operation because this area is one of the most important bird migration routes in the world. This study will monitor the effects of a mitigation strategy to shut down the turbines for 3 weeks during Broad-winged Hawk, Mississippi Kite, and Swainson's Hawk migration on avian mortality and economic performance. This study hasn't begun yet.

WEST, Inc. (In progress; contact: Dale Strickland [11/2006])

WEST is conducting research at Altamont Pass in California to evaluate the effectiveness of seasonal wind turbine shut-downs, relocating or removing high-risk turbines, and replacing old turbines with newer, larger ones.

Summary of Existing Policies and Guidelines and Related Research Studies

This matrix combines existing policies and guidelines with existing mitigation research in order to identify gaps and overlaps between the two. The mitigation strategies listed in Column A are sorted by type of strategy (e.g., construction-stage, operational-stage) and are taken directly from existing policies or guidelines; the author is listed in Column B. Column C presents existing research related to the policy or guideline topic; where no research was found to support the policy or guideline, the field was left blank. Column D indicates whether research supports the mitigation strategy advocated in the policy or guidelines. The numbers next to Related Study authors correspond to the Annotated Bibliography, where detailed description of each study can be found. Finally, the Status of Supporting Studies column, Column E, offers anecdotal information pertaining to the research conducted.

GAPS / OVERLAPS MATRIX

A Mitigation Stated in Policies and Guidelines	B Whose Policy / Guideline?	C Related Studies	D Support Policy?	E Status of Supporting Studies & Notes
Design Stage				
Avoid lattice-type construction - use monopoles/tubular towers	ABC, WA Audubon, KS, MD, WA, CESA	Anderson et al. 2004 (1) Hunt 2002 (7) Orloff & Flannery 1992 (11) Thelander & Rugge 2000 (14)	Y Y Y N	research inconclusive . but, mortality rates at tubular towers increased when located on an end-row and close to canyon 57% bird fatalities at Altamont associated with tubular towers
Perching opportunities should be reduced or removed	Canada, KS, BLM	Osborn et al. 1998 (9) Smallwood & Thelander 2004 (12)	N Y	indent
Construct towers no more than 199 feet above ground level	USFWS			USFWS proposed to address 2 issues: (1) met towers should be unguyed, unlit, < 200 ft AGL, based on documented impacts from guy wires. (2) If wind turbine rotor swept area exceeds 199 ft AGL requiring turbine lighting, use minimum intensity, maximum off-phased white strobe, followed by red strobe, followed by red-blinking incandescent lighting, in decreasing order of priority. No L-810 lights should be used.
Larger turbines reduce mortality	England, Canada	Hunt 2002 (7) Smallwood 2006 (13)	N Y	Based on Diablo Wind Energy repowering project
Situate turbines in a way that does not interfere with wildlife movement corridors (turbine design)	ND, KS, CESA			
Group turbines rather than spreading them widely	England, USFWS	Larsen & Madsen 2000 (34)	N	Habitat loss for PFGO per turbine higher in farms with turbines arranged in a large cluster. USFWS policy supports minimizing overall footprint, reducing habitat fragmentation, disturbance and site avoidance esp. by grassland-sage-steppe-obligate songbirds and “prairie grouse.”
Orient rows of turbines parallel to known bird movements	England, USFWS			USFWS policy suggests; where known bird passageways (i.e., staging or migration) have been documented in historically compass-like directions, turbine orientation should minimize potential contacts. Been witnessed with seabird passage.
Spacing between turbines (should be greater than 200m)	Australia, England, (Canada)	Larsen & Madsen 2000 (34)	Y	Habitat loss for PFGO per turbine less in farms with turbines in small clusters or lines (no optimal distance suggested)
Lines of turbines should be broken up	England			
Avoid sensitive & large tracts of native habitat (don't fragment) /locate turbines on altered landscapes	England, USFWS, ND, Australia, WA, KS, CESA, CA	Larsen & Madsen 2000 (34) Leddy et al. 1999 (35)	Y Y	Wind farms placed close to roads or other 'avoidance zones' resulted in less impact to PFGO CRP grasslands 180+m from turbines found to support 4x more nesting birds USFWS policy recommends avoiding placing wind turbines within 5 miles of known leks. We now recognize that since recommending our 5-mile volunteer metric, separations will vary between species – least for Lesser and Greater Prairie-chickens (~3.75 mi), and greatest for migratory populations of Sage-grouse (~12.5 mi).
Avoid landscape features that attract raptors	BLM	Erickson et al. 1999 (4) Orloff & Flannery 1992 (11) Hoover 2002 (5) Hoover & Morrison 2005 (6)	Y Y Y	Rim edges should be avoided Rim edges should be avoided Avoid steep slopes(RTHA) & narrow E-W corridors that open up onto valley floor (GOEA)
Avoid areas heavily used by birds/bats	England, USFWS, Australia, MD, WA, CESA, CA	Osborn et al. 2000 (10) Huppop et al. 2006 (31)	Y Y	no supporting research for management suggestion turbines should not be placed in dense migratory zones between resting and foraging grounds While avoiding areas heavily used by birds and/or bats is intuitive, the premise of the USFWS's voluntary wind guidance is based on avoiding locations that are bird and/or bat unfriendly (i.e., heavily used for whatever purposes).

Do not locate projects in areas with high incidence of fog and mist	USFWS, BLM	Kerlinger & Kerns 2004 (18) Young et al. 2003 (22) Pettersson 2005 (59)	N N N	No correlation between wind speed, direction, temperature, or fog/precipitation and bat fatalities. No strong correlations found between avian/bat acualties and weather events Radar monitoring indicated waterfowl migration in fog and mist limited While weather has been well correlated with mass nighttime bird deaths at communication towers, power lines, building windows, and monuments, no mass mortality events have yet been documented at wind facilities. In an effort to avoid or at least minimize that problem, the USFWS suggested this guideline.
Locate turbines and roads away from wetlands	Australia			
Avoid known daily movement flyways	USFWS			While avoiding areas heavily used by birds and/or bats is intuitive, the premise of the USFWS's voluntary wind guidance is based on avoiding locations that are bird and/or bat unfriendly (i.e., heavily used for whatever purposes).
Create road siting plan (using constraint mapping)	CESA, WA			
Use existing transmission corridors	WA, MT, CA			
Route power cable to avoid need to remove native veg and habitat, and	Australia			
Establish buffer zones around turbines	CA			
Construction-Stage				
Perch guards and other APLIC endorsed technologies recommended	WI, WA	Smallwood & Thelander 2004 (12) Nelson & Curry 1995 (30)	N Y	54% reduction in perching estimated with perch guards, but no statistical support
Bury power lines underground	ABC, USFWS, SD, MI, KS, WI, Canada, MD, WA, CESA, CA			Mentioned by numerous studies as recommended management, but couldn't locate research testing this suggestion. USFWS policy suggests: Where risk of power-line strikes and electrocutions exists, bury lines to minimize injury and death, and reduce habitat fragmentation, esp. to "prairie grouse."
Guy wires should be avoided	ABC, WA Audubon, Canada, BLM, MD, WA, CA			
Follow APLIC standards	Wisconsin, ABC, CA			
Establish buffer zones around raptor nests, bat roosts, and biota if facilities pose significant concern	BLM			
Construction should be done when ground is frozen or soils are dry and native veg dormant	KS			
Minimize area disturbed by construction and operation	BLM, CESA			
Installation of towers should avoid disruption of important wildlife behaviors - seasonal restrictions on construction	England, USFWS, Canada, SD, VT, BLM, Australia, MD			USFWS policy suggests: Construction of access roads, drainage ditches, tower platforms, and the installation of towers and turbines can severely disrupt breeding, feeding, roosting, nesting, fledging, staging and resting birds; as well as breeding (maternity colony), feeding, and overwintering (hibernaculum) bats. By not constructing during these time periods, behavioral disruptions to birds and bats can be avoided.
Minimize roads & fences; those built should follow natural land contours and minimize stream crossings and side hill cuts	USFWS, SD, BLM, KS, Canada, WA, CESA	Smallwood & Thelander 2004 (12) Trombulak & Frissell 2000 (70)	Y Y	Access roads should be minimized - unsure of supporting research Unlikely the consequences of roads will be completely mitigated so critical to retain roadless areas in natural state USFWS policy suggests: Grassland-sage-steppe-obligate songbirds and "prairie grouse" have been shown to be especially susceptible to human disruption, including from road development and use, fences, and other "tall" structures. Efforts should be taken to minimize their presence, and where they are constructed to reduce their effects.
Noise-reduction devices should be maintaind in good working condition on vehicles and equipment	VT, BLM			
Dust abatement techniques should be used	BLM			
Develop plan to prevent intro of weeds/invasive flora	SD, Australia, WA			
Minimize creation of edge habitat	BLM	Arnett et al. 2005 (57)	Y	Turbine locations within forest openings and near edges may be miconstrued by bats as favorable roosting sites
Implement strict speed limits	Australia, WA			

Vehicle storage and standing areas should be away from native veg and habitat, and at least 200m from wetlands	Australia			
Monitor and repair erosion	Australia			
Minimize chemical use	England	Trombulak & Frissell 2004 (70)	Y	Accumulations of salts & heavy metals been shown to disrupt natural stratification patterns (other studies cited)
Operational-Stage				
Adjust tower height where rotor height area poses high risk for wildlife	USFWS			While it is infeasible to generally consider elevating rotor swept areas due to generation inefficiencies, where low flying avifauna such as "prairie grouse" occur USFWS suggests this policy to mitigate interactions.
Older turbines that cause high mortality should be moved or retrofitted	USFWS, CA			USFWS made this recommendation initially with Altamont Pass in mind, but it has applicability elsewhere such as at some of the older CA sites. The retrofit refers to a replacement of 1 new, larger turbine for every 7 older turbines.
Decompact disturbed agricultural areas to 18"	NY			
Reseeding with native vegetation	WA, KS, Canada, BLM			
Certified weed-free mulch should be used when stabilizing disturbed soils	BLM			
Higher height veg encouraged along transmission corridors to minimize foraging in these areas	BLM			
Re-vegetate access roads not used after construction	Canada			
Plant area under turbine with less attractive crop	Canada, BLM			
Disturbed lands fully reclaimed to habitat functions prior to construction	ABC			
Markers on guy wires	USFWS, Canada, WA, CA	Alonso et al. 1994 (25) Brown & Drewien 1995 (3) Janss & Ferrer 1997 (27) Morkill & Anderson 1991 (28)	Y Y Y Y	Significant decrease in collisions between spans marked with red PVC spirals and those without Both yellow spirals and yellow swinging plates reduced mortality 75% reduction in mortality seen with black spiral and black crossed band markers While USFWS recommended marking guy wires (both met tower and guyed turbines) where guys were shown to be necessary but could impact avifauna – e.g., Whooping Crane migratory corridor, Spectacled and Steller's Eider pathways, because of the paucity of published literature in refereed journals, USFWS recommend only limited use of markers until more research can be shown to reduce collisions, especially for night-migrating songbirds in inclement weather.
Use of sodium vapor lights should be minimized or avoided	WA Audubon, BLM, MD, CESA	Kerlinger & Kerns 2004 (18)	Y	
Avoid using solid red or pulsating red warning lights at night	England, USFWS	Kerlinger & Kerns 2004 (18)	N	FAA lighting (L-864 red strobes) did not appear to attract nocturnal migrants, but steady burning red, L-810 lights did USFWS policy suggests that solid/steady-burning L-810 lights should not be used on turbines or met towers. The Service provisionally recommended using minimum intensity red blinking/pulsating lights when minimum intensity, maximum off-phased white strobe lights could not be used.
Security lighting on ground should be down-shielded	USFWS, CA			USFWS policy suggests: Steady-burning sodium, halogen, quartz, or related ground-based security lighting have been implicated in moderate to high levels of bird mortality, especially during inclement weather at night. Security lighting was implicated in the largest yet recorded wind turbine kill in WV; when the lights were extinguished yet the fog continued, bird kills appeared to end.
Site lighting should be 'off' unless needed for specific tasks	CESA, CA			
Strobe lights only, min number of flashes and briefest flashes permintable	England, USFWS, Canada, CA			USFWS recommends as a first option, minimum intensity, maximum off-phased white strobe lights. When infeasible, minimum intensity, maximum off-phased red strobe lights are suggested – provided no steady-burning lights are used.
Minimize number of lit turbines	ABC, MD, WA, Australia, BLM, CESA	Johnson et al. 2003 (17) Erickson et al. 2004 (15) Huppop et al 2006 (31) Arnett et al. 2005 (57)	N N Y N	Presence of lighting did not affect number of bat collisions No statistically significant difference found between lit and unlit turbines and bat/bird mortality Large-scale continuous illumination should be avoided (research pre-construction - off-shore) Lighting does not appear to be a significant source of attraction to bats
Lit turbines should use simultaneously pulsing red or white strobes, 20 pulses per minute if possible	ABC			
Synchronization of lights	FAA, MD	Patterson 2004	Y	Study was conducted by FAA (Patterson) for purposes of pilot safety, not wildlife

Wildlife and plant composition needs to be considered when setting mowing schedule	KS			
Reduce availability of carrion	USFWS, Australia			While this was one of many USFWS recommendations focused on the somewhat unique situation at Altamont Pass, to avoid similar future scenarios, it was also recommended elsewhere.
Shut down turbines during certain periods of time	ABC, USFWS, Canada, CA	Barrios & Rodriquez 2004 (2) Hoover 2002 (5) Hoover & Morrison 2005 (6) Huppop et al. 2006 (31)	Y Y Y Y	Suspend turbines causing most deaths under wind speeds that are problematic Close down turbines where valley plateaus meet sloping hillsides and power down turbines located on steep slopes when there are high winds perpendicular Turn turbines off during few nights there is a combo of adverse weather and high migration USFWS suggests: While we still have only an N=1 of turbine samples feathered during bat migration (i.e., Backbone Mt., WV), other study results are pending and will be assessed with great interest. If bats are present and feeding during periods of minimal electrical generation, "feathering" may soon be scientifically validated as a "conservation measure" recommended to the industry as an option for use
Limited and periodic feathering durin low wind nights	CA	Arnett et al. 2005 (57)		
Prey control program (extensive rabbit control, squirrel control)	Canada, Australia	Hunt 2002 (7) Smallwood & Thelander 2004 (12)	Y N	No supporting research for management suggestion
Use of rodenticides is discouraged around base of turbines	WA			
Reduce motion smear by painting blades	England, Canada	Smallwood & Thelander 2004 (12) Howell & Noone 1991 (16) Hodos 2003 (21) Young et al. 2003 (22)	Y Y Y N	Unproven, but believed to be highly effective (Hodos et al. scheme) Painting of blades (red/white) reduced collisions but not statistically significant Painting of blades (bk/wh) useful up to 19m, then patterns lose advantage - thin-bk stripes best UV painted blades not significantly different than non-painted
Maximum speed of turbines less than 30rpm	WA Audubon	Hodos 2003 (21) Arnett et al. 2005 (57)	N N	20-m diameter turbine rotating at 45rpm with painted blades was visible up to 21m Low wind nights (17rpm) found to result in highest amount of bat fatalities.
Any nesting/maternity areas disturbed shall be reestablished as feasible	MD			
Habitat modifications to make site less attractive	CA			
Other				
Posting of a bond, or other financial instrument, to cover the cost of mitigation actions	OR, WA			
Education and collaboration with county commissoiners, industry, and government	MT, CA			
Apply adaptive management and effectiveness monitoring processes to better achieve management objectives	CA			
Off-site Habitat Enhancement				
Acquisition of replacement habitat (conservation easement, wetland, etc)	SD, OR, VT, WA, KS, MD, CA, Canada	Smith et al. 2005 (38) Trulio 1995 (39) . Roby et al. 2002 (41) Balcombe et al. 2005 (47) Darnell & Smith 2004 (48)	Y/N Y/N . Y Y N	BUOW boxes positive mitigaiton, but must have preexisting BUOWs for artificial nests to succeed Passive relocaiton of BUOW effective mitigation, but cannot move long distances and must protect enough foraging habitat Example of successful CATE colony relocation project Despite differences in veg and invertebrates, mitigation and reference wetlands very similar Mitigation wetland had high salinity, inundation too frequent, and necessary habitat too narrow
Provide alternative habitat off-site to attract at-risk birds from near turbines	Australia			

Conclusions and Recommendations

The impacts of windpower on wildlife has generated a great deal of debate among windpower's advocates and its opponents, often generating a great deal of heat but little light. This Mitigation Toolbox is not directed at determining what the impacts are, nor does it comment on what level of significance those impacts might have. It does, however, take the general position that there are cost-effective opportunities to lessen wind's impacts where they may be determined to have significance. The purpose of the toolbox is to catalog existing mitigation measures and to further explore others, and bring them to light for discussion, research and innovation.

While numerous studies currently exist pertaining to wildlife management in general, there are few studies that specifically look at the effectiveness of mitigation techniques, and even fewer that focus on mitigation techniques in the context of wind turbines. As a result, there are few verified tools available for use in mitigating wildlife impacts from wind development at this time. However, it is clear from the research conducted for this report that the opportunities for mitigation in windpower have just begun to be explored. In addition to those tools or techniques discussed in this report, there are surely useful tools from other industries that could be applied in the windpower context, including those involving adaptive management or offsite mitigation. Industry, advocates and the scientific community should seek out these opportunities and bring them forward for discussion and evaluation. This report is intended to be the first installment of an ongoing process to highlight, in one document, mitigation strategies.

The process of researching for this report has raised a number of themes that need more attention, such as the straightforward preference for siting wind farms in already disturbed areas rather than in more pristine landscapes. However, this document is not intended to be a prescriptive set of best practices such are typically found in siting guidelines. Instead it is intended to be a discussion of the many mitigation opportunities that have either been tried or represent potential means of lowering wind projects' impacts on wildlife.

Siting guidelines building on the U.S. Fish & Wildlife Service's mitigation definition have tended to focus on avoiding impacts to begin with, which often means not building at all in the highest impact areas. This document picks up from that point, asking the follow-up question to "where shouldn't we build", which is the practical question of what we do to mitigate impacts when a decision has been made to build a wind project. It is accepted by many that avoiding all impacts is not a likely or perhaps even achievable goal. We also recognize that some mitigation techniques will prove to be too expensive to be practical, and others may offer the promise of achieving a given goal at a far lower cost. This toolbox may encourage a discussion of those techniques that can achieve goals at the lowest reasonable cost so that they can be broadly utilized and accepted by industry, advocates, regulators, and other interested parties.

With the expected growth of the wind industry over the next few decades, there is a need to address the existing gaps between what is on the research agenda for wind and the practice of planning, constructing and operating wind farms. This need includes research into the question of "where shouldn't we build", focusing on pre-construction studies to avoid the most problematic areas and examining whether pre construction studies can consistently predict post construction impacts to wildlife. Additionally, post-construction studies are needed to determine what impacts are occurring and methods to reduce those impacts in a cost-effective manner. Expanding the amount of research focused on mitigation strategies will not only improve our knowledge of wildlife management, but it will also help to guide policymakers, regulators, industry and the public in developing guidelines or policies that are beneficial for wildlife and cost-effective for development. Expanding the range and scope of mitigation techniques being utilized, including those that may not appear in this report, is also crucial to a vibrant investigation of the most effective ways of achieving the goal of lowering wind energy's impacts at a reasonable cost that encourages adoption by industry. This toolbox is intended to be a living document, adding new techniques as they are developed and applied.

The existing mitigation techniques described in this toolbox emphasize local mitigation methods to reduce impacts. There is a challenge in the need to create mitigation practices that focus on a landscape scale rather than generalized practices that are constrained by political boundaries. Landscape scale planning and offsite habitat evaluations may provide opportunities to enhance wildlife management. It is clear that many jurisdictions are reinventing the wheel again and again, because of a lack of comprehensive and accessible resources documenting current knowledge. This toolbox is a source of compiled information, which will be available to regulatory agencies and other stakeholders making real-time decisions. By integrating this valuable existing information database at the local and landscape scales, we can help to ensure that wind development occurs in a way that will not diminish sensitive migration corridors, breeding grounds, and wintering areas.

APPENDIX A: Comparison of existing policies and guidelines pertaining to wind development and mitigation efforts

	MONITORING		MITIGATION STRATEGIES				
	Pre-Construction	**Post-Construction**	**Design-Stage**	**Construction-Stage**	**Operational-Stage**	**Off-site**	**Other**
LOCAL							
Washington - east of Cascades Department of Fish and Wildlife *Wind Power Guidelines* August 2003 http://wdfw.wa.gov/hab/engineer/windpower/wind_power_guidelines.pdf . Dr.Jeff Koenings (360) 902-2200	Site-specific components and duration of assessment should depend on the size of project, availability and extent of exisgint data, habitats potentially affected, likelihood and timing of occurrence of sensitive species at site, and other factors such as issues and concerns identified during public scoping. At a minimum, 1 raptor nest survey during breeding season within 1-mile of site should be conducted At a minimum, 1 full season of avian use surveys (spring/summer) is recommended - additional seasonal data recommended if avian site use is high, there is little existing data on site, or project is especially large	Monitoring studies are required, but the duration and scope of the monitoring should depend on the size of the project and the availability of existing monitoring data at projects in comparable habitat types A Techincal Advisory Committee (TAC) is recommended to be responsible for reviewing results of monitoring data and making suggestions to the permitting agency regarding the need to adjust mitigation and monitoring requirements	Developers should be encouraged to site wind power projects on disturbed lands.		No mitigation is required for cropland, developed or disturbed areas Temporary habitat impact may implement a WDFW approved restoration plan for the impacted area, including: site preparation, reseeding with appropriate vegetation, noxious weed control, and protection from degradation	All permanent habitat impacts require the acquisition of replacement habitat that is: like kind, equal/higher habitat value, given legal protection, protected from degradation for the life of the project, in the same geographical region, and jointly agreed upon by developer and WDFW (imminent development, grassland, CRP 1:1; Shrub0Steppe or Other High Value 2:1) All temporary habitat impacts have option to acquire suitable replacement habitat for every acre temporarily impacted (grassland, CRP 0.1:1; Shrub-Steppe 0.5:1)	Annual Fee for life of project based on Alternative Mitigation Fee Rate of $55/acre/year for each acres of replacement habitat that would be owed (using ratios found in Off-Site section) The fee is based on habitat in 'average' condition and can be increased or decreased by 25% to account for differences in habitat quality
STATE							
California CA Energy Commission & CA Department of Fish and Game *DRAFT Guidelines for Reducing Wildlife Impacts from Wind Energy Development* December 2006 http://www.energy.ca.gov/2006publications/CEC-700-2006-013/CEC-700-2006-013-SD.PDF http://www.energy.ca.gov/renewables/06-OII-1/documents/index.html#041607 Rick York (916) 654-3945, ryork@energy.state.ca.us	Data and information gathering should be conducted early in process, be collaborative and include experts A scientific advisory committee of relevant experts should be established for life of project, ideally composed of a member from: the lead agency, CDFG, USFWS, developer and conservation organization Minimum of 1 year data collection for birds/bats - nightly acoustic monitoring for bats, weekly bird use counts (BUCs) for birds Small Bird Counts (SBC) may be required in special cases One year bird/bat carcass study to determine natural predation rates Raptor nest searches and bat roost searches conducted within 5 km of proposed site	2 years of carcass searches and bird/bat use surveys recommended, with carcass searches every 2 weeks More frequent searches necessary if pre-permitting studies indicated potential for impacts to bats or small birds Monitoring for repowering projects should use same methodology as for new projects Searcher efficiency trials and carcass removal trials to be conducted seasonally over 2 years More or less monitoring may be appropriate depending on project Science advisory committee and/or USFWS and CDFG should be consulted in determining study protocols and duration	Macro-siting, then micro-siting to maximize impact avoidance Minimize fragmentation and habitat disturbance. Reduce impacts with appropriate turbine layout. Establish buffer zones to minimize collision hazards. Avoid guy wires Power lines should be placed underground, unless burial would result in greater impacts to biological resources All aboveground lines, transformers, or conductors should comply with APLIC standards, including use of deterrents		Decommision non-operational turbines, which includes turbine foundations 3 ft below ground level, access roads, unnecessary fencing and auxillary structures Avoid lighting that attracts birds - use lights with short flash durations that emit no light during "off phase", with minimum number of flashes per minute and briefest flash duratino allowable Lights on auxilary buildings should use motion-sensitive lights and be downcast Limited and periodic feathering during low wind nights Removal of problem turbines Seasonal shutdowns of turbines Habitat modifications to make site less attractive	Mitigation site must provide for long-term conservation of target species and its habitat Site must be large enough to be ecologically self-sustaining Site must be permanently protected through fee title and/or conservation easement Resource managment plan should be approved and provisions made for implementation prior to sale of property/ easement or credits at mitigation bank Provisions for long-term management of property should be made Provisions should be made for monitoring/reporting on identified species and managment objectives	Post-construction monitoring may not be needed if findings from pre-contruction monitoring indicate low bird use and no special-status species or issues of concern, or if the site is near or adjacent to a recently well studies and comparable site with low fatality numbers.

Kansas Renewable Energy Working Group *Siting Guidelines for Windpower Projects in Kansas* January 22, 2003 http://www.krewg.org/reports/KREWGSitingGuidelines.pdf Jim Plogger (785) 271-3349, j.ploger@kcc.state.ks.us http://www.energy.ca.gov/renewables/06-OII-1/documents/index.html#041607	Biological and environmental experts should be used No time frame mentioned Landscape-level examinations should be used Detailed evaluation may not be worthwhile on sites with high potential for biological and environmental conflict		When feasible locate on altered landscapes Infrastructure should be able to withstand periodic burning of vegetation No perches allowed on nacelles Avoid lattice-type construction or other designs that provide perches Turbines should be situated in a way that does not interfere with important wildlife movement corridors and staging areas Avoid damage to unfragmented landscapes and high quality prairie remnants	Power lines underground when feasible Roads and fences should be minimized Avoid sensitive habitats Ideally, construction and maintenance should be done when the ground is frozen or when soils are dry and native vegetation is dormant	Native vegetation of local ecotype should be used to reseed disturbed areas Wildlife and plant composition should be considered in setting mowing schedule Potential adverse affects of warning lights should be addressed If there is significant ecological damage, mitigation for habitat loss should be considered, including: ecological restoration, long-term mangement agreements, conservation easements		
Maryland Wind Energy Technical Advisory Group *<u>DRAFT</u> Siting Guidelines to Mitigate Avian and Bat Risks from Windpower Projects* July 6, 2006 . Michael Dean (410) 767-8149, mdean@psc.state.md.us	Consult with DNR and NHP biologists Request Environmental Review be conducted - minimization or mitigation plans identified at this point will become part of conditions filed in CPCN proceeding Determine limits of physical construction disturbance with NHP biologist and clearly mark boundaries 1 year monitoring data for birds/bats (must be spatially and seasonally appropriate), assessment of potential bat habitat, results of Phase 1 avian risk assessment, and survey results of breeding birds required with CPCN application Additional monitoring may be required for rare, threatened and endangered species	Monitoring shall be conducted for minimum of 3 years Maryland PPRP will establish a peer review group external to State Agencies and comprising of relevant experts to assess monitoring plans and data Data shall be reported to NHP, PPRP, and external peer review group after each migration period (twice/year); and shall include species impacted and weather conditions Additional studies identified by State will not be responsibility of applicant	Avoid lattice-type construction or other designs that provide perches Construct no permanent towers supported by guy wires Avoid locations identified as high risk to birds/bats, have unique habitat features, or are occupied by species of concern	Bury onsite electrical collector cables when possible Avoid or minimize disruptions during bird/bat breeding seasons Any nesting/maternity areas distrubed shall be reestablished as feasible	Minimize lighting by lighting fewest number of turbines possible, synchronizing flashing cycles, installing red rather than white strobes, and avoiding high intensity lights (i.e. sodium vapor) Corrective actions will be sought by State if unforeseen adverse impacts occur	Mitigation plan may involve onsite and/or offsite activities, but offsite may be inappropriate for species of concern	Projects are exempt from CPCN process and guidelines only if the generated power is to remain onsite Mitigation actions should be graded in their implementation so as to reflect the level of the observed impact and the probability of successful mitigation, while defining and bounding the operational limitations or costs associated with the mitigation action
Massachusetts Executive Office of Environmental Affairs *<u>DRAFT</u> Guidance on the Siting of Wind Turbines* . Josh Bagnato (617) 626-1041, Josh.Bagnato@state.ma.us	Guidelines are in the final draft stage - they have been reviewed, but have not yet been released for public comment. Release expected by the end of 2006.						
Michigan Department of Labor & Economic Growth *Michigan Siting Guidelines for Wind Energy Systems* December 14, 2005 http://www.michigan.gov/documents/Wind_and_Solar_Siting_Guidlines_Draft_5_96872_7.pdf . John Sarver (517) 241-6280	3rd party analysis no time frame mentioned special scrutiny required for wildlife refuges, other areas where birds are highly concentrated, bat hibernacula, wooded ridge tops that attract wildlife, sites that are frequented by endangered species, signifant bird migration pathways, and areas that have landscape features known to attract large numbers of raptors	Analysis shall indicate whether a post construction wildlife mortality study will need to be conducted	The applicant will take appropriate measures to minimize, eliminate, or mitigate adverse impacts identified in analysis	Power lines underground when feasible	Applicant shall identify and evalutate the significance of any net effects or concerns that remain after mitigation efforts		
Minnesota Public Utilities Commission *Wind Turbine Siting Requirements* February 7, 2002 http://energyfacilities.puc.state.mn.us/wind.html . Alan Mitchell (651) 296-3714	An applicant for a site permit shall include with the application an analysis of the potential impacts of the project, proposed mitigative measures, and any adverse environmental effects that cannot be avoided, in the following areas: wildlife, rare and unique natural resources, wetlands, vegetation...						

New York Department of Agriculture and Markets *Guidelines for Agriculture Mitigation for Windpower Projects* March 25, 2003 http://www.agmkt.state.ny.us/AP/agservices/constructWind.html . Contact Unknown (800) 554-4501		2+ years of data needs to be collected			All disturbed agricultural areas will be decompacted to a depth of 18 inches with a deep ripper or heavy-duty chisel plow . All rocks 4 inches and larger will be removed prior to and after the replacement of topsoil. Topsoil will be replaced to original depth and the original contours will be reestablished where possible. Access roads will be regraded and original surface drainage patterns will be restored. Restored agricultural areas will be seeded with the seed mix specified by landowner. Topsoil deficiency and trench settling shall be mitigated with imported topsoil that is consistent with the quality of the topsoil on the affected site. Appropriate rehabilitation measures will be determined and implemented when subsequent crop productivity within the affected area is less than that of the adjacent unaffected agricultural land. Where representative subsoil density of the affected area exceeds the representative subsoil density of the unaffected area, shattering of the soil profile will be performed.		
New York Department of Environmental Conservation . Jack Nasca (518) 402-9172, janasca@gw.dec.state.ny.us	Guidelines are in the final draft stage - they have been reviewed, but have not yet been released for public comment. Release expected by the beginning of December 2006.						
Oregon Department of Fish and Wildlife *Fish and Wildlife Habitat Mitigation Policy for Siting Non-Nuclear Energy Facilities* September 1, 2000 http://www.dfw.state.or.us/OARs/415.pdf . Contact Unknown (503) 947-6000	Departmental recommendations or requirements for mitigation will be based on: location, physical characteristics, duration of action and its impacts, alternatives available, fish and wildlife species and habitats affected	Department requires submission of a mitigation plan, which includes protocols, methods, and a reporting schedule for monitoring the effectiveness of mitigation measures				Any habitat not considered irreplaceable (Habitat Category 1) that is damaged must be mitigated through the acquisition of in/out-of-kind, in/off-proximity habitat depending on the habitat category level.	The Department may require or recommend the posting of a bond, or other financial instrument, to cover the cost of mitigation actions based on the nature, extent, and duration of the impact and/or the risk of the mitigation plan not achieving mitigation goals.
Pennsylvania Pennsylvania Wind Farms and Wildlife Collaborative http://www.dcnr.state.pa.us/wind/index.aspx . Kerry Campbell (717) 772-5985, kcampbell@state.pa.us	Pennsylvania recently intitiated a collaborative approch to develop a set of Pennsylvania-specific principles, policies, best management practices, guidelines, and tools that can be used to assess risk to habitat and wildlife from wind power development, and to mitigate* for the impact of that development. This process is expected to be lengthy. PA does already have a process in place that developers must go through to ensure wildlife is protected entitled the Pennsylvania National Heritage Program. An index (PNDI) is used to evaluate any project that requires a permit from the PA Dept. of Environmental Protection (DEP). Developers enter information about their project into an online review system (www.naturalheritage.state.pa.us) and are notified if there are any potential conflicts with the species or habitats of concern within the database. If they receive a "hit", they're directed to contact the appropriate jurisdictional agency, which will evaluate the project further. PGC evaluates projects that will impact birds and mammals; PFBC evaluates projects that impact fish, aquatic organisms, reptiles, and amphibians; DCNR evaluates plant impacts; and the US Fish and Wildlife Service evaluates impacts on federally listed species.						

