Baseline Avian and Bat Fatality Rates at the Tres Vaqueros Wind Project, Contra Costa County, California

Report to the East Bay Regional Park District

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ABSTRACT: To inform proposed plans to repower the Tres Vaqueros Wind Farm in the Contra Costa County portion of the Altamont Pass Wind Resource Area (APWRA), I relied on data from fatality searches over the last four years (2005-2009) to estimate avian and bat fatality rates at Tres Vaqueros, as well as at the other old-generation wind turbines throughout the APWRA and at the modern wind turbines at two repowered projects, i.e., Diablo Winds and Buena Vista. I relied on data outside the Tres Vaqueros Wind Farm because fatality rates were relatively low at Tres Vaqueros from 2005 to 2009, likely due to declining operations of the Howden model wind turbines. Therefore, I developed several sets of baseline fatality rate estimates, but I recommend the set presented in Table 4 that I believe is most robust and most representative of fatality rates that likely were caused by the Howden turbines prior to their decline in operations. My recommended baseline estimates were derived from least-squares regression models fitted to fatality rates estimated among turbine sizes, ranging from 0.04 MW to 1 MW in size (see Table 3). Fatality rates of most species and species groups declined with increasing turbine size, so I used the variation among all turbine size classes to predict the likely fatality rates among the 0.33 MW Howden turbines prior to their decline.

My models predicted that the 25-MW Tres Vaqueros project likely killed averages of 0.5 golden eagles (i.e., 1 every other year), >12 red-tailed hawks per year, 9 American kestrels per year, 51 burrowing owls per year, 57 raptors per year (38 to 77 per year), 206 birds per year (149 to 259 per year), overall, and >7 bats per year. Relying on data from Tres Vaqueros alone, I estimated that over the past four years the Howden wind turbines killed on average 0.75 golden eagles per year (i.e., 3 eagles every 4 years),10 red-tailed hawks per year, 2 American kestrels per year, 39 burrowing owls per year, 65 raptors per year, 218 birds per year (20 to 417 per year), but no bats. As an indicator of the fatality rates that could be expected if the new wind turbines are not sited carefully to minimize impacts, the fatality rates at the Buena Vista project can be compared, though these were based on fatality searches only over the past two years, January 2008 thorugh November 2009. The fatality rates at Buena Vista, projected to 25 MW at Tres Vaqueros, would predict mean annual fatalities of 3.5 golden eagles, 8.5 red-tailed hawks, 6.7 American kestrels, 0 burrowing owls, 20 raptors, 80 birds of all types, and 31 bats. Unless the repowered turbines are sited to minimize impacts, the repowering of Tres Vaqueros might increase fatalities of golden eagles and bats, but should reduce fatality rates by at least 65% for raptors as a group and at least 61% for all birds as a group.

INTRODUCTION

East Bay Regional Park District (EBRPD) holds title to land in the Altamont Pass Wind Resource Area (APWRA) where an existing wind power project – Tres Vaqueros -- may soon be repowered with modern, larger wind turbines. The APWRA, with between 4,000 and 5,000 existing wind turbines, is known to cause a significant number of avian deaths, estimated at 9,300 birds, including 2,230 raptors, annually (Smallwood and Karas 2009). The mission of the EBRPD is to preserve natural resource values for future generations, while the State of California has set high goals for developing renewable energy sources. Given that renewable energy development in the APWRA appears to adversely affect both birds and bats, the EBRPD places a premium on obtaining the most accurate and scientifically defensible estimates of wind generation impacts to assess both current threats to birds and bats as well as to discern means by which to reduce those impacts. Thus, the EBRPD needs estimates of baseline fatality rates resulting from operation of the existing Tres Vaqueros wind turbines. These baseline rates then need to be compared to predicted and measured fatality rates caused by the repowering of the Tres Vaqueros Wind Farm.

As of November 2009 the Tres Vaqueros Wind Farm included addresses for 85 330 kilowatt (kW) Howden turbines and one 750 kW turbine, though at least 8 of those addresses were vacant since 2000. Repowering the Tres Vaqueros Wind Farm will likely involve replacing all 86 of the originally sited Howden turbines with either 26 to 28 Turbines of 1.5 MW each or 21 to 23 turbines of 2 MW each. The repowered turbines will likely be larger than the 1 megawatt (MW) Mitsubishi turbines used in the Buena Vista project across Vasco Road. Comparing the baseline fatality rates of the existing Tres Vaqueros Wind Farm to predicted and measured fatality rates following repowering would enable EBRPD to assess whether and to what degree the repowering project changed avian and bat fatality rates. The goal, of course, would be to reduce fatality rates to the lowest levels possible. Remaining fatality levels would likely serve as the basis for compensatory mitigation.

I initially sought to develop three types of baseline estimates, and I added a fourth as the analysis progressed:

(1) Total annual fatalities caused by the Tres Vaqueros project;

(2) Fatalities per MW per year (rated capacity);

(3) Fatalities per GWH per year (actual production); and,

(4) Fatalities per MW per year projected from a model of mean fatality rates regressed on wind turbine size (MW) among all models used throughout the APWRA.

An estimate of the total annual fatalities caused by the existing Tres Vaqueros project (baseline estimate #1) informs of the total impact, regardless of the other goals of the project, such as power generation. It can contribute to concluding whether the repowering reduced the total number of fatalities. However, total annual fatalities does not provide an estimate of the number of deaths relative to the size or power output of the project, so to compare this project's impacts

to those of other projects the rates need to be normalized by a common denominator. Comparing fatalities per MW per year (baseline estimates #2) using rated capacity of the wind project provides information on the project's impacts relative to its size, and enables comparisons of impacts between wind farms in the APWRA and other wind resource areas. However, comparing fatalities per MW per year does not account for variation in power output between turbine models and turbine locations within a wind farm; in other words, it does not factor in turbine performance. Comparing fatalities per gigawatt-hour (GWH) per year (baseline estimate #3) relates the number of birds or bats killed to the actual electric power produced by a wind project. This comparison can be useful for assessing the balance achieved between turbine-caused fatalities and renewable energy generation. Additionally, the number of fatalities per GWH is a useful metric for comparing the relative impacts of existing wind turbines if the location and output of individual wind turbines is known, which might help with future turbine siting and decisions about turbine operations.

Baseline fatality rates projected from a regression model based on turbine size (baseline estimates #4) emerged during the analysis as I discovered that the Howden wind turbines had been declining rapidly since the start of fatality monitoring in 2005 (Figure 1). In fact, none of the Howden turbines continued to operate after November 2008. Using the fatality monitoring data from Tres Vaqueros alone could prove misleading as the foundation for baseline fatality rates because the baseline conditions were rapidly changing. The regression model projections from thousands of wind turbines that were not declining at the same rate as Tres Vaqueros might represent more robust baseline fatality rates typical of the Tres Vaqueros Wind Farm prior to fatality monitoring in 2005.

The objectives for this study were to: (1) Estimate fatality rates and total annual fatalities among the Howden turbines in the Tres Vaqueros project over the past four years (fall 2005 to fall 2009); (2) Estimate fatality rates among all old-generation wind turbines in the APWRA over the past four years; (3) Estimate fatality rates of repowered modern turbines; (4) Estimate monthly fatality rates; and (5) Test whether fatality rates at the most similar repowered project (Buena Vista) relate to topographic features. The first three objectives were intended to establish baseline fatality rates for comparison to fatality rates that may be realized by the repowering of the Tres Vaqueros project. Objectives 4 and 5 were intended to identify opportunities for minimizing fatality rates through turbine siting and turbine operations.

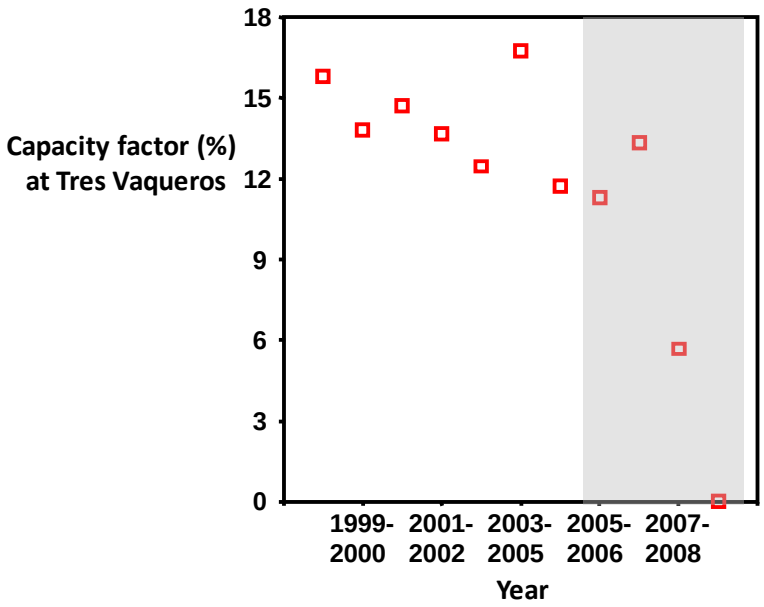

Figure 1. Project-wide capacity factor declined since 1998, but dropped to zero during the four year period of fatality monitoring that was used to establish baseline fatality rates at Tres Vaqueros Wind Farm.