South Dakota Bat Working Group & Game, Fish and Parks *Siting Guidelines for Wind Power Projects in South Dakota* http://www.sdgfp.info/Wildlife/Diversity/windpower.htm . Alyssa Kiesow (503) 947-6000	Prepare a monitoring and mitigation plan for protection of sensitive resources during construction and operation of the project Use biological and environmental experts to conduct a preliminary biological reconnaissance of the likley site area Communicate with personnel from wildlife agencies and universities		Situate turbines so they do not interfere with important wildlife movement corridors and staging areas Avoid large, intact areas of native vegetation Avoid lattice-designed towers or other designs providing perches Develop a stringent plan for preventing the introduction or establishment of non-native/invasive flora Consider turbine designs	Minimize the number of roads or fences Power lines underground and/or place turbine near existing transmission lines and substations Consider timing of construction and maintenance activities (including mowing). Avoid construction and maintenance activities during breeding season (April to July) and, if possible, during migration (April-June and August October)	Mitigate for habitat loss through: ecological restoration, long-term management agreements, conservation easements, or fee title acquisitions Address potential adverse affects of turbine warning lights on migrating birds and bats.		
Vermont Fish and Wildlife Department *DRAFT Guidelines for the Evaluation and Mitigation of Impacts to Wildlife Associated with Wind Energy Development in Vermont* April 20, 2006 http://www.energy.ca.gov/renewables/06-OII-1/documents/other_guidelines/VERMONT_GUIDELINES_2006-04.PDF . Julie Moore (802) 241-3687	The applicant should establish the presence or absence of different wildlife species and significant habitats so that appropriate mitigation and avoidance practices can be used. Studies need to be completed during breeding and migratory seasons The Department will review all survey results to determine if the project will result in undue adverse impacts, and may seek revisions to the project.	A minimum of 3 years of rigorous post-construction bird and bat mortality surveys are necessary for any utility-scale wind project in Vermont. Monitoring is to be conducted from April 15 to October 31	ANR reviews initial resource assessment with project layout and works with applicant to identify potential indirect and direct impacts and means of addressing them	Construction activities should be scheduled to avoid important periods of wildlife courtship, breeding and nesting Any clearing of montane spruce-fir must take place outside the breeding period for Bicknell's Thrush Construction activities within ¼ mile of significant black bear hard mast habitat or spring feeding areas should take place outside the feeding periods September 1 – November 21 and May 1 – July 15. Noise-reduction devices should be maintained in good working order on vehicles and construction equipment ANR may recommend the retention of an independent engineer to oversee construction	Habitat restoration activities should be initiated as soon as possible after construction is complete If a project is considered to have undue adverse impacts, mitigation measures will be required, which may include the following: modified operations, modified lighting, on-site habitat management, habitat protection		
Wisconsin Department of Natural Resources *Wind Farm Siting Guidance* August 31, 2005 http://www.dnr.state.wi.us/org/es/science/energy/wind/studies.htm . Steve Ugoretz (608) 266-6673, Steven.Ugoretz@dnr.state.wi.us	A baseline wildlife evaluation should be conducted for each site under serious consideration for windfarm development. To allow comparison with other studies, this evaluation should follow accepted standard protocols for windfarm evaluations (such as the NWCC study guidelines).	At least 2 years of monitoring recommended for the first wind farms in any ecological region in the state	Mitigation measures proved to minimize collisions and mortality should be designed into the windfarm An adaptive mangement approach is highly recommended	Power lines underground is highly recommended Perch guards and other APLIC endorsed technologies recommended			
FEDERAL							
BLM *Programmatic Environmental Impact Statement on Wind Energy Development on BLM-Administered Lands in the Western U.S.* June 2005 https://www.eh.doe.gov/nepa/otheragency/fes0511/index.html . Lee Otteni (505) 599-8911	Avian and bat use of the project area should be evaluated using rigorous survey methods Operators shall evaluate avian and bat use of the project area and design the project to minimize or mitigate the potential for bird and bat strikes Scientifically rigorous avian and bat use surveys shall be conducted - the amount and extent of ecological baseline data required shall be determined on a project basis.		Minimize area distubed by installation of tower Individual towers shall not be located in sensitive habitats or in areas with sensitive ecological resources Installation of towers shall be scheduled to avoid disruption of wildlife reproductive activities or other important behaviors Operators shall develop a plan for control of noxious weeds and invasive species Maximize use of existing roads Configure turbines to avoid landscape features known to attract raptors and desgin facilities to discourage perching and nesting Avoid locations heavily used by migratory birds and bats Minimize habitat disturbance by locating facilities in previously disturbed areas Projects should not be located in areas with high incidence of fog and mist	Noise-reduction devices should be maintained in good working order on vehicles and construction equipment Explosives should be used only within specified times and at specified distances from sensitive wildlife or surface waters Dust abatement techniques should be used Refueling should occur in a designated fueling area that includes a temporary berm to limit the spread of any spill Certified weed free mulch should be used when stabilizing areas of disturbed soil Fill materials that originate from areas with known invasive vegetation problems should not be used Minimize area disturbed by construction and operation	Measures to reduce raptor use at project site shall be considered, including: minimization of road cuts, and the maintenance of either no vegetation or non-attractive plant species around the turbines All unnecessary lighting should be turned off at night to limit attracting migratory birds Higher-height vegetation should be encouraged along transmission corridors to minimize foraging in these areas by raptors to the extent local conditions will support this vegetation The use of sodium vapor lights should be minimized or avoided		

				Topsoil from all excavations and construction activities shall be salvaged and reapplied during reclamation along with weed-free native grasses, forbs, and shrubs Guy wires on permanent towers shall be avoided Access roads should follow natural contours of topography and minimize side hill cuts and stream crossings Minimize the creation of, or increase in, the amount of edge habitat between natural and disturbed lands Construction activities should avoid important periods of wildlife behavior Stream crossings should be designed to provide in-stream conditions that allow for and maintain uninterrupted movment and safe passage of fish Establish buffer zones around raptor nests, bat roosts, and biota and habitats of concern, if facilities are beleived to pose a significant concern			
USFWS *Service Interim Guidance on Avoiding and Minimizing Wildlife Impacts from Wind Turbines* July 2003 http://www.fws.gov/habitatconservation/wind.pdf . For general use of guidance contact: David Stout, Chief, Division of Habitat and Resource Conservation, 703-358-2555 For technical issues contact: Robert Blohm, Chief, Division of Migratory Bird Management, 703-358-1714	Pre-development evaluations should be conducted by a team that includes Federal and/or State agency wildlife professionals with no vested interest (e.g., monetary or personal business gain) in the sites selected. Any site evaluations conducted by teams that do not include Federal and/or State agency wildlife professionals will not be considered valid evaluations by the Service Site evaluations are to be conducted using a series of checklists, which are them compiled to determine a ranking for the site	The Service recommends that all sites be monitored for impacts on wildlife after construction is completed – monitoring is not expected to exceed 3 years.	Avoid placing turbines or towers in documented locations of any species protected under the ESA, or where species reside that are sensitive to human disturbance Avoid locating turbines or towers in known local bird/bat migration pathways or in areas where birds/bats are highly concentrated, unless mortality risk is low. Avoid known daily movement flyways and areas with a high incidence of fog, mist, low cloud ceiling, and low visibility. Configure turbines to avoid potential avian mortality where feasible (i.e. group turbines rather than spreading them widely, orient rows of turbines parallel to known bird movements). Avoid fragmenting large contiguous tracts of wildlife habitat. Where practical, place turbines on disturbed habitats. Reduce availability of carrion Develop a habitat restoration plan for the proposed site that avoids or minimizes negative impacts on vulnerable wildlife while maintaining or enhancing habitat values for other species. Construct towers no more than 199 feet above ground level, using construction techniques that do no	Road access and fencing should be minimized If significant numbers of breeding, feedings or roosting birds are known to habitually use the proposed tower construction area, relocation to an alternate site should be recommended. If this is not an option, seasonal restrictions on construction may be advisable tin order to avoid disturbance during periods of high bird activity. Minimize roads, fences and other infrastructure. Infrastructure should be capable of withstanding periodic burning of vegetation.	Where feasible, turbines should be shut down during periods when birds are highly concentrated. Towers using guy wires for support which are proposed to be located in known raptor or waterbird concentration areas or daily movement routes, or in major diurnal migratory bird movement routes or stopover sites, should have daytime visual markers on the wires. Where feasible, power lines should be underground or on the surface as insulated, shielded wire. Where the height of the rotor-swept area produces a high risk for wildlife, adjust tower height where feasible. It is recommended that older turbines that have been shown to cause high mortality be retrofitted or relocated The use of solid red or pulsating red warning lights at night should be avoided. White strobe lights should be used at night – the minimum number, minimum intensity, and minimum number of flashes per minute allowable by FAA. Security lighting for on-ground facilities and equipment should be down-shielded		
USFS *DRAFT 36 CFR 251: Special Use Permits* . Kristin Nelson (202) 205-1406	The planning process must include the development and analysis of information regarding ecological components at a variety of spatial and temporal scales, as determined by the responsible official.		Plan decisions affecting ecosystem or species diversity must provide for maintenance or restoration of the characteristics of ecosystem compositions and structure within the range of variability that would be expected to occur under natural disturbance regimes in accordance with paragraphs (b)(1)(i) through (v) of 36 CFR 219.20				

FAA *FAA Advisory Circular: Obstruction Marking and Lighting, Ch.13* February 1, 2007 http://www.energy.ca.gov/2005publications/CEC-500-2005-180/CEC-500-2005-180.PDF . Scott Larwood (530) 752-7479, smlarwood@ucdavis.edu					Maximum separation gap between lights along a row to be 0.5 mi Omission of lighting within clusters (unless turbines are taller than perhiphery) Lighting of end turbines or end rows. Synchronization of lights for entire project. No daytime lighting necessary if white or off-white paint is used. Omit steady burning lights - Use of red (L-864) flashing lights recommended at night, or white(L-865) flashing lights possible if used alone without red lights and positioned in same manner as red flashing lights. Light fixtures should be placed as high as possible on the nacelle. Stray turbines should be lit High concentrations of lights should be avoided		
INTERNATIONAL							
Australia Wind Energy Association *Best Practice Guidelines for Wind Energy Projects* March 2002 www.auswea.com.au	A radius of up to 30km from the potential site should be used when gathering information on flora and fauna present within the site	Bird/bat utilization studies should be continued for at least 2 years after operation begins.	Avoid development sites and turbine sites with high bird usage Locate turbines and roads well away from wetlands and other bird-rich habitats Consider widening turbine spacing to permit movement of birds around and between turbines Design roads and tracks so that changes to surface water runoff are avoided and erosion is not initiated Route power cable to avoid the need to remove native vegetation and habitat Ensure power cables are not placed across regular bird flight paths Locate switchyard to avoid areas of native vegetation or habitat	Monitor for any downslope deposition of material from construction areas and ensure weeds are controlled and areas are revegetated. Implement strict speed limits where tracks are within 200m of wetlands or other habitats where birds could be disturbed. Locate storage areas and vehicle standing areas away from native vegetation and habitat and at least 200m from wetlands. Avoid building roads and placing turbines on areas of native vegetation and fauna habitat Avoid construction during the most sensitive times of year, and/or stage construction work to ensure adequate distance between works and sensitive habitats	Avoid human disturbance to any wetlands or other habitats that hold bird groups potentially vulnerable to collision Undertake an extensive rabbit control program to minimize the attractiveness of the site to birds of prey Clear away sheep and cattle carcasses rapidly Monitor and repair any erosion and reduce surface water pooling or concentration of runoff Do not illuminate wind turbines as this can attract insects, and confuse night-flying birds	Provide alternative habitat off-site to attract at-risk birds from near turbines	
Canada Environment Canada & Canadian Wildlife Service *A Guidance Document for Environmental Assessment* July 2005 http://www.energy.ca.gov/renewables/06-OII-1/documents/other_guidelines/CANADIAN_GUIDELINES_2005.PDF Final April 2007 Version: http://www.cws-scf.ec.gc.ca/publications/eval/index_e.cfm . Contact Unknown (819) 997-1095	Depends upon Level of Concern Matrix (Site Sensitivity + Facility Size): VERY HIGH CONCERN = 2+ years HIGH CONCERN = comprehensive survey MEDIUM = basic baseline surveys LOW = minimum amount of baseline information • Any turbine taller than 150m in height should be subject to closer scrutiny, especially for sites close to arrival and departure sites of nocturnal migrants, on mountain tops or in foggy areas.	Depends upon Level of Concern Matrix (Site Sensitivity + Facility Size): VERY HIGH CONCERN = 3+ years HIGH CONCERN = 2+ years MEDIUM = 2 years LOW = 1 year	A smaller number of larger turbines may pose less of a risk to birds than a larger number of smaller turbines. Tubular and meteorological towers without guy wires are recommended in commercial wind energy projects Configuration should avoid creating barriers to bird movement - spacing between the turbines should be greater than 200m in order to avoid inhibiting movement. Perching opportunities such as lattice towers, guy wires, hydro poles or other structures should be reduced or removed whenever possible.	Intense construction should be focused outside the core breeding and migration seasons to reduce disturbance to birds. Keep the number of access roads constructed to a minimum. When roads need to be constructed, habitat destruction, fragmentation and disturbance of breeding and wintering grounds should be minimized as much as possible. Power lines underground when possible. When above-ground lines, the following mitigation techniques should be considered: bird flappers or other flight diverters, increased size of wire, parallel to prevailing wind directions, removal of small lighting shield wires, placement close to trees and below tree tops, oblique rather than right angles when crossing rivers, avoidance of water crossings.	• Access roads that are not used after construction should be allowed to re-vegetate (with native not invasive plant species). • If grassland birds are being killed during aerial displays, consider delaying hay cutting If there are high densities of raptors in the area, implement a prey control program In agricultural sites, the areas under the turbines can be planted in a crop that is less attractive to birds Minimize or eliminate lighting. Use strobe lights only, with the minimum number of flashes per minute and the briefest flash duration allowable. Avoid steady-burning or other bright lights such as sodium vapor or spotlights on turbines and other structures. • Measures should be t	Encourage proponent to purchase and protect a parcel fo land of similar size and habitat Decommission or move problem turbines to a new location	

England Department for Environment, Food and Rural Affairs *Nature Conservation Guidance on Offshore Windfarm Development* March 2005 http://www.defra.gov.uk/WILDLIFE-COUNTRYSIDE/ewd/windfarms/windfarmguidance.pdf	Survey data from at least 2 years are necessary, with more survey data (preferably 3 years) will be required in circumstances where important concentrations of birds occur. Whole windfarm area plus surrounding buffer of 1-2 km should be surveyed – observers should be trained by ornithologists.	Surveys should be carried out for at least 3 years following construction and some monitoring may be required for the full lifetime of the development.	Avoid areas with concentrations of species of conservation importance or important migratory paths. Construction of larger turbines may provide greater visibility. Appropriate siting and design in terms of orientation, spacing and location should be used: allow wide corridors between clusters of turbines, with a line formation parallel to the main flight direction, and with the lines of turbines broken up.	Time construction works and construction methods should avoid critical times such as molting. Employ methods of chemical use that minimize release of polluting materials into the water column and only using chemicals selected from the List of Notified Chemicals. Construction works must not be undertaken between December 16 and March to minimize impacts on over-wintering Common Scoter. Cable laying along the beach from October to April should avoid the sensitive period 2 hours either side of high water for overwintering wader species. Cable laying should also occur outside of the molting period for the Common Scoter (July to September). Piling work for turbine foundations should only be carried out between high tide – 3 hours and high water +3 hours to minimize disturbance to Little Terns. No work should be carried out between May 1 and August 1 near to nesting/breeding areas.	Use intermittent rather than continuous navigation lighting, particularly strobing lights. Clusters of turbines will reduce the single point source and provide a more diffuse light distribution. Floodlighting of turbines should be avoided, particularly in times of bad weathers. White lights are preferable to red. High contrast patterns should be used on turbine blades to reduce motion smear		

OTHER								
American Birding Conservancy *Wind Energy Policy* October 12, 2004 http://www.abcbirds.org/policy/windpolicy.htm . Unknown Contact (540) 253-5782	1 year minimum, 2 years suggested Seasonal observations and detailed evaluation of site recommended, including surveys for noctrunal migrants Conducted by qualified professionals without a vested interest in the outcome	2 year minimum, statistically robust If legitimate mortality concerns, then studies should continue until monitoring demonstrates resolution of concerns	Location, design, operation, and lighting should be cafefully evaluated to prevent, or at least minimize, adverse impacts Towers and turbines should be monopoles, not of lattice construction, and have no guy wires	Power lines should be underground Above ground lines and poles should comply with Avian Power Line Interaction Committee (APLIC) standards Disturbed areas should be fully reclaimed to approximate the same habitat functions for wildlife that existed before the disturbance	The number of turbines tha are lit should be minimized Lit turbines should use simultaneously pulsing red or white strobes, suggested at 20 pulses per minute if possible If significant mortality rates cannot be resolved, then turbines should be shut down during periods of peak risk to birds or bats			
Audubon Washington *Wind Power Policy for Washington State* September 23, 2002 http://www.audubon.org/chapter/wa/wa/DOCs/Sept2002_WindPowerPolicy_ExecSummary.doc . Nina Carter (360) 786-8020	2+ years of baseline data of project area and surrounding buffer zone - potentially reduced to 1 year if use radar system such as BIRDRAD	Environmental monitoring must be conducted to assess the level of bird mortality caused by collisions, and must follow standard protocols. Monitoring reports and data must be submitted quarterly to EFSEC and WDFW for the first 2 years following commencement of operations, and annually thereafter.	Designs need to include technologies that are through to, or have been shown to reduce detrimental impacts on birds (i.e. tubular towers, absence of guy wires, absence of lights that may attract night-migrating birds) There must be a contingency plan established to be implemented when operational monitoring shows detrimental effects to birds and/or bird habitat		• Maximum speed of turbines less than 30rpm.			
CleanEnergy States Alliance *Model State Guidance Document Governing Avian and Bat Impacts from Wind Facilities* October 2006 . Mark Sinclar (802) 223-2554, msinclair@cleanegroup.org								

APPENDIX B: Wind Development and Wildlife Mitigation Studies Outline

The following collection is a compilation of literature on wind turbine mitigation efforts that has been separated according to the review process utilized (peer, none, or unknown). Within the 'Reviewed' section, documents are sorted into two primary categories (Journal or Report) and by the primary topic of the mitigation efforts and research (i.e., lighting alterations vs. location of turbines within site). The numbers located next to the citation correspond to the Annotated Bibliography, where detailed descriptions of each study can be found.

REVIEW PROCESS UTILIZED

Journals

Turbine Location/Turbine Type

2. Barrios, L. and A. Rodriguez (2004). "Behavioral and environmental correlates of soaring-bird mortality at on-shore wind turbines." Journal of Applied Ecology **41**: 72-81.
6. Hoover, S. L. & M. L. Morrison (2005). "Behavior of Red-Tailed Hawks in a Wind Turbine Development." Journal of Wildlife Management **69**(1):150-159.
8. Johnson, G. D., M. K. Perlik, et al. (2004). "Bat activity, composition, and collision mortality at a large wind plant in Minnesota." Wildlife Society Bulletin **32**(4): 1278-1288.
9. Osborn, R. G., C. D. Dieter, et al. (1998). "Bird Flight Characteristics Near Wind Turbines in Minnesota." American Midland Naturalist **139**(1): 29-38.
10. Osborn, R. G., K. F. Higgins, et al. (2000). "Bird Mortality Associated with Wind Turbines at the Buffalo Ridge Wind Resource Area, Minnesota." The American Midland Naturalist **143**(1): 41-52.

Lighting

17. Johnson, G. D., W. P. Erickson, et al. (2003). "Mortality of Bats at a Large-scale Wind Power Development at Buffalo Ridge, Minnesota." American Midland Naturalist **150**: 332-342.

Marking Power lines

24. Alonso, J.C., J.A. Alonso & R. Munoz-Pulido. (1994). Mitigation of Bird Collisions With Transmission Lines Through Groundwire Marking. Biological Conservation **67**: 129-134.
25. Brown, W. M. and R. C. Drewien (1995). "Evaluation of Two Power Line Markers to Reduce Crane and Waterfowl Collision Mortality." Wildlife Society Bulletin **23**(2): 217.
26. Janss, G. F. E. and M. Ferrer (1997). "Rate of Bird Collision with Power Lines: Effects of Conductor-Marking and Static Wire-Marking." Journal of Field Ornithology **69**(1): 8-17.
27. Morkill, A. E. and S. H. Anderson (1991). "Effectiveness of Marking Power Lines to Reduce Sandhill Crane Collisions." Wildlife Society Bulletin **19**(4): 442-449.

Curtail Turbines

30. Huppop, O., J. Dierschke, et al. (2006). "Bird migration studies and potential collision risk with offshore wind turbines." Ibis **148**: 90-109.

Reports

Turbine Location/Turbine Type

1. Anderson, R., N. Neuman, et al. (2004). Avian Monitoring and Risk Assessment at the Tehachapi Pass Wind Resource Area, Prepared for National Renewable Energy Lab: 1-102.
4. Erickson, W. P., G. D. Johnson, et al. (1999). Baseline Avian Use and Behavior at the CARES Wind Plant Site, Klickitat County, Washington, Prepared for the National Renewable Energy Lab**:** 1-75.

5. Hoover, S. (2002). The Response of Red-tailed Hawks and Golden Eagles to Topographical Features, Weather, and Abundance of a Dominant Prey Species at the Altamont Pass Wind Resource Area, California, Prepared for the National Renewable Energy Lab: 1-64.
7. Hunt, W. G. (2002). Golden eagles in a perilous landscape: Predicting the effects of mitigation for wind turbine blade-strike mortality, Prepared for the California Energy Commission: 1-72.
11. Orloff, S. & A. Flannery. (1992). Wind Turbine Effects on Avian Activity, Habitat Use, and Mortality in Altamont Pass and Solano County Wind Resource Areas Tiburon, California, Prepared for the Planning Departments of Alameda, Contra Costa and Solano Counties and the California Energy Commission.
12. Smallwood, K.S. & C.G. Thelander. (2004). Developing Methods to Reduce Bird Mortality in the Altamont Pass Wind Resource Area, Prepared for the California Energy Commission: 1-363.
14. Thelander, C. G. & L. Rugge. (2000). Avian Risk Behavior and Fatalities at the Altamont Wind Resource Area, Prepared for the National Renewable Energy Laboratory: 1-22.

Lighting

52. Arnett, E. B., W. P. Erickson, et al. (2005). Relationships between Bats and Wind Turbines in Pennsylvania and West Virginia: An Assessment of Fatality Search Protocols, Patterns of Fatality, and Behavioral Interactions with Wind Turbines, Prepared for the Bats and Wind Energy Cooperative: 1-187.
15. Erickson, W. P., J. Jeffrey, et al. (2004). Stateline Wind Project Wildlife Monitoring Final Report, July 2001 - December 2003, Prepared for FPL Energy, the Oregon Energy Facility Siting Council, and the Stateline Technical Advisory Committee: 1-105.
12. Smallwood, K.S. & C.G. Thelander. (2004). Developing Methods to Reduce Bird Mortality in the Altamont Pass Wind Resource Area, Prepared for the California Energy Commission: 1-363.

Visual Blades

20. Hodos, W. (2003). Minimization of Motion Smear: Reducing Avian Collisions with Wind Turbines, Prepared for the National Renewable Energy Laboratory: 1-43.
21. Young, D. P., W. P. Erickson, et al. (2003). Comparison of Avian Responses to UV-Light-Reflective Paint on Wind Turbines, Prepared for the National Renewable Energy Lab: 1-67.

Sound Devices

52. Arnett, E. B., W. P. Erickson, et al. (2005). Relationships between Bats and Wind Turbines in Pennsylvania and West Virginia: An Assessment of Fatality Search Protocols, Patterns of Fatality, and Behavioral Interactions with Wind Turbines, Prepared for the Bats and Wind Energy Cooperative: 1-187.
23. Dooling, R. (2002). Avian Hearing and the Avoidance of Wind Turbines, Prepared for the National Renewable Energy Lab: 1-17.

Perch Guards

12. Smallwood, K.S. & C.G. Thelander. (2004). Developing Methods to Reduce Bird Mortality in the Altamont Pass Wind Resource Area, Prepared for the California Energy Commission: 1-363.

Baseline Data

53. Erickson, W. P., G. D. Johnson, et al. (2002). Synthesis and Comparison of Baseline Avian and Bat Use, Raptor Nesting and Mortality Information from Proposed and Existing Wind Developments, Prepared for Bonneville Power Administration: 1-129.

Post Construction Data

56. Arnett, E. B., W. P. Erickson, et al. (2005). Relationships between Bats and Wind Turbines in Pennsylvania and West Virginia: An Assessment of Fatality Search Protocols, Patterns of Fatality, and Behavioral Interactions with Wind Turbines, Prepared for the Bats and Wind Energy Cooperative: 1-187.

Offshore

58. Pettersson, J. (2005). The Impact of Offshore Wind Farms on Bird Life in Southern Kalmar Sound, Sweden, at the request of the Swedish Energy Agency: 1-128.

Curtail Turbines

56. Arnett, E. B., W. P. Erickson, et al. (2005). Relationships between Bats and Wind Turbines in Pennsylvania and West Virginia: An Assessment of Fatality Search Protocols, Patterns of Fatality, and Behavioral Interactions with Wind Turbines, Prepared for the Bats and Wind Energy Cooperative: 1-187.

NOT PEER REVIEWED

Turbine Location/Turbine Type

13. Smallwood, K.S. (2006). Biological Effects of Repowering A Portion of the Altamont Pass Wind Resource Area, California: The Diablo Winds Energy Project.

Lighting

19. Larwood, S. (2005). FAA Obstruction Lighting Standards for Wind Energy Plants, Prepared for California Wind Energy Collaborative, sponsored by the California Energy Commission Public Interest Energy Research (PIER) program.

Marking Power lines

28. Organ, C. A., M. Timewell, et al. (2003). Bird Surveys along the proposed Musselroe Wind Farm Transmission Line - Ringarooma Ramsar area, north-east Tasmania, Prepared for Hydro-Electric Corporation: 1-62.

UNKNOWN REVIEW PROCESS

Turbine Location/Turbine Type

25. Brown, W. M., R. C. Drewien, et al. (1985). Mortality of cranes and waterfowl from power line collisions in the San Luis Valley, Colorado. 4th Crane Workshop, Grand Island, Nebraska, Platte River Whooping Crane Habitat Maintenance Trust.

Lighting

16. Howell, J. A., J. Noone, et al. (1991). Visual experiment to reduce avian mortality related to wind turbine operations, Prepared for Altamont U.S. Windpower, Inc.: 1-25.
18. Kerlinger, P. and J. Kerns (2004). A Study of Bird and Bat Collision Fatalities at the Mountaineer Wind Energy Center, Tucker County, West Virginia: Annual Report for 2003, Prepared for FPL Energy and Mountaineer Wind Energy Center Technical Review Committee: 1-39.

Visual Blades

1. Howell, J. A., J. Noone, et al. (1991). Visual experiment to reduce avian mortality related to wind turbine operations, Prepared for Altamont U.S. Windpower, Inc.: 1-25.

Microwaves

22. Kreithen, M. L. (1996). Development of a Pulsed Microwave Warning System to Reduce Avian Collisions with Obstacles. 2nd International Conference on Raptors. Urbino, Italy.

Sound Devices

76. Szewczak, J. & E.B. Arnett. (N/A). Evaluation of Acoustic Deterrents to Reduce Bat Fatality at Wind Facilities.

Perch Guards

29. Nelson, H. K. and R. C. Curry (1995). Assessing Avian Interactions with Wind Plant Development and Operations. 61st North American Wildlife and Natural Resources Conference. Washington, D.C.

Baseline Data

54. Percival, S.M. (2003). Birds and Wind Farms in Ireland: A Review of Potential Issues and Impact Assessment: 1-25.
55. Young, Jr., D.P, W. P. Erickson, et al. (2003). Avian and Bat Mortality Associated with the Initial Phase of the Foote Creek Rim Windpower Project, Carbon County, Wyoming, Prepared for Pacificorp, Inc., Bureau of Land Management and SeaWest Windpower, Inc.: 1-50.

Curtail Turbines

75. Sherwell, J. (N/A). Developing a mitigation strategy for bat impacts from windpower development in Maryland.

No Effect

57. Lucas, M. D., G. F. E. Janss, et al. (2005). "A bird and small mammal BACI and IG design studies in a wind farm in Malpica (Spain)." Biodiversity and Conservation **14**: 3289-3303.

APPENDIX C: Habitat Mitigation Studies Outline

The following is a compilation of literature on habitat mitigation efforts that has been separated according to the review process used (peer, none, or unknown). Within each section, documents are sorted by the primary topic of the mitigation effort and research (e.g., livestock fencing). The numbers located next to the citation correspond to the Annotated Bibliography, in which descriptions of each study can be found.

REVIEW PROCESS USED

Wetland Creation

46. Balcombe, C.K., J.T. Anderson, et al. (2005). "Wildlife Use of Mitigaiton and Reference Wetlands in West Virginia." Ecological Engineering **25**: 85-99.
47. Darnell, T.M. & E.H. Smith. (2004). "Avian Use of Natural and Created Salt Marsh in Texas, USA." Waterbirds **27**(3): 355-361.

Livestock Fencing

42. Dobkin, D.S., A.C. Rich, et al. (1998). "Habitat and Avifaunal Recovery from Livestock Grazing in a Riparian Meadow System of the Northwestern Great Basin." Conservation Biology **12**(1): 209-221.
45. Maron, M. and A. Lill. (2005). "The influence of livestock grazing and weed invasion on habitat use by birds in grassy woodland remnants." Biological Conservation **124**: 439-450.
12. Smallwood, K.S. & C.G. Thelander. (2004). Developing Methods to Reduce Bird Mortality in the Altamont Pass Wind Resource Area, Prepared for the California Energy Commission: 1-363.

Cave Gating

41. Martin, K.W., D.M. Leslie Jr., et al. (2003). "Internal Cave Gating for Protection of Colonies of the Endangered Gray Bat (*Myotis grisescens*)." Acta Chiropterologica **5**(1): 1-8.

Relocation

40. Roby, D., K. Collins, et al. (2002). "Effects of Colony Relocation on Diet and Productivity of Caspian Terns." Journal of Wildlife Management **66**(3): 662-673.

Artificial Nests

35. Belthoff, J.R. & R.A. King. (2002). "Nest-site Characteristics of Burrowing Owls (Athene Cunicularia) in the Snake River Birds of Prey National Conservation Area, Idaho, and Applications to Artificial Burrow Installation." Western North American Naturalist **62**(1): 112-119.
37. Smith, M.D. C.J. Conway, et al. (2005). "Burrowing owl nesting productivity: a comparison between artificial and natural burrows on and off golf courses." Wildlife Society Bulletin **33**(2): 454-462.
69. Trombulak, S.C. and C.A. Frissell. (2000). "Review of ecological effects of roads on terrestrial and aquatic communities." Conservation Biology **14**(1): 18-30.
38. Trulio, L.A. (1995). "Passive Relocation: A Method to Preserve Burrowing Owls on Disturbed Sites." Journal of Field Ornithology **66**(1): 99-106.

Habitat Alterations

31. Grindal, S.D. and R.M. Brigham. (1998). "Short-term Effects of Small-scale Habitat Disturbance on Activity by Insectivorous Bats." Journal of Wildlife Management **62**(3): 996-1003.
34. Leddy, K. L., K. F. Higgins, et al. (1999). "Effects of Wind Turbines on Upland Nesting Birds in Conservation Reserve Program Grasslands." Wilson Bulletin **111**(1): 100-104.

33. Larsen, J.K. & J. Madsen. (2000). “Effects of Wind Turbines and Other Physical Elements on Field Utilization by Pink-footed Geese (Anser Brachyrhynchus): A Landscape Perspective.” Landscape Ecology **15**: 755-764.
67. Rowland, M.M., M.J. Wisdom, et al. (2005). “Effects of Roads on Elk: Implications for Management in Forested Ecosystems.” In M.J. Wisdom (technical editor), The Starkey Project: a synthesis of long-term studies of elk and mule deer. Reprinted from the 2004 Transactions of the North American Wildlife and Natural Resources Conference, Alliance Communications Group, Lawrence, Kansas: p.45-52.
69. Trombulak, S.C. & C.A. Frissell. (2000). Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. Conservation Biology 14(1): 18-30.

Conservation Easements (CRPs, ECAs, etc)

32. Herzog, F., S. Dreier, et al. (2005). “Effect of ecological compensations areas on floristic and breeding bird diversity in Swiss agricultural landscapes.” Agriculture, Ecosystems and Environment **108**: 189-204.

Wildlife Corridors

49. Aresco, M.J. (2005). “Mitigation measures to reduce highway mortality of turtles and other herpetofauna at a north Florida lake.” Journal of Wildlife Management **69**(2): 549-560.
50. Cain, A.T., V.R. Tuovila, et al. (2003). “Effects of a Highway and Mitigation Projects on Bobcats in Southern Texas.” Biological Conservation **114**: 189-197.
51. Dixon, J.D., M.K. Oli, et al. (2006). “Effectiveness of a Regional Corridor in Connecting Two Florida Black Bear Populations.” Conservation Biology **20**(1): 155-162.
52. Ng, S.J., J.W. Dole, et al. (2004). “Use of highway undercrossings by wildlife in southern California.” Biological Conservation **115**: 499-507.

UNKNOWN REVIEW PROCESS

Wetland Creation

48. Federal Highway Administration. (1992). Evaluation of Wetland Mitigation Measures, Volume 1: Final Report: 1-353.

Livestock Fencing

43. Earnst, S.L., J.A. Ballard, et al. (2004). Riparian songbird abundance a decade after cattle removal on Hart Mountain and Sheldon National Wildlife Refuges. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191: 9 pgs.
44. Manier, D.J. & N.T. Hobbs. (2006). “Large Herbivores Influence the Composition and Diversity of Shrub-Steppe Communities in the Rocky Mountains, USA.” Oecologia **146**: 641-651.

Relocation

39. Matthews, K.R. (2003). Response of Mountain Yellow-Legged Frogs, *Rana muscosa*, to Short Distance Translocation. Journal of Herpetology **37**(3): 621-626.

Artificial Nests

36. Smith, G.C. & G. Agnew. (2002). “ The Value of ‘Bat Boxes’ for Attracting Hollow-dependent Fauna to Farm Forestry Plantations in southeast Queensland.” Ecological Management & Restoration **3**(1): 37-46.

Habitat Alterations

73. McNew, L.B., B.K. Sandercock & S.M. Wisely. (N/A). Effects of Wind Power Development on the

Demography of the Greater Prairie-Chicken.
74. Schroeder, M.A., C.E. Braun & J.W. Connelly. (N/A). Effects of Wind Power Development on Sage-Grouse.

Habitat Enhancement

71. Lehn, K. & F. Bairlein. (2006). Is mulching a suitable method for improving the nesting habitat of the Northern Lapwing? Journal of Ornithology **147**(5): N/A. **(THIS STUDY HAS NOT YET BEEN PUBLISHED)**

APPENDIX D: Personal Interview Contacts and Responses

The following list includes individuals that were contacted via phone or e-mail in order to gather information about existing research pertaining to mitigation. A list of interview questions is in Appendix E.

TELEPHONE

1) **Wayne Walker, Director of Project Development, Horizon Wind Energy, 713-265-0247, wayne.walker@horizonwind.com;** He is "not aware of a plethora of mitigation studies." Horizon looking into conservation banks, but hasn't implemented any yet. Mentioned Wild Horse study as only example of conservation/development that Horizon is currently involved in – it was not set up for mitigation specifically. He also mentioned www.bambergerranch.org as an example of someone taking a heavily degraded habitat and returning it to pre-European levels. Includes a manmade cryptorium for free-tailed bats. I looked it up, but seems a little 'fluffy'. (Follow up with the WA Nature Conservancy pertaining to Wild Horse study still necessary) – L/M with Horizon WA office on 11/1/06 for more info, 509-962-1122; also spoke with Jeff Compton of TNC-WA, 206-343-4345.

2) **Ed Arnett, Conservation Scientist – Wind Energy, Bat Conservation International, 512-327-9721, earnett@batcon.org;** no studies/research to his knowledge concerning habitat enhancement and bats. Says most species killed by turbines live in trees, so mitigation of caves/mines does little for repairing damage. Said research on insects/bats at turbines and stopping blades needs to be further researched.

3) **Jill Shaffer, Ecologist, USGS Northern Prairie Wildlife Research Center, 701-253-5547, jshaffer@usgs.gov;** she spoke with a few people about the existence of research that directly examines the effectiveness of any mitigation techniques and "we have come up mostly blank." Mitigation can include creating new habitats as well as protecting what exists – "both are important avenues to consider because placing wind developments in already disturbed land might preclude needing mitigation for habitat impacts or displacement of animals at all." Suggested I contact Habitat and Population Evaluation Team, DOT, FHWA, and SD State University.

She also mentioned the 'Effects of Management Practices on Grassland Birds' research http://www.npwrc.usgs.gov/resource/literatr/grasbird/index.htm. I looked into management suggestions for the Ferruginous Hawk and Burrowing Owl to determine how well supported they were. The research cited is from before the mid-90s, so appears to be a bit dated. When I looked into some of the papers cited, the management suggestions didn't appear to be overwhelmingly supported statistically. Jill did mention that they were updating the publication and that I should contact her to send me the updated versions – I am currently awaiting response from her.

4) **Jim Lowe, Birds in Forested Landscapes, Cornell Ornithology Lab, 607-254-2413;** said they have not studied applied mitigation – just surveys. Suggested contacting Stefan Hames who is their 'wind guru'. Left him a message on 8/22, but have not received a response. Stefan contact is 607-254-2496, rsh5@cornell.edu.

5) **Gail Garber, NM Avian Protection Working Group, HawksAloft (?), 505-828-9455, gail@hawksaloft.org;** the organization has never looked at mitigation as a research project. They have set up nesting platforms, but no research was conducted on its effectiveness. They have done

some pre-site assessments for wind turbines to identify raptors in area and if potential site is in way of migratory pathway. She suggested I contact Wally Erickson and David Young.

6) **Sandy Vana-Miller, USFWS in Colorado (Energy aspect), 303-236-4748;** suggested I call Al Manville. No idea about research pertaining to mitigation or habitat enhancement.

7) **Nick Myatt**, **Access and Habitat Coordinator, Oregon Department of Fish and Wildlife, 503-947-6087;** he doesn't do anything pertaining to habitat enhancement studies himself, but sent word out to co-workers for help with the question. Received response from one woman, who was going to look into studies that have been conducted within her area and send contacts for more information. Nick also suggested looking at the Conservation Plan for OR at www.dfw.state.or.us which outlines how to manage wildlife. Like npwrc research, however, it focuses more on individual species of concern. I emailed him and the woman again this week to see if they had come up with anything or anyone for me to speak with, but I haven't heard back from them yet.

8) **Rob Manes, Director of Conservation, The Nature Conservancy, 620-672-5677, rmanes@tnc.org;** he said that "definitive studies are not out there" pertaining to mitigation and its effects on birds/bats. He did send me some information on a mitigation proposal that TNC has been working on in the Smokey Hills, as well as some studies pertaining to Prairie Chickens and mitigation in Kansas.

9) **John Sherwell, Power Plant Research Program, Maryland Department of Natural Resources, 410-260-8667, jsherwell@dnr.state.md.us;** I called him specifically about a study that he intends to present at the conference in November pertaining to wind turbine rotation speed and bat interactions. He stated that the study modeled risk at low wind speeds, finding that lower rpms significantly decreased the risk to bats. He is looking for comments on whether or not the risk model is reasonable presently.

10) **Paul Garrett & Lamar Smith, Federal Highway Administration;** left messages with both of them, not sure if they are the correct contacts at this department though. Spoke with John Fagan 8/23, who said he would look into the best contact but has yet to get back with me. Left message for Jeff Peterson with the CDOT on 11/1/06 – Jeff.Peterson@dot.state.co.us, 303-512-4959

11) **Al Manville, Wildlife Biologist, Division of Migratory Bird Management, USFWS, albert.manville@fws.gov;** "No one has any idea what is going on in relation to bird/bat mortality and mitigation." He said that it was very important to assess populations, and that post-construction monitoring was a big part of this. Mitigation strategies mentioned included blade-painting strategies (Strickland), Bat-Be-Gone (Arnett) which is currently being testing in the field in TX – acoustic deterrents that do not appear to be cost effective, and Lesser Prairie Chicken studies (Robell, USFWS recommends >5m buffer from leks, BLM recommends ¼ mile) – surrogate structures used to date, need to test at wind facilities. Europe is ahead of US in this department – British, German (Franz Bairlein).

An interesting study that he mentioned was one in Oaxaca, Mexico. They are currently in the process of constructing a very large wind power plant, but World Bank will not fund unless they agree to shut down the turbines for 3 weeks during Broad-winged Hawk, Mississippi Kite, and Swainson's Hawk migration. Monitoring program has been set up to see the effects of this mitigation strategy on avian mortality, as well as on economic performance of plant. Study hasn't begun yet.

12) **Mike Estey, Habitat Population and Evaluation Team, USFWS, 701-355-8540;** he suggested I speak with Ron Reynolds. Did mention that HAPET is currently identifying potential

problems with the siting of a wind power plant in ND (pertaining to wildlife migration); "the biggest problems are identifying any real problems."