METHODS

Study Site

APWRA.--The Altamont Pass Wind Resource Area encompasses about 165 km^2 (16,500 ha) of ridges and hills generally extending northwest to southeast in eastern Alameda and southeastern Contra Costa Counties, California. Located in the Inner Coast Range geomorphic province and bordering the Central Valley province, slopes are steep above intermittent streams, springs, and stock ponds. Elevations range 78 m to 470 m above mean sea level. Slopes are covered mostly by non-native, annual grasses, which grow mostly during January through March and are dead or dormant by June. Cattle grazers hold most of the land, leasing out wind energy rights to wind power companies. Wind turbines in the APWRA are arranged in rows of 2 to 62 turbines, typically along ridge crests (i.e., peaks of the ridge features) and ridgelines extending down toward ephemeral streams. Wind turbine rows also occupy slopes, valleys, and hill peaks, and all operate in winds from any direction, although most winds originate from the southwest or northwest. Old-generation wind turbine models are listed in Smallwood and Thelander (2008).

Tres Vaqueros.—The Tres Vaqueros Windfarms LLC (Tres Vaqueros) proposed repowering project site is located within the northern portion of the APWRA, where elevations range 70 m to 300 m. The site is about 6 km southwest of Byron. The land encompassed by Tres Vaqueros includes a portion of the 2,983.35 acre Vasco Caves Regional Preserve, which is owned and managed by the East Bay Regional Park District (EBRPD) and a portion of the Los Vaqueros Reservoir watershed, which is owned and operated by the Contra Costa Water District (CCWD). However, no wind turbines are currently situated on CCWD land. Wind right ownership is complex. Blackhawk Nunn Partners and Vaquero Farms, Inc. retain wind rights to all of the land

encompassed by Tres Vaqueros Windfarms LLC except for a 249.7 ha parcel situated within Vasco Caves Regional Preserve. The EBRPD retains the wind rights over this parcel, known as Souza 1. Pattern Energy owns the 75 330-KW Howden wind turbines on Tres Vaqueros and has wind leases with EBRPD, Blackhawk Nunn Partners and Vaquero Farms, Inc. The original total rated capacity of the project was 28.8 MW, but the operating capacity was closer to 25 MW in 2005.

Avian Fatality Monitoring in the APWRA

Field methods have been described in multiple reports (Smallwood and Thelander 2008, Smallwood and Karas 2009, Smallwood et al. 2009b, Smallwood et al. 2010, Insignia Environmental 2009). A team of investigators funded by the California Energy Commission searched for fatalities at systematically selected turbine rows in Tres Vaqueros during 2002-2003, but only twice and separated by about 90 days (Smallwood and Thelander 2004, 2008). Given the number of surveys performed in more recent fatality monitoring, I did not see much value in relying on the earlier surveys to establish baseline fatality rates for repowering. Therefore, the baseline fatality rates considered herein were estimated from surveys performed since 2005. (However, most estimates of monthly fatality rates presented here were based on surveys performed in the APWRA from 1998 through 2009.)

The Alameda County Avian Monitoring Team searched for fatalities among about 2,700 turbines beginning in 2005 (Table 1). Searches were performed at all very small turbines (40-65 KW), all large turbines (250-400 KW), all Diablo Winds repowered turbines (660 KW), and randomly selected blocks of medium-sized old-generation turbines (95-200 KW). Thus, all Tres Vaqueros turbines were searched beginning in fall 2005. In spring 2006, EBRPD took over the fatality searches among 42 of the Tres Vaqueros turbines, consisting of all the turbines on the Souza 1 parcel of Vasco Caves Regional Preserve. These 42 turbines were searched by EBRPD through September 2007, but they were not searched by anyone afterwards. The other Tres Vaqueros turbines have been searched by the Alameda County Avian Monitoring Team since fall 2005.

Data Management

The data collected from the Alameda County Avian Monitoring Team were made publicly available in July 2009, but the complexity of the data base required considerable data management and coordination with the Monitoring Team to understand the data and correct errors. I also had to transfer the data to a professional analytical software package, i.e., to SPSS. Most of the assumptions I used in this analysis were debated and finally agreed upon by the Alameda County Scientific Review Committee (SRC) and Avian Monitoring team.

Study Design

WEST, Inc. initially designed the current APWRA fatality monitoring program. Begun in the fall of 2005, this monitoring program relied on a stratified sampling design based on wind turbine size classes (Table 1). The APWRA monitoring team has since implemented modifications to the sampling design as recommended by the SRC. It is important to understand the sampling design because I estimated fatality rates separately for each of five sampling strata.

Table 1. Summary of fatality searches in the APWRA since 2005, including searches by Alameda County Avian Monitoring Team (Alameda), Insignia environmental (Insignia), and East Bay Regional Park District (EBRPD).

Sample	Searched	Search team	No. towers	MW of rated capacity	Search radius (m)	Mean search interval (days)	Mean years	Dates
Diablo Winds 660 KW	All	Alameda	31	20.46	75	32.08	4.33	Apr 2005 to Oct 2009
Buena Vista 1 MW	All	Insignia	38	38.00	75	15/30	1.92[a]	Jan 2008 – Nov 2009
Old turbines 95-200 KW	Random blocks	Alameda	1,869	188.69	50	34.75	3.72	Oct 2005 – Oct 2009[b]
Small turbines 40-65 KW	All	Alameda	759	45.10	50	35.91	3.90	Oct 2005 – Oct 2009
Old turbines 250-400 KW	All	Alameda/ EBRPD	135	45.54	50-60	34.63	3.08	Oct 2005 – Oct 2009
-- Tres Vaqueros 330 KW	All off Souza	Alameda	41	13.53	60	35.70	3.88	Nov 2005 – Oct 2009
-- Tres Vaqueros 330 KW	All on Souza	EBRPD	34	11.22	60	15.90	1.31	Jun 2006 – Sep 2007
Northwind (65 KW)	All on Souza	EBRPD	20	1.30	50	18.22	0.98[c]	Oct 2006 – Sep 2007

[a] Monthly searches were performed for 8 months, then bimonthly searches performed over following 15 months.
[b] Added 536 turbines to the search rotation in March 2007, increasing turbine sample from 1,233 to 1,869.
[c] Although these turbines were searched, the majority of Northwind turbines located off EBRPD property were not searched and therefore fatality rates for the Northwind wind farm were not calculated here.

Furthermore, all of the Tres Vaqueros wind turbines fell within the stratified sampling design framework. In the initial design, all very small turbines were selected for fatality searches, including all turbines rated 40 KW to 65 KW (Stratum 1). All large old-generation turbines (except, inexplicably, for 2 KVS-33 turbines) were also selected for fatality searches, including all turbines rated 250 KW to 400 KW (Stratum 2). All of the Vestas V-47 turbines in the Diablo Winds repowering project were searched (Stratum 3). All of the 38 1-MW turbines in the repowered Buena Vista project were searched by Insignia Environmental since January 2008 (Stratum 4). The remaining 430.9 MW of old-generation wind turbines in the APWRA were divided into blocks of turbine rows, where the blocks included turbines of similar type and location (Stratum 5). The pool of blocks was divided into north and south substrata, divided by Old Altamont Pass Road and I-580. Blocks were selected randomly from each substratum, but when estimating fatality rates, I ignored the north-south stratification in the initial design. Fatality rates from the randomly selected turbine blocks (Stratum 5) were the only rates that required extrapolation to turbines that were not searched, extrapolating from 188.69 MW to 430.9 MW. The Northwind turbines were excluded from the selection process because Northwind Energy refused to cooperate with the Alameda County Avian Wildlife Protection Program.

At Tres Vaqueros, specifically, all Howden turbines were searched beginning in late 2005 and early 2006, but EBRPD took over the searches of 42 of the turbines in June 2006 (Smallwood et al. 2009b). These turbines were on the Souza 1 parcel, which EBRPD obtained in 2005. The searches were modified from about monthly to about bimonthly and they continued through October 2007. The other Howden turbines at Tres Vaqueros were searched through 2009, but turbine operations ceased after October 2008.