13) **Ron Reynolds, Habitat Population and Evaluation Team, USFWS, 701-355-8535;** study currently being conducted to examine the effectiveness of a mitigation strategy to remedy problems caused to Ruddy Ducks on their wintering grounds as a result of an oil spill in the Patauxent River, MD. Board of Trustees decided that mitigation for spill required the organization to return new Ruddy Ducks into the population to make up for the ones that were lost. In order to do this, HAPET is helping organization to restore/create new habitat on the breeding grounds which are in ND. Evaluations of mitigation will begin as soon as the mitigation treatments are completed, and they will last for 10 years. Mitigation includes restoring the function of degraded wetlands or replacing drained wetlands, largely through conservation easements on agricultural lands. They are currently targeting areas with high RUDU breeding populations because they are already supportive landscapes.

14) **Karen Kronner, President, Northwest Wildlife Consultants Inc., 541-278-2987, kronner@oregontrail.net;** stated that there wind is relatively new compared to other types of mitigation, so mitigation approaches have largely been based on mitigation efforts from gas projects, transmission lines, oil pipes, highways, etc. Mitigation depends on the scale of the project, and NWC works directs with state to minimize impacts. She doesn't "believe something needs to be formerly researched if other studies have shown how a habitat/species responds to change." A lot of mitigation efforts are based on intuition which is developed by being in the field and "gaining a sense of things in the area." People don't know what to do – you can learn from other regions, but you will need to tailor strategies to local conditions. They keep asking for more certainty, but you "can study a site for three years and still not know everything." Mentioned BLM in Nevada is currently developing regional specific wind power guidelines that will include pre-construction, environmental, and fatality monitoring. Also mentioned Cotterall Mountain (sp??) project in Idaho, where she though Sage Grouse mitigation tools were developed (Lynn Sharp was mentioned as contact).

Stateline project is the largest in Oregon, and has the largest post-construction study done thus far, which includes grassland bird displacement studies, raptor studies, and recovery of temporary disturbed areas (grass seeding). Pre-construction monitoring was conducted, and gaps were left in saddles when placing turbines as a result. Report on post-construction monitoring is expected January 2007. Stateline was found to exceed the raptor kill threshold established by the state, however, and a three part mitigation plan was developed, including: 1) construction of artificial nest structures, 2) protection of riparian habitat (raptor habitat) through exclosures of riparian area and upland livestock, and 3) provision of financial support to wildlife rehabilitator to purchase food to rehabilitate raptors and chicks. Mitigation efforts are only ¾ completed at this point, and effectiveness monitoring with be conducted on platform usage but not on effects of fencing due to long time period required for effects to be evident.

15) **Sara McMahon, Wildlife Biologist, PPM Energy, 503-796-7000, Sara.McMahon@PPMEnergy.com;** a lot of mitigation not based on research, but based on recommendations and observations. Efforts follow more of a precautionary principle approach, such that "it wouldn't hurt to set the turbines back from the canyon edges." Studies like the Altamont are not useful for the NW because there are different biological characteristics there.

Andy Linnenhahn (??) has been involved with Arnett's study on acoustic deterrents, where high frequency noise generators are used to block the ability of bats to relocate. Initial field trials have been completed and the deterrents appear to be positive at this point. He is not sure how far effects will extend, and mentioned that the devices are still in prototype development.

16) **David Klute, All-bird Conservation Coordinator, Colorado Division of Wildlife, 303-291-7320;** left message, no response

17) **Gregory Johnson, Ecologist/Project Manager, WEST Inc, 307-634-1756;** left message, no response

18) **Jim Lindsey, Principal Biologist Florida Power and Light, 561-691-7032;** left message, no response

E-MAIL

1) **Bruce Johnson, Starkey Experimental Forest (Biologist), johnsobd@eou.edu;** brief initial correspondence, but no response to questions

2) **Franz Bairlein, Editor-In-Chief, Institute for Avian Research, franz.bairlein@ifv.terramare.de;** responded that he was at the International Ornithological Congress and would get back to me when he returned to Germany. Received an email from co-worker Ommo Hueppop, who stated that he didn't "know of any such studies where artificial modifications of habitats around windfarms" were used as a measure to mitigate wildlife interactions. He suggested I pose this question to the Yahoo-group on Wind-turbines and birds/bats, http://tech.groups.yahoo.com/group/wind turbines birds/ . He additionally sent me a paper on offshore-windfarms entitled "Bird migration studies and potential collision risk with offshore wind turbines".

3) **Ellen Paul, Executive Director, The Ornithological Council, ellen.paul@verizon.net;** stated that she isn't aware of what mitigation measures have been taken, and that people tend to make educated guesses about things that will work but that they don't do any studies to determine the outcome. "No one has ever determined if the site selection has reduced mortality." There has been work done with regard to the surrounding vegetation (contact Carl Thelander), and Ed Arnett was suggested as a good contact on bats. "It would be possible that you are looking for information that doesn't exist."

4) **Dave Cowan, VP Environmental Affairs, UPC Wind Management, 207-829-6055, dcowan@upc.wind;** HCP for Hawaii project includes a "very comprehensive mitigation component", but there is not any hard data or research as of yet that can be cited. The project came on-line in June, and mitigation provisions are just getting started. Study has made some headway on documenting behavioral avoidance of turbines by birds that regularly pass through the site, but again, the data is not ready to present as a research paper. Rigorous impact avoidance protocol was implemented during construction phase to "ensure that no birds were accidentally disturbed or killed by clearing, earthwork, or vehicles and heavy equipment moving around the site." HCP plan itself is largely based on uncertainties, so it contains a lot of contingencies. "Track 1 if A happens, but Track 2 if B happens – it's as much a protocol as a prescription." He sent me a copy of the HCP for review.

5) **Dr. Michael L. Rosenzweig, Professor of Ecology and Evolutionary Biology, University of Arizona, scarab@email.arizona.edu;** he had heard of dozens of mitigation cases, but does not keep a formal file of them and is too "freighted with commitments to accomplish this in any reasonable time-frame." He does state, however, that many of them appear in his book "Win-Win Ecology", and although they are not labeled 'mitigation' per se, the will have the fingerprint of mitigation all over them. Additional resources included:

- Rosenzweig, M.L. (2006). Beyond set-asides. In Goble, D., D. Scott, J. Michael, and F.W. Frank (eds), *The Endangered Species Act at Thirty: Renewing the Conservation Promise.* Island Press, Washington, D.C.: p.259-273.
- Rosenzweig, M.L. (2005). Avoiding mass extinction: basic and applied challenges. *American Midland Naturalist* 153: 195-208.

6) **Ryan Burnett, Terrestrial Ecologist, Point Reyes Bird Observatory**, 530-258-2414, **rdburnett@prbo.org;** he stated that "PRBO hasn't done too much work but I know we have at least looked into doing some work and done some research". He suggested I contact Katie Fehring, who does most of the raptor work for the organization. Katie stated that PRBO is currently conducting surveys at a proposed wind site in Marin, but that is all the organization has done with wind development thus far. Her contact info is 415-868-0655 x380, kfehring@prbo.org.

APPENDIX E: Personal Interview Questions

The National Wind Coordinating Committee's Wildlife Workgroup Mitigation Subgroup is collecting information about research that has been conducted to determine the effectiveness of wildlife mitigation strategies, especially as they might apply to wind turbine sites. This research will be presented as case studies that will be included in a mitigation toolbox being developed by the Subgroup.

Questions:

1. Are you familiar with any such studies that have been conducted/are being conducted within your company/organization?
2. If so:
    a. Can you describe the study to me?
    b. What have you learned from this research?
    c. Has it definitively shown certain mitigation strategies to be effective or ineffective?
    d. Can you send me any documentation of this research, especially approach, methodologies, and analyses/results?
3. If not:
    a. Are you familiar with any such research that might be useful to this study?
    b. Has your organization/company implemented any mitigation strategies? Did you find them to be effective/ineffective?
    c. Does your company/organization plan to do any such research in the future?

APPENDIX F: Economic Analysis

This matrix compares the economic costs of certain mitigation strategies with the estimated effect on mortality of that strategy. The mitigation strategies presented in Column A came from both mitigation research and existing policies and guidelines. Column B briefly describes what the mitigation strategy encompasses. Associated Research is presented in Column C and shows existing or current research that has tested the mitigation strategy; the results of that research (in terms of effectiveness) are presented in Column D. Finally, Column E presents the estimated costs of the mitigation strategy.

ECONOMIC ANALYSIS

Mitigation Strategy	Description	Associated Research	Estimated effect on mortality	Estimated Cost
Install beneficial turbine designs	Place turbines in locations that minimize the chances of negatively affecting wildlife - includes placing turbines away from rim edges, away from flyways, creating wind walls, etc.	Orloff & Flannery 1992, Thelander & Smallwood 2004	Estimate 4% decrease in bird/raptor mortality by creating wind wall; untested	Pre-assessment surveys
Avoid areas heavily used by birds/bats	This would include migration pathways and breeding grounds.		untested, but presumably significant	Pre-assessment surveys
Locate turbines on altered landscapes	This would include areas such as agricultural lands - avoid constructing turbines in sensitive or large tracts of native habitat			N/A
Reduce and minimize lateral edge	Cuts into hillsides for wind turbine lay-down areas and access roads should be minimized	Smallwood & Thelander 2004	Ground squirrels avoided zone, but pocket gophers were attracted to it; untested	
Establish buffer zones	Establish areas where there will be no construction or development occuring around areas of high bird/bat use			
Alter tower type	Tower type altered, but existing turbine blade not changed			
Paint blades	One blade painted black (or thinly striped black/white) and two painted white	Hodos et al. 2003	untested	
	Red and white stripes	Howell et al. 1992, Thelander & Smallwood 2004	90% reduction (n=10) according to Howell; 2-3% increase according to Thelander	
	Paint blades with UV gel	Young et al. 2003	52% more fatalities at UV turbines - not significant and nocturnal species; degeneration of gel	

Rodent control	Live-trapping and relocation of rodents.	Hunt 2002	Potential increase in mortality for species that depend upon burrows &/or prey; no compelling evidence that rodent control reduces bird mortality; potential bioaccumulation and biomagnification issues	
	Poisoning of rodents using bait of some form.	Thelander & Smallwood 2004		
Fence around turbines to exclude livestock	Livestock congregate around wind turbines (wind-breaks, shade?), which increases cow pats and subsequent insect numbers. 50-m exclusion area may suffice, but may be necessary to fence off groups of turbines in order to minimize length of fencing and perching opportunities.	Thelander & Smallwood 2004	Estimated 18-22% reduction in avian fatalities; untested	
Rock piles	Establish rock piles to create denning habitat for Kit Fox prey population			
	Move artificial rock piles as far away from wind turbines as possible	Thelander & Smallwood 2004	not believed to reduce mortality substantially by itself; untested	Low
Perch guards	Treatments designed to discourage perching by raptors on lattice-style turbines	Thelander & Smallwood 2004, Nelson & Curry 1995, Curry & Kerlinger 2001	Reduction in perching observed to be 0-54%; Increase in hawk mortality of 2% (Thelander & Smallwood)	
Repower turbines	Older turbines replaced within newer ones (e.g., lattice-style towers replaced with tubular towers).	Thelander & Smallwood 2004, Anderson et al. 2004, Hunt 2002, Orloff & Flannery 1992, Thelander & Rugge 2000, WEST (unpublished)	90% decrease (Hunt), Tubular towers associated with 6-35% increased mortality (Thelander); WEST currenlty testing in CA (Altamont)	
Mark power lines	Placement of various markers on groundwires or power lines to increase visibility.	Alonso et al. 1994, Brown & Drewien 1995, Janss & Ferrer 1997, Morkill & Anderson 1991	60% decrease (Alonso), 76-81% decrease (Janss); 56% decrease (Morkill)	
Install bird flight diverters	Benign pole structures placed beyond the ends of strings and edges of turbine clusters.	Thelander & Smallwood 2004	untested	

Provide alternative perches	Establishment of alternative perches in order to attract birds away from turbines.	Thelander & Smallwood 2004	untested	
Barricade the rotor plane	Erection of barriers to keep birds from flying into moving blades.	Thelander & Smallwood 2004	untested	believed to be overwhelmingly costly & impractical
Accoustic deterrents	Modifying the acoustic signatures of turbine blades in order to make them more audible to birds/bats.	Dooling 2002, Arnett et al. 2005, Szewczak & Arnett (unpublished)	acoustic signatures for birds untested; sonar "jamming" testing in progress	associated costs for decreasing bat fatalities believed high
Retrofit turbine-tower pads				
Reduce availability of carrion	Remove carcasses to discourage scavengers from approaching turbines		untested	
Minimize number of lit turbines		Johnson et al. 2003, Erickson et al. 2004, Huppop et al. 2006, Arnett et al. 2005	lighting did not appear to affect bats/birds (Johnson, Erickson, Arnett); lights observed to cause disorientation and be attractant - needs to be field tested (Huppop)	save $
Avoid sodium vapor lights		Kerlinger & Kerns 2004	47.8% decrease after lights were turned off	
Synchronize lighting	Lights on turbines should flash at same time.	Larwood 2005	untested (only looked at effects on pilots)	N/A
Relocate selected turbines	Dependent upon species/location. Relocation of turbines that cause disproportionately large numbers of fatalities (i.e. isolated turbines, turbines in canyons).	Hoover 2002, Hoover et al. 2005, Thelander & Smallwood 2004, WEST (unpublished)	2-5% decrease in bird/raptor mortality by removing isolated turbine (Thelander); 100% decrease in GOEA mortality from turbines by removing from canyon (Hoover); WEST currenlty testing in CA (Altamont)	
Coordinate timing of operational turbines				
Remove derelict and non-operating turbines	Evidence suggests raptors are killed disproportionately more often by turbines adjacent to broken ones.	Thelander & Smallwood 2004	5-9% increase in mortality at or next to derelict turbines	

Suspend operation during high risk periods	Dependent upon species/location. Includes combinations of adverse weather, high migration, high/low winds, and topography.	Arnett et al. 2005, Hoover 2002, Hoover et al. 2005, Barrios & Rodriquez 2004, Huppop et al. 2006, Sherwell (unpublished), Villegas-Patraca et al. (unpublished), WEST (unpublished)	Currently being tested by Sherwell in MD, WEST in CA (Altamont), and Villegas-Patraca in Mexico.	
Repower using turbines with high rotor planes	Rotor planes should be no lower than 29m above the ground.	Thelander & Smallwood 2004	untested	
Acquire off-site conservation easements	Improving habitat/wildlife population by purchasing/improving habitat in another location.	USFWS (Ron Reynolds contact) unpublished		
Reestablish nesting/maternity areas	Any bird/bat nesting/maternity areas that are disturbed by the construction/operation of the turbines should be reestablished.			

From: Albert_Manville@fws.gov
Subject: Re: "Small" wind turbines
Date: December 6, 2011 6:39:58 AM PST
To: Dan Silver <dsilverla@me.com>
Cc: Albert_Manville@fws.gov, Eric_Kershner@fws.gov, Kelly Fuller <kfuller@abcbirds.org>

Dan,

Received your voicemail. My quick response and terse review of the San Diego County regulations: there is absolutely no mention about impacts to migratory birds protected by the Migratory Bird Treaty Act (totalling 1,007 species) nor impacts to eagles, especially Golden Eagles, protected by the Bald and Golden Eagle Protection Act. "Small" is an incredibly subjective term. Even 1 "small," 80 ft AGL 3-bladed turbine can be a high risk to eagles and other birds if placed in the wrong locations and/or subjected to inclement weather events when birds are present. That has been made quite clear in studies at Altamont Pass (Smallwood and Thelander, Hunt, and others) where some of the small turbines were deemed "killers."

"Small" also does not define the parameters of what kind of turbine is being permitted -- at least what I could find in the regs. Would these be the standard 2- or 3-bladed vertical turbines or would they be vertical helix turbines? While vertical helix turbines are being touted as "bird safe," I'm unaware of any studies yet published in the peer-reviewed, scientific literature that validate this hypothesis. There is a new turbine design that uses a vortex cone and pressure differentials to create electricity. It may, however, still just be a prototype.

Again, whether "small" or "large," if a turbine is placed in a bird- and/or bat-unfriendly location, even one turbine can be damaging, resulting in take. FWS does not issue incidental or accidental take permits under MBTA.

We are developing a take provision under BGEPA (50 CFR 22.26), but the acquisition of a take permit for Golden Eagles (take primarily including disturbance with a very limited allowance for take resulting in mortality) would almost certainly be a programmatic permit. To receive a programmatic take permit, the developer would have to pursue all steps necessary to show that "take is unavoidable." This could require some considerable pre-construction monitoring. Currently, we are recommending at least 2 years pre-construction studies in our evolving Eagle Conservation Plan Guidance -- an earlier draft on our FWS website -- with the latest draft still under development.

If eagle take occurs without a permit, this is a criminal violation of

BGEPA with some significant legal consequences. Officials who were to permit such a facility where unpermitted take occurs could also be legally culpable. A single, small turbine could take a CA Condor -- which would also be problematic.

I'm going to be involved in a conference call later today and most of tomorrow. If you still need to chat, I'll be available for part of the day on Thursday. Otherwise, hopefully I've answered your questions and addressed your concerns about take at "small" turbines. Bottom line: we just don't know until a site is selected and risk assessment calculated for the site. Risk can be significant even for a "small" turbine. The County needs to build a pre-construction monitoring requirement into their permitting process focused primarily on impacts to birds, bats and other wildlife. I failed to see such a provision. Given ongoing risks to Golden Eagles and CA Condors in the County, that would be a prudent path to follow even for a "small" turbine.

I'm also copying my colleague, Dr. Eric Kershner, who just came to us from Southern California. Gotta run. -Al-

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Bend Field Office
20310 Empire Ave, Ste A-100
Bend, Oregon 97701
Phone: (541) 383-7146 FAX: (541) 383-76381

Reply To: 6320.0010(10)
File Name: 2010 EFSC ASC Summit Ridge Cmts 09202010
TS Number: 10-1494
TAILS: 13420-2009-FA-0217

September 20, 2010

Sue Oliver
Energy Facility Siting Officer
Oregon Department of Energy
245 Main Street, Suite C
Hermiston, OR. 97838

Subject: Request for Comments on the Application for Site Certificate for the proposed Summit Ridge Wind project, Wasco County, Oregon

Dear Ms. Oliver:

The Fish and Wildlife Service (Service) has reviewed the August 24, 2010, Application for a Site Certificate (ASC) for the proposed Summit Ridge Wind Project (Project) to be located in Wasco County, Oregon. The proposed Project will include up to 87 wind turbines (2.0 to 3.0 MW each) with a total nominal generating capacity of approximately 200 MW of electricity. The Project will include about 19 miles of new access roads, turbine foundations, underground and overhead electrical collection systems, meteorological towers, and an operations and maintenance building. The Project will also include a communications system, a substation, and interconnection facilities to tie into the transmission line, located to the west of the project. The transmission feeder line will be an overhead 230 kV (kilovolt) line and will be approximately eight miles long.

Much of the project site is agricultural land used for dry land winter wheat production. The proposed facility would be built on land one to four miles west of the Deschutes River Canyon extending from approximately river mile 7 on the north end of the project boundary to river mile 31 on the south end. The Service supports the use of disturbed habitats for the placement of wind energy generation. However, we remain concerned regarding short and long-term Project impacts to migratory birds including bald and golden eagles, and bats.

The Service supports renewable energy and the economic benefits that wind energy generation brings to local communities. We also recognize wind power development has the potential to impact wildlife and habitat resources. The Service provided comments on the Notice of Intent to Apply for an Energy Facility Site Certificate (NOI) for the Project in a letter dated July 13, 2009, and Preliminary ASC in a letter dated November 18, 2009. We appreciate the opportunity to provide additional comments, and we look forward to working with you and LotusWorks on this important project.

Our previous comment letters focused on: (1) the potential for project specific mortality to birds and bats, including cumulative impacts of wind energy projects within the Columbia River corridor; and (2) measures to avoid or minimize Project impacts and adequate mitigation to offset unavoidable project impacts to biological resources. The Service subsequently received information in an email on June 24, 2010, from LotusWorks documenting the presence of golden eagles, large stick nests, and bald eagles in the project vicinity. Our comments below will focus on project impacts to bald and golden eagles and other migratory birds. We refer you to our previous two letters referenced above regarding other issues of concern.

Migratory Bird Treaty Act and Bald and Golden Eagle Protection Act

The Migratory Bird Treaty Act (MBTA) prohibits the taking, killing, possession, and transportation, (among other actions) of migratory birds, their eggs, and nests except when specifically permitted by regulations. While the MBTA has no provision for allowing unauthorized take, the Service realizes that some birds may be killed during specific wind project operations even if all known reasonable, effective measures to protect birds are implemented. The Service's Office of Law Enforcement (OLE) carries out its mission to protect migratory birds through investigations and enforcement as well as by fostering relationships with individuals, companies, and industries that have taken effective steps to avoid take of migratory birds. It is not possible to absolve individuals, companies, or agencies from liability even if they implement bird mortality avoidance or other similar protective measures. However, the OLE focuses its resources on investigating and prosecuting individuals and companies that take migratory birds without identifying and implementing all reasonable, prudent and effective measures to avoid that take.

Additionally, the Bald and Golden Eagle Protection Act (BGEPA) prohibits the taking of golden and bald eagles except when specifically authorized by the Department of the Interior (16 U.S.C. 668-668d). The Service has new regulations (Federal Register 74:46836-46879; 11 September 2009) (USFWS 2009) that may eventually allow a wind project to receive a permit to take golden or bald eagles under the BGEPA (50 CFR 22.26), for programmatic actions that are consistent with the goal of stable or increasing eagle breeding populations. Therefore, we encourage LotusWorks to work closely with the Service to identify available protective measures and develop an Avian and Bat Protection Plan (ABPP) and implement those measures prior to and during Project construction and operation.

The Service's goal for golden and bald eagles is stable or increasing breeding populations. Data from long-term studies of golden eagle migration, population models, and surveys sponsored by the Service indicate cause to be concerned about population trends for golden eagle (Millsap and Allen 2006, Good et al. 2007, Farmer et al. 2008, Smith et al. 2008, USFWS 2009). The Service was sufficiently concerned regarding the status of golden eagles that we determined, until further data shows golden eagle populations can withstand additional take, we will only consider BGEPA permit issuance of new golden eagle take for safety emergencies and for projects that result in net benefits to golden eagles. Bald eagle permit issuance criteria would limit permits to only 5% of the Maximum Sustainable Yield.

Project Impacts and Service Recommendation

Golden eagles and other bird species are known to collide with wind turbines and transmission lines. Studies for the Project document the presence of golden eagles (12 detections) and three inactive large stick nests that were likely golden eagle nests, with a fourth nest that may have been built by golden eagles. These nests were located within 1,000 to 10,000 feet from Project wind turbines (Northwest Wildlife Consultants, Inc. 2010). Additionally, adult bald eagles were observed (4 detections) on or in proximity to the Project. The Service is concerned regarding the potential for injury or mortality from a turbine strike, transmission line collision, or other Project-related disturbance to bald and golden eagles. The Project studies and reports provide only a limited eagle impact analysis.

With the expected growth of the wind industry in the western United States, the Service anticipates that the number of golden eagles killed annually will multiply. The Service is concerned that the population trend of golden eagle will drop even more rapidly as a result of collisions with wind turbines, resulting in greater conflicts between renewable energy industry and agencies. Ultimately, fewer golden eagles will exist unless we find solutions to either greatly reduce golden eagle mortalities at wind projects, reduce other sources of mortality to off-set losses of golden eagles from wind farms, or enhance golden eagle populations with habitat or other reforms.

In the absence of clear solutions to address golden eagle mortalities at wind energy projects, to enhance populations through conservation measures, or to off-set losses in other ways, our best efforts should be directed at avoidance of mortalities by siting wind turbines well away from areas where resident and migrating eagles are known to concentrate their activities. The Service believes the Project, including all turbines, transmission and roads, and associated facilities has the potential to result in injury and mortality of individual golden eagles and potential loss of nest sites over the life of the Project.

The Service recommends that LotusWorks prepare an Avian and Bat Protection Plan consistent with the Service "white paper" titled *Consideration for Avian and Bat Protection Plans* (FWS 2010) that addresses bald and golden eagles, other migratory bird species of concern, and bats. We recommend that the Oregon Department of Energy defer the approval of the Project site certificate until an Avian and Bat Protection Plan is completed, and available for review. We further recommend the following measures be incorporated into any site certificate approval:

To reduce the likelihood of golden eagle take and to minimize Project impacts, we recommend the following measures be included in the development of the Project:

1. Minimize the potential for resident golden eagle collisions by locating individual Project wind turbines a sufficient distance from golden eagle nest sites. Based on the best information available to us, a radius of a minimum of six miles from a golden eagle nest to the nearest turbine will likely avoid take of adult golden eagles associated with that nest. Any wind turbines proposed closer than six miles to golden eagle nests should not

be constructed until specific golden eagle studies have been implemented that define areas where no golden eagle use occurs (see studies in #2, below). These golden eagle-specific data should then be integrated into a protective turbine location "micrositing" design where turbines within six miles of a golden eagle nest are only sited in areas determined to be golden eagle non-use locations;

2. Conduct site specific studies to help define areas of use and non-use by golden eagles including:

    - Complete nest surveys within six miles of the Project location;
    - Conduct observation-post studies to observe the behavior of the adults (if present) without disturbing nesting behavior. These studies collect information on territory occupancy, productivity, fledging success, foraging and winter habitat and other information per the Interim Golden Eagle Inventory and Monitoring Protocols (Pagel et al. 2010); and
    - Satellite telemetry of nesting golden eagles within six miles of Project location.

3. Develop a Project construction plan that fully integrates avoidance of golden eagle disturbance during construction activities by implementing concurrent protective timing windows and distance buffers during sensitive nesting and fledging activities.

    - Distance and timing: Construction and maintenance activities between January 1 and July 15 should not be conducted within 1 mile of an active golden eagle nest (or ½ mile if not line-of-sight), unless site specific surveys indicate otherwise.

The Service has regulations in place that allow us to issue 'Programmatic Permits' to project applicants whose developments have the potential to incidentally 'take' golden eagles over extended periods of time. The Service is not currently issuing those permits, but is developing conditions that will likely be components of them. Permit conditions will likely include,, appropriate Advanced Conservation Practices - measures that represent the best available techniques to reduce take to a level where additional take is unavoidable: and permit conditions will also likely include mitigation measures to offset whatever birds are taken so that the effect of the Project on eagles will be consistent with the Service's goal of stable or increasing breeding populations. It is possible that a programmatic permit issued by the Service when it becomes available, would include as permit conditions many of the recommendations for monitoring, adaptive management and conservation actions described below:

1. Develop and implement a golden eagle monitoring plan (including monitoring of Project-related golden eagle mortality, golden eagle territory occupancy, nest success, and productivity) over the life of the Project to ensure all golden eagles injured or killed by wind turbines or other impacts to golden eagles are immediately identified and reported.

2. Develop and implement an adaptive management plan to address new information that is obtained during operation of the Project, including all turbines, transmission, and roads, and connected wind projects that effectively address any identified problems.

- Utilize turbine feathering and cut-in speeds of 5 m/sec to 6 m/sec at times of low wind speed to reduce bird (and bat) fatalities;
- Lock rotors during daytime and at night during peak migration periods and peak presence of migrating birds and bats;
- Specific commitment to integrate turbine operation curtailment (seasonally or permanently) into Project management to minimize impacts to bald and golden eagles;
- Specific commitment to remove turbines if they are found to cause repeated mortalities of golden or bald eagles;
- Experimental procedures (e.g. blade painting for higher visibility);
- Minimize lighting associated with the Project including:
    - a) FAA visibility lighting of wind turbines should employ only strobed, strobe-like, or blinking incandescent lights, preferably with all lights illuminating simultaneously; and
    - b) Keep lighting at both operation and maintenance facilities and substations located within ½ mile of the turbines to a minimum level by using motion or infrared light sensors and switches to keep lights off when not required, shield operation lights downward, and do not use high intensity, steady burning, bright lights; and
- Commitment to implement future technology when available.

Additionally, specific conservation actions should be collaboratively developed with the Service to meet the conservation goal of stable or increasing breeding populations of golden and bald eagles. The Service cannot permit take of golden eagles; however were we able to, we would look for the types of measures identified below to potentially offset such take in a manner that is consistent with the goal of stable or increasing breeding populations of golden eagles. The local-area eagle population of concern in this case is the area encompassed by a circle 140 miles from the Project boundary, by definition (USFWS 2009). This is the area within which we would expect evaluations of the effects of this Project on eagles would take place. The following should guide any collaborative development of proposed conservation measures:

- Ensure no net loss or an increase in golden eagles in the local-area population via:
    - Land acquisitions or easement purchases;
    - Nest site protection;
    - Habitat enhancement via:
        - Restoration projects (e.g. juniper removal in shrub-steppe systems that will enhance prey base);
        - Grassland restoration efforts with native grasslands;
        - Cheatgrass control programs;
        - Nest platforms;
        - Nest enhancements;
    - Reduce electrocution mortality via partnering with utilities to implement Avian Power Line Interaction Committee standard (APLIC 2006) retrofits of problem distribution lines;
    - Reduce losses to lead poisoning via:
        - Education program on lead poisoning;

  - Raptor rehabilitation centers;
- Contribute to regional or population-wide monitoring and research on golden eagles and wind turbines to better inform management across the West.

Conclusion

The Service appreciates the opportunity to comment on the ASC for the Summit Ridge Wind Project. We support well-designed wind projects that are carefully sited on habitats that will result in less impacts to Service trust resources. We recommend that the Oregon Department of Energy defer the approval of the Project site certificate until an Avian and Bat Protection Plan is completed, and available for review. We further recommend the measures outlined in this letter be incorporated into any site certificate approval. The Service is available to continue to work with LotusWorks in the review, development, mitigation, and monitoring of the Project.

If you have any questions regarding the Service's comments or desire to meet with us to discuss these issues further, please contact Jerry Cordova or me at (541) 383-7146.

Sincerely,

Nancy Gilbert

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Field Supervisor

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CALIFORNIA
ENERGY
COMMISSION

Golden Eagles In A Perilous Landscape: Predicting The Effects Of Mitigation For Wind Turbine Blade-Strike Mortality

CONSULTANT REPORT

JULY 2002
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Gray Davis, *Governor*

CALIFORNIA ENERGY COMMISSION

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Legal Notice

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Figure 1. Juvenile Golden Eagle in the WRA (photo by Daniel Driscoll)

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research.

What follows is the final report for the **“**Golden Eagles in a Perilous Landscape: Predicting the Effect of Mitigation for Wind Turbine” project, Contract Number: 500-97-4033, conducted by Predatory Bird Research Group, University of California, Santa Cruz. The report is entitled **“**Golden Eagles in a Perilous Landscape: Predicting the Effect of Mitigation for Wind Turbine.” This project contributes to the Energy-Related Environmental Research program.

For more information on the PIER Program, please visit the Commission's Web site at: http://www.energy.ca.gov/research/index.html or contact the Commission's Publications Unit at 916-654-5200.

Executive Summary

The Predatory Bird Research Group, University of California, Santa Cruz, has been conducting a long-term study of golden eagles (*Aquila chrysaetos*) in the Diablo Mountains of west-central California. The initial work (1994-1997), funded by the wind industry and by the National Renewable Energy Laboratory (NREL), used aerial tracking of radio-tagged eagles to address the question of whether eagle deaths resulting from wind turbine blade strikes at the Altamont Pass Wind Resource Area (WRA) were seriously affecting the population. Estimates are that wind turbines kill 40-60 subadult and adult golden eagles each year, on average. Golden eagles, being naturally slow to reproduce, are particularly sensitive to changes in adult and subadult survival rates. For this reason, and because of its popularity, the species is afforded special protection by both federal and state governments. There is no legal provision for the killing of golden eagles.

Wind turbine blades also kill other protected species in the WRA, including several hundred red-tailed hawks (*Buteo jamaicensis*) and American kestrels (*Falco sparvarius*) each year. The fatalities have caused adverse public perception of wind power plants, and the threat of fines and lawsuits has delayed, modified, or even stopped wind energy development in some states, including California. Alameda County, for example, has imposed a moratorium on increase over current electrical production (~580 MW) until progress is made toward resolving the bird-strike issue. To address the problem, research must determine whether the fatalities threaten the birds on a population basis, what kinds of turbine/tower configurations are most destructive, and what management actions could reduce the number of fatalities.

We began the current investigation in June of 1998 under the support of the California Energy Commission's Public Interest Energy Research (PIER) Program. At that time, extensive repowering appeared imminent in the WRA. Of particular interest was the intended replacement of some 1300 turbines with a larger and possibly more benign type, at an approximate ratio of seven removed for every one replaced. Our objectives were to increase the samples of radio-tagged eagles and to continue monitoring them for the purpose of (1) further understanding the demographics, (2) tracking the net result of repowering, and (3) exploring other measures that might effectively reduce the incidence of golden eagle mortality. As time passed, it became apparent that difficulties within the wind industry would delay the repowering process beyond the scope of the study. We therefore focused upon eagle deaths relative to existing turbine configurations in an attempt to identify the factors contributing most to blade-strike mortality. This approach, with its emphasis on radio-telemetry, a technique with virtually no distributional bias, offered a measure of prediction regarding the efficacy of expected changes in the WRA.

Our earlier (1994-1997) study, which focused primarily on the demographic question, was based on the aerial monitoring of survival within a sample of 179 radio-tagged golden eagles and an annual survey of 60-70 pairs nesting within about 30-km of the WRA. Two population dynamics models yielded widely different estimates of population trend. One of them, developed by an NREL-appointed panel of scientists, concluded that the population was declining rapidly during the period of study. In fall 1998, when we began capturing additional eagles for radio-tagging, we encountered significantly fewer subadults and nonbreeding adults ("floaters") in the study area than previously, an observation that supported the demographic

predictions of the NREL model. However, our telemetry data on the movements of both juveniles and older eagles suggested a greater tendency than before to leave the study area. Possible reasons were that (1) prolonged periods of rainfall in winter 1997-1998 had reduced overall prey density, and (2) land-use changes had reduced habitat and prey abundance.

We recorded the deaths of 100 radio-tagged eagles during the seven-year study. Wind turbine blades killed at least 42, the actual number being higher because the blades occasionally destroyed the transmitter. Adding 12 electrocutions, all outside the WRA, at least 54 percent of all fatalities were attributed to electrical generation or transmission. Wire strikes, vehicle strikes, and poisoning brought human-related fatalities to at least 68 percent of the total.

Blade-strike mortality did not affect all golden eagle life-stages equally. Only one juvenile eagle was struck among a radio-tagged sample of 117 free-ranging individuals (juveniles are 3-15 months of age). In contrast, there were 31 blade-strike deaths among 155 subadults (ages 1-3 years) and floaters (4+ years). We attribute the apparent immunity of juveniles to their lesser tendency to hunt live prey, a fact suggesting that eagles tend to be struck while hunting. Radio-tagged breeders were rarely killed by turbines (2 among 47) because their relatively small home ranges kept most of them out of the WRA.

Five of the 42 blade-strike casualties wandered away from the turbines that had rendered them flightless, leaving 37 for an analysis of their distribution relative to the 25+ types of turbines in the WRA. At least 27 (73%) of these eagles were killed by Type-13 (Kenetech 56-100 on an 18.3-meter lattice tower), not surprising because 56 percent of all turbines were Type-13. However, a comparison of the distribution of radio-tagged eagles and that of fatalities revealed that disproportionate numbers of eagles died in areas containing Type-13 turbines. We then focused on two areas where relocations of radio-tagged eagles were of high density, one containing Type-13 turbines and the other containing other types. Eagle distribution during the 10-month period prior to each of 21 fatalities in the Type-13 area showed comparable numbers of relocations in the two areas but highly disproportionate numbers of Type-13 kills. We concluded from this circumstantial evidence that conditions in the Type-13 area were more hazardous to eagles than conditions in the area occupied by other types of turbines.

Our data did not reveal whether the perceived lethality stemmed from the Type-13 configuration itself or from other factors such as spacing between the turbines or extraneous environmental differences between the areas we compared. Type-13s were on relatively short towers, so their blades passed closer to the ground than 95 percent of the other turbine types. However, Type-13s in the WRA were set closer together than all other turbine types we measured. The distance between blade and wing-tip of a golden eagle passing exactly between two adjacent, wind-aligned Type-13 rotors of normal placement was less than three meters. Turbulence associated with high winds and steep terrain in the WRA, and the fact that golden eagles there typically hunt by actively coursing over long distances within a few meters of the ground, give reason to suspect that flight control difficulties for eagles trying to pass between or under Type-13 turbines may sometimes have lethal consequences.

These circumstantial data suggest that the planned removal of 644 Type-13s as part of the repowering project in the WRA may benefit eagles, especially if the removals were to occur in areas where eagles concentrate. Observations of foraging eagles suggest that the new, larger (Type-28) turbines might be safer than the Type-13 turbines they are intended to replace.

However, even if Type-28 were to prove more lethal on a per-turbine basis, its far greater generating capacity may render it preferable because few are necessary to match the generating capacity of many Type-13s, that is, assuming that overall energy production does not increase in the WRA.

The California ground squirrel (*Spermophilus beecheyii*) was the principal prey of golden eagles in the WRA throughout our study, and we found significantly higher numbers of radio-tagged eagles in areas of high squirrel concentration. A primary reason for squirrel density differences was that some ranchers controlled them while others did not. No control program was in effect within a large area of Type-13 turbines in the northwest portion of the WRA and, not surprisingly, this area contained high eagle relocation densities and the highest concentration of blade-strike fatalities. We conclude from this that ground squirrel control throughout the WRA could profoundly reduce the incidence of blade strike mortality among golden eagles.