Estimation of fatality rates

I included fatalities for estimating fatality rates if the fatalities were determined to have been possibly, probably, or certainly caused by wind turbines, and death estimated to have occurred within 90 days of carcass discovery. Also, carcasses must have been discovered within 125 m of a turbine, formerly birds capable of flying (i.e., not a nestling), and they were with certainty not counted twice due to scattered or remaining body parts. Included fatalities were tallied by species per row of turbines, so fatality rates were first calculated by turbine row and then averaged among the rows in the sample stratum. Fatalities were tallied per row of turbines because fatality searches were made at turbine rows as opposed to at individual turbines and because the close distances separating old-generation turbines often made it difficult to determine which turbine killed a bird.

Fatality rates were represented as means and standard errors among the rows of wind turbines and per period of time with distinct search intervals, and weighted means were taken when search intervals differed substantially between series of searches. The rates were then adjusted for the fatalities not found due to scavenger removal and searcher detection errors:

$$F_A = \frac{F_U}{p \times R_C},$$

where p was the proportion of fatalities found by searchers, and R_C was the estimated cumulative proportion of carcasses remaining since the last fatality search, assuming wind turbines will deposit carcasses at a steady rate through the search interval. Both p and R_C were averaged from trials throughout the U.S. (Smallwood 2007), but I also use new R_C values based on novel scavenger removal trials performed in Vasco Caves Regional Preserve (Smallwood et al. 2010):

$$R_C = \frac{\sum_{i=1}^{I} R_i}{I},$$

where R_i was the model-predicted proportion of carcasses remaining by the ith day following the initiation of a scavenger removal trial, and I was duration of the scavenger removal trial. I carried the error terms from the adjustments by using the Delta Method (Goodman 1960). Fatality rates were calculated only for species for which carcasses were detected.

For estimating monthly fatality rates, I used the same carcass inclusion rules as described previously, but my calculation of these rates differed slightly from the conventional method. Rather than expressing years as the time span from start to finish of contiguous, periodic fatality searches, I expressed years as the number of times a particular month (e.g., April or September) was covered by the fatality searches. During the current APWRA monitoring program, all 12 months would have been covered 4 times for most turbine rows, though fewer times for those rows added to the search rotation in spring 2007 and up to 5 times for turbine rows including Diablo Winds turbines.

Besides estimating fatality rates for each species, I also estimated fatality rates for groups of species. **All bats** included Mexican free-tailed bat, Hoary bat, Western red bat, and Unknown bat. **All native small birds** included Pied-billed grebe, Killdeer, Mourning dove, Dove spp., Common poorwill, White-throated swift, Northern flicker, Hammond's flycatcher, Pacific-slope flycatcher, Say's phoebe, Western kingbird, Flycatcher spp., Loggerhead shrike, Warbling vireo, Vireo spp., Western scrub-jay, American crow, Horned lark, Corvid spp., Tree swallow, Violet-green swallow, Cliff swallow, Barn swallow, Swallow spp., Rock wren, House wren, Western bluebird, Mountain bluebird, Bluebird spp., Swainson's thrush, Northern mockingbird, American pipit, Yellow warbler, Black-throated gray warbler, Wilson's warbler, Western tanager, Spotted towhee, Savannah sparrow, Fox sparrow, Lincoln sparrow, Golden-crowned sparrow, Sparrow spp., Red-winged blackbird, Tricolored blackbird, Western meadowlark, Brewer's blackbird, Brown-headed cowbird, Blackbird spp., House finch, Lesser goldfinch, and Unknown bird. **All native medium and large birds** included Mallard, Ring-necked duck, Duck spp., Brown pelican, Double-crested cormorant, Great blue heron, Great egret, Cattle egret, Black-crowned night-heron, American coot, Sandhill crane, Black-necked stilt, American avocet, Lesser yellowlegs, Bonaparte's gull, Ring-billed gull, Western gull, California gull, Herring gull, Gull spp., and Common raven. **All native nonraptors** included all native small birds and all native medium and large birds. **All exotic birds** included Cockatiel, Wild turkey, Rock pigeon, European starling, and House sparrow. **All target raptors** included Golden eagle, Red-tailed hawk, American kestrel, and Burrowing owl. **All raptors** included all target raptors and Turkey vulture, White-tailed kite, Northern harrier, Red-shouldered hawk, Swainson's hawk, Ferruginous hawk, Buteo spp., Hawk spp., Peregrine falcon, Prairie falcon, Falcon spp., Raptor,

Large raptor, Small raptor, Barn owl, and Great-horned owl. **All birds** included all native nonraptors, all raptors, and all exotic birds.