However, even though ground squirrel control is a well known and frequent practice, it is not without secondary environmental costs. Animals, including many sensitive species, prey upon ground squirrels in the WRA, and some depend upon their burrows. Another downside of ground squirrel control is the collateral destruction of non-target species which eat the poison grain. We therefore recommend less destructive control methods, for example, trapping ground squirrels in areas near turbines where the squirrels exceed a threshold density. If ground squirrel control becomes more widespread in the WRA, it would be appropriate to mitigate the loss for all affected wildlife, including eagles, by encouraging ground squirrels outside the WRA. This might take the form of conservation easements purchased from ranchers in areas of open grassland.

We resolved the paradox of the two population models that earlier gave such widely divergent estimates of population trend. The first (NREL-supplied model), which incorporated a parameter (alpha) for the rate at which floaters acquired breeding territories, and computed a precipitous decline, proved defective. The computation by matrix algebra of the annual rate of change in population size, requires that all parameters remain constant in time, a feature that produces a stable stage distribution, regardless of trend. However, alpha is a parameter whose value responds to changes in floater numbers such that, during a decline, alpha increases in value, thereby compromising both the computation of the population change rate and its variance. Both the model and its alarming result must therefore be discarded.

A better and more parsimonious model is the traditional one describing the maximum potential rate of population change under the hypothetical assumption that all eagles acquire breeding territories upon maturity. A growth prediction by this model would yield a population at equilibrium in which a stable contingent of floaters buffers the breeding population against decline, whereas a decline estimate predicts the loss of floaters altogether. The parameters of this model, refined by our recent data on eagle survival and reproduction, yielded a point estimate approximating the condition of no annual rate of change in population size, but no production of a floater buffer. The variance of this estimate falls more or less equally into the alternatives of increase and decrease. If the point estimate of the model is correct, any further decrease in survival or reproduction, e.g., as might accompany increasing human development, would be mitigated only by immigrant floaters from outside the study area.

Several current (Spring 2000) indicators of population health are apparent. First, the number of breeding pairs in the broad region surrounding the WRA has remained unchanged, i.e., virtually all territories occupied by pairs in one year have remained occupied in the next, a clear sign that floaters quickly filled vacancies. Second, we observed very few subadults as members of breeding pairs. A high proportion of subadults in the breeding population would suggest a paucity of floaters. Whether the floaters currently buffering the breeding population are generated within the study area or arrive as immigrants is unknown. We recommend a continuation of the nesting surveys every two or three years as a system of early warning, should a decline actually be occurring.

Figure 2. Subadult Golden eagle (photo by Daniel Driscoll)

Abstract

The Predatory Bird Research Group, University of California, Santa Cruz, has been conducting a long-term field investigation of the ecology of golden eagles (*Aquila chrysaetos*) in the vicinity of the Altamont Pass Wind Resource Area (WRA) where turbine blade strikes kill an estimated 40-60 eagles per year. Our seven-year study was based on the aerial tracking of 257 radio-tagged eagles and an annual nesting survey of 60-70 pairs within about 30-km of the WRA. Of 100 deaths recorded among the tagged eagles, 42 were attributed to wind turbines, although the actual number was higher because the blades occasionally destroyed the transmitter. Comparisons of eagle location data with the distribution of blade-strike fatalities in the WRA showed that conditions within areas containing Type-13 turbines (the Kenetech 56-100 on an 18.3-meter lattice tower) were more dangerous to eagles than those in areas containing other types of turbines. It is unknown whether this lethality arose from the Type-13 configuration itself or from other factors such as spacing between turbines or extraneous environmental influences. Type-13s are set closer together than other turbines in the WRA, and eagles may have particular difficulty passing between (or under) them, especially in conditions of high winds and turbulence. California ground squirrels were the principal prey of golden eagles in the WRA, and eagles were attracted to areas of high squirrel concentration. Reduction of ground squirrel numbers around the wind turbines would reduce the incidence of blade strike deaths. Squirrel control would impact other wildlife in the WRA, but could be partially mitigated by off-site conservation easements. A demographic analysis produced a point estimate of no annual change in population size, but the variance fell equally into the alternatives of increase and decrease. If the point estimate of the model is correct, the population is failing to maintain a contingent of nonbreeding adults (floaters) which buffer the breeding sector in healthy populations. However, throughout the study, virtually all nesting territories occupied by adult pairs in one year were reoccupied the next, suggesting either a demographic balance in the local population or buffering by immigrant floaters.

Figure 3. Southeast Portion of the Altamont Pass WRA (photo by Daniel Driscoll)

1.0 Introduction

Powering of the Altamont Pass Wind Resource Area (WRA) began in 1982 and produced about 6,500 wind turbines by 1987. At some point during this growth period, the U.S. Fish and Wildlife Service began receiving reports of raptors killed by turbine blade strikes. The most numerous fatalities encountered were red-tailed hawks (*Buteo jamaicensis*), American kestrels (*Falco sparvarius*), and golden eagles (*Aquila chrysaetos*), with lesser numbers of turkey vultures (*Cathartes aura*), common ravens (*Corvus corax*), barn owls (*Tyto alba*), and others. In 1994 alone, 348 raptor fatalities in the WRA were reported to Alameda County, 35 of which were golden eagles and 194 red-tailed hawks (Alameda County 1998).

On the basis of foot surveys conducted along the rows of turbines, Orloff and Flannery (1992) estimated in their report to the Commission that about 40 golden eagles and several hundred other raptors died in the WRA each year. During a six-year period (1994-1999), the general magnitude of that estimate was reaffirmed by wind industry employees who, while servicing the turbines, happened upon 21-42 dead golden eagles per year (mean=28). However, these likely represented only a fraction of the total fatalities present, considering the lack of surveys and the incidental nature of the reports. All of these considerations suggested that Orloff and Flannery's estimate of 40 golden eagle fatalities was conservative.

The golden eagle is of particular concern, not only because it is less abundant than most of the other species killed at the WRA, but because it is also naturally slow to mature and reproduce, characteristics that render its populations especially sensitive to increases in adult and subadult mortality. The species has declined in southern California as a result of urban encroachment (Scott 1985, Harlow and Bloom 1987), and the California Fish and Game Department (1992) lists it as a Fully Protected Species and a Species of Special Concern. Moreover, the federal government affords the golden eagle special protection under the Eagle Protection Act as amended in 1963. There are no provisions within the Act that would allow the killing ("taking") of golden eagles.

During 1994-1997, the Predatory Bird Research Group (PBRG) sought to determine the extent to which eagle deaths resulting from wind turbine blade strikes were influencing the trend of the population. The work, funded by the wind industry and by the National Renewable Energy Laboratory (NREL), involved placing radio-transmitters on 179 golden eagles in the vicinity of the WRA and tracking their movements in weekly surveys by airplane over a 48-month period. Each transmitter contained a sensor indicating whether the eagle was alive or dead. Results of the aerial surveys showed that eagles killed by turbines were primarily from a local resident population whose density, as determined in annual nest surveys, was among the highest known in the world. Sixty-nine territorial pairs have been found within 30 km of the WRA boundary (Hunt et al. 1995, 1996, 1999).

The majority of deaths recorded among radio-tagged eagles during the 1994-1997 study resulted from electrical generation or transmission. Most of these were caused by wind turbine blade strikes, the remainder by electrocutions on distribution lines outside the WRA. Additional turbine-related fatalities went unrecorded because blade strikes destroyed the transmitter in an estimated 25 percent of cases. These data on mortality within a continuously monitored sample, together with estimates of golden eagle reproduction in the study area, were sufficiently precise for modeling experts from Colorado State University (Franklin et al. 1998) to estimate (incorrectly, as we shall show) that, during the four-year period, the population was declining at an annual rate of 9.3 percent (SE=3.2 percent). A second, more parsimonious model proposed by PBRG, produced a decline rate of 1.2 percent, a value indistinguishable from a condition of no persistent decline by its standard error (3.9 percent). Neither model precluded the possibility that immigrants from less lethal environments buffered the population. PBRG predicted that, in the absence of turbine-related mortality, the population would be self-sustaining and a source of recruits to the surrounding landscape.

1.1. Project Objectives

In addition to the question of which of the two population models most accurately described the trend of the population, the demographic study also left unanswered that of how eagle deaths in the WRA might be mitigated. At the time of the study's conclusion, it appeared that extensive changes within the WRA were imminent and that these changes might effect a reduction in blade-strike mortality among golden eagles. Of particular interest were industry plans to replace the Kenetech 56-100 turbines on 18.3-meter lattice towers (Type-13) with larger turbines on tubular towers (Section 2.2). The latter, producing far more electrical energy, would replace the Type-13 turbines at a ratio of one new structure for every seven or eight removed. Whether the new, larger turbines were individually more benign was unknown, but biologists noted that eagles were less apt to perch on the tubular towers and speculated that their blades, being higher off the ground, would allow eagles to more easily pass under them. Moreover, the slower rotation of larger turbines might render their blades more visible and more negotiable (Tucker 1996a, b).

PBRG proposed to continue the radio-tagging and tracking of golden eagles as a way of determining the efficacy of these changes, specifically, by comparing new data on eagle distribution and mortality with those recorded during the earlier study. As it turned out, difficulties within the industry postponed the repowering program beyond the time frame of this study. However, as we proceeded, it became clear that factors affecting eagle distribution and mortality could still be investigated, and that we could explore the distribution of eagle deaths relative to existing turbine configurations in an attempt to identify those conditions most lethal. Such an approach offers a measure of prediction of the effects of changes expected to occur in and around the WRA and adds to the scientific foundation upon which regulators and industry can make management decisions. The work is consistent with the mission of PIER funding, namely to "… conduct public interest energy research that seeks to improve the quality of life for California's citizens by providing environmentally sound, safe, reliable, and affordable energy services and products."

1.2. Report Organization

We begin by describing the study area, our general methods, and those aspects of golden eagle life history that pertain to our study. We then explain our findings in the context of the entire investigation dating from 1994. We discuss the numerical and distributional changes we observed within our samples of radio-tagged eagles and detail the numbers and sources of mortality recorded throughout the study area. We then focus on mortality within the WRA and its relationship to the various kinds of wind turbines, with emphasis on those features, including placement that contribute to their lethality. We discuss the relationship of eagles to prey distribution within the WRA. We examine two population models that would predict the population trend, discarding one in favor of another. We end our report with an overview discussion of our findings and recommendations. For further details on methodology and overall findings, we recommend that the reader have on hand copies of our earlier reports to NREL (Hunt et al. 1995, 1996, 1999).

2.0 Background and Project Approach

This study centers on the use of radio-telemetry to monitor the survival and movements of golden eagles in and around the WRA. This approach overcomes the bias associated with observer location and visibility within differing terrain and vegetation typical of other methods. All radio-tagged eagles are equally detectable from an airplane so that virtually all are accounted for within the study area (Hunt 1987). GPS enhances the precision of establishing the location of tagged eagles, and GIS electronic mapping facilitates the comparison of eagle distribution with that of wind turbines and other landscape features.

During the earlier study (1994-1997), we radio-tagged 179 golden eagles within ca. 40 km of the WRA with backpack-style transmitters (Hunt et al. 1995) designed to last four years. The sample included 79 juveniles, 45 subadults, 17 floaters (nonbreeding adults), and 39 breeders. Effective sample sizes in the older stages increased as eagles matured or became territorial. Thus, by the end of the study, we had obtained telemetry data on 106 subadults, 40 floaters, and 43 breeders, in addition to the 79 juveniles. Some of these transmitters were still operating when we began the current study and, to increase the overall sample, we tagged an additional 78 eagles during 1998-1999, including 53 juveniles, 19 subadults, four floaters, and two breeders. Each transmitter contained a motion (mortality) sensor yielding a recognizably faster pulse rate when the instrument was motionless for four or more hours. We monitored eagle movements and fatalities by means of fixed-wing aircraft surveys conducted one to four times per month (weather permitting) through October 2000. We performed final surveys in spring 2001 to determine the number of eagles still residing in and near the study area. We used GPS to fix and record eagle relocations (accuracy within ca. 0.6 km). We traveled without delay to sites where fatalities were detected, collected data on cause of death, and, where possible, identified the responsible turbine. Wounds and / or dismemberment easily identified blade-strike kills, and, in most cases, the latter were in immediate proximity to turbine towers, the location of which was substituted for the less accurate GPS fixes recorded from the airplane. In a few cases, eagles struck by turbine blades survived the event and were encountered and saved, though they remain flightless in animal care facilities. We regarded these casualties as deaths because they were permanently lost to the population.

We used the Kaplan-Meier estimate of stage-specific survival rates as developed by Pollock et al. (1989) for staggered entry of radio-tagged individuals. Assumptions were that (1) individuals were sampled randomly, (2) survival time was independent for each eagle, (3) the radio-tag did not influence survival, and (4) censoring was not related to the eagle’s fate (Heisey and Fuller 1985, Bunck 1987). Censored eagles (those suspended from analysis when their fate was unknown) fell into two classes: those carrying failed transmitters and those absent from the study area, the two possibilities being indistinguishable. Possible causes of transmitter failure included battery discharge, component malfunction, and transmitter destruction, all but the latter fairly regarded as occurring independently of the eagle's fate. The assigned date of deletion was midway between the date of last detection and that of the first indication of signal disappearance. The first assumption that of random sampling, is problematic to the extent that tagging sites were chosen opportunistically. However, the very high mobility of nonbreeding eagles throughout the study area and the long duration of the tracking study render this bias negligible.

Our estimate of reproductive rate was based on the number of fledged young per territorial pair, the latter being only those observed during or before incubation. This method avoids the bias relating to the fact that successful pairs are easier to locate and identify late in the breeding season than pairs that have failed (Steenhof and Kochert 1982, Steenhof 1987). We therefore began our surveys in January and February of each year when eagles were conspicuously engaged in territorial (undulation) displays prior to egg laying. We revisited areas to see whether eagles were incubating, and later returned to nests where we had observed incubation to determine whether broods were present and to count the number and ages of young. Young were considered to have fledged if they reached approximately eight weeks of age.

We used GIS (ArcView™) software to map ranch boundaries and the positions of the 5,382 operational wind turbines in the WRA. Some of the wind companies had electronic data while others provided contour maps of varying scale showing turbine positions. We scanned these and manipulated the resulting images to correspond to electronic topographical maps (Maptech™). We verified the accuracy of turbine positions in the field by spot-checking. Information provided by the wind-energy companies and attached to each data point included turbine serial number, turbine type, tower type, and tower height.

2.1. Study Area

The 9,000 km^2 study area, selected on the basis of the overall movements of radio-tagged eagles, is bounded on the north by the Sacramento River delta, to the east by the San Joaquin Valley, to the west by the urban area along San Francisco Bay, and to the south by State Highway 152 between Morgan Hill and San Luis Reservoir (Figure 4). This largely pastoral region of the Diablo Mountains supports grasslands, oak savanna, oak woodland, chaparral/scrub, and contains a band of urban communities extending from Livermore to Concord.

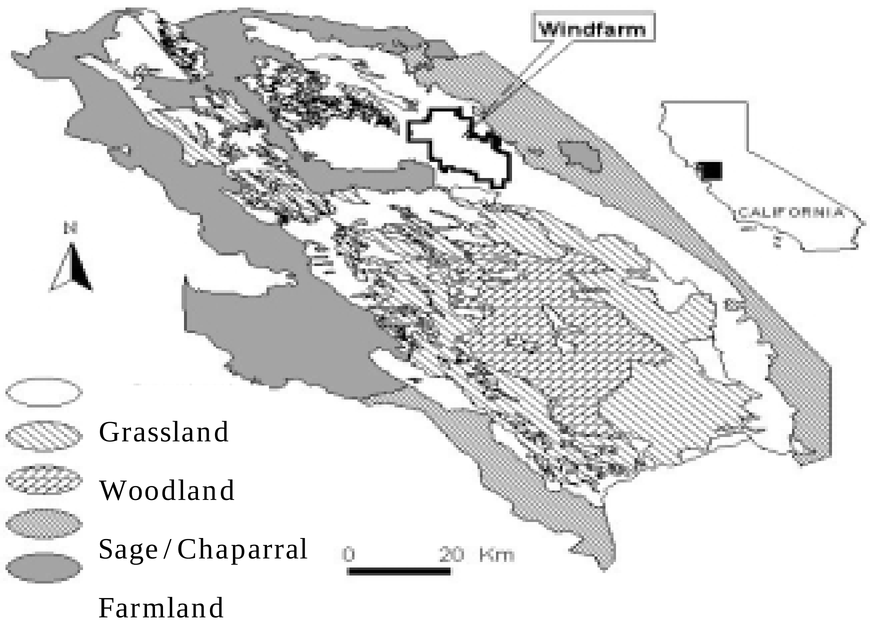


Figure 4. The Diablo Range Study Area

The WRA itself is a 160-km^2 tract of privately owned cattle ranches in hilly grassland (elevation 60-550 m) covered almost entirely by European annual grasses and with occasional oaks (*Quercus* spp.), eucalyptus (*Eucalyptus* spp.), and California buckeye (*Aesculus californica*). Terrain is generally less steep in the eastern portion of the WRA, giving way to continuous farmland. A valley containing urban sprawl lies below the hilly western boundary. Running west to east through the Diablo Mountains and the WRA is Altamont Pass, through which strong winds are drawn from the ocean to the Central Valley, especially during the warmer months.

The California ground squirrel (*Spermophilus beecheyii*), the principal prey of golden eagles in the region, was abundant in portions of the WRA, particularly during the early years of our study (Hunt et al. 1995). Ranchers throughout the region control ground squirrel numbers with summer applications of anticoagulant rodenticides (Section 3.6). Two other important prey species, the black-tailed jackrabbit (*Lepus californicus*) and cottontail rabbit (*Sylvilagus auduboni*) occur within the WRA.

The WRA contains about 5,400 wind turbine structures of about 27 types (Appendix I) operated by a variety of energy companies. Principal differences among the turbines include the degree of power generation (40-750 kW), tower type (e.g., tubular versus lattice structure), blade number (2 or 3), rotor-swept diameter (13-46 m), tower height (14-43 m), and blade rotation axis (horizontal versus vertical) (Figure 5). The most common type is the Kenetech 56-100 on an 18.3 m lattice tower (Type-13) of which there are currently about 3000 (56 percent of total) in service (Figure 6).

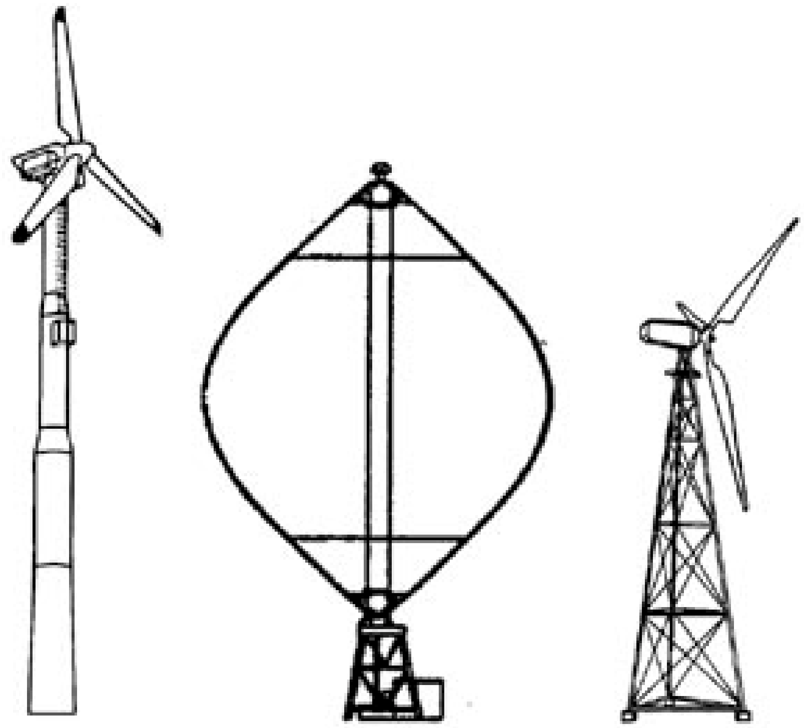


Figure 5. Examples of the Three Basic Wind Turbine Designs in the Altamont Pass WRA: Tubular Tower (Type-8), Vertical Axis (Type-9), and Lattice Tower (Type-13)

2.2. The Repowering Plan

When we proposed this study, the plan for repowering of the Altamont Pass WRA involved the replacement of existing turbines with a lesser number of larger, more energy-productive turbines by three wind-energy developers (Alameda County 1998). Green Ridge Services and Altamont Power proposed to replace existing turbines with NEG-Micon 700 kwh turbines on either 114-foot (34.7 m) or 131-foot (40 m) tubular towers (Type-28). The new turbines would have a 157-foot-rotor-diameter (48 m) and a 22 rpm maximum rotational speed. Green Ridge Services would replace 644 Type-13 (100 kwh lattice tower) turbines, including all those associated with more than one known raptor fatality, with 92 Type-28 turbines, a ratio of seven removed to one constructed. Altamont Power proposed to replace all 194 Flowind Vertical Axis turbines (Type-9) with 45 Type-28 turbines (ratio = 4.3 to 1), and possibly replace 25 Danwin 110 kwh turbines (Type-17) with five of the new turbines (ratio = 5 to 1). Sea-West would replace 432 of the 433 existing turbines with 42-50 NedWind 500 kwh or NEG-Micon 750 kwh or MHI-MWT 600 kwh turbines, replacement ratios from 8.6 to 1 to 10.3 to 1.

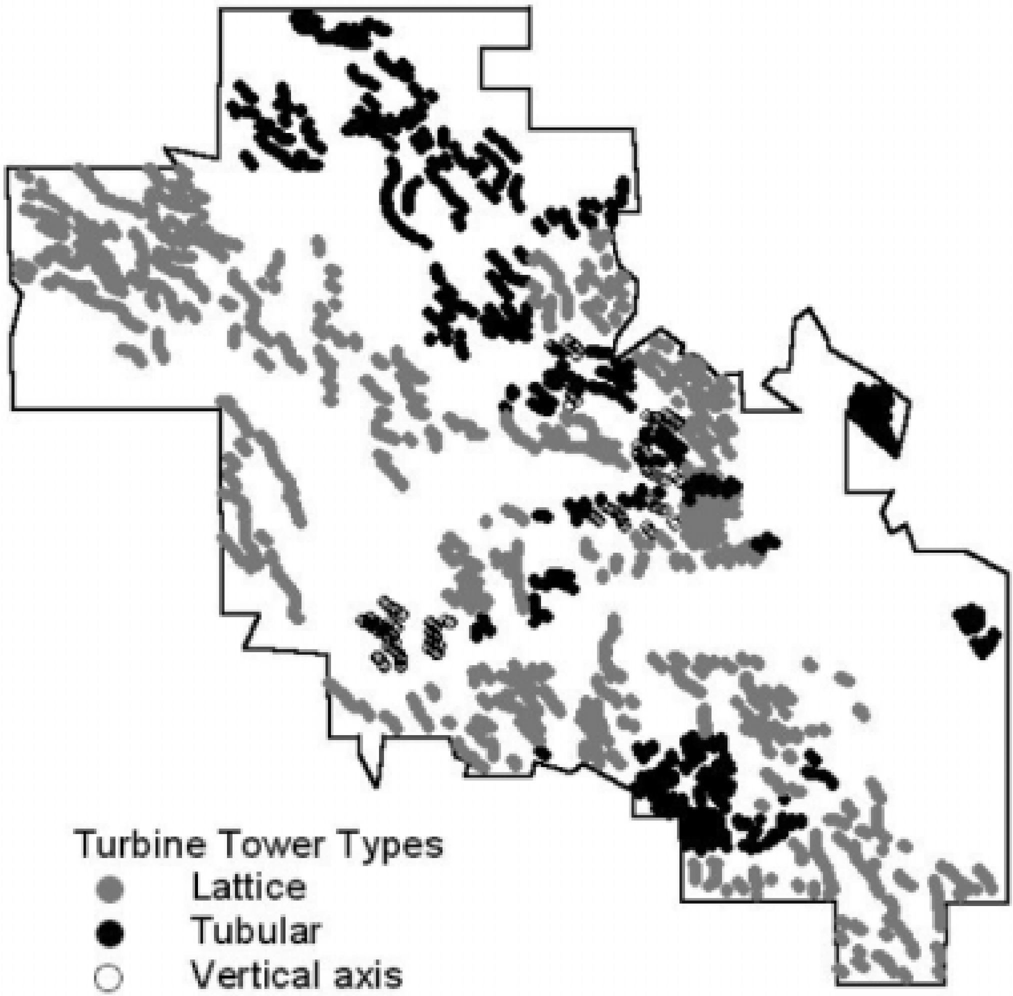


Figure 6. Distribution of the basic Turbine Configurations in the WRA

2.3. Study Species

Golden eagles occur throughout the Northern Hemisphere and are among the largest of raptors, with wingspans of up to 2.2 m and weights approaching 5 kg (Watson 1997). Females are about 25 percent heavier than males, an evolutionary adaptation relating to their divergent roles during the breeding season. Golden eagles in our study area forage primarily on live mammals in open grassland habitats, but in winter may rely heavily on carrion, including deer and cattle carcasses, and may exploit waterfowl concentrations. California ground squirrels are the main prey in the study area. Among 339 prey items from collections made at golden eagle nests in the study area in 1994, we estimated that the California ground squirrel represented 69 percent of prey numbers and 64 percent of prey biomass (Hunt et al. 1995). The second most important species was the black-tailed jackrabbit at 8 percent biomass, and the third was the black-tailed deer (*Odocoileus hemionus*) at 6 percent. In all, mammals accounted for 92 percent of prey biomass, followed by 7 percent for birds, and 1 percent for reptiles.

Although these figures represent only a single breeding season, numerous subsequent observations have verified the predominant role of California ground squirrels in the diet of golden eagles in the WRA and its environs. The reason doubtless relates to the abundance of squirrels in the region and their availability to eagles throughout the year. In this respect, they differ from many other ground squirrel species that aestivate and / or hibernate for long periods. California ground squirrel populations do not appear to cycle in abundance over multi-year periods as do, for example, jackrabbits, the main prey of golden eagles in most western states. However, prolonged winter rainfall in some years may reduce ground squirrel availability and overall numbers (Grinnell and Dixon 1918; this study).

Golden eagles in the interior central coast ranges of California occur primarily in grazed, open grasslands and oak savanna, with lesser numbers in oak woodland and open shrub lands. With increasing urbanization, much of the remaining golden eagle habitat in central and southern California is located within private ranches used for livestock grazing. Over much of their range, golden eagles prefer cliffs for nesting, but these are scant in the Diablo Range study area, and all but a few pairs nest in trees, including four oak species (*Quercus lobata, Q. douglasii, Q. agrifolia, and Q. wislizenii*), three pines (*Pinus sabiniana, P. radiata,* and *P. coulteri*), California bay laurel (*Umbellularia californica*), eucalyptus (*Eucalyptus* spp.), and western sycamore (*Platanus racemosa*). The Diablo Range eagles nest mainly in oak savanna and oak woodland. Open grasslands are generally unsuitable for nesting due to lack of structures, but a few pairs of eagles nest on electrical transmission towers traversing grasslands. Golden eagle pairs in the Diablo Range participate in courtship and nest building in December and January, lay 1–3 eggs in February and March (incubation lasts 6.5 weeks), and fledge their 10- to 11-week-old young from mid-May to late June. Fledglings usually stay within their natal territories until mid-August, although some individuals may remain in the vicinity until December.

Healthy golden eagle populations contain four population segments: breeders, juveniles, subadults, and floaters. Differing environmental and behavioral factors may influence the numbers of each within a population. Breeders are individuals four years old or older that defend breeding territories. Because golden eagle pairs partition the landscape into a mosaic of territories from which other adults are excluded, there is an upper limit to the number of breeders and therefore the number of young produced in any defined area. Territorial boundaries tend to remain fairly stable from year to year (Marzluff et al. 1997, this study), and, in years of low prey availability, eagles may forgo breeding but still occupy and maintain their territories. This tendency for the number of territories to remain somewhat constant, together with the limit on area productivity, form the basis for stability in overall population size, i.e., Moffat’s equilibrium (Hunt 1998).

Juveniles are eagles less than one year old, and subadults are one, two, and three years of age. Floaters are adults without breeding territories (Brown 1969), and their existence implies that territorial pairs occupy all habitat suitable for breeding (Hunt 1988,1998). Floaters effectively safeguard the breeding segment by quickly replacing breeders that have died, but if the proportion of floaters is very large, competition for nesting territories may reduce the reproductive rate and breeder survival (Hansen 1987, Haller 1996). For further information on golden eagle natural history and population ecology, we refer the reader to Haller (1996), Tjernberg (1985), Watson (1997), Kochert et al. (in press), and to Section 3.0 in Hunt et al. 1995 and our other NREL-sponsored reports (Hunt et al. 1997, 1999).

2.4. Other Studies of Avian Fatalities

Several investigations of wind-energy-related bird fatalities have been conducted at Altamont Pass after Anderson and Estep (1988) brought attention to the issue. Howell and DiDonato (1991a) surveyed 359 turbines biweekly from September 1988 to August 1989 and found 42 avian fatalities. They noted that fatalities tended to be associated with topographical features such as swales and the shoulders of hills (Howell and DiDonato 1991b). Howell (1995) compared the Type-13 and the larger more energy-productive Type-12 (33 meter rotor diameter) turbines and found the number of raptor kills per turbine to be equal, i.e., 0.264 and 0.278, respectively.

Orloff and Flannery (1992) documented 182 fatalities in two years, of which 119 (65 percent) were raptors. They found that kills were related to turbine location (end-of-row turbines), topography (near canyons), and tower type (lattice towers). They estimated annual raptor mortality at 164 to 403 birds. They reported that turbine-related mortality did not appear to be related to species abundance, and suggested that other factors such as behavior or flight characteristics may contribute to collisions. Further analysis of their data suggested that some factors specific to turbine types (tip speed, tower type, and the percent of time the turbine was in operation) were significantly correlated with fatalities, while others (rotor diameter, rotor swept area, turbine height, turbine spacing, and rotor orientation) were not (Orloff and Flannery 1996).

Curry and Kerlinger (1998) examined the fatality data submitted to Alameda County and noted that golden eagle and red-tailed hawk fatalities were correlated with turbine location and topography. They determined that end-of-row and second-from-end turbines accounted for 46 and 44 percent of all the golden eagles and red-tailed hawks killed, respectively. Mid-string turbine fatalities of the two species appeared to be associated with topographical features (dips and notches) and gaps (irregular spacing) between turbines. In an analysis of multiple-kill turbines, Kerlinger and Curry (1997a) found that 439 (91 percent) of golden eagle and red-tailed hawk fatalities were at single-kill turbines, 36 (7.5 percent) at turbines responsible for two kills, and 7 (1.5 percent) at turbines connected with three kills.

3.0 Project Outcomes

3.1. Evidence for a Change in Eagle Distribution

Our earlier study showed that subadults and floaters were by far the most frequently killed by turbine blade strikes. We therefore targeted these life-stages for radio-tagging in the current study. However, when we resumed our capture program in fall 1998, it was soon apparent that fewer subadults and floaters were present in the study area than previously encountered. In the early sampling period (January 1994 – July 1996) we had captured 54 subadults/floaters in 100 trapping days for an average of 0.540 individuals per day, whereas later (November 1998 – January 2000) we caught only 28 subadults/floaters in 168 trapping days, or 0.167 eagles per day, a highly significant difference (X^2=28.5, d.f.=1, p<0.001). Trapping techniques, locations, and months of fieldwork were similar during the two periods, so our results could not have arisen from differences in sampling.

Not only were attempts to capture subadults and floaters less successful, but we caught more juvenile eagles (n=28 in 168 days) in the current study than in the earlier one (n=7 in 100 days). The disproportion between the two periods in the number juveniles trapped per day (X^2=3.77, d.f.=1, p=0.052 with Yates' correction) suggests a change in density, but may have resulted not from a greater number of juveniles present overall but from less competition with older eagles for access to the bait stations. The ratios of juveniles to older itinerants (non-territorial eagles) in the capture samples between the two study periods were significantly different: 7:54 (12.9 percent) during 1994-1997 versus 28:28 during 1998-2000 (X^2=20.6, d.f.=1, p<0.001). Figure 7 shows these age-class ratios.

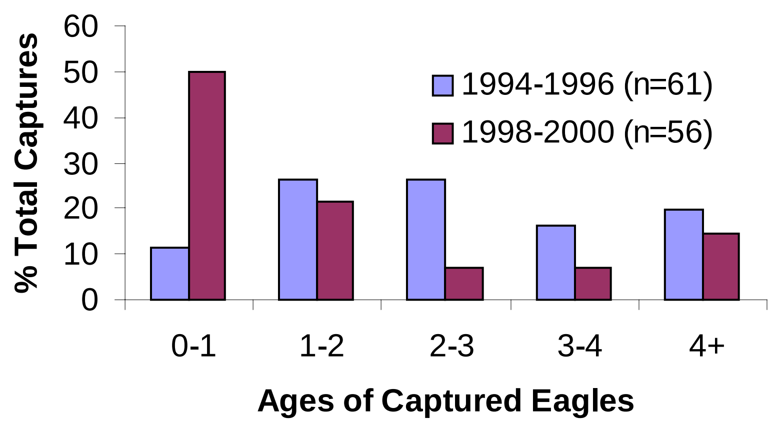


Figure 7. Ages of golden eagles captured in 1994-1996 versus 1998-2000

We thought that annual differences in reproduction (range=0.46–0.90 fledglings per occupied site) might explain the change in age ratios between the trapped samples. However, we found no correspondence. Reproduction was far above average in spring 1994 and yet, among the 19 free-ranging eagles we captured the following spring, only 4 (20 percent) were juveniles. The year 1998 was one of below average reproduction, and yet 18 (47 percent) of 38 itinerants captured the following winter and spring were juveniles (X^2=3.70, d.f.=1, p=0.0544, though p=0.1020 with Yates' correction).

The weight of evidence therefore implies that far fewer free-ranging subadults and floaters existed in the study area during 1998-2000 than were present during 1994-1996, a finding consistent with the modeled (point estimate) predictions of an overall-declining trend in population as reported by Hunt et al. (1999). However, an alternative hypothesis is that free-ranging eagles may have had a greater tendency to emigrate in the later period, e.g., in response to possible changes in prey availability in the study area or elsewhere. Let us examine this possibility.

Figure 8 graphs the behavior of four yearly cohorts of golden eagles (tagged as fledglings) from September of the natal year through the following September. Note the suggestion of an increasing tendency to leave the study area by comparing the proportions of eagles that remained with those that either disappeared or left and returned, the latter being those gone two months or more. Disregarding the proportion of deaths and combining the two classes of emigrants in Figure 8, the difference between the apparent behavior of cohorts in the earlier study (1994-1997) and that fledging in 1999 is significant (X^2=4.72, d.f.=1, p=0.0299, with Yates' correction). The suggestion of a change in tenure is even more convincing when one compares the activities of the 1994–1995 cohorts with those of 1996–1999 (X2=7.46, d.f.=1, p=0.0063, with Yates' correction). We surmise that, although most of the juvenile eagles not detected in the surveys eventually returned, conditions in the study area were less hospitable during the later years of study.

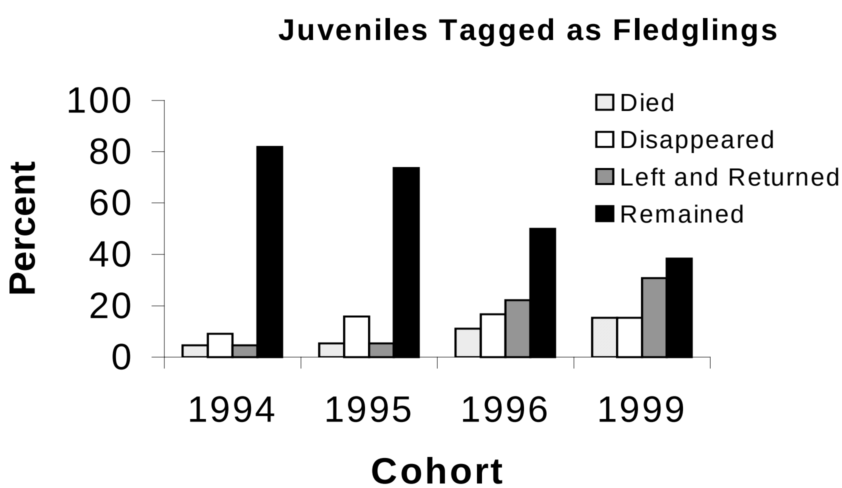
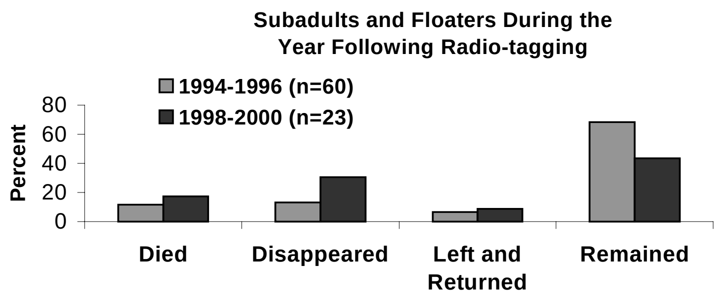


Figure 8. Fates of Tagged Juveniles from September of the Tagging Year through the following September

Sample sizes are as follows: 1994 (n=22), 1995 (n= 19), 1996 (n=18), and 1999 (n=26). Some eagles remained continually within the study area throughout the 13 month period while some temporarily departed. The disappeared category includes eagles that departed the study area and did not return within the year or those whose radios failed, the two possibilities being indistinguishable. Deaths include only those occurring within the study area.