I estimated fatalities/year (Baseline estimate #1) and fatalities/MW/year (Baseline estimates #2 and #3) using the fatality monitoring data collected by the Alameda County Avian Monitoring Team and by me and EBRPD during our Vasco Caves study (Smallwood et al. 2010). These fatality rate estimates were adjusted for scavenger removal rates reported in both Smallwood (2007) and Smallwood et al. (2010). Baseline estimate #3 required additional data from Pattern Energy, namely power output data from individual turbines. I received the output data for the Howden turbines in the Tres Vaqueros Wind Farm, but not for any other wind project in the APWRA. Information on individual wind farm energy production tends to be carefully guarded by energy companies. Fatality rates in baseline estimates #3 were adjusted for scavenger removal rates reported in Smallwood et al. (2010).

Baseline estimate #4 was derived by estimating fatality rates separately for each size of wind turbine (i.e., MW of rated capacity) and then using least-squares regression to estimate average fatality rates of wind turbines of the same size as the Howden model turbines, namely 330 KW. In this way the error and bias in the fatality rates that were specific to the Howden turbines were softened in their impacts on the estimates by including fatality rate estimates from thousands of other turbines operating concurrently throughout the APWRA. The intent of baseline estimate #4 was to represent typical fatality rates at Tres Vaqueros that would have preceded the decline in operations of the Howden model wind turbines since 2005. The turbine sample size was small for a couple of size classes, so I excluded these size classes as outliers when 0 values or otherwise extreme values were obtained. For burrowing owls, I excluded turbine size classes that generally occurred either along the western side of the APWRA or on the relatively flat terrain of the far eastern side, because burrowing owl abundance and fatalities were generally much lower in those areas. Fatality rates in baseline estimates #4 were adjusted for scavenger removal rates reported in Smallwood et al. (2010).

Golden eagle age classes

To help interpret patterns of fatalities of golden eagles, and to perhaps contribute to formulating more effective mitigation measures for golden eagle fatalities, I also tested whether monthly fatality rates differed by age class among golden eagles APWRA-wide. This test has become possible now that sufficient data are available.

RESULTS

Total fatalities (Baseline estimate #1)

Using fatality rates as adjusted by Smallwood et al. (2010), I estimated that the 24.75 MW of Tres Vaqueros wind turbines killed 225 birds per year over the past four years (2005-2009), including 91 native small birds, 67 raptors, <1 golden eagle, 2 American kestrels, 10 red-tailed hawks, and 40 burrowing owls (App. 1). Over the past nearly two years (2008-2009), I estimated that the 38 MW of Buena Vista wind turbines killed 122 birds per year, including 74

native small birds, 31 raptors, 5 golden eagles, 10 American kestrels, 13 red-tailed hawks, and 0 burrowing owls (App. 3).

Fatalities per MW per year (Baseline estimate #2)

Avian fatality rates were lower at Tres Vaqueros ($\bar{x}$ = 7.3-8.7) and among all the large old-generation wind turbines ($\bar{x}$ = 6.2-7.3) than observed at small and medium-sized wind turbines during 2005-2009 ($\bar{x}$ = 21.7-28.8 and 14.3-17.2, respectively), but they were greater than observed at the repowered Buena Vista wind turbines ($\bar{x}$ = 2.5-3.2) during the past two years (App. 1 and 2). However, golden eagle and American kestrel fatality rates were lower at Tres Vaqueros ($\bar{x}$ = 0.017-0.029 and 0.086-0.087) than they were at Buena Vista ($\bar{x}$ = 0.084-0.143 and 0.228-0.267). Also, no bats were found dead under Tres Vaqueros wind turbines, whereas >1 bat/MW/year was found at Buena Vista (App. 2 and 3). On the other hand, burrowing owl mortality was much greater at Tres Vaqueros than at Buena Vista ($\bar{x}$ = 1.36-1.56 compared to 0 fatalities at Buena Vista).

Monthly fatality rates.—Over the past decade and among all wind turbines monitored in the APWRA, fatality rates of golden eagle increased steadily through spring and summer and declined in fall to a winter-time nadir (Figure 2A). Fatality rates of red-tailed hawk decreased through spring and summer and jumped higher over fall and winter (Figure 2A). Fatality rates of American kestrel were relatively constant throughout the year, but dipped in April and October, and fatality rates of burrowing owl peaked in late summer/early fall and during winter (Figure 2A). The monthly trend in fatality rates of all raptors combined resembled those of red-tailed hawks and burrowing owls (Figure 2B), because their rates were among the highest among raptors and paralleled each other. The fatality rates of all birds combined peaked in mid-winter and May, and were lowest in late winter/early spring and early fall (Figure 2B). The monthly fatality rates of all bats as a group peaked in August/September with a secondary peak in March/April (Figure 2B).