The trend of tenure among radio-tagged subadults and floaters between the earlier study and the current one appears similar to that of the juveniles. Figure 9 graphs the tenure categories of subadult/floater eagles over the 12 months following radio-tagging. Although sample sizes were small in the current study owing to the increased difficulty of catching subadults and floaters for radio-tagging, a comparison between the two study periods yielded a nearly significant difference in behavior between the two periods (X^2=3.03, d.f.=1, p=0.0818, with



Yates' correction). Again, there is the suggestion that a change in habitat quality (e.g., prey densities) has affected golden eagle tenure within the study area.

Figure 9. Fates of Subadult and Floater Eagles during the 12 Months Following Radio-Tagging

Sample sizes are as follows: 1994 (n=24), 1995 (n= 22), 1996 (n=14), 1998 (n=12), and 1999 (n=11).See the Figure 8 legend for explanation of categories.

We conclude from these findings that fewer subadult and floater eagles existed within the study area during 1998-2000 than during 1994-1997. Although one would expect this on the basis of the predictions of population decline detailed in our report to NREL (Hunt et al. 1999, but see Section 3.7), our data suggest a greater tendency for itinerant eagles to leave the study area. Because the overall distribution of radio-tagged subadults and floaters within the study area was somewhat similar between the two study periods (Table 1), one may hypothesize that the difference in itinerant numbers related to broad-scale changes in prey availability.

Table 1. Relocations of Radio-Tagged Subadults and Floaters in the Previous versus the Current Study

	Percent of Relocations			
	Within WRA	Within 5 km	Within 10 km	Within 20 km
1994-1997 (n= 4851)	19.6%	42.0%	58.1%	75.8%
1998-2000 (n= 859)	23.7%	40.7%	53.5%	74.6%

These data include only those aerial surveys during which we recorded the positions of all tagged eagles.

Exploring this and other explanations for why greater proportions of nonbreeding eagles left the area during the second period of our study, we note that a number of habitat alterations and land use changes occurred that may have reduced habitat suitability for foraging eagles. These changes included (1) the creation near the WRA boundary of the 6.3 km^2 Los Vaqueros Reservoir (which filled in winter 1997-1998), an area that had supported high densities of ground squirrels, (2) the conversion of grasslands to vineyards and housing developments in the Livermore Valley and elsewhere, and (3) prolonged rains during winter 1997-1998. The latter may have significantly reduced ground squirrel numbers throughout the study area, i.e., 114 days of rainfall were reported during January – May 1998. Jim Woollett, wildlife biologist for Lawrence Livermore Laboratories told us in 2001 that squirrel numbers had yet to recover at Site-300 along the southeast border of the WRA after the 1997-1998 winter rains flooded the burrows. Jim Smith, biologist for the Alameda County Agricultural Department (ACAD) affirmed that rainfall caused a drastic reduction in ground squirrel numbers throughout the county in early 1998.

3.2. Eagle Mortality

We recorded 113 deaths over 88 months among a radio-tagged sample of 257 eagles. Fifty-two were attributed to wind turbine blade strikes. However, the total sample must be reduced by five deaths occurring after radio failure or censoring, three with transmitters destroyed by turbine blades and found by industry workers, and by five other eagles that died outside the study area. The latter included one killed by a wind turbine blade at the Solano WRA, some 35 km from the Altamont WRA. In all, at least 68 (68 percent) of the 100 uncensored deaths were human-related (Table 2), the unknown category likely containing additional human-caused fatalities, though none were turbine-related. Two of the unknowns were in the WRA but neither involved trauma. Figure 10 shows the distribution of the 42 uncensored blade-strike casualties in the WRA.

3.2.1. Turbine Blade-strike Mortality among the Four Life-stages

The four population segments, i.e., juveniles, subadults, floaters, and breeders, may be expected to experience different mortality regimes owing to differences in life style and experience. Juveniles must learn to survive, and in doing so, they rely more heavily on carrion and piracy than do the older age classes more proficient at capturing live prey. California ground squirrels, the principal prey in the area, reproduce in spring, but it is not until September that most juvenile eagles become independent of their parents, a time when ground squirrels are fully-grown and wary. We believe that juveniles transition to hunting ground squirrels about eleven months after fledging, when an abundance of young, somewhat easy-to-catch squirrels appears above ground. We have also observed numerous young cottontails in portions of the WRA in spring.

Table 2. Causes of Death among 100 Radio-Tagged Golden Eagles

Mortality Agent	Juveniles (17 fatalities)	Subadults (49 fatalities)	Floaters (22 fatalities)	Breeders (12 fatalities)	Total Fatalities
Turbine Blade Strike	5.9%	63.3%	36.4%	16.7%	42
Electrocution	23.5%	10.2%	13.6%	-	12
Fledging Mishap	35.3%	-	-	-	6
Hit by Car	-	6.1%	4.5%	-	4
Wire Strike	5.9%	4.1%	4.5%	-	4
Eagle	-	-	9.1%	16.7%	4
Lead Poisoning	-	4.1%	-	8.3%	3
Botulism	-	-	-	8.3%	1
Brodificoum Poisoning	-	-	-	8.3%	1
Shot	-	-	4.5%	-	1
Hit by Train	5.9%	-	-	-	1
Unknown	23.5%	12.2%	27.3%	41.7%	21

3.2.1.1. Juvenile Mortality

The apparent latency in the onset of active hunting by juvenile golden eagles may confer an immunity to wind turbine interaction, i.e., we found only one turbine blade-strike fatality (0.9 percent) among 117 radio-tagged (free-ranging) juveniles, a profoundly lower incidence than that recorded among subadults and floaters (see below). The single fatality occurred in the last month of the juvenile year. This very low incidence occurred despite the common appearance of juveniles within the WRA, i.e., 264 (13.7 percent) of 1921 relocations during September through May when almost all juveniles had become independent (Hunt et al. 1999).

3.2.1.2. Subadult and Floater Mortality

Unlike juveniles, radio-tagged subadults and floaters are highly vulnerable to turbine blades. We recorded 31 blade-strike fatalities (20.0 percent) within our sample of 155 subadults with working radios and 8 such fatalities (14.8 percent) among 54 floaters. We attribute this susceptibility both to their frequent occurrence in the WRA and their greater tendency, compared with juveniles, to hunt live prey.

Many of these itinerants were originally tagged as fledglings (n=102), and we were able to monitor those remaining in the study area through the three-year period of subadulthood and, in some cases, beyond. The numbers of blade-strike deaths among these subadults and floaters were large among some cohorts. We tagged 25 fledgling eagles in 1994, and a year later, six of these had died or disappeared (emigration plus radio-failure), leaving 19 in the study area as first-year subadults. From January 1995 to November 1999, turbine blades killed 11 of these eagles (including censored ones), an attrition rate of at least 57.9 percent arising from this single mortality agent. Only one was known to have died of other causes within the study area during this period. Of 16 radio-tagged eagles from the 1995 cohort detected in the study area as subadults, six (37.5 percent) were eventually killed by wind turbines (March 1997 – May 1999). There were five blade-strike deaths among 13 subadults and floaters remaining in the study area from the 1996 cohort, a kill rate of 38.5 percent. We have only short-term information for the 1999 cohort, i.e., only one year of subadulthood. Among 19 of these eagles detected in the study area as subadults, four (21.0 percent) have thus far been killed by turbine blades. Note that all these figures on turbine-related mortality represent minimum incidence because the blades destroy the transmitters in a proportion of cases.

We were interested to know if eagles fledging from nests near the WRA were more likely to be killed there than those originating from more distant sites. To test this, we considered only those eagles tagged as fledglings in 1994, 1995, and 1996, the reason being that we were able to monitor them through all subadult years. Our results showed no difference in median or mean distance from the WRA between those killed by turbines and those that were not. The median distance from the natal site to the WRA for 22 turbine-killed subadults and floaters was 11.3 km (mean=13.2, SD=9.1), while the median for 38 such eagles not killed by wind turbines was 11.7 km (mean=13.3, SD=9.1), a near-perfect match.

3.2.1.3. Breeder Mortality

Breeding golden eagles are less exposed to wind turbines than subadults and floaters because of the tendency of breeders to remain within and near their breeding territories, only some of which are near the WRA. There were 12 fatalities among the 47 radio-tagged breeders in the study area, two of which (16.7 percent) were killed by turbine blade strikes. The nesting territory of one of the turbine fatalities was adjacent to the WRA, while the other was some 12.7-km distant. As a matter of interest, we know of 18 regularly occupied golden eagle territories within 10 km of the WRA (minimum density = 1 pair per ca. 30 km^2), 30 in the 10-20 km range, 21 at 20-30 km, 15 at 30-40 km, and 9 territories 40-50 km from the WRA. Our surveys doubtless account for a greater proportion of the actual number of territories in areas closest to the WRA than in zones of greater distance where logistical, landowner, and budgetary restrictions hampered detailed searches.

Thus, in contrast with the other eagle life-stages, the relatively small home ranges of breeding eagles keep most of them out of the WRA (Figure 11, Figure 12, Figure 13, and Figure 14). Only 42 (1.0 percent) of 3986 breeder detections were within the WRA boundary; these visits were by 12 (25.5 percent) of the 47 tagged breeders. This contrasts with 14 percent of juvenile detections being in the WRA (n=1917), 18 percent for floaters (n=2063), and 20 percent for subadults (n=4693). The tendency of breeders to remain within their territories is of particular benefit to the population because the trend in the latter is much more sensitive to adult survival rates than to any other demographic parameter (Hunt 1998, Hunt et al. 1999). We calculate, for example, that a chronic change of two percent in adult survival in this population may exert the same effect on the population trend as a change of about 13 percent in juvenile survival or reproduction.

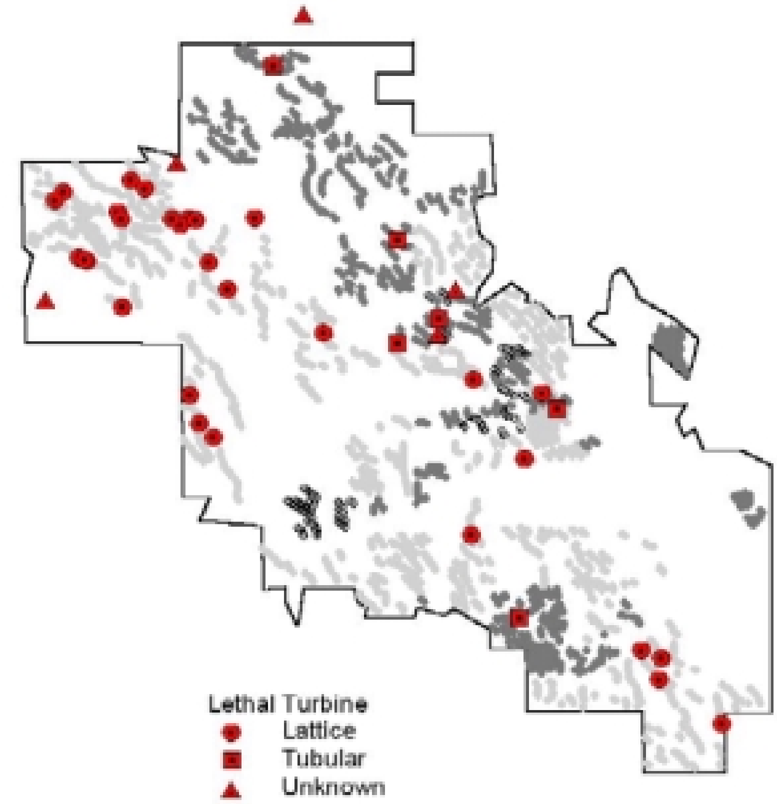


Figure 10. Distribution of 42 Turbine Blade-Strike Casualties of Uncensored, Radio-Tagged Golden Eagles in the WRA

(See Figure 6 and Figure 15 for distribution of turbine configurations.)

The ratio of blade-strike deaths to total relocations within the WRA among breeders (2 / 42 = 0.05), though imprecise as a measure of risk, is comparable with that observed among subadults and floaters (42 / 1412 = 0.03) and suggests that breeders are similarly vulnerable when in the vicinity of wind turbines. Circumstantial evidence suggests that breeding pairs living very close to the WRA experience higher mortality than those living further away. Despite the high apparent suitability as breeding habitat of those portions of the WRA containing trees or small cliffs, we observed very few pairs and those only temporarily.

3.3. Seasonal Differences

One would expect the frequency of blade-strike fatalities to rise and fall in correspondence with the windy season at Altamont Pass which extends from the end of March to the end of September. Indeed, turbines killed 27 tagged eagles in spring and summer (21 March to 21 September) compared with 15 in fall and winter (X^2=3.43, d.f.=1, p=0.064). The latter figure appears (to us) surprisingly high, considering that Green Ridge Services (personal communication) generates only about 20 percent of its power outside the windy season. A goodness-of-fit calculation based on the hypothesis that 80 percent of fatalities would occur during the windy season differed significantly from the expected (X^2=6.48, d.f.=1, p=0.011). Our first thought was that a greater proportion of tagged eagles might visit the WRA outside the windy season, but such was not the case, the proportions being identical, i.e., 23.8 percent of relocations during the windy season were inside the WRA and 23.7 percent during the nonwindy season. These findings suggest the possibility of seasonal differences in eagle hunting behavior, although we know of none, or perhaps that the turbines, spinning only occasionally and therefore unexpectedly in fall and winter, are more likely perceived benign by eagles in their vicinity. The cooler seasons are also times when bad weather, e.g., fog and rain, often obscure visibility.

3.4. Turbine Configuration and Lethality

A variety of considerations reflect upon whether one turbine / tower configuration is more likely to kill golden eagles than another. The first step of inquiry is to determine the kinds of turbines that actually killed the radio-tagged eagles in our sample, considering that there is likely no detection bias associated with the distribution of the 42 uncensored blade-strike casualties. We find that only four or possibly five kinds of turbines are on the list (Table 3) and that, among them, Type-13 accounted for at least 27 (73 percent) of the 37 deaths in which eagles died in the vicinities of the turbines that struck them. Referring to Figure 5 and Appendix I, we see that Type-13 is the Kenetech 56-100 turbine on an 18.3-meter lattice tower.

We are first tempted to compare the allocation of deaths with the relative abundance of Type-13 turbines (n=ca. 2997) versus that of all the other turbines combined (n= ca. 2385), assuming (probably incorrectly) that none of the eight ambiguous fatalities (no assigned turbine type in Table 3) was attributable to Type-13. The result of the comparison is not significant, therefore suggesting that the relative abundance of Type-13 is sufficient to explain its lethality (X^2=1.26, d.f.=1, p=0.26). Also not significant is a comparison of the abundance of Type-13 with the subset of only those types of turbines that killed the eagles in our sample (X^2=0.74, d.f.=1, p=0.38).

However, in looking for differences, we must also consider the distribution of live eagles within the WRA, that is, the pattern of their exposure in relation to the distribution of turbines. For example, a high kill rate by a certain type of turbine would imply a high degree of lethality were eagles known to only rarely visit areas containing it. To examine this possibility we drew a crude set of polygons (Figure 15) around the areas containing Type-13 turbines and another set enclosing the other types (n=1917 turbines), 79 percent of which were of tubular tower configuration, 20.5 percent lattice towers, and less than one percent vertical axis machines. The Type-13 area contains several other types of lattice-tower turbines, making up 12.3 percent of the total.

Figure 11, Figure 12, Figure 13, and Figure 14 compares aerial relocation distributions between breeders, floaters, subadults, and juveniles These distributions represent only those surveys in which we determined the positions of all tagged eagles in the study area. See Figure 4 for habitat types.

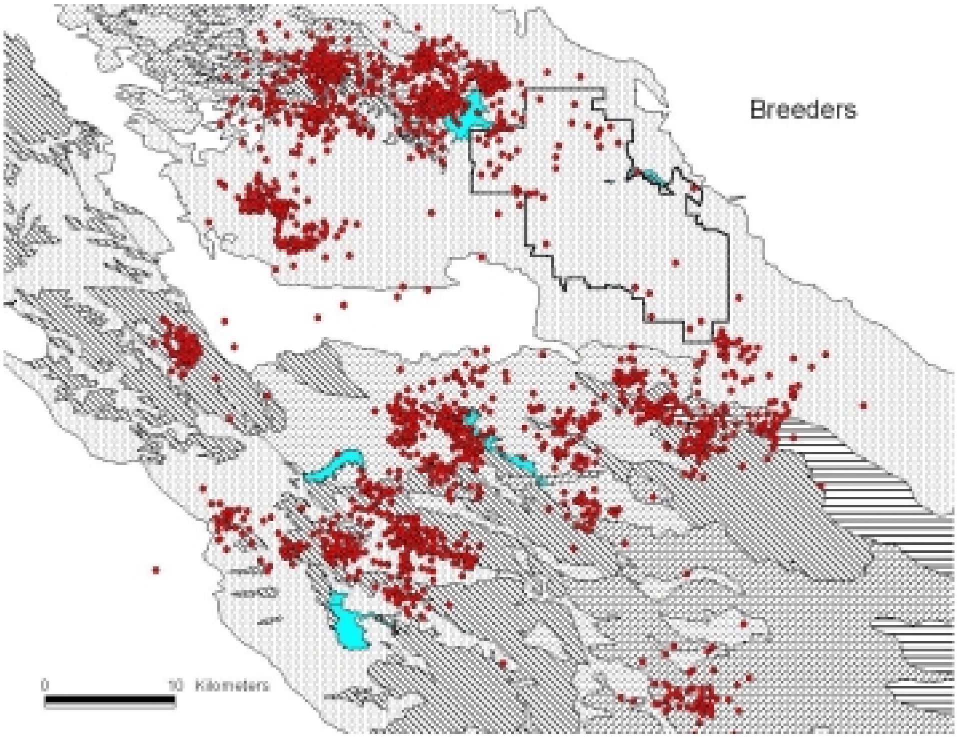


Figure 11. Relocations of Breeders

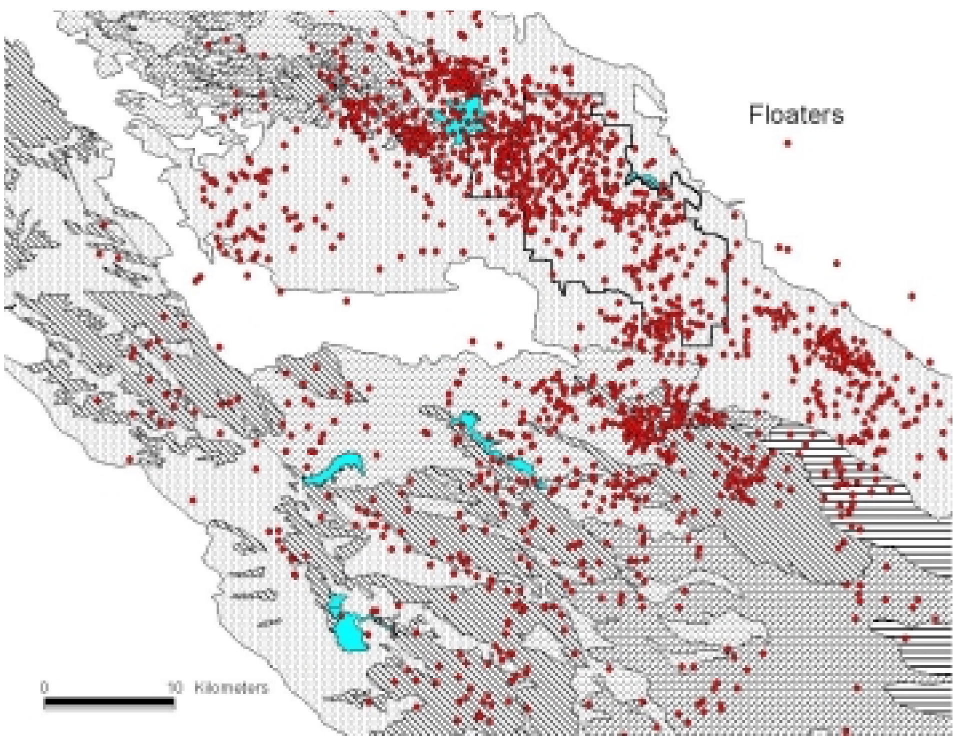


Figure 12. Relocations of Floaters

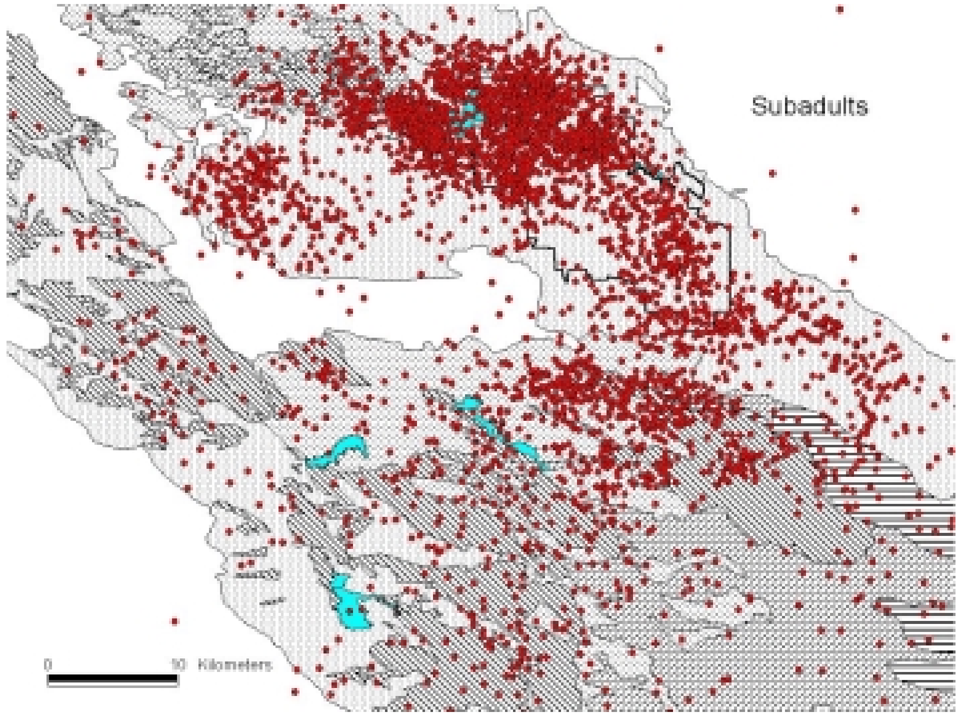


Figure 13. Relocations of Subadults

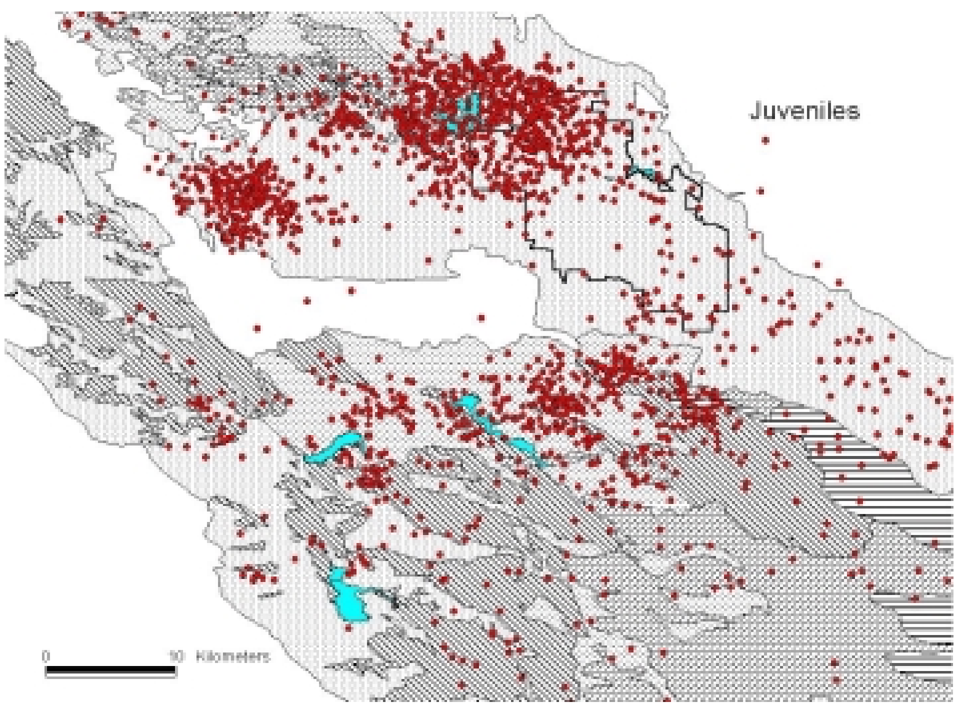


Figure 14. Relocations of Juveniles

Table 3. Wind Turbine Configurations Responsible for killing 42 Radio-Tagged Golden Eagles in the WRA

(See Appendix I, Table 3.)

Type	Turbine	kW	Rotor Dia. (ft.)	Tower	Height (ft.)	Approx. Number	Fatalities
4	Micon	60	52'	tubular	60	219	1
5	Nordtank	65	52'	tubular	80	312	2
8	Dangren Vind/Kraft Bonus	150	76'	tubular	80	100	2
8	Dangren Vind/Kraft Bonus	120	63'	tubular	80	230	1
13	Kenetech 56-100	100	59'	lattice	60	2997	27
23	Kenetech 56-100	100	59'	lattice	140	195	1
13 or 23	--	--	--	--	--		1
12 or 13	--	--	--	--	--		1
8 or 9	--	--	--	--	--		1
Unknown	--	--	--	--	--		5

Table 4 summarizes our calculations of polygon areas, the numbers of turbines they contained, and the overall number of subadult/floater relocations falling within polygon boundaries. We find that turbine and relocation densities are somewhat comparable between the two sets of polygons (84.3 percent and 84.8 percent parity, respectively), whereas the fatality distribution is highly disproportionate (X^2=6.3, d.f.=1, p=0.010). This suggests that eagle distribution is not the sole predictor of blade-strike risk, and that the areas occupied by Type-13 may be more dangerous to eagles than those of other turbines.

Table 4. Densities (km^2) of Turbine Types versus the Densities of Subadult/Floater Relocations and Blade-Strike Fatalities in the WRA

(See Table 3 and Figure 15.)

	Polygons Containing Type-13	Polygons Containing All Other Turbines
Area (km^2)	62.3	40.9
Turbines	3460	1917
Turbine Density (per km^2)	55.5	46.9
Relocations	588	455
Relocation Density (per km^2)	9.4	11.1
Fatalities	30	7
Fatality Density (per km^2)	0.5	0.2

There is bias in these calculations to the extent that the distribution of radio-tagged eagles recorded since the beginning of the study cannot be expected to correspond very well with the distribution of eagles around the time of each fatality. To overcome this, we plotted the distribution within the WRA of 21 eagles killed within the Type-13 area. We then plotted the relocations of those corresponding samples of subadult/floater relocations during the four-month period prior to each fatality that were sufficient in number to provide a ratio of relocations between the two arrays of turbine-specific polygons. Figure 16 provides an example by showing the data layout for one of these eagles, and Table 5 summarizes the results of all 21 comparisons. Note in the table that there is no suggestion of greater use by eagles of the Type-13 areas versus those occupied by other types of turbines. In the months prior to fatalities, relocation density, on average, was actually lower in the Type-13 polygons (median=44.7 percent, mean=44.2 percent) than the others. If these data represent the behavior of eagles comprising the larger sample of 30 fatalities in the Type-13 areas, we would again conclude that conditions there are more hazardous to eagles than conditions in areas occupied by other types of turbines.

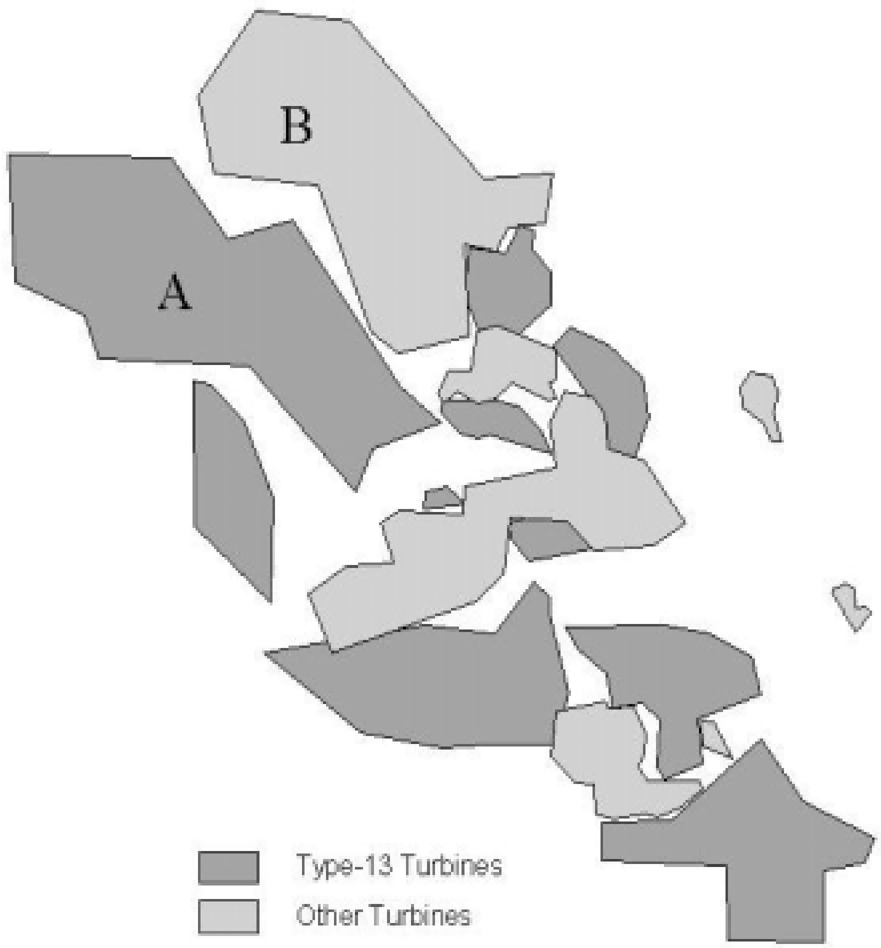


Figure 15. These two sets of polygons enclose the areas containing Type-13 turbines (totaling 62.3 km^2) versus those containing only other types of turbines (40.9 km^2) occurring within the WRA (see text)

Focusing on the entire northern section of the WRA, note in Figure 11, Figure 12, Figure 13, and Figure 14 the high density of subadult and floater relocations there, and then in Figure 10 that the great majority of fatalities lie within the region of lattice (principally Type-13) turbines, while only a few are within the comparable area of other turbines to the northeast. These two adjacent regions are represented in Figure 15 by the two largest polygons (labeled A and B), together containing 71 percent of all WRA relocations. Overall, we find that the Type-13 polygon (Polygon-A, 24.4 km^2) contained 358 relocations, a density over time of 14.7 relocations per km^2, whereas the area of other turbines Polygon-B, 21.7 km^2) contained 455 relocations, a density of 21.0 relocations per km^2. Polygon-A had a higher density of turbines, i.e., there were 47.2 turbines per km^2 as compared with 27.1 per km^2 in Polygon-B (Figure 17). Whereas these comparisons can be regarded as pseudoreplicative to the extent that the relocations of individual eagles are not completely independent, the effect is slight, given the small size and adjacency of the polygons relative to the considerable vagility of these non-territorial eagles (Hunt et al. 1995).

Table 5. Relocation Counts within Areas Containing Type-13 Turbines versus Areas with other Turbine Types as Recorded during the Last Four Months of Life among 21 Subadult and Floater Eagles

			Relocations of Subadults and Floaters				Relative
Fatality	Stage	Lethal Turbine	Type-13 Area	Density (km2)	Other Area	Density (km2)	Density in Type-13 Area
55M51	sub	Type-13	6	0.096	14	0.342	22.0%
97F92	sub	Type-13	19	0.305	28	0.685	30.8%
55M54	floater	Type-13	23	0.369	33	0.807	31.4%
88M111	juv	Type-13	23	0.369	33	0.807	31.4%
66M85	sub	Type-13 or -23	27	0.433	38	0.929	31.8%
52M34	sub	Type-13	42	0.674	53	1.296	34.2%
51F46	floater	Type-12 or -13	33	0.530	33	0.807	39.6%
5AM41	floater	Type-13	66	1.059	62	1.516	41.1%
51M68	floater	Type-23	66	1.059	62	1.516	41.1%
52M38	floater	Type-13	11	0.177	10	0.244	41.9%
42M03	sub	Type-13	16	0.257	13	0.318	44.7%
44M28	sub	Type-13	82	1.316	64	1.565	45.7%
42M02	sub	Type-13	74	1.188	57	1.394	46.0%
53M39	sub	Type-13	78	1.252	57	1.394	47.3%
44F16	sub	Type-13	26	0.417	15	0.367	53.2%
44M27	sub	Type-13	74	1.188	41	1.002	54.2%
44F22	sub	Type-13	90	1.445	46	1.125	56.2%
64F50	sub	Type-13	90	1.445	46	1.125	56.2%
41F08	sub	Type-13	32	0.514	16	0.391	56.8%
44M19	sub	Type-13	79	1.268	35	0.856	59.7%
44F19	sub	Type-13	64	1.027	24	0.587	63.6%

We recorded 19 blade-strike deaths in Polygon-A and only two in Polygon-B. Deaths in Polygon-A included one attributable to a Type-23. The latter, of which there are some 66 machines, representing only 1.9 percent of the turbines in Polygon-A, has the same generator and blades as Type-13 but is situated on a 43-meter lattice tower, rather than the 18-meter tower characteristic of Type-13. Type-23s are virtually always placed parallel and adjacent to Type-13s in a windwall configuration (Figure 18). Polygon-A contains seven windwalls, three of which were associated with eagle fatalities. Table 6 provides data on the relocations of 12 eagles killed in Polygon-A for which subadult/floater relocation samples during the four months prior to each death were sufficient to construct area-use ratios. Again, we calculate a higher average density of relocations in Polygon-B and a higher number of deaths in Polygon-A.

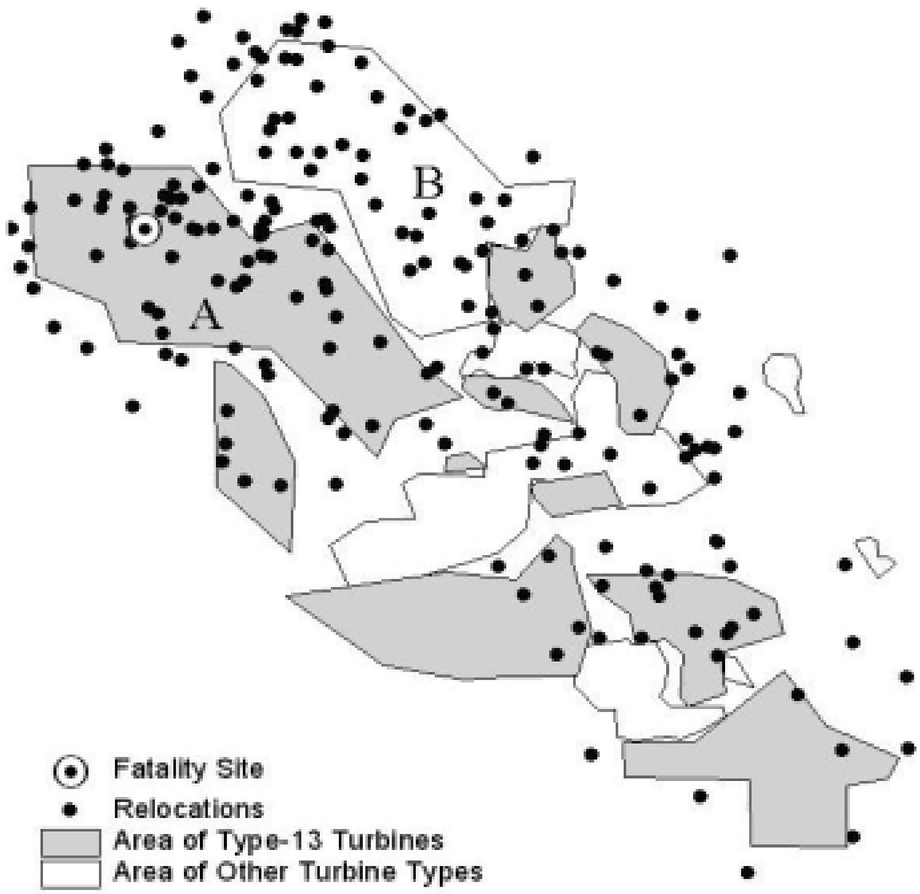


Figure 16. Relocations of Radio-Tagged Subadults and Floaters in the WRA during the Four Months Preceding the Death of Subadult No. 52M27
This example is one of 21 such comparisons.

3.5. Are the Type-13 Turbines in the WRA Particularly Dangerous to Eagles?

Circumstantial evidence presented thus far in our analysis offers grounds for suspecting that Type-13 may be more lethal to eagles than the other turbines, albeit certain types within the latter category might have been suspect were their numbers and the overall sample of fatalities greater. At present, we must ask what features, besides their abundance, distinguish Type-13s from the aggregate of other types and, in particular what features might explain a higher degree of lethality, if such is the case. Our data, being specific to conditions within the WRA, necessarily reflect its peculiarities, and so we must consider that other factors besides the configuration of the turbine itself may contribute to, or even solely account for, its lethality, i.e., we must also acknowledge the possible role of turbine spacing and that of environmental differences between areas containing differing types of turbines.

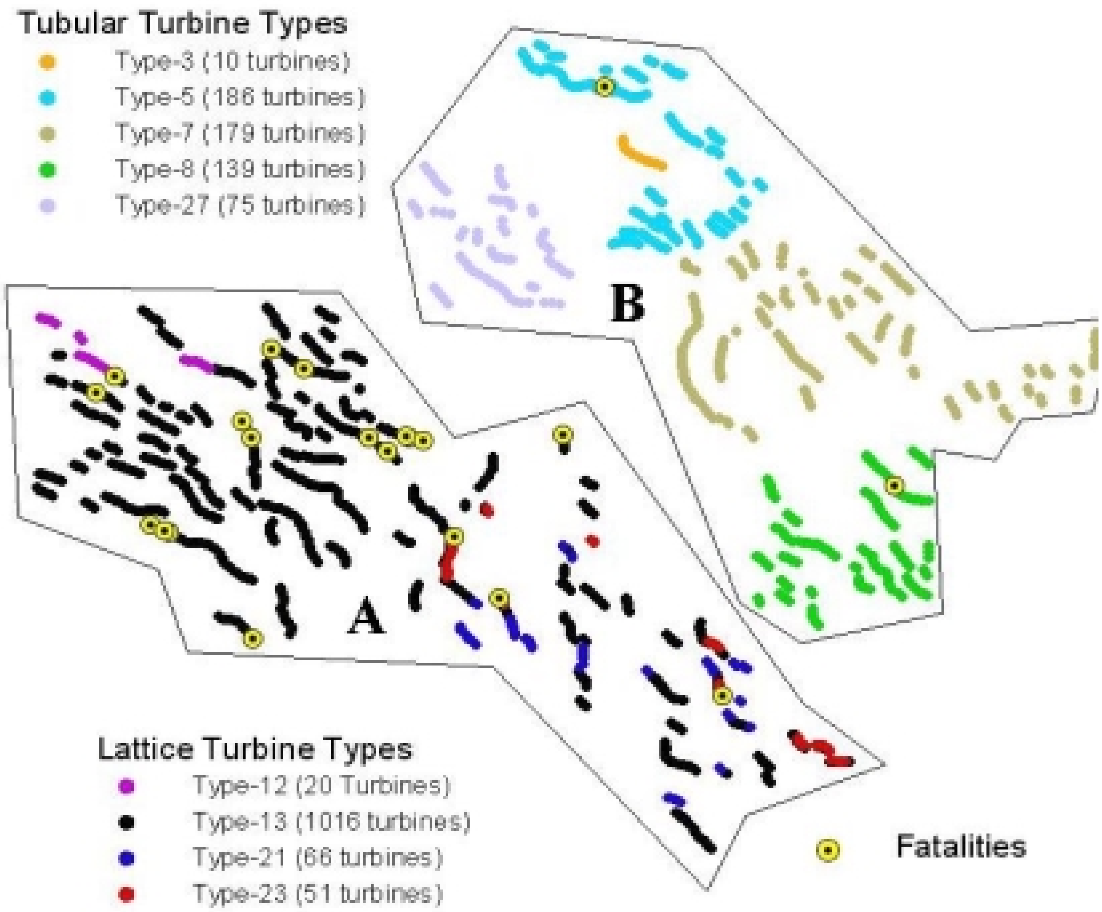


Figure 17. These Two Polygons in the Northern Region of the WRA are the Largest of those Depicted in Figure 19

Polygon-A contains only lattice tower turbines (n=1153), 88 percent of which are of the Type-13 configuration. Polygon-B contains only tubular tower turbines (n=589).

3.5.1. Tower-Height

The Type-13 turbine is positioned on an 18.3-meter tower, shorter than most tubular turbines, 90.5 percent of which are on 24.4-meter structures. Of the 821 lattice turbines other than the 2997 Type-13s, only 33 are on shorter (13.7 m) towers, whereas 171 are on towers of equal size (18.3 m), 422 are on 24.4-meter towers, and 195 are on 42.7-meter towers. Thus, considering that Type-13 turbine towers are shorter than 85 percent of all other towers in the WRA, we should consider whether turbines on short towers might be inherently more lethal than those on taller ones.

Figure 18. A Windwall consisting of a Row Type-13 Turbines and another row of the Taller Type-23 Turbines (photo by Daniel Driscoll)

Table 6. Twelve Golden Eagle Blade-Strike Fatalities that occurred in Polygon-A, together with Counts of Subadult and Floater Relocations occurring within the Previous Four Months in both Polygon-A and Polygon-B (See text)

		Subadult and Floater Relocations				Relative Density
Fatality	Lethal Turbine	Area A	Density A	Area B	Density B	in Area A
55M54	Type-13	11	0.451	28	1.290	25.9%
88M111	Type-13	11	0.451	28	1.290	25.9%
97F92	Type-13	10	0.410	25	1.152	26.2%
66M85	Type-13 or -23	15	0.615	32	1.475	29.4%
51F46	Type-12 or -13	17	0.697	29	1.336	34.3%
51M68	Type-23	33	1.352	54	2.488	35.2%
42M02	Type-13	45	1.844	48	2.212	45.5%
44M28	Type-13	47	1.926	49	2.258	46.0%
53M39	Type-13	46	1.885	45	2.074	47.6%
44M27	Type-13	45	1.844	33	1.521	54.8%
44F22	Type-13	57	2.336	39	1.797	56.5%
44F19	Type-13	42	1.721	23	1.060	61.9%

Our observations in the WRA and elsewhere in the study area confirm that contour hunting is the principal mode by which golden eagles hunt ground squirrels. This well-known behavior involves flying or gliding very low over the ground (1-5 m), often over considerable distances, hugging the terrain and concealing their approach so as to surprise unsuspecting squirrels at close quarters (Carnie 1954, Bergo 1987, Dekker 1985, Watson 1997). Eagles approaching prey may sometimes use fences and other overt objects to hide their approach (Dixon 1937). Golden eagles are particularly apt to contour hunt during windy conditions (Dekker 1985), and in a sample of 41 hunting flights observed in the WRA in spring 1994, 34 (83 percent) were contour hunts (Hunt et al. 1995). Eight of these ended in attempts to seize prey, four of which were successful. Contour hunts may originate from soaring flight, from elevated perches or from the ground. In a sample of 94 sightings of perched eagles in the WRA, 33 (35 percent) were on the ground and 61 (65 percent) were on elevated perches.

Consequently, golden eagles in the WRA are often very close to the ground, especially when hunting. It follows that eagles may occasionally attempt to pass low under the spinning blades of turbines, and although we have not observed this, we should consider the space available for this maneuver. We calculate that the blades of Type-13 pass within about 9.3 meters of the ground. Only 125 (5.4 percent) of 2304 other turbines (for which we have data) have blades that pass closer to the ground than those of Type-13. Of the remainder, 918 (40 percent) pass within 11-15 meters and 1336 (58 percent) more than 15 meters from the ground (Appendix I). While, at most approach angles, the position of the tower likely prevents an eagle from passing below the lowest point of the rotor, the Type-13 turbine is nonetheless among the most likely of turbines in the WRA to strike a low-flying eagle.

3.5.2. Tower Spacing

We observed golden eagles occasionally flying between turbines within a turbine string, a factor suggesting an examination of their spacing. Spacing, though not a property of the turbine itself, may be a component of eagle mortality. Let us examine to what extent the spacing of Type-13 turbines differs from that of other turbines in the WRA.

Using GIS, we measured the distance in meters between 912 Type-13 turbines within 88 strings in Polygon-A. The median distance between them was 25.3 meters (mean=27.1, S.D.=3.9). Likewise, we measured distances between 589 tubular turbines in 100 strings in polygon-B, representing five types. The median spacing was 47.0 meters (mean=48.4, S.D.=13.9). All five types of turbines in Polygon-B were more widely spaced than the Type-13s: the measurements included 10 Type-3s (median spacing=57.3 m), 186 Type-5s (31.8 m), 179 Type-7s (56.6 m), 139 Type-8s (Bonus Mark-150) (41.4 m), and 75 Type-27s (57.5 m) (Appendix I).

The relevant measure of risk to a golden eagle trying to fly between turbines is the distance between the spinning blades rather than the distance between turbine towers. The rotor diameter of Type-13 is 18 meters (59 feet rather than 56 feet as sometimes reported), meaning that the rotor tips of two adjacent, wind-aligned turbines are roughly 18 meters closer together than the vertical centerlines of their towers. Under such conditions, the interblade distance between two Type-13s in Polygon-A is about 7.3 meters. Considering that the wingspan of a female golden eagle is about 2.1 meters (Watson 1997), the distance between blade and wingtip of an eagle flying exactly between two adjacent, wind-aligned rotors of average spacing is 2.6 meters. For the four tubular turbine types we measured in Polygon-B, the average blade-to-wingtip distances would be 5.9 meters (Type-5), 7.0 meters (Type-8), 10.8 meters (Type-27), and 13.7 meters (Type-7), spacing ranging from over twice to more than five times the average of Type-13 clearance.

We measured the spacing from 27 Type-13 turbines that killed radio-tagged eagles to the nearest neighbor turbines in the string. Five (18.5 percent) of the lethal turbines were at the ends of rows (Orloff and Flannery 1992), meaning that the eagle may have been on the outside of the string rather than between turbines when the strike occurred. Of the remainder, nine (33 percent) were killed by the second turbine, two (7.4 percent) by the third, one (3.2 percent) by the fourth, and 10 (37 percent) in the central region (5th to 21st position) of the string. Excluding the five end-of-row kills, we found no difference between a sample of 44 space measurements between lethal Type-13 turbines and adjacent turbines and a sample of 471 spaces between Type-13 turbines that did not kill tagged eagles (t-test, p=0.579). As a matter of interest, the mean number of Type-13 turbines in strings where fatalities occurred was 20.6 (SD=11.4 turbines, range 8-48), as compared with 9.0 for all other Type-13 strings occurring in Polygon-A (SD=7.1, range=2-48) (t-test, p=0.010).

3.5.3. Wind and Terrain

We may conclude from the foregoing that an eagle trying to pass under or through a typical Type-13 turbine string must do so with precision. Strong winds in areas of steep terrain may present additional problems for eagles attempting to negotiate wind turbines. Consider a string of turbines along the top of a ridge, the latter oriented at a right angle to the direction of the wind. A low-flying eagle approaching fast from upwind first encounters an updraft, but as the ridge levels out, downdrafts and turbulence develop, factors that strongly reduce flight control. Even in more gentle terrain, deflected wind almost always produces near-ground turbulence, but all other things being equal, the steeper the terrain, the stronger are the forces affecting eagle flight.

As an example of terrain effects, we quote from the field notes of PBRG biologist Daniel Driscoll:

> "22 April….Wind 35-40 mph from the west…1000 hrs. Pigeons, red-tails, and gulls … having trouble flying in this wind …flying very low to the ground, and when they crest a ridge, the updraft pushes them skyward out of control…1321 hrs. I observed a red-tail flying into the wind above turbine row 4286-4294… was grounded below a powerline, then when it lifted from the ground, it was thrown up and nearly struck the line [being blown]sideways… 1422 hrs. Subadult golden [eagle] slowly slope-soaring [westward] into the wind below [downslope of] turbine row 2950-2972. The eagle appeared to be having difficulty [flying] and was being harassed by a red-tail… [the eagle] was hit by a gust of wind [as it crested the next ridge] and shot up [being blown backwards], just missing the blades of turbine 2915." Note that this ridge slopes very steeply westward some 400 feet to a canyon bottom.

With GIS software, we calculated an index of the overall degree of terrain steepness within Polygon-A (n=19 blade-strike fatalities) and Polygon-B (n=2 fatalities) by measuring contour line density. We began by extending twelve equally-spaced lines from the approximate center of each polygon in a directional rose toward the edges of the polygon. We then counted the number of 20-foot contour intervals encountered by each line and measured line length in kilometers. Our results showed Polygon-A with 29.9 contour-line crossings per kilometer (911 crossings in 30.44 linear km) and Polygon-B with 25.3 per kilometer (756 crossings in 29.92 km). This difference reflects only a 15.6 percent disparity in the relief index between the two polygons.

Figure 19 focuses on a 15 km^2 circle containing 16 of the 19 blade-strike kills in Polygon-A. Note that four turbine strings killed ten (62 percent) of the 16 tagged eagles and that five eagles in the eastern quadrant died within a radius of only about 250 meters. We cannot speculate on why these kill sites are so distributed, but no consistent relationship with distinctive terrain features is apparent, nor is the distribution of kills associated with high eagle relocation densities that might suggest, for example, corresponding prey concentrations.

3.5.4. Tower Perchability

It has been proposed that lattice tower turbines like Type-13 are more perilous to eagles than those on tubular towers because eagles can perch more easily on the former. Indeed, in our experience, eagles often perch on lattice towers and only rarely on tubular towers. From May through November 1994 we conducted weekly road surveys of the entire WRA to determine the extent of perching on wind turbines (Hunt et al. 1995). We recorded 23 incidents of eagles perching on lattice towers, 17 (74 percent) of which were Type-13 turbines, and none on tubular towers. Similarly, of 651 observations of red-tailed hawks perched on turbine towers, 633 (97 percent) were on lattice towers, 513 (79 percent) of which were Type-13s. Of the remaining 18 perchings (three percent of total), 14 hawks perched on the rail cages of non-functional tubular turbines (Type-16), three on Type-9 (vertical axis turbines), and one on a Type-4 tubular tower turbine. These data only partly reflect the greater abundance of lattice towers in the WRA. We constructed perchability indices for both species based on the total numbers of perchings and types of turbine towers surveyed. The results showed that both species conspicuously avoided perching on the 723 tubular tower turbines in our survey (Hunt et al. 1995).

Golden eagles and red-tailed hawks appeared to avoid perching on the towers of spinning turbines. In the only observed instance involving an eagle, the latter had perched on the third cross-member (half-way up the tower) of an end-of-row turbine that was not operating. The turbine powered-up and reached operating speed before the eagle dropped off, flying beneath the arc of the blades. Only 15 (2 percent) of 651 red-tailed hawks were observed perched on operating turbines (Hunt et al. 1995).

One attractive hypothesis that perchable towers present increased risk involves the idea that eagles may grow accustomed to them during the days of little or no wind characteristic of fall and winter. Eagles may thus fail to appropriately regard them as dangerous when the blades begin spinning on windy days. Indeed, the perception of danger is illusive because death or debilitating injury are virtually the only avenues of negative reinforcement, i.e., there is no way to learn. At this time, the question of whether these considerations are factors in eagle mortality remains unanswered.

3.6. Eagles and Ground Squirrels in the WRA

The large size and conspicuousness of both golden eagles and their prey in the open landscape of the WRA made it relatively easy to ascertain which prey species were most important. Numerous field observations of foraging eagles and examination of prey remains (Hunt et al. 1995) quickly led us to conclude that California ground squirrels were the principal prey of golden eagles in and around the WRA during the period of our investigation. Although eagles preyed to some extent on jackrabbits and cottontails, and these may be expected to increase in importance in some years, we hypothesize that the occurrence and distribution of golden eagles in the WRA during the years of our study mainly correlated with the occurrence and distribution of ground squirrels.

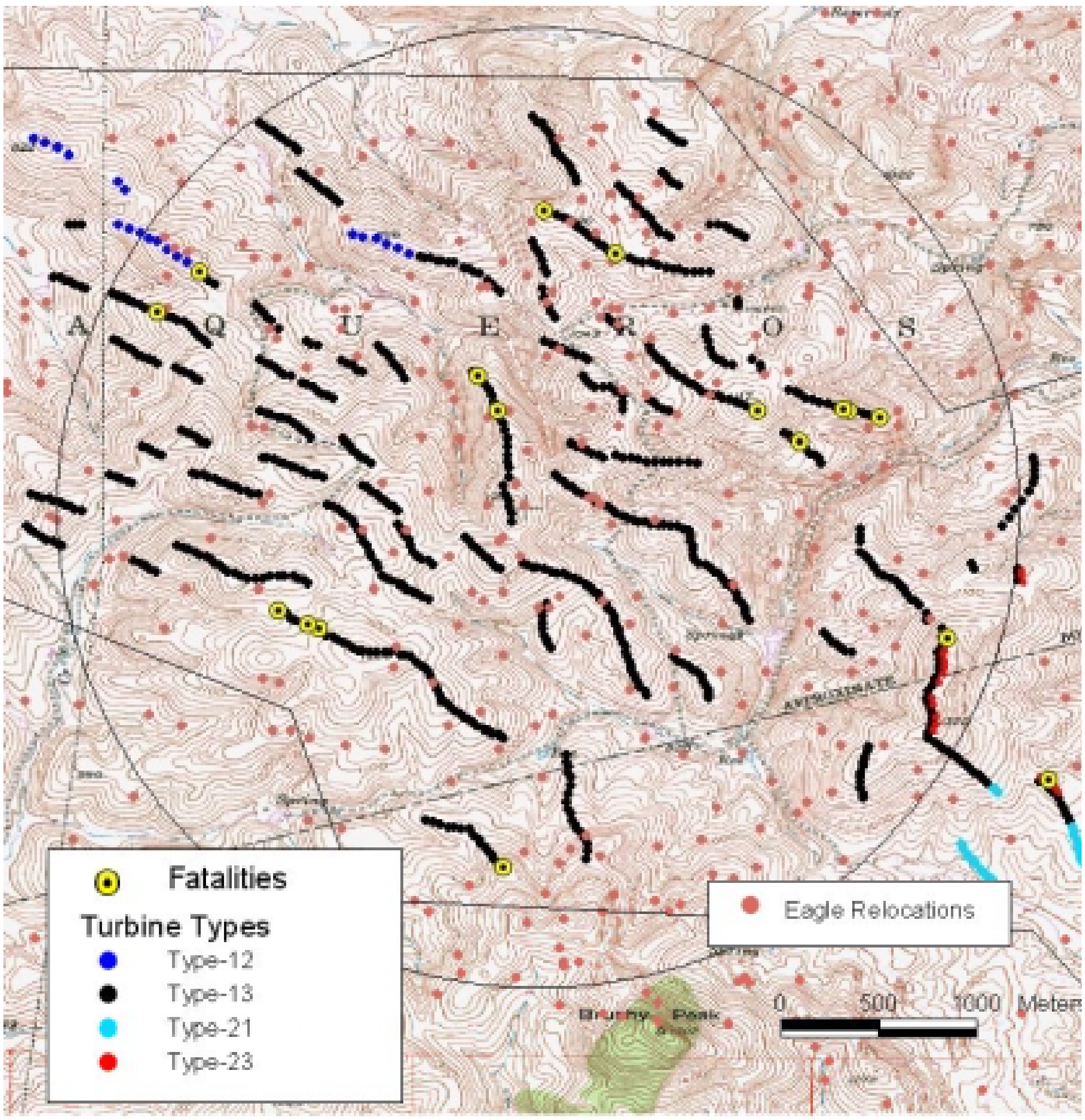


Figure 19. A 15 km^2 circle containing 16 of the 19 blade-strike kills in Polygon-A

To test this, we first examined the eagle relocation data to determine whether gross changes in eagle distribution had taken place in the WRA. Table 7 suggests that the proportional distribution of relocations of subadults and floaters in the northern (108 km^2) versus the southern (51 km^2) section of the WRA (north and south of Interstate 580) did indeed change over the years of our study. Note that the percentages of relocations in the southern portion of the WRA diminished during the 1996-1997 period. The difference between individual eagle use of the southern portion of the WRA in 1994-1995 (n=47 individuals, mean proportional use = 0.27) versus 1996-1997 (n= 72, mean use = 0.16) was significant (t-test, p=0.03), although a comparison between 1996-1997 and 1998-2000 (n=47, mean use = 0.21) was not (p=0.19). \

Table 7. Changes in the Proportion of Subadult and Floater Relocations in the Northern and Southern Areas of the WRA (North and South of Interstate 580)

	Eagle Relocations			Turbine Kills		
Year	North	South	% in South	North	South	% in South
1994-1995	284	84	22.8%	3	1	25%
1996-1997	631	96	13.2%	16	1	6%
1998-1999	149	34	18.6%	12	1	8%
2000-2001	92	44	32.4%	4	3	43%

Wondering if these differences might be related to ground squirrel densities, we visited two large ranches on June 4, 1997, one in the northern and one in the southern section of the WRA. Beginning at 1248 hrs.(cloudy, temperature 71-76 degrees F), we conducted a 22-minute visual survey for ground squirrels on all major roads of a 12.6 km^2 ranch south of Patterson Pass Road and observed one ground squirrel. We quickly traveled to a 3.7 km^2 ranch in the north zone and, beginning our survey at 1330 hrs, we counted 136 ground squirrels in 21 minutes (partly cloudy, temperature 71-74 degrees F). Subadult/floater relocations within the boundaries of the southern ranch during the ten months prior to the survey totaled four (0.3 relocations per km^2), as compared with 26 relocations (7 per km^2) on the northern ranch. The manager of the southern ranch explained that a ground squirrel control program normally in place had lapsed in 1994, but had been resumed in late summer 1995.

Encouraged by these observations, we conducted a visual survey of ground squirrels in the area administered by Kenetech Windpower, Inc., comprising about one-half of the WRA. Green Ridge Services provided funding for the survey, conducted over a 13-day period in mid-June. Two teams, each with two persons, counted ground squirrels by driving all accessible roads at 10-15 mph during periods of highest above-ground activity i.e., in the morning (once sunlight was upon burrows) and early evening (after midday temperature declined), and only when temperatures remained below 32.2˚C (Appendix II). The purpose of the survey was not to estimate the numbers of ground squirrels present, but to identify areas within the WRA containing high and low ground squirrel densities.

We began by surveying the entire area twice. Each survey segment was then categorized as containing high, moderate, or low numbers of ground squirrels, while areas of poor visibility, e.g., due to high, dense vegetation, were excluded from categorization. We defined high-density areas as those where more than 12 ground squirrels were counted per 0.3 mile, and low-density areas as those with less than three seen per 0.3 mile. We repeated surveys (3-5 repetitions) in segments scored as medium-density and some in low-density segments to validate designations. For example, a high-density population might have initially been scored at a lower value because an unseen disturbance (predator, car) prior to our arrival caused squirrels to go into burrows. Thus, we based final determinations on the highest numbers observed, irrespective of a lower count on a different day.

From ground squirrel survey data, we identified five ranches of high squirrel density and four of low density (Figure 20). In gross data on subadult/floater eagle relocations (n=39 eagles) during the 10-month period prior to the surveys, there were 3.5 relocations per km^2 on ranches scoring high in ground squirrel density (93 relocations in 26.5 km^2) and 0.51 per km^2 on the low density ranches (14 in 27.6 km^2), a ratio of seven to one. Note in Figure 20 that areas with medium density scores showed intermediate relocation densities (2.2 per km^2). To correct for pseudoreplication, we compared the relocation frequencies among each of 38 eagles visiting the high- and low-scoring ranches (relocations weighted for the slight difference in ranch areas) and found that 33 (87 percent) favored the ranches with high squirrel density (X^2=19.1, d.f.=1, p=0.0001).

We learned that the distribution of ground squirrels within the WRA has largely to do with whether or not ranchers control their numbers, a practice occurring throughout the pastoral and agricultural regions of California (Alameda County Agriculture Department). The principal control method involves either broadcasting or setting up bait stations of grain laced with the anticoagulants diphacinone and chlorophacinone. The Alameda County Agriculture Department and those of many other counties within California's central valley region have voluntary programs in place for ranchers who wish to control ground squirrels on their lands. Ranchers in Alameda County may receive poison grain from the county for a 50-cent per pound surcharge which supports research on ground squirrels and control methods. The county maintains records of the quantity of grain received annually by each rancher. The ranchers may broadcast the grain themselves, although the county also offers this service. The grain is scattered over the entire ranch, or in selected areas of squirrel abundance, with a subsequent survey to determine effectiveness.

According to Jim Smith (Alameda County Agriculture Department), the county was not highly involved in ground squirrel control on the WRA until the summer of 1996, when rancher awareness of the control program became widespread. In summer 1997, Kenetech, working with Alameda County, initiated a ground squirrel control program on the WRA to assure uniformity of treatment and broad-based rancher participation (Kerlinger and Curry 1997b, Curry and Kerlinger 1998). Since then, the county control agent has regularly treated many ranches within the WRA, although there are large areas of the WRA not included in the program, including the Los Vaqueros watershed extending into the northwest portion of the WRA. Overall, the Department distributes an average of about 42 tons of treated grain annually throughout the county (Jim Smith, Alameda County Agriculture Department, pers. comm.).

Expecting an inverse relationship between the history of rodenticide use and our squirrel density surveys, we consulted the county agriculture departments who provided data on the amount of rodenticide acquired by each ranch in the WRA from 1990-99. Inferring that these purchases reflected use levels, we categorized the ranches based on number of assumed treatments from 1994-1997 as (1) not treated consistently (0-2 years of treatment), and (2) treated consistently (three or more years of treatment). The distributions of ground squirrel density scores (Figure 20) corresponded with the distributions of ranches within these categorical designations as follows: 93.2 percent of the area of high squirrel density was within Category 1, and none in Category 2, whereas 98.5 percent of the area of low squirrel scores was within Category 2.

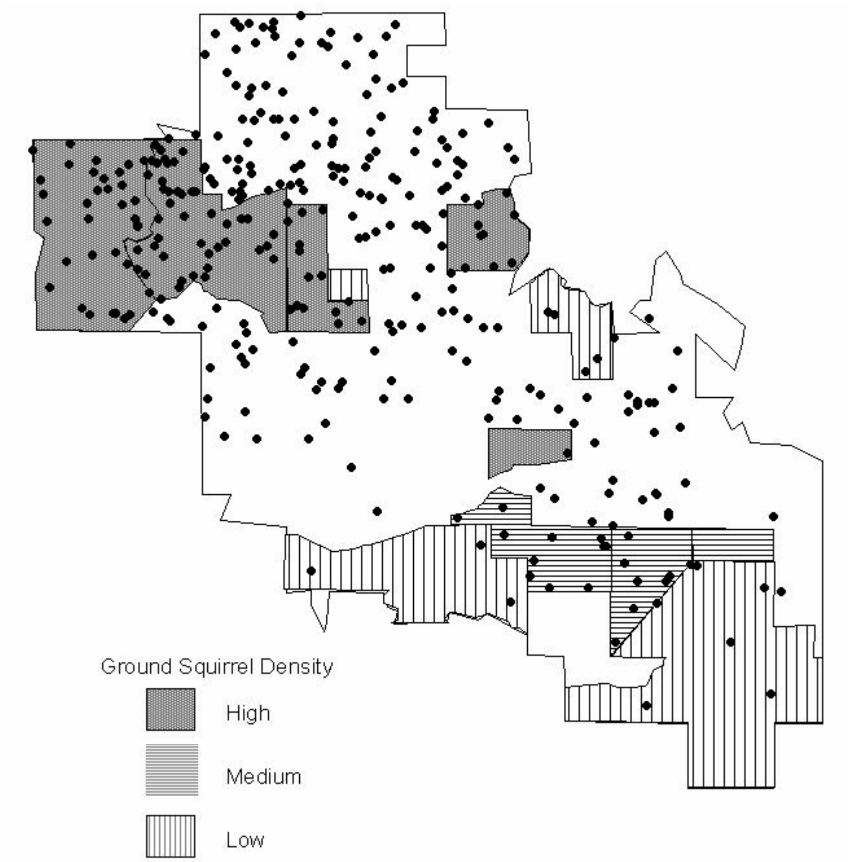


Figure 20. Eagle Relocations in Areas of Differing Ground Squirrel Densities as Estimated from Road Surveys

Relocations are those of subadults and floaters during the ten month period prior to the ground squirrel survey. Undelineated regions of the WRA (in white) were those either not surveyed (outside Kenetech area) or areas of poor visibility or access, the latter comprising ca. 16.3 km^2 (10.2 percent of total area).

3.7. Eagle Population Trend

Our final report to NREL, completed in early 1998, was directed solely toward analyzing the extent to which wind turbines at the WRA were affecting the trend of the golden eagle population inhabiting the surrounding region. Included in the analyses were our estimates of (1) the reproductive rate, as based on annual surveys of the nesting population, (2) survival rates of juveniles, subadults, floaters, and breeders, as obtained from radio-tagging and aerial surveys, and (3) the rate at which floaters became breeders.

3.7.1. The Alpha Model

The last-mentioned parameter was required for a trend analysis model developed especially for our project by a team of researchers at Colorado State University at Fort Collins (CSU) under separate support and direction from NREL (Shenk et al 1996, Franklin et al. 1998). The equations of the Alpha Model (Model #1 in Hunt et al. 1999), solved by matrix algebra, described the eagle life cycle in a graph of transition probabilities from one life-stage to another. This model was intended to produce an estimate of the annual rate of population change (λ). According to its authors, "…λ=1 indicates a stationary population, λ>1 an increasing population, and λ<1 a decreasing population" (Franklin et al. 1998). The Alpha Model, when supplied with data we obtained during 1994-1997, yielded a λ estimate of 0.9068 (SE=0.0322). The 95 percent confidence interval of this estimate (0.8437 - 0.9699) did not include λ=1.0, the minimum value for stability (see below). This meant that, if the model and its assumptions were valid, the population was declining during the period of our study, and if the point estimate for λ was correct, the decline rate was 9.3 percent per annum, an alarming value.

We have since determined that the Alpha Model is fundamentally flawed and therefore invalid. We first observe that the model, typical of Leslie matrix projections, requires that none of its parameters vary over time, a condition that would, in standard models, produce a stable age distribution regardless of population trend. However, one of the parameters of the Alpha Model cannot remain constant in the presence of floaters unless the population is at Moffat's equilibrium (Hunt 1998, Hunt and Law 2000, and see below). This parameter is α, the floater-to-breeder transition rate.

Using an idealized scenario to explain our reasoning, consider a remote island where there is nowhere else to go and only ten places to nest. Each nest is occupied by a pair of adult eagles who produce, on average, one fledgling per year or, collectively, an annual cohort of ten for the entire island. Natural attrition allows only 5 of these to survive the four-and-one-half years to adulthood. Two (10 percent) of the 20 breeders die annually, although a few live as long as 20 years. This means that only two vacancies are available each year for occupancy by the accumulating contingent of nonbreeding adults. However, these do not continue to increase indefinitely because 20 years after all sites are filled, the annual loss comes to match the annual gain, and the population is at Moffat's equilibrium (Hunt 1998). If survival and reproductive rates remain constant, our island population will stabilize at 42 adults and 31 younger eagles at fledging time. As usual, twenty of the adults will be breeders, but 22 will be floaters, unable to obtain a territory until a vacancy appears. In this idealized example of Moffat's equilibrium where vital rates remain constant over time, the proportions of age- and stage-classes will themselves remain constant from year to year.

Note that α is unnecessary in the formulation of Moffat's equilibrium, although the value of α can be easily calculated from the equilibrium number of floaters and the proportion acquiring breeding sites. We must therefore conclude, in this instance that α is not an independent parameter, but rather is determined entirely by the other parameters of the model.

Let us now suppose that our island, where the eagles have for many years been at equilibrium, has acquired through human misadventure a destructive pesticide that attacks eagle eggs to the extent that the annual cohort of fledglings is reduced by 70 percent, i.e., only three appear each spring. If this new reproductive rate remains constant, the population declines at an initial rate of about 16 percent per year (λ=0.84), annually losing a few floaters (some to the breeding segment and some to mortality) until the supply runs out about 14 years after the change in the reproduction. In, say, the fifth year of decline, two of 20 floaters (10 percent) acquire a territory, but by the tenth year, two of only seven remaining floaters (29 percent) so transition (Figure 21).

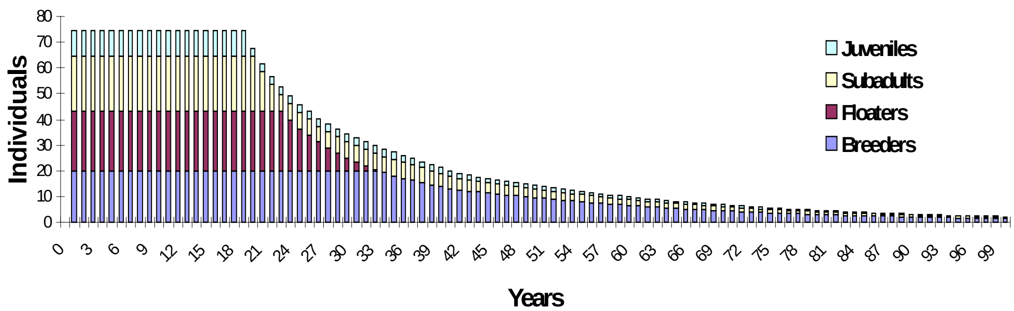


Figure 21. In a Hypothetical Population Declining from Moffat's Equilibrium, the Breeding Segment is Exposed to Decline only after the Loss of the Floating Segment

Obviously, α fails to remain constant in either a declining or an increasing population when floaters are present. The Alpha Model incorporates α, even though, by the nature of the model's mathematics, parameter constancy over time is both assumed and required. A projection from the matrix model based on a particular "snapshot" value of α discounts any further adjustment that true α may make in response to changes in the floater-to-breeder ratio. By placing α within the mathematical context of fixed parameters that effect rather than respond to population change, the Alpha Model is intractable and must be discarded.

3.7.2. A Better Trend Model

A healthy population at Moffat's equilibrium maintains a supply of floaters that buffers the breeding segment against decline. Our island scenario demonstrates that floaters accumulate in populations where (1) breeding opportunities are limited and (2) reproduction and / or survival are robust. The first of these criteria most assuredly applies to the nesting population of golden eagles in the Diablo Mountains where almost every territory known occupied in one year has remained occupied the next, where vacancies arising from breeder deaths have been immediately filled, and where a tightly-packed mosaic of nesting territories in favorable habitat remains virtually constant in structure from year to year (Hunt et al. 1999).

However, the second criterion, that of robust vital rates, cannot be satisfied on the basis of having recently observed floaters, because these may, in reality, be in gradual, collective decline (Figure 21) or may have arrived as immigrants from outside the study area. The question we ask, therefore, is whether the studied population is self sustaining, i.e., whether reproduction and survival are sufficient to generate more adults than there are places for them to nest. If this is not the case, the eagle population is either in decline (λ<1) or poised (if at equilibrium) at its brink (λ=1), although the second of these alternatives has an important exception we shall soon discuss.

It follows that the model we are looking for is one that can distinguish between $\lambda>1$ and $\lambda<1$ by estimating the growth potential (λ_p), i.e., a model that assumes territory acquisition by all maturing eagles. This model is a standard age-based growth model (Model #2 of Franklin et al. 1998) as proposed by PBRG as an alternative to the Alpha Model and discussed by Hunt et al. (1999). As in our island example, parameters include the reproductive rate and the survival rates of juveniles, subadults, and breeders. If these parameters remain constant at all stages of growth or decline, any value for λ_p exceeding 1.0 will predict a current or eventual population at Moffat's equilibrium, and we will then switch to an alternative model to estimate its stable stage distribution (Hunt 1998, Hunt et al. 1999, Hunt and Law, unpublished manuscript). $\lambda_p<1$, on the other hand, predicts that the supply of floaters will be exhausted (without immigration), and at that point, both α and floater survival (f) become moot as model parameters. We therefore maintain that the correct way of estimating λ_p is to ignore both of them, i.e., why wait to dispense with α and f in a declining population when their demise is inevitable? This leaves a model with fewer parameters than the Alpha Model, and we can therefore expect a more precise estimate of population trend, considering that the variance of every parameter adds to the variance of the model estimate (Appendix III).

3.7.3. Survival Estimates

The additional samples of radio-tagged eagles and continued aerial monitoring during 1998-2000 increased the precision of survival estimates and slightly altered their values from those reported by Hunt et al. (1999). For the latter study, the CSU team used Program Mark (White and Burnham 1999) to select the most parsimonious groupings of life-stages and sexes from which to calculate Kaplan-Meier survival estimates. The solution was a pooling of data from juveniles, subadults, and floaters of both sexes to produce a single estimate of annual survival for non-territorial eagles at 0.7867 (SE=0.0263). The estimate for territory-holders (breeders) was 0.8964 (SE=0.0371). In calculating estimates for the current study, which considers all data collected back through 1994, we departed from the CSU grouping in one respect: we considered juveniles separately. We did so because of differences between their lifestyle and that of older eagles (Section 3.2.1) and because the mortality regime for juveniles in our study area is also quite different, i.e., they are rarely killed by wind turbines (Table 2). The new Kaplan-Meier survival estimates are as follows: juveniles = 0.8397 (SE=0.0367), subadults / floaters = 0.7944 (SE=0.0215), and breeders = 0.9087 (SE=0.0246).

3.7.4. Estimate of Reproduction

The current study adds two additional years of data with which to calculate a natality estimate (Table 8). Even though the overall sample of years remains small, these new values reveal greater natural variation than previously observed, i.e., a comparatively high reproductive rate in 1999 (0.90 fledglings per occupied site) and a low one in 2000 (0.46). Parenthetically, 1994 was also a year of high productivity, despite our inability to meet Steenhof's (1987) criteria for a reproductive estimate (Section 2.0). Both 1994 and 1999 were characterized by a lack of prolonged winter rainfall, a factor we believe influences egg laying, egg survival, and ground squirrel availability (Appendix II).