Among golden eagles assigned an age class (37%), golden eagle fatality rates were similar among age classes except for substantial deviations during fall and winter (Figure 3). Fatalities of subadult eagles declined to low levels during fall, while fatality rates of adults and juveniles increased. By the middle of winter, however, fatality rates of adult eagles declined to 0, while fatality rates of juveniles and subadults surged. Fatality rates of subadult eagles declined to 0 during spring.

Monthly fatality rates of all birds and all raptors as groups were similar between Tres Vaqueros and the repowered wind projects over the past four years (2005-2009), though there was a notable exception (Figure 4). An exception was the lack of a January peak in fatality rates of all birds at the repowered wind turbines.

Fatalities per GWH per year (Baseline estimate #2)

At Tres Vaqueros, the number of fatalities/GWH/year corresponded with energy generation for all birds and for burrowing owls in particular (Figure 5). When power output increased in 2006,

so did the fatality rates. And when power output decreased after 2006, fatality rates also decreased. Fatalities continued to be found after the Howden wind turbines were completely shut down over the last year, but they numbered 78% fewer for all birds as compared to the preceding three years. For burrowing owls, they numbered 77% fewer during the last year compared to the preceding three years, and 83% fewer compared to the first two years of monitoring. Similar to the result reported in Smallwood et al. (2010), burrowing owl fatalities/GWH/year declined with increasing average capacity factor among turbine rows (Figure 6). Fatality rates established from the old-generation turbines across the APWRA as well as solely from Tres Vaqueros Wind Farm appear in Table 2.