For modeling purposes, the reproductive estimate of this particular golden eagle population must be tempered by the sex ratio. Measurements of eagles tagged as fledglings have indicated a consistent male bias. During the four years of radio-tagging (1994, 1995, 1996, and 1999), the ratios were 18:13, 13:9, 16:9, and 21:8, the aggregate of 107 fledglings for the years of sampling showing a ratio (proportion of males) of 0.63 (males / both sexes), a significant departure from unity (G=7.96, d.f.=1, p=0.005). The samples of free-ranging, nonterritorial eagles showed a similar preponderance of males. Among the eagles captured for radio-tagging in the current study were 34 males and 20 females (0.61 males), and in previous years, the ratio was 42 males and 27 females (.63 males), the pooled samples significantly departing from 1:1 (G=6.90, d.f.=1, p=0.009). The fact that the ratios calculated for fledglings and free-ranging eagles were almost identical gives support to earlier results in Program MARK detecting no sex bias in overall survival rates (Franklin et al. 1998, Hunt et al. 1999). Note that we cannot attest to the perfect accuracy of the ratios we report for these samples because all these sexing data were obtained from body measurements (e.g., hallux, tarsus, culmen, wing chord, etc). While most of these age-specific measurements are virtually non-overlapping between the sexes, and we used a combination of measurements in each case, blood analysis is the unequivocal method.

Table 8. Results of Golden Eagle Nest Surveys in the Study Area

	1994	1995	1996	1997	1998	1999	2000
Pairs surveyed	-	-	59	59	64	69	67
Total young	47	25	39	35	37	62	31
Young per pair	-	-	0.66	0.59	0.58	0.90	0.46
Broods	29	17	27	22	29	40	22
Brood size	1.62	1.47	1.44	1.59	1.28	1.55	1.41
Success rate	-	-	0.51	0.37	0.45	0.65	0.33

The reader, possibly wondering what sex ratio has to do with reproductive rate, may again consider Moffat's equilibrium. Recall that a healthy population of golden eagles fills all serviceable breeding locations, and that floaters of both sexes fill territory vacancies as they become available. As floater numbers dwindle in a declining population, the sex represented by the least number of floaters is depleted first, at which point the number of occupied territories, no longer buffered by floaters of that sex, begins to decline. In most other studied populations of raptors, females have been in surplus to males thereby rendering males the limiting sex (Ian Newton, pers. comm.), whereas our data imply that females, being fewest among the nonbreeding segment, are the limiting sex among golden eagles in the Diablo Range.

We calculated the overall natality estimate for the model by first averaging the annual number of 8-week-old fledglings per territorial pair (Table 8), and then multiplying by the average proportion of females each year. We calculated the standard error of the estimate by the Delta Method applied to the product of the two variables (Appendix III). The resulting productivity estimate was 0.2313 (SE=0.040) female fledglings per female territory-holder.

3.7.5. The Population Trend Estimate and What it Means

With these data on survival and reproduction, the λ_p model projects a potential growth rate of 1.0047 (SE=0.0240, 95 percent CI=0.9577-1.0517), a more encouraging point estimate than that in our previous study where λ_p was 0.9880. The current estimate, with its variance easily falling into the alternatives of both increase and decrease, is ambiguous to the extent that it can firmly predict neither Moffat's equilibrium nor decline (Appendix III). The matrix model overestimates λ_p to the extent that it cannot account for finite longevity, i.e., the oldest band-recovered golden eagle in North America was 23 years 10 months, and the oldest two such eagles in Europe were 26 and 32 years (Watson 1997). To test the effect on λ_p, we employed an age-based Moffat model that truncated longevity at 25 years and calculated $\lambda_p = 0.9982$. Again, both these point estimates, being so near 1.0, must remain ambiguous with respect to indicating the direction of population trend.

We observe that λ_p=1.0 does not imply stability, the latter being the effect of a floater reserve sufficient to comfortably buffer the breeding segment against decline. As explained above, a true value of λ_p=1.0 means that, at equilibrium, the population generates no floater buffer. However, that does not imply that no internally-generated floaters currently exist in the population, i.e., the model cannot ascertain if the population has so recently declined that it retains a remnant of a formerly robust floating segment. All that can be said is that, if λ_p is truly 1.0, the population is unable to maintain a floater buffer and is therefore vulnerable to any decrease in survival or reproduction that might, for example, accompany increasing human development in the landscape.

If, in reality, the population trend is currently negative, an important biological consideration must be taken into account, and that is the likely tendency of adult golden eagles in a reduced population to gravitate toward high quality breeding sites. In a 32-year study of a growing population of a related species, the Spanish imperial eagle (*Aquila adalberti*), Ferrer and Donozar (1996) found that average annual productivity of all occupied territories decreased as the number of territories increased. The reason for the overall decrease in fecundity was that the original pairs had selected sites in the best habitat, leaving new pairs to settle in those of lower quality (see also Dohndt et al. 1992). If golden eagles are similarly proficient in habitat selection, we would expect per capita productivity to increase in a declining population such that the trend might, at some point, stabilize (λ=1), albeit at lower level. Such a population would contain no floaters and yet be at equilibrium. Hunt and Law (2000) refer to this as the "recruitment wave limit" of site occupancy, a condition that derives from the restricted extent to which sites producing surplus recruits can augment those failing to meet that criterion. The alternative, of course, is the "site-serviceability limit" in which all sites that are adaptively suitable (in the evolutionary sense) are occupied, and floaters accumulate, this limit being the natural state for golden eagles.

To illustrate the effect of breeding site preemption (if our golden eagles are so disposed), let us suppose that the population is declining and that remaining breeders perfectly select those territories yielding the highest numbers of offspring (the "ideal preemptive distribution" of Pulliam and Danielson 1991). In our study area, the upper 50th percentile of breeding sites have produced about 0.39 female fledglings per territorial females as compared with 0.10 for the lower 50th percentile. If the breeding segment in this idealized scenario declined to one half its number but perfectly gravitated to the best sites, then λ_p would equal 1.03, a figure that would ordinarily predict a healthy state of Moffat's equilibrium with 0.62 female floaters per female breeder. Of course, this scenario could not obtain in nature because those hypothetical floaters would be occupying that fringe area of low quality sites describing the recruitment wave limit, and λ_p would be 1.0.

3.7.6. Is there Evidence of a Decline?

All this discussion leads to the conclusion that a healthy golden eagle population generates adults in excess of those required to fill breeding vacancies. Without floaters, the breeding segment of a population at the recruitment wave limit responds more or less immediately to vital rate changes, while a population at the site-serviceability limit may be comfortably buffered against change by its floater reserve. We must ask, therefore, if there are signs of breeding site saturation and a floating segment.

Our nesting surveys give no indication of a decline in territory occupancy. Only one nesting territory among 59-69 surveyed became vacant, this one close to activity associated with the development of Los Vaqueros Reservoir and both pair members killed by wind turbines within an 8-month period. Otherwise, throughout our study, all surveyed territories found occupied by pairs in one year have remained occupied by pairs in the next, a sign that floaters filled vacancies. Field evidence of rapid mate replacement include the reoccupancy of a territory where both adults died within two months of one another, and several cases where breeders were killed and replaced by floaters. We observed no nesting territories held by lone adults.

A clear sign of a reduced floating segment would be a high incidence of subadults as members of breeding pairs (Newton 1979, Watson 1997). For example, Bergo (1984) recorded a high proportion of subadult pair members in a Norwegian population of golden eagles that he believed was below carrying capacity. In Idaho, Steenhof et al. (1983) observed more subadult golden eagles as pair members when winter adult densities were low and concluded that subadults were less capable than adults of obtaining and holding territories. We are thus encouraged by a low overall 2.9 percent incidence of territory-holding subadults per surveyed pair in our study area over five breeding seasons (1996-2000) and no apparent trend (2.7 percent, 0.0 percent, 3.1 percent, 4.4 percent, and 1.5 percent in the five years, respectively). Were no adults available to fill vacancies, we would expect the incidence of subadult territory-holders to approximate the breeder mortality rate, about ten percent in our study area. The smaller observed incidence suggests either that floaters are being produced in the study area or they are arriving as immigrants, the number required per year being about 20 per hundred pairs.

3.7.7. The Net Effect of Blade-strike Deaths

In our last report to NREL (Hunt et al. 1999), we modeled the state of the population in the absence of wind turbines. To do this, we recalculated the subadult/floater survival rate after removing all blade-strike kills from consideration, i.e., we censored the eagles killed by the turbine strikes on their estimated death dates. This method has been generally avoided in other survival studies because of the bias of competing risk factors, a reasonable assumption if, for example, the risk were that of predation. The elimination of a predator might simply provide opportunity for another, or for other sources of mortality, such as starvation, associated with increased numbers (Heisey and Fuller 1985). We reasoned that these considerations would apply in the case of eagles and wind turbines only if causal density-dependent (crowding) factors came into play. For example, in the absence of wind turbines, a larger population of eagles might experience increased food competition such that the proportion starving would be comparable to those otherwise lost to wind turbines. Another and more plausible possibility is that increasing numbers of floaters might interfere with nesting success (Haller 1996).

We are skeptical that blade-strike mortality is compensatory. While it is true that density-feedback will inevitably influence vital rates at some point in the course of unlimited growth, the eagle population may settle into Moffat's equilibrium before that point is reached (Hunt and Law 2000). Free-ranging golden eagles have no obvious predators (the role of parasites in eagle demography is poorly known), and insofar as starvation is concerned, golden eagles are highly mobile, have a wide food-niche, and there are large areas of grasslands without trees for nesting (survival habitat), although, admittedly, the latter is being reduced by development. Floater interference with reproductive success might occur if there were large numbers of floaters, and so we must ask what would the floater-to-breeder ratio be in the absence of wind turbines.

Censoring the blade-strikes, the point estimate of subadult / floater survival increases from 0.7944 to 0.8997, and that of breeders from 0.9093 to 0.9240. If these and the other vital rates remained constant, λ_p becomes 1.036, meaning that a population of 100 pairs would reach Moffat's equilibrium at about 241 females at fledging time, and there would be about 61 floaters per 100 female breeders (*F:B*=0.61). Such a population would be considered intrinsically stable, and it is unlikely, in our opinion that a floater reserve of this magnitude would grossly interfere with the reproductive rate. Going a step further, with the censoring of all the known human-related mortality we recorded in our telemetry study, the Moffat model projects an *F:B* of 0.99. For comparison, vital estimates for a bald eagle population in Alaska by Bowman et al. (1995) yielded *F:B*=1.0 at Moffat's equilibrium (Hunt 1998).

4.0 Conclusions and Recommendations

The golden eagle population in our study area is part of a larger population inhabiting the mid-coastal mountains of California, and that population is part of yet a larger one, and so on. This is not to say we chose the dimensions of our study area randomly. In the first two years of study, the movements of subadults and floaters we radio-tagged in the WRA vicinity revealed that the region surrounding the Livermore valley retained the vast majority of them, as well as those eagles we tagged as fledglings (Figure 11, Figure 12, Figure 13, and Figure 14). The urban and delta regions to the west and north gave the appearance of containment, and relocation density attenuated rapidly in the area south of San Luis Reservoir and Hollister, ca. 75 km to the southeast of the WRA. Some eagles emigrated, and we believe a greater proportion did so after 1996 or 1997 (Section 3.1), although the overall proportion of those permanently leaving the study area was obscured by an unknown rate of transmitter failure. Some eagles returned after being away for months, and a few appeared to alternate between widely separated areas.

Wind turbine destruction of golden eagles at Altamont Pass might therefore be regarded as local in its effect on the health of the population of west-central California, the direct influence of the WRA extending southeastward perhaps 60 km and affecting the issue of perhaps 180 pairs. Thus far, no decrease is apparent in the number of territories occupied by adults. However, any reduction in survival or reproduction must decrease the floater-to-breeder ratio, and while it is conceivable that lowering competition might be mitigating this effect, the modeled scenario of life in the absence of turbines increases F:B to only 0.61, an unexceptional value when compared with studies of other raptor species (Newton 1979, Bowman et al. 1995, Watson 1990, Kenward et al. 2000). Our study shows a prevalence of human-related mortality in our study area (Table 2), a situation also expected in many other regions of California. Whereas the annual loss of 50 or more golden eagles to wind turbines, added to other human influences, has the net affect of reducing the overall floater buffer, the latter, whether originating from inside or outside the WRA, has yet to be eliminated, even in areas fairly close to the WRA.

4.1. Conclusions

Regardless of the population impact of blade strike mortality, society nevertheless regards the killing of golden eagles as an impropriety that should be mitigated, an attitude reflected in both state and federal law. While the evidence we report is circumstantial rather than experimental, our findings do suggest solutions, some of which would almost certainly reduce the incidence of golden eagle mortality in the WRA. A prime example would be the reduction of ground squirrel numbers in the vicinities of the turbines. Section 3.6 gives evidence that areas of high ground squirrel density attract golden eagles. The fact that eagles hunt ground squirrels and other prey by gliding close to the ground (contour hunting) brings them well within the horizon of the rotor blades, these being more difficult to avoid when the wind is strong and turbulent near the ground.

Even though ground squirrel control is a well known and frequent practice and would reduce golden eagle blade-strike mortality in the WRA, it is not without secondary environmental costs. Animals, such as badgers, foxes, coyotes, bobcats, rattlesnakes, gopher snakes, and others, prey upon ground squirrels in the WRA. Species such as burrowing owls and snakes depend on their burrows. If, on behalf of eagles, ground squirrel control becomes more widespread in the WRA, it would be proper to mitigate the loss of prey for all predators, including eagles, by encouraging ground squirrels outside the WRA. This might take the form of purchasing conservation easements from ranchers in areas of open grasslands (without suitable nest trees) to attract nonbreeding eagles. An example of such an area is the military installation known as Camp Parks near Dublin, whose policy is to protect ground squirrels and other prey species, and where our telemetry surveys have revealed a concentration of nonbreeding eagles.

Another downside of ground squirrel control is the collateral destruction of non-target species such as mice and rabbits which eat the poison grain. Perhaps the way to reduce ground squirrel numbers in the WRA is to trap them in areas near turbines where the squirrels exceed a threshold density. Such mitigation might be strengthened were repowering to proceed as planned (Section 2.2). Our density comparisons of eagle relocations and fatalities in the two northern polygons, both of which contained relatively high numbers of relocations, suggested that the one containing Type-13 turbines (Polygon-A) was more lethal than that containing other types of turbines (Polygon-B). Whereas we were unable to differentiate the lethal aspects of Type-13's configuration from its spacing, length of strings, or its relationship to terrain features, an absolute reduction in the number of Type-13s as part of the repowering would very likely benefit eagles, especially if the removal of the 644 Type-13s were to occur in areas where eagles concentrate.

Our observations of foraging eagles suggest that the new Type-28 turbines may be safer for eagles than the Type-13 turbines they are intended to replace. The turbines in Polygon-B that killed only two tagged eagles differed from Type-13s (19 died in Polygon-A) in the following ways: (1) the blades of the turbines in Polygon-B were higher off the ground, (2) the towers were more widely-spaced, and (3) their tubular towers offered little perching opportunity. The new Type-28 turbines are expected to have all these characteristics, in addition to a slower rotational speed which may allow eagles to more easily avoid the blades (Tucker 1996 a, b). Whereas the absolute relationship of any one of these factors to eagle mortality is unknown, we can say that eagles attempting to pass between or underneath the Type-28s would have far more room to maneuver. However, even if Type-28 were to prove more lethal on a per-turbine basis, its far greater generating capacity might render it preferable because few are necessary to match the generating capacity of many Type-13s, that is, assuming that overall energy production does not increase in the WRA. Tucker (1996b) incorporates such considerations within his safety index of turbine characteristics.

4.2. Recommendations

For further research, we recommend a continuation of the breeding surveys for golden eagles, perhaps every two or three years, with the purpose of monitoring territory reoccupancy, reproduction, the proportion of subadults as members of breeding pairs, and verification of sex ratio by blood sampling. An increase in the number of subadult territory holders can be expected as an early warning of a decline in territory occupancy and so must be regarded as primary among these objectives. Numerous land-use changes occurring during our studies have had the effect of reducing the overall amount of habitat for both breeding and nonbreeding eagles. Annual field work should include an assessment of these developments in relation to the eagle population to provide insight into ways of accommodating golden eagles within the changing landscape.

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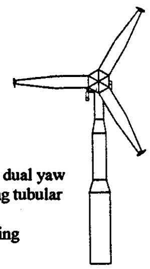
Appendix I

Types of Turbines in the Altamont Pass WRA

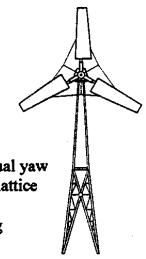
TURBINE TOWER TYPES

1 HOLEK/POLENKO (Dutch)



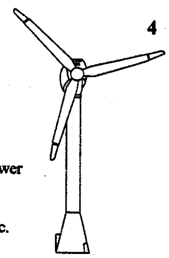
Size of Turbine:	100 kW
Rotor Diameter:	59 ft.
Cut-in Speed:	14 mph
Rated Wind Speed:	31 mph
Cut-out Speed:	67 mph
Number Installed:	12
Description:	Upwind, fixed pitch, dual yaw rotors, self-supporting tubular tower
Operator:	Thompson Engineering Management

2 HOLEC/WINDMATIC (Danish)



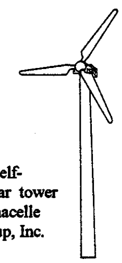
Size of Turbine:	65 kW
Rotor Diameter:	48 ft.
Cut-in Speed:	12 mph
Rated Wind Speed:	35 mph
Cut-out Speed:	56 mph
Number Installed:	26
Description:	Upwind, fixed pitch, dual yaw rotors, self-supporting lattice tower
Operator:	Thompson Engineering Management

3 HOWDEN (Scottish)



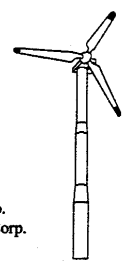
Size of Turbine:	330 kW	750 kW
Rotor Diameter:	102 ft.	149 ft.
Cut-in Speed:	11 mph	12 mph
Rated Wind Speed:	27 mph	29 mph
Cut-out Speed:	55 mph	58 mph
Number Installed:	85	1
Description:	Upwind, steel tubular tower with conical base	
Operator:	Altamont Energy Corp. Howden Wind Parks, Inc.	

4 MICON (Danish)



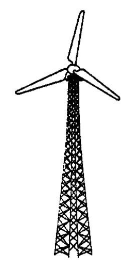
Size of Turbine:	60 kW
Rotor Diameter:	52 ft.
Cut-in Speed:	9 mph
Rated Wind Speed:	34 mph
Cut-out Speed:	None
Number Installed:	221
Description:	Upwind, fixed pitch, self-supporting steel tubular tower with inside ladder to nacelle
Operator:	SeaWest Energy Group, Inc.

5 NORDTANK (Danish)



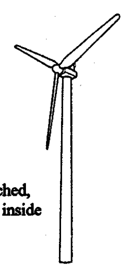
Size of Turbine:	65 kW
Rotor Diameter:	52 ft.
Cut-in Speed:	8 mph
Rated Wind Speed:	34 mph
Cut-out Speed:	None
Number Installed:	394
Description:	Upwind, fixed pitch, steel tubular tower
Operator:	Altamont Energy Corp. LFC Power Systems Corp. Wintec Ltd.

6 VESTAS (Danish)



Size of Turbine:	65 kW	100 kW
Rotor Diameter:	50 ft.	56 ft.
Cut-in Speed:	7 mph	8 mph
Rated Wind Speed:	34 mph	42 mph
Cut-out Speed:	50 mph	62 mph
Number Installed:	2	200
Description:	Upwind, lattice tower	
Operator:	Altamont Energy Corp. Zond Systems, Inc.	

7 HMZ-WINDMASTER (Belgian)

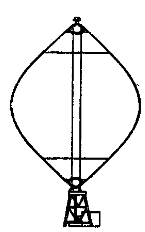


Size of Turbine:	75	200	250	300 kW
Rotor Diameter:	72	72	76	82 ft.
Cut-in Speed:	10	11	11	11 mph
Rated Wind Speed:	20	33	32	34 mph
Cut-out Speed:	50	50	56	56 mph
Number Installed:	5	129	30	15
Description:	Upwind, hydraulically pitched, blades, tubular tower with inside ladder to nacelle			
Operator:	WindMaster			

8 DANREGN VIND/KRAFT BONUS (Danish)

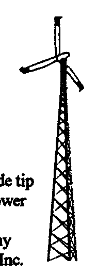
Size of Turbine:	65	120	150 kW
Rotor Diameter:	50	63.5	76 ft.
Cut-in Speed:	9	9	9 mph
Rated Wind Speed:	40	40	40 mph
Cut-out Speed:	67	67	67 mph
Number Installed:	211	250	100
Description:	Upwind, fixed pitch, self-supporting steel tubular tower		
Operator:	LFC Power Systems Corp.		

9 FLOWIND



Size of Turbine:	150 kW	250 kW
Rotor Diameter:	56 ft.	62 ft.
Cut-in Speed:	12mph	14 mph
Rated Wind Speed:	38 mph	38 mph
Cut-out Speed:	60 mph	60 mph
Number Installed:	148	21
Description:	Vertical axis steel tubular tower	
Developer:	FloWind Corp.	

10 ENERTECH

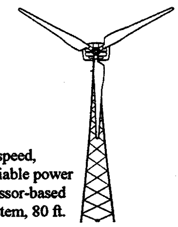


Size of Turbine:	40 kW	60 kW
Rotor Diameter:	44 ft.	44 ft.
Cut-in Speed:	8 mph	10 mph
Rated Wind Speed:	30 mph	35 mph
Cut-out Speed:	50 mph	60 mph
Number Installed:	192	36
Description:	Downwind, free yaw, blade tip brakes, self-supporting tower	
Operator:	Altamont Energy Corp. Altamont Power Company SeaWest Energy Group, Inc.	

11 WIND POWER SYSTEMS

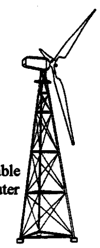
Size of Turbine:	40 kW
Rotor Diameter:	39 ft.
Cut-in Speed:	11 mph
Rated Wind Speed:	30 mph
Cut-out Speed:	60 mph
Number Installed:	20
Description:	Downwind, tilt-down lattice tower, no nacelle
Operator:	American Windpower, Inc.

12 KENETECH



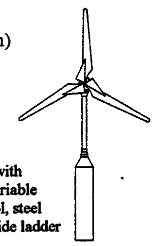
Size of Turbine:	300kW - 400kW
Rotor Diameter:	108 ft.
Cut-in Speed:	9 mph
Rated Wind Speed:	29 mph - 32 mph
Cut-out Speed:	Variable
Number Installed:	38
Description:	Upwind, variable speed, variable pitch, variable power factor, microprocessor-based turbine control system, 80 ft. lattice tower
Operator:	Kenetech Windpower

13 KENETECH



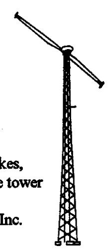
Size of Turbine:	100 kW
Rotor Diameter:	59 ft.
Cut-in Speed:	12 mph
Rated Wind Speed:	29 mph
Cut-out Speed:	44 mph
Number Installed:	3,500
Description:	Downwind, free yaw, variable pitch blades, remote computer control, 60 ft. tripod tower
Operator:	Kenetech Windpower

14 DANISH WIND TECHNOLOGY (Danish)



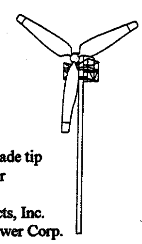
Size of Turbine:	300 kW
Rotor Diameter:	97 ft.
Cut-in Speed:	12 mph
Rated Wind Speed:	30 mph
Cut-out Speed:	56 mph
Number Installed:	3
Description:	Downwind, free yaw with hydraulic damping, variable pitch, computer control, steel tubular tower with inside ladder
Operator:	Atkinson Mechanical

15 ENERGY SCIENCES, INC.



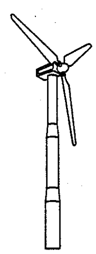
Size of Turbine:	50	65	80 kW
Rotor Diameter:	54	54	54 ft.
Cut-in Speed:	14	11	11 mph
Rated Wind Speed:	30	40	37 mph
Cut-out Speed:	55	55	55 mph
Number Installed:	99	96	109
Description:	Downwind, blade tip brakes, free yaw, tilt-down lattice tower		
Operator:	Altamont Energy Corp. SeaWest Energy Group, Inc. TERA		

16 FAYETTE



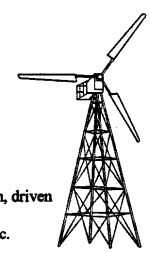
Size of Turbine:	75	95	250 kW
Rotor Diameter:	33	36	80 ft.
Cut-in Speed:	12	12	12 mph
Rated Wind Speed:	40	37	35 mph
Cut-out Speed:	none		
Number Installed:	222	1202	30
Description:	Downwind, free yaw, blade tip brakes, guyed pipe tower		
Operator:	Altamont Energy Corp. American Energy Projects, Inc. Arcadian Renewable Power Corp.		

17 DANWIN (Danish)



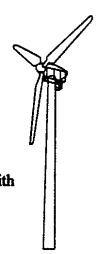
Size of Turbine:	110 kW
Rotor Diameter:	62.3 ft.
Cut-in Speed:	7.8 mph
Rated Wind Speed:	30 mph
Cut-out Speed:	57 mph
Number Installed:	25
Description:	Upwind, tubular tower
Operator:	FloWind

18 BSW/WAGNER (German)



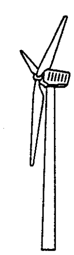
Size of Turbine:	65 kW
Rotor Diameter:	56 ft.
Cut-in Speed:	8 mph
Rated Wind Speed:	30 mph
Cut-out Speed:	67 mph
Number Installed:	15
Description:	Upwind, fixed pitch, driven yaw, lattice tower
Operator:	Energy Projects, Inc.

19 ALTERNERGY/AEROTECH (Danish)



Size of Turbine:	75 kW
Rotor Diameter:	51 ft.
Cut-in Speed:	8.6 mph
Rated Wind Speed:	30 mph
Cut-out Speed:	66 mph
Number Installed:	4
Description:	Upwind, tubular tower with inside ladder to nacelle
Operator:	Tempest, Inc.

20 W.E.G. (Brittish)



Size of Turbine:	250 kW	300kW
Rotor Diameter:	82 ft.	108 ft.
Number of blades:	3	2
Cut-in Speed:	11 mph	11 mph
Rated Wind Speed:	30 mph	26 mph
Cut-out Speed:	56 mph	56 mph
Number Installed:	20	1
Description:	Upwind, tubular tower, variable pitch	
Operator:	U.S. W.E.G.	

21 KENETECH

Size of Turbine:	100 kW
Rotor Diameter:	59 ft.
Cut-in Speed:	12 mph
Rated Wind Speed:	29 mph
Cut-out Speed:	44 mph
Number Installed:	nd
Description:	Downwind, free yaw, variable pitch blades, remote computer control, 80 ft. lattice tower
Operator:	Kenetech Windpower

22 KENETECH

Size of Turbine:	100kW
Rotor Diameter:	59 ft.
Cut-in Speed:	12 mph
Rated Wind Speed:	29 mph
Cut-out Speed:	44 mph
Number Installed:	nd
Description:	Downwind, free yaw, variable pitch blades, remote computer control, 80 ft. tripod lattice tower
Operator:	Kenetech Windpower

23 KENETECH

Size of Turbine:	100 kW
Rotor Diameter:	59 ft.
Cut-in Speed:	12 mph
Rated Wind Speed:	29 mph
Cut-out Speed:	44 mph
Number Installed:	nd
Description:	Downwind, free yaw, variable pitch blades, remote computer control, 140 ft. lattice tower
Operator:	Kenetech Windpower

24 KENETECH

Size of Turbine:	300 kW - 400 kW
Rotor Diameter:	108 ft.
Cut-in Speed:	9 mph
Rated Wind Speed:	29 mph - 32 mph
Cut-out Speed:	Variable
Number Installed:	1
Description:	Upwind, variable speed, variable pitch, variable power factor, microprocessor-based turbine control system, 80-ft. modified tubular tower
Operator:	Kenetech Windpower

25 KENETECH

Size of Turbine:	300 kW - 400 kW
Rotor Diameter:	108 ft.
Cut-in Speed:	9 mph
Rated Wind Speed:	29 mph - 32 mph
Cut-out Speed:	Variable
Number Installed:	1
Description:	Upwind, variable speed, variable pitch, variable power factor, microprocessor-based turbine control system, 120 ft. tubular tower
Operator:	Kenetech Windpower

26 KENETECH

Size of Turbine:	300 kW - 400 kW
Rotor Diameter:	108 ft.
Cut-in Speed:	9 mph
Rated Wind Speed:	29 mph - 32 mph
Cut-out Speed:	Variable
Number Installed:	1
Description:	Upwind, variable speed, variable pitch, variable power factor, microprocessor-based turbine control system, 120 ft. lattice tower
Operator:	Kenetech Windpower

27 BORING

Size of Turbine:	**330 kW**
Rotor Diameter:	**104 ft.**
Cut-in Speed:	**nd**
Rated Wind Speed:	**nd**
Cut-out Speed:	**nd**
Number Installed:	**83**
Description:	**Upwind, tubular tower**
Operator:	**EnXCo**

28 NEG-MICON

Size of Turbine:	**700-750 kW**
Rotor Diameter:	**48 m (157 ft.)**
Cut-in Speed:	**4 m/s**
Rated Wind Speed:	**14 m/s**
Cut-out Speed:	**25 m/s**
Number Installed:	**nd**
Description:	**Upwind, tubular tower**
Operator:	**Green Ridge Services Altamont Power Sea West Energy Group**

nd = no data available

This information was obtained from the *Altamont Pass Wind Power Plant* brochure prepared through the cooperative efforts of the Pacific Gas and Electric Company and Kenetech Windpower, Inc., April 1992. Current information was not available regarding the number installed and numbers may have changed.

Appendix II

General Information on California Ground Squirrels

Early research on the California ground squirrel largely focused on eradication efforts associated with bubonic plague and the cattle industry's concern over the loss of forage to squirrels (Grinnel and Dixon 1918, Snyder 1923, Storer 1930, Evans and Holdenried 1943, Linsdale 1946, Fitch 1948). As knowledge accumulated, it became apparent that geographical variation in temperature and precipitation regimes strongly affected the annual cycles of ground squirrel breeding, aestivation, hibernation, daily activity, and even demography. These and other life history traits indeed vary between populations in different geographic regions of California. Fortunately, in attempting to understand the ecology of the California ground squirrel population at Altamont Pass, we found that many studies were conducted within that region.

Grinnel and Dixon (1918) studied California ground squirrels at various elevations, from sea-level to about 6,000 feet ASL. Variations in the reproductive cycle were reported by Snyder (1923) in Tulare County, and Storer (1930) in a range extending from Ventura and Tulare counties north to Contra Costa and San Joaquin counties. Detailed population and behavior studies were conducted by Evans and Holdenried (1943) at Calaveras Reservoir in Alameda County, Linsdale (1946) at the Hastings Wildlife Reservation, and Fitch (1948) at the San Joaquin Experimental Range near Madera. These early works on ground squirrel life history continue to provide the basis of our ecological understanding of the species, whereas later research has focused largely on specific aspects of behavior. Tomich (1962) studied ground squirrels in the agricultural region near Davis (Yolo and Solano counties), Owings and Borchert (1975) and Owings et al. (1977) at the University of California Davis Wildlife Area, Stroud (1983) at the University of California Hopland Field Station in Mendocino County, Holekamp and Nunes (1989) at the University of California campus in Santa Cruz, and Boellstorff et al. (1994), Boellstorff and Owings (1995) and Trulio (1996) at Camp Ohlone, in Alameda County.

Population Survey Methods

When we began our study of golden eagles in the Altamont Pass area in 1994, we observed ground squirrels throughout the WRA. Our observations of foraging eagles quickly revealed their importance as a prey base and our need of a method to quantify their relative density in the various parts of the WRA. Ground squirrel survey methods varied in the literature, and some promised more accuracy than others.

Social behavior and alarm calls of the ground squirrel make visual surveys difficult. Grinnel and Dixon (1918) and Fitch (1948) noted that when walking transects across study areas, squirrels would call and run into burrows at distances over 100m away and remain underground for extended periods. Emergent young were less conspicuous than older squirrels in visual counts and sometimes retired to burrows for days, making them unavailable to surveys (Fitch 1948). Burrow entrance counts have been found inaccurate when sampling numbers of California ground squirrels and similar species (Fitch 1948, Van Horne et al. 1997a, Powell et al. 1994). For example, Fitch (1948) found burrow systems had an average of 17.2 holes per squirrel. The most accurate population estimates have been obtained by mark-recapture techniques (Evans and Holdenried 1943, Fitch 1948, Van Horne et al. 1997a). Fitch

(1948) noted that virtually every adult squirrel was trapped each year, during late winter and spring, and the numbers trapped approximated the breeding population. The road surveys we conducted in our study were more practical as a means of indexing the relative density of ground squirrels in various regions of the WRA (to compare with eagle use) than to precisely estimate the number of ground squirrels in specific areas.

Daily Activity and Foraging

In regions with annual snowpack, all California ground squirrels hibernate during winter (Fitch 1948, Dobson and Davis 1986), whereas ground squirrels may aestivate where summer food is scarce. However, in milder climates and in habitats offering diverse food sources, such as in our study area, conditions may be favorable for surface activity throughout the year. More, accurately, in such regions, not all sexes or age-classes are simultaneously dormant (Fitch 1948). On a population level, there are great differences from year to year in the frequency and duration of dormancy, correlated with feeding conditions and weight gain in early summer.

In our study area, periods of daily activity can vary according to temperature and other weather conditions. During winter, some activity occurs every day unless rain is continuous.

Squirrels often do not emerge until mid-morning, when the sun is on their burrows, but then remain active until mid-afternoon. The normal winter surface activity period is 1000-1600 hours (Fitch 1948); however, squirrels may become active as early as 0830 hrs. (Holekamp and Nunes 1989). Wind, cold fog, and rain limit surface activity, and if squirrels do emerge, foraging periods are short and hurried. On a warm clear winter day following several cold and stormy ones, squirrel activity is at a peak, each animal foraging ravenously after the period of fasting. Food is usually abundant in winter due to the new growth of herbaceous species, so squirrels forage closer to their burrows than in summer months (Fitch 1948).

Foraging periods lengthen during spring with increased daylight and warmer temperatures. Surface activity becomes bimodal as summer temperatures increase, with squirrels retiring to their burrows or to shaded areas during the mid-day heat. The normal summer surface activity periods are 0500-0900 hrs. and 1600 hrs. to dusk. Squirrels may be active throughout cloudy or unseasonably cool days.

Breeding and Productivity

In Alameda County, the ground squirrel breeding season usually commences in February (Evans and Holdenried 1943). Holekamp and Nunes (1989) found that the gestation period spanned 28-30 days, followed by a lactation interval of six weeks. Young squirrels emerge from burrows during March through June at 6-7 weeks of age. Litter size, averaging about seven, varies with food supply, female condition, and age (Snyder 1923, Van Horne et al. 1997b, Holekamp and Nunes 1989).

Almost all female squirrels in the population breed (Grinnel and Dixon 1918, Evans and Holdenried 1943, Fitch 1948, Tomich 1962), and few are reproductively unsuccessful (Holekamp and Nunes 1989). The period of behavioral estrus for each adult female is 4-5 hours, and she mates with an average of seven males (Beollstorff et al. 1994). Generally, females produce only one litter per year; however, second litters may be produced following the loss of first litters (Grinnel and Dixon 1918, Evans and Holdenried 1943, Fitch 1948, Tomich 1962, Holekamp and

Nunes 1989). Evans and Holdenried (1943) found no evidence of females giving birth during the first year of life.

Timing of the breeding cycle within a population of ground squirrels can vary. Most pregnant females have been captured during January to May, although Storer (1930) found pregnant females in every month of the year. We documented emergent juveniles in the WRA as late as 22 October.

There is some evidence that productivity may be higher in areas where control measures are enforced. Snyder (1923) found consistently larger litters in areas where control operations had been in place for two or more years. He attributed the increase in productivity to increased food availability, resulting from relaxed competition.

Mortality and Survival

Males fight constantly during the breeding season, defending their territory and entering those of others to mate with receptive females. The males often forgo foraging during this period, and their weight drops drastically (Fitch 1948). Weakness and injuries are common, making the males particularly susceptible to predation.

The cohort of emerging young are vulnerable to bobcats, coyotes, foxes, badgers, rattlesnakes, gopher snakes, golden eagles, red-tailed hawks, prairie falcons, northern harriers, great horned owls, and others (Grinnel and Dixon 1918, Evans and Holdenried 1943, Fitch 1948). Fitch (1948) found annual juvenile survival ranged from 36 to 50 percent and that of adults from 40 to 58 percent. Squirrels died most frequently after periods of unusually cold and wet weather in winter and spring. California ground squirrels have been diagnosed with pneumonia and bubonic plague (*Pasteurella pestis*) (Storer 1930, Evans and Holdenried 1943). Grinnel and Dixon (1918) estimated maximum life-span at five to six years.

Population Density

The California ground squirrel population studied by Fitch (1948) was stable, exhibiting an annual cycle of sudden appearance and subsequent gradual attrition of each year's crop of young. During the six years of his study, there was no extensive reduction by disease, plague, or starvation. Grinnel and Dixon (1918) found that, under natural conditions the factors apparently limiting a population of ground squirrels, in order of importance were (1) food supply in summer and fall, (2) predators, (3) weather (especially inundation of burrows), (4) disease, and (5) physiological longevity. Evans and Holdenried (1943) reported a total population density (adults and young) of seven per acre, and Boellstorff et al. (1994) found densities of 70 to 92 adult squirrels per hectare; both studies were in Alameda county.

Home Range and Dispersal

The home ranges of California ground squirrels vary with habitat and food supply, often overlapping the ranges of neighbors (Evans and Holdenried 1943, Fitch 1948, Holekamp and Nunes 1989, Boellstorff and Owings 1995). A male's range is relatively exclusive of other males, wheras the ranges of females overlap extensively (Evans and Holdenried 1943, Owings et al. 1977). The range of an adult male may overlap that of 2-4 adult females (Holekamp and Nunes 1989), while the range of an adult female (100 m^2, versus $50m^2$ for males) can overlap that of seven males (Boellstorff and Owings 1995).

Young males disperse to new areas from July - September (Grinnel and Dixon 1918, Evans and Holdenried 1943), usually remaining within about one km of their natal site. Young females; however, establish burrows in areas overlapping or adjacent to their mother's home range (Boellstorff and Owings 1995). This behavior leads to groups of related females (siblings and daughters) with adjacent ranges. In a study where squirrels were marked for visual identification, core areas of unrelated females never overlapped (Boellstorff and Owings 1995).

Boellstorff and Owings (1995) found multi-year site fidelity for both sexes at established burrow systems. However, in locations where populations have been depleted by poisoning, squirrels will move from areas of high density toward those of low density, but there is no indication of large-scale emigration over great distances (Evans and Holdenried 1943). Linsdale (1946) noted that ground squirrels disappeared from the Hastings Reservation when grazing was terminated, and Evans and Holdenried (1943) reported ground squirrels were rarely seen in heavy tree and brush growth, or on ungrazed land where grass was dense and exceeded one meter in height.

Appendix III

Potential Growth Model

To write a matrix model for the computation of λ_p, we parameterize the model as a postbreeding-census, birth-pulse model. In this case, the population is presumed censused immediately after “breeding” and so the youngest age class included in the census is that of 0-year olds. With $J(t)$, $S_1(t)$, $S_2(t)$, $S_3(t)$, and B(t) the number of juveniles, one-, two-, and three-year-old subadults, and breeders in year t, respectively, and with *f* the birth rate, and *j*, *s*, and *b* the juvenile, subadult and breeder survival rates, respectively, one has

$$J(t+1) = fB(t+1) = f[S_3 s + bB(t)]$$

$$S_1(t+1) = J(t)j$$

$$S_2(t+1) = S_1(t)s \qquad (1)$$

$$S_3(t+1) = S_2(t)s$$

$$B(t+1) = S_3(t)s + B(t)b$$

and so the matrix model is

$$\begin{pmatrix} 0 & 0 & 0 & fs & fb \\ j & 0 & 0 & 0 & 0 \\ 0 & s & 0 & 0 & 0 \\ 0 & 0 & s & 0 & 0 \\ 0 & 0 & 0 & s & b \end{pmatrix}. \qquad (2)$$

Note that the term *fs* presumes that subadults surviving to adulthood are immediately effective as breeders. While this assumption may be biologically unrealistic, the model thereby produces the largest value of λ_p.

The eigenvalue equation for the matrix (2) is

$$-\lambda(\lambda^4 - b\lambda^3 - jfs^3) = 0 \qquad (3)$$

and so λ_p solves

$$\lambda^4 - b\lambda^3 - jfs^3 = 0\,. \qquad (4)$$

Hence, the value of λ_p for this model is the largest solution of this equation. Equation (4) was solved with MATLAB to yield λ_p = 1.0047 when f = 0.2313 j = 0.8397 s = 0.7944 b = 0.9087

The corresponding stable-stage distribution, scaled so that its components sum to one, is (J, S_1, S_2, S_3, B) = (0.136199,0.113801,0.090028,0.071134,0.588839).

Note that when 1.0047 is substituted into (4) the result is zero to four decimal places, this calculation serving as a check on the value for λ_p.

To compute the variance of λ_p by the delta method, one requires the partial derivatives of λ with respect to each of the other parameters. These partial derivatives may be computed easily by implicit differentiation of equation (4). One obtains:

$$\frac{\partial \lambda}{\partial f} = \frac{js^3}{\lambda^2 (4\lambda - 3b)}$$

$$\frac{\partial \lambda}{\partial j} = \frac{fs^3}{\lambda^2 (4\lambda - 3b)}$$

$$\frac{\partial \lambda}{\partial s} = \frac{3fjs^2}{\lambda^2 (4\lambda - 3b)}$$

$$\frac{\partial \lambda}{\partial b} = \frac{\lambda}{4\lambda - 3b}.$$

The variance-covariance matrix is diagonal since the parameters are independent:

$$\Sigma = diag(Var(f), Var(j), Var(s), Var(b)).$$

If $V = (\frac{\partial \lambda}{\partial f}, \frac{\partial \lambda}{\partial j}, \frac{\partial \lambda}{\partial s}, \frac{\partial \lambda}{\partial b})$ the delta method asserts that

$$Var(\lambda) = V \Sigma V^T,$$

where V^T denotes the transpose of the row vector V. Consequently,

$$Var(\lambda) = Var(f)\left(\frac{\partial \lambda}{\partial f}\right)^2 + Var(j)\left(\frac{\partial \lambda}{\partial j}\right)^2 + Var(s)\left(\frac{\partial \lambda}{\partial s}\right)^2 + Var(b)\left(\frac{\partial \lambda}{\partial b}\right)^2$$

Computation yields *Var*(λ) = 0.00057 and SE(λ) = 0.0240. Hence the confidence interval for λ_p, $\lambda_p \pm$ (1.96)SE(λ), is the interval (0.9577,1.0517).

GUIDELINES FOR SITING WIND TURBINES RECOMMENDED FOR RELOCATION TO MINIMIZE POTENTIAL COLLISION-RELATED MORTALITY OF FOUR FOCAL RAPTOR SPECIES IN THE ALTAMONT PASS WIND RESOURCE AREA

Draft of 23 May 2010

Alameda County SRC

SECTION 1. INTRODUCTION

The Scientific Review Committee (SRC) for Alameda County's Altamont Pass Wind Resource Area (APWRA) avian mortality monitoring program has prepared the following guidelines to assist the wind power companies in the APWRA with re-siting of wind turbines recommended by the SRC for removal or relocation. Relocation or removal recommendations were made for the purpose of minimizing the potential for collision-related mortality of four focal raptor species in the APWRA.

As a result of the SRC's process of identifying hazardous turbines and exploring and evaluating the topographic, wind pattern, bird behavior, and turbine siting variables related to hazardous conditions, the SRC was also able to provide guidance on relocation of hazardous turbines to sites that pose lower hazard to the four focal species.

These guidelines are intended to provide the wind companies with basic information regarding avian collision hazards associated with turbine siting in the APWRA that can be used to evaluate the risk of potential relocation sites as well as the possible increased risk created by non-operational turbines and removal of turbines. Initially released in August 2008, the guidelines were updated following the ratings of additional wind turbines by an SRC subcommittee composed of Jim Estep and Shawn Smallwood during March 2010.

Background

The Altamont Pass Wind Resource Area (APWRA) is known to cause hundreds of raptor fatalities per year due to wind turbine collisions alone (Howell and DiDonato 1991, Orloff and Flannery 1992, Smallwood and Thelander 2004, 2005, 2008, WEST, Inc. 2007). Because collision-related mortality of long-lived, protected species has continued largely unabated since the initial development of the APWRA, the recent renewal of the conditional use permits (CUPs) for the continued operation of existing, old-generation wind turbines proved controversial. To alleviate concerns expressed by members of the public and the resource agencies about the APWRA's impacts on raptors and other birds, the Alameda County Board of Supervisors introduced new requirements along with the renewal of the CUPs.

The Alameda County Board of Supervisors issued a resolution on 22 September 2005, which required the shutdown or relocation of Tier 1 and 2 turbines[1] according to a schedule (Exhibit G-2), as well as the removal of all derelict and non-operating turbines[2] by 22 September 2006. Following a settlement agreement between the County of Alameda and the plaintiffs in a legal challenge of the CUP renewals under the California Environmental Quality Act, the Board of Supervisors amended the resolution and associated CUPs on 11 January 2007. This amendment applied to the wind companies agreeing to the settlement. It maintained the shutdown and relocation requirements, but expanded them to the removal of all Tier 3 turbines by 31 October 2008. It also maintained the requirement that all derelict and non-operating turbines be removed by 22 September 2006. The original and amended resolution included additional requirements, but the most relevant requirements for the foregoing document were the shutdowns and relocations of the most hazardous wind turbines and the removal of derelict and non-operating wind turbines.

The resolution by the Board of Supervisors also required the formation of a scientific review committee (SRC), which was to "investigate, monitor and evaluate the effectiveness of the [Avian Wildlife Protection] Program" (Exhibits G-1 and G-2). After receiving input from the Permittees, the monitoring team, and state-sponsored research, the SRC was also to "recommend adjustments [to the Program], and design and implementation of alternative strategies" (Exhibits G-1 and G-2). The original resolution (Exhibit G-2) charged the SRC with recommending management actions aimed at achieving "progressive and substantial reductions in avian mortality and injuries," whereas the amended resolution (Exhibit G-1) charged the SRC with recommending management actions aimed at achieving a 50% reduction in wind turbine-related mortality of golden eagles, red-tailed hawks, American kestrels and burrowing owls, while also minimizing losses to wind power generation. Thus, the goals were not exactly the same for settling and non-settling companies, but the SRC's role was consistent in terms of recommending management actions to reduce bird mortality.

[1] Most hazardous wind turbines, based on a classification of hazard level developed by Smallwood and Spiegel (2005a,b,c).

[2] The CUPs did not explicitly define the term "derelict," but its use followed from language used in Smallwood and Thelander (2004), who intended it to mean towers lacking turbines or supporting non-functional turbines. Indeed, the CUPs address derelict and "non-operational turbines" in the same phrase. Confusion over the term emerged when the companies said that many of the towers without turbines or with non-functional turbines are simply "vacant," which means they are awaiting repair or new turbines to be mounted on them and placed back into service. Regardless of whether a tower is *vacant* or *derelict*, it poses an increased hazard to raptors, and is essentially the same thing until either the tower is removed or it supports a functional turbine.

As part of the SRC's investigation directed toward management recommendations, the full SRC visited the APWRA on 29 November – 1 December and on 10 December 2007. An SRC subcommittee consisting of Jim Estep and Shawn Smallwood visited the APWRA to rate more wind turbines during March 2010. The SRC relied on available research reports and their combined expertise to review the configuration and environmental setting of wind turbines at sites associated with large numbers of fatalities relative to the majority of the APWRA, and they identified candidate wind turbines that could be deemed relatively more hazardous to raptors (see SRC documents P67, P68, and P69). The SRC evaluated and ranked wind turbines according to their hazard to raptors, with the intent to consider mitigation actions involving permanent shut down and removal of the most dangerous turbines. The SRC ultimately recommended removal of high-ranking wind turbines, as well as removals of additional wind turbines if the wind companies' decided to shutdown all old-generation wind turbines for only part of the winter instead of the SRC's recommended four months over the winter. The SRC specifically recommended the following:

- Remove all towers and turbines rated 8 through 10 (SRC document P69);
- If the winter shutdown is not extended to at least 3 full search rotations (anticipated to be about 3 months), then remove towers and turbines rated 7 and 7.5; and,
- The SRC evaluates turbines and towers not previously evaluated for hazard and removal.

These recommendations were revised slightly based on the March 2010 visit by the subcommittee (see below). The SRC's rankings were later assessed by comparing mortality estimates from recent fatality monitoring data, and were found to contribute disproportionately to the mortality of golden eagles, red-tailed hawks and American kestrels (Smallwood 2008, 2010).

During the field trip, the SRC noticed many derelict or vacant wind towers which sometimes create vertical or lateral gaps[3] that raptors may incorrectly perceive as safer to fly through (SRC document P67). Also, raptors perch disproportionately more often on derelict or vacant towers, or on towers of non-operating turbines (Smallwood and Thelander 2004, 2005; Smallwood et al. 2009), which often places these raptors in close proximity to adjacent, functional turbines. Whenever derelict or vacant towers lure raptors closer to functional wind turbines, whether for

[3] Gaps refer to spacing between functional turbines that are wider than the average spacing along the row of turbines as originally sited or as has emerged due to one or more turbines being removed or becoming non-functional.

crossing perceived gaps or for perching, there is the chance of conspecific[4] or inter-specific interactions that could distract the raptors, leading to collisions.[5]

During the field trips, the SRC observed multiple opportunities for relocating wind turbines from relatively hazardous to safer locations, or to locations where overall safety to birds could be increased. The SRC concluded that the companies could likely relocate at least some of the wind turbines the SRC recommended for removal, with relocation sites subject to SRC approval. In order to provide a common understanding of the safest relocation sites and to facilitate the identification of these sites by wind energy companies, the SRC developed guidelines characterizing preferred relocation sites as well as sites to be avoided (see Section 3). In addition to the need for developing written guidelines, the SRC recognized that consultation with the companies' engineers may be needed to identify opportunities for relocation, as well as technical restrictions.

The primary goal of these guidelines and of subsequent deliberations between the companies and the SRC is to relocate turbines from more hazardous to less hazardous sites and remedy existing hazardous conditions due to vacant or derelict sites, ultimately contributing to a 50% reduction in raptor mortality in the APWRA.

SECTION 2. DESCRIPTION OF SITING FACTORS

The SRC's guidelines are based largely on published and unpublished results of research in the APWRA and personal observations and experience of SRC members. Some of the most influential experience was obtained during the SRC's four-day field trip, when the SRC was able to view the cumulative distribution of fatalities recorded by the Wildlife Reporting and Response system (WRRS)[6] and scientific research studies (Orloff and Flannery 1992, Smallwood and Thelander 2004, and unpublished, on-going monitoring data). The SRC related the distribution of these fatalities to topography and wind patterns, as well as to the arrangement of wind turbines. Research reports that identified factors associated with fatalities included Orloff and

[4] "Conspecific" refers to individual(s) of the same species.

[5] Smaller birds often harass raptors while they are flying, causing them to defend themselves while fleeing the harassment. Larger-bodied raptors sometimes attack smaller-bodied raptors, in predatory-prey relationships. Also, raptors often chase individuals of the same species to defend territories or foraging space. While raptors are flying they often flush perched raptors, because the perched bird is at a strategic disadvantage. Flying raptors also sometimes change their flight direction to avoid another perched raptor, and if close by, the flying raptor will keep watch of the perched raptor. All of these types of interactions are distracting to a flying bird, and can lead to collisions.

[6] WRRS is the self-monitoring program used by the wind companies.

Flannery (1992, 1996), Smallwood and Neher (2004), Smallwood and Thelander (2004, 2005), Smallwood et al. (2007), and Smallwood et al. (2009). The biological resources section of the repowering EIR (Alameda County 1998) also contributed to the SRC's knowledge of factors associated with raptor fatalities.

The causal factors of raptor collisions with wind turbines appear to be interaction effects of raptor flight patterns with topography, wind patterns, and the arrangement of functional and non-functional wind turbines/towers. Flight patterns associated with foraging, e.g., hovering and kiting, have been most often linked to collisions, largely because most of the eye-witness accounts of red-tailed hawk and American kestrel collisions involved these behaviors. Raptors often forage where they can utilize slope-accelerated winds[7] to power their flights and to hold their positions while scanning for prey items. The spatial patterns of golden eagle fatalities among wind turbines also appear consistent with contour hunting by golden eagles.[8] Clusters of fatalities also occur where raptors have often been viewed foraging and crossing the terrain, including relatively low-lying areas, such as through canyons, ravines, saddles in and between ridges, and at the base of shoulders of hills or ridges. Steeper slopes are also associated with more fatalities.

Raptor fatalities at wind turbines have also been associated with wind turbines at the ends of turbine rows. Behavior data suggest at least some raptor species may perceive both the individual wind turbine and the row of wind turbines as units to be avoided, prompting raptors to more often attempt to fly around the entire turbine row. More frequent flights by the end-of-row turbine may be one reason why these turbines are often associated with more fatalities. Another reason for the association would be the frequent occurrence of end-of-row turbines at locations lower on the slopes, or on steeper slopes, where raptors often fly or where they may have less control of their flights. More recently, the wind companies have left derelict towers at the ends of rows as an alternative to perch-free flight diverters recommended by Richard Curry Associates (1997) and Smallwood and Thelander (2005a,b), and these derelict towers may have increased fatalities at the last functional turbine in the row, next to the derelict tower, because the end-of-row derelict towers likely attract raptors looking for perch sites. Wind turbines next to gaps in turbine strings have also sometimes been associated with fatalities, perhaps because raptors misperceive gaps created by vacant tower pads[9] or derelict or vacant towers as safe

[7] Slope-accelerated winds are winds that are accelerated due to being pushed up the slope or through a ravine or canyon. Typically, winds are strongest at the top of the slope facing the wind, or where the slope facing the wind breaks over to a gentler gradient.

[8] Contour hunting is flying relatively close to the terrain, quickly adjusting flight surfaces in complex winds to maintain a similar distance from the ground while traversing multiple slopes. The strategy is intended to surprise prey items by suddenly appearing from over a narrow ridgeline or from around the corner.

[9] "Vacant tower pads" are turbine addresses lacking turbines or towers.

crossing points through the turbine row. Also, raptor behavior and fatality data have indicated an avoidance of denser turbine fields[10] (Smallwood and Thelander 2004, 2005; Smallwood, Lee Neher, Doug Bell, Joe DiDonato, Brian Karas, Sara Snyder, and Sal Lopez, unpublished data in submitted final report to Public Interest Energy Research Program), and greater mortality at more isolated turbines and at turbines at the edges of the wind farm or local turbine fields (Smallwood and Thelander 2004, 2005).

Additional fatality associations have been documented or suspected, including at wind turbines nearby rock piles, trees, ponds, transmission towers, litter control fences outside the perimeter of the landfill, and electric distribution poles. Some of these features might attract perching raptors, thereby placing perched raptors near functional wind turbines. As suggested earlier, perched raptors can interact with other animals. They can attack prey items from the perch, they can change flight paths of conspecifics or other smaller-bodied raptor species, and they can be flushed by other raptors. These types of interactions can distract birds, leading to collisions with wind turbines.

SECTION 3. SITING GUIDELINES

The siting guidelines apply primarily to wind turbine relocations. *Relocation* refers to turbines that have been recommended for removal due to hazardous conditions for which these guidelines can assist the wind companies in selecting a less hazardous relocation site. The guidelines may also apply to turbines that are removed or become derelict in the future, causing hazardous conditions that can be created by newly vacant or derelict sites. The guidelines may also be useful for siting new wind turbines as part of repowering.[11] However, these guidelines apply specifically to wind turbine 'addresses,' which are the locations permitted for wind turbine operations.

These guidelines, which are not intended for any other locations that were not permitted with an existing wind turbine address as of January 2006, list the features of preferred sites or settings into which wind turbines can be relocated. The guidelines also list features of sites or settings into which wind turbine relocations are discouraged. The guidelines are deliberately not ranked, because the SRC recognizes that each of the thousands of wind turbine addresses in the APWRA have unique combinations of conditions that can mitigate or enhance the hazard associated with individual factors. As the SRC continues its efforts to understand the conditions under which a turbine location presents excessive hazards to birds, then there may be additional settings or

[10] A turbine field is a group of turbines, sometimes but not always of the same model, that are relatively separated from other groups of turbines. An example would be the AES-owned Micon 65-KW turbines near Mountain House.

[11] Repowering is the replacement of existing, old-generation wind turbines with new, modern turbines.

situations not covered in these guidelines that the SRC later determines to be too hazardous for a wind turbine relocation.

Preferred Relocation Sites or Settings

a. Hill peaks, ridge crests, and relatively even terrain to fill gaps due to presently derelict or vacant towers, or empty pads (Photos 1 and 2);

b. Wind walls[12] where vacant or derelict towers create vertical or lateral gaps between functional turbines (Photo 3);

c. Into turbine rows that already occur in high density, i.e., to increase the density of an already dense turbine field (Photo 4);

d. Interior to the turbine row to fill small gaps created by the removal of a turbine or where vacant towers occur as potential perch sites, except in cases where a gap in the interior of a turbine row is large enough to provide a safe flight path, and where relocating a turbine into that gap would result in a smaller unsafe gap (Photos 5 and 6);

e. Slopes that are leeward to one or two prevailing wind directions or that are set back from slopes facing prevailing wind directions (Photo 7); and,

f. Interior to a turbine field, unless the location is within a ridge saddle or on a steep slope, or unless other factors about the site outweigh the hazard reduction that may be achieved by the site's interior location.

Discouraged Relocation Sites or Settings

a. Sites classified as Tier 1, Tier 2, or Tier 3 according to any of the Tier classifications developed by Smallwood and Spiegel (2005a,b,c), unless the proposed new turbine arrangement creates a situation where a relocation to one of these addresses would improve safety to birds;

b. Ends of turbine rows, especially where the end of the row is at the edge of a steep slope, on a steep slope, or in a saddle, ravine, or canyon (Photo 8);

[12] Wind walls are rows of wind turbines mounted on towers at two heights above the ground, so that turbines on shorter towers are immediately in front of turbines on taller towers.

c. Where raptor fatalities have been reported previously, or potential flight paths have been identified such as through excessively long rows, unless the conditions associated with greater hazard have since changed so that the particular locations are no longer as hazardous;

d. Saddles of ridges or saddles between ridges, and especially where saddles form the apex of ravines that face a prevailing wind direction (Photos 9 through 13) or especially where these types of slope conditions occur in combination with nearby electric distribution lines (Photo 14) or other tall structures;

e. On benches of hill slopes or ridges, or just at the base of shoulders of hills, i.e., in locations of sudden elevation changes, where a raptor more often decides to fly while contouring around the slope (Photos 15, 16, and 20);

f. On or immediately adjacent to steep slopes (Photo 17);

g. At the edges of turbine fields or at the edge of the wind farm, unless the relocation somehow reduces the hazard posed by other nearby wind turbines occurring at the edge;

h. Next to artificial rock piles or natural rock formations, so long as addresses of equal or lesser hazard are available where there are no rock piles or rock formations within 100 meters (Photo 18);

i. Next to streams or ponds (Photo 13);

j. Next to transmission towers, electric distribution poles, or litter control fence around the landfill (Photos 19 and 20);

k. Where slope-accelerated winds would likely position a raptor at the height domain of the rotor plain of functional turbines (Photo 21), including where lips in the slope can locally accelerate winds used by hovering or kiting American kestrels (Photo 22);

l. Gaps in strings that are large enough for birds to safely cross (Photo 223);

m. Locations remote from other functional wind turbines, or more isolated locations; and,
n. Where turbine rows suddenly change directions (Photo 24).

Photo 1. The two derelict towers to either side of this functional turbine on the ridge crest should either be removed or put back into service. If the derelict towers are removed, then the interior functional turbine should also be removed.

Photo 2. A derelict tower interior to the turbine row and at the top of the hill would be a relatively safer relocation site.

Photo 3. Turbines missing from tall towers in wind walls (e.g., red highlight at left) can create vertical and lateral gaps in turbine operations, which might be misperceived by raptors as safe perches or fly-through locations. Turbines removed from shorter towers, such as the functional one highlighted on the right, can also create vertical and lateral gaps.

Photo 4. Where possible, turbine relocations should be directed to the interior aspect of relatively denser turbine fields.

Photo 5. Turbine relocations would be relatively safer at towers interior to the turbine rows and atop a hill or ridge.

Photo 6. Turbine relocations would be relatively safer at towers interior to the turbine rows and atop a hill or ridge.

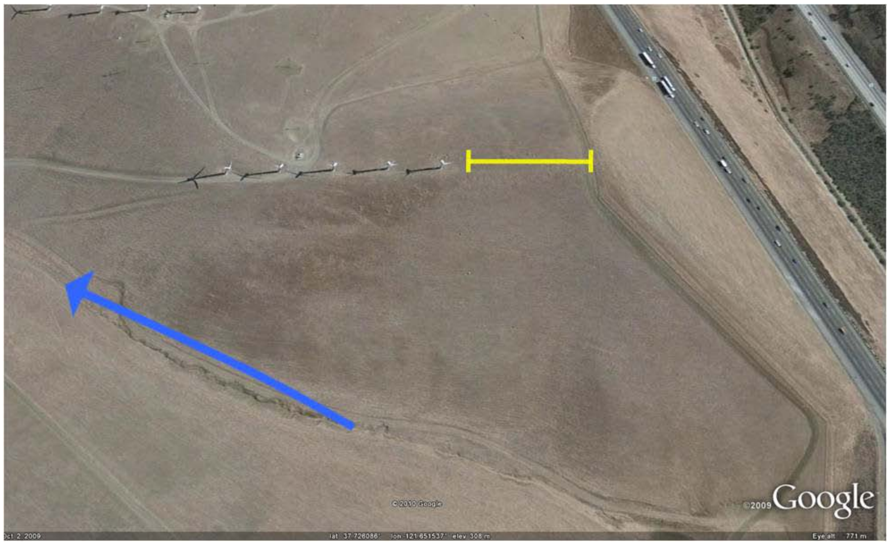


Photo 7. Turbine relocations would be relatively safer where they are set back (see yellow bar) from steep slopes facing prevailing wind directions (blue arrow).

Photo 8. Turbines should not be relocated to ends of turbine rows, especially where the towers are next to steep slopes or ravines, such as the derelict tower on the right side of the turbine row in the foreground.

Photo 9. Turbines should be relocated to hill peaks or ridge crests (e.g., green highlight), but not to saddles in the ridge (red highlight).

Photo 10.   Turbines should not be relocated to ridge saddles, especially in a situation like above, where trees and rock formations occur nearby.

Photo 11. Turbines should not be relocated to ridge saddles, especially where declivity winds from a prevailing wind direction funnel into the saddle, as in the red zone at the right side of this photo.

Photo 12. Wind turbines should not be relocated to saddles formed by the meeting of two ridges.

Photo 13. Wind turbines should not be relocated to saddles or to the lower aspects of a ravine or canyon, especially not next to a pond or stream.

Photo 14. Slope-accelerated winds can be hazardous where wind turbines are sited, and especially if electric distribution lines or other tall structure provide American kestrels or other raptors additional perching opportunities near the wind turbines.

Photo 15. Wind turbines should not be relocated to shoulders of the ridge or hill, or where the slope suddenly changes, such as seen in this photo.

Photo 16. Wind turbines should not be relocated to shoulders of the ridge or hill, or where the slope suddenly changes, such as seen in this photo. This is especially true for long turbine rows like this one, where opportunities for raptors to fly through gaps are absent.

Photo 17. Derelict towers should not be put back into service where they abut steep slopes or ravines.

Photo 18. Derelict towers should not be put back into service where they occur near rock piles or trees or other structures that may be attractive for perching or hunting. In the photo above, rock piles appear just this side of the derelict tower, which should be removed. Note, however, that removing the derelict tower would result in a potentially hazardous gap in the turbine string, suggesting the importance of fully evaluating all hazardous conditions before a relocation or removal decision is made.

Photo 19. Avoid relocating wind turbines next to transmission towers or other perch sites.

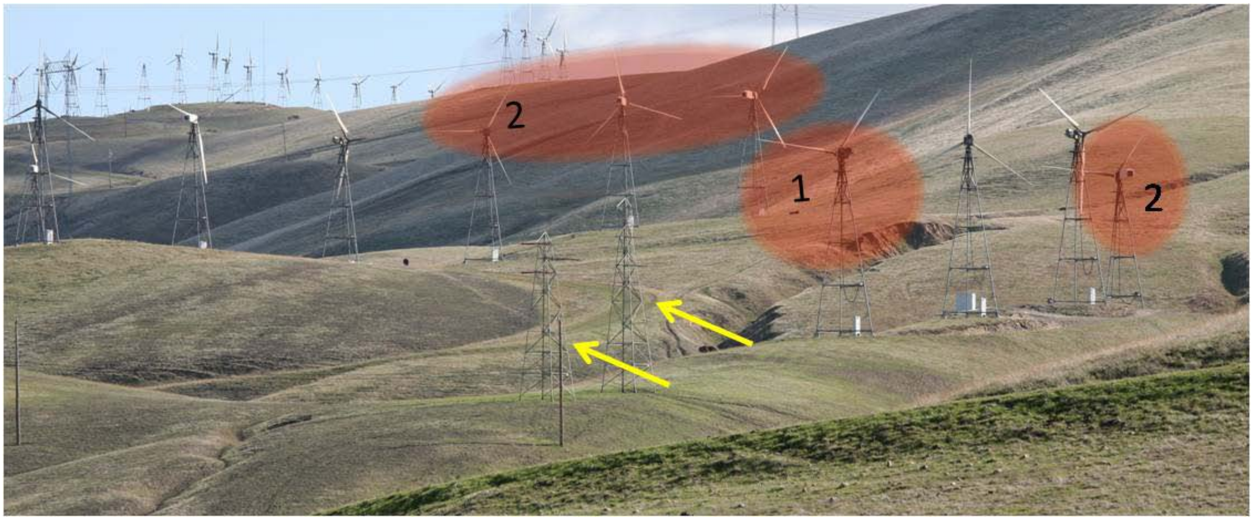


Photo 20. Avoid relocating wind turbines near transmission towers (1) or other perch sites, or to shoulders of the hill (2).

Photo 21. Wind turbines should not be relocated to locations on the slope where downslope hill morphology pushes the wind toward these locations from two different prevailing wind directions. In this photo, the red highlight identifies a portion of the air space where winds will be pushed to greater speeds by winds blowing from the northwest, west, southwest, and south.

Photo 22. Lips formed in the slope either naturally or due to grading for roads or wind turbine laydown areas might also encourage American kestrels to hover or kite in moderate and strong winds in front of wind turbines.

Photo 23. Wind turbines should not be relocated to towers within otherwise wide gaps between other turbines, such as seen above.

Photo 24. Wind turbines can be more hazardous where turbine rows zig-zag in direction (yellow arrow), especially where slope-accelerated winds (blue arrows) intersect the change in direction of the turbine row.

SECTION 4. IMMEDIATE NEXT STEPS

The SRC proposes the following steps for developing a near-term relocation plan:

1. The companies decide how many and which of the wind turbines they wish to relocate rather than remove, following the SRC's recommended removals of identified wind turbines;

2. The companies decide where they would prefer to relocate the removed turbines, and then provide a map of these locations to the SRC, as well as all current locations of potential other relocation addresses (empty pads, and derelict or vacant towers);

3. The SRC reviews the proposed relocation sites and considers other identified addresses, if needed;

4. The companies' engineers inform the SRC of which of their suggested alternative relocation addresses are infeasible and why; and

5. The SRC recommends a final relocation plan following steps 1-4, and which is directed toward immediate implementation.

The final relocation plan would be intended for immediate implementation for the purpose of achieving a 50% mortality reduction of raptors during the interim period preceding repowering of the Altamont Pass Wind Resource Area. Following the final relocation plan, the SRC recommends a relocation program for the future, during which the companies take the lead on using the SRC's relocation guidelines to evaluate the hazards associated with candidate relocations.

SECTION 5. RELOCATION PROGRAM FOR THE FUTURE

Given that wind turbine removal and relocations will continue throughout the time when wind turbines are operating in the Altamont Pass, and given that these removals and relocations will change the arrangement of wind turbines, there is a need to initiate a program to assess the collision hazards of wind turbines as they are removed or relocated. As wind turbines are removed or relocated, not only will the hazard status of the relocated turbines change, but so will the adjacent turbines from where the turbine was removed and to where the turbine will be relocated. The SRC recommends that the companies regularly update the SRC or a subcommittee of the SRC on planned or recent turbine removals and relocations. Alternatively, the companies could work with the SRC to train a company employee to assess the hazard status of turbines as removals and relocations are planned. These steps are necessary to ensure sustained confidence by the SRC in effectiveness of the turbine relocation management strategy outlined in these guidelines.

The final near-term relocation plan recommended by the SRC (see step 5 in Section 4) could identify turbine addresses to where the SRC feels it would be safer to relocate turbines during the subsequent relocation program. The SRC should meet and confer annually to identify new candidate relocation sites in order to remain current with changes in the APWRA. These new candidate addresses could be put into map form for implementation by the designated company employee or the SRC subcommittee.

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Bird Mortality in the Altamont Pass Wind Resource Area, California

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ABSTRACT The 165-km^2 Altamont Pass Wind Resource Area (APWRA) in west-central California includes 5,400 wind turbines, each rated to generate between 40 kW and 400 kW of electric power, or 580 MW total. Many birds residing or passing through the area are killed by collisions with these wind turbines. We searched for bird carcasses within 50 m of 4,074 wind turbines for periods ranging from 6 months to 4.5 years. Using mortality estimates adjusted for searcher detection and scavenger removal rates, we estimated the annual wind turbine–caused bird fatalities to number 67 (80% CI = 25–109) golden eagles (*Aquila chrysaetos*), 188 (80% CI = 116–259) red-tailed hawks (*Buteo jamaicensis*), 348 (80% CI = −49 to 749) American kestrels (*Falco sparverius*), 440 (80% CI = −133 to 1,013) burrowing owls (*Athene cunicularia hypugaea*), 1,127 (80% CI = −23 to 2,277) raptors, and 2,710 (80% CI = −6,100 to 11,520) birds. Adjusted mortality estimates were most sensitive to scavenger removal rate, which relates to the amount of time between fatality searches. New on-site studies of scavenger removal rates might warrant revising mortality estimates for some small-bodied bird species, although we cannot predict how the mortality estimates would change. Given the magnitude of our mortality estimates, regulatory agencies and the public should decide whether to enforce laws intended to protect species killed by APWRA wind turbines, and given the imprecision of our estimates, directed research is needed of sources of error and bias for use in studies of bird collisions wherever wind farms are developed. Precision of mortality estimates could be improved by deploying technology to remotely detect collisions and by making wind turbine power output data available to researchers so that the number of fatalities can be related directly to the actual power output of the wind turbine since the last fatality search. (JOURNAL OF WILDLIFE MANAGEMENT 72(1):215–223; 2008)

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KEY WORDS Altamont Pass, bird fatalities, mortality estimate, raptor mortality, wind energy, wind turbine.

The Altamont Pass Wind Resource Area (APWRA) began operations during the 1980s and by 1998 included about 5,400 wind turbines of various models (Fig. 1). The rated capacities of these wind turbines ranged from 40 kW to 400 kW but most ranged from 100 kW to 150 kW. If the APWRA were to generate the 580 MW of capacity for which the wind farm was rated, it would have supplied emission-free electric power sufficient for the needs of about 230,000 homes. However, beginning with the first installations, these wind turbines also killed birds that flew into the rotating blades, most species of which are protected by the Migratory Bird Treaty Act (MBTA) and some of which are protected by other state and federal laws (Table 1). Accurate estimates of the APWRA's impacts on birds are needed to decide how much effort to direct towards mitigating the impacts and to alert decision-makers of the potential impacts on birds that could be caused by other wind farms.

Annual deaths previously attributed to the APWRA's wind turbines included 28–43 golden eagles (*Aquila chrysaetos*) reported by the wind power companies (Hunt et al. 1999). Scientific estimates during 1989 and 1990, respectively, were 81 ± 112 (95% CI) and 0 ± 112 golden eagles, 121 ± 136 and 104 ± 234 medium-sized raptors such as Buteo hawks, 227 ± 416 and 82 ± 451 American kestrels (*Falco sparverius*), and 429 and 186 raptors of all species (Orloff and Flannery 1992). Estimates of annual mortality during 1998–2003 were 76–116 golden eagles, 881–1,300 raptors, and 1,767–4,721 birds (Smallwood and Thelander 2004, 2005), though these estimates were admittedly crude.

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Our first objective was to estimate mortality, which could serve as a comparative baseline to assess the effectiveness of future mitigation measures and to assess potential impacts of other proposed wind farm projects. Mortality estimates also may help with formulation of compensatory mitigation and might contribute to cumulative impacts analysis of other proposed activities in the region. Our second objective was to critically assess the precision of estimates to identify needed improvements in methodology applied to mortality monitoring. This assessment is needed because mortality estimates are being compared among wind farms for hypothesis testing (Madders and Whitfield 2006, Barclay et al. 2007) and for assessing the relative magnitude of impacts caused by wind turbines (Erickson et al. 2001), even though most estimates compared have not been peer reviewed or examined closely for consistency in methods and assumptions.

STUDY AREA

The APWRA encompassed about 165 km^2 of hilly terrain covered mostly by nonnative, annual grasses in eastern Alameda and southeastern Contra Costa Counties, California, USA (Fig. 1). Grasses and forbs grew during the rainy months of January through March, and were dead or dormant by early June. Elevations ranged from 78 m to 470 m above mean sea level. Ridges and hills generally extended northwest to southeast, bisected by intermittent streams and ravines. Cattle grazers held most of the land, leasing out wind energy rights to wind power companies.

Wind turbines were arranged in rows of up to 62 turbines, typically along ridge crests (i.e., peaks of the ridge features)