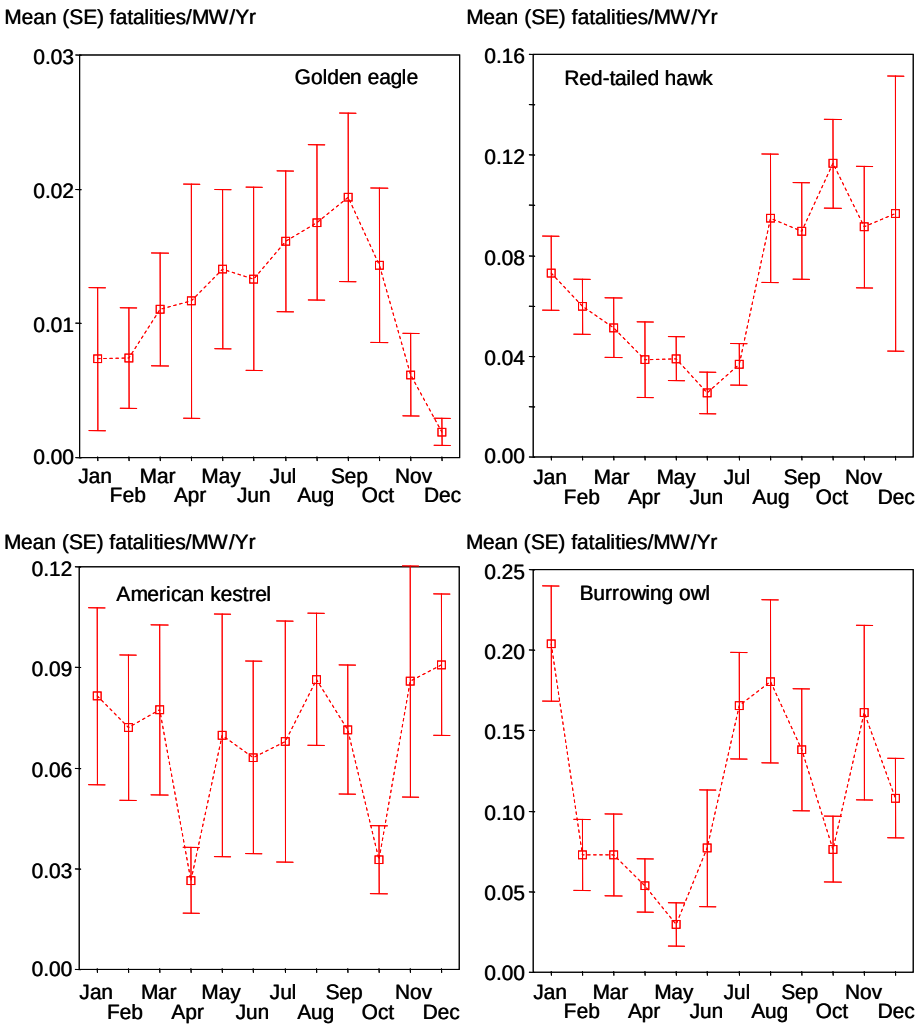

Figure 2A. Mean (and standard error) monthly fatality rates of Golden eagle, red-tailed hawk, American kestrel, and burrowing owl across all time periods and all wind turbines monitored in the APWRA from 1998 through 2009.

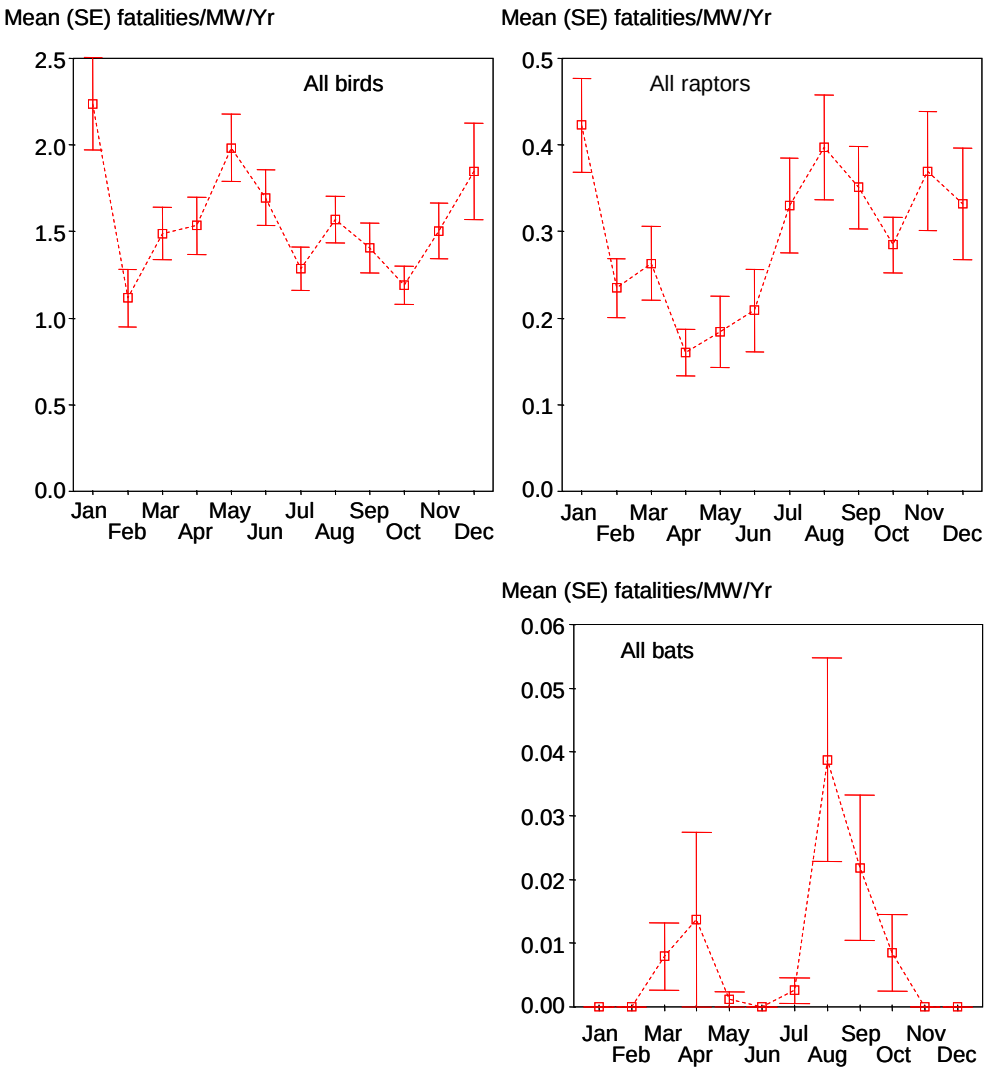

Figure 2B. Mean (and standard error) monthly fatality rates of all birds, all raptors and all bats across all time periods and all wind turbines monitored in the APWRA from 1998 through 2009.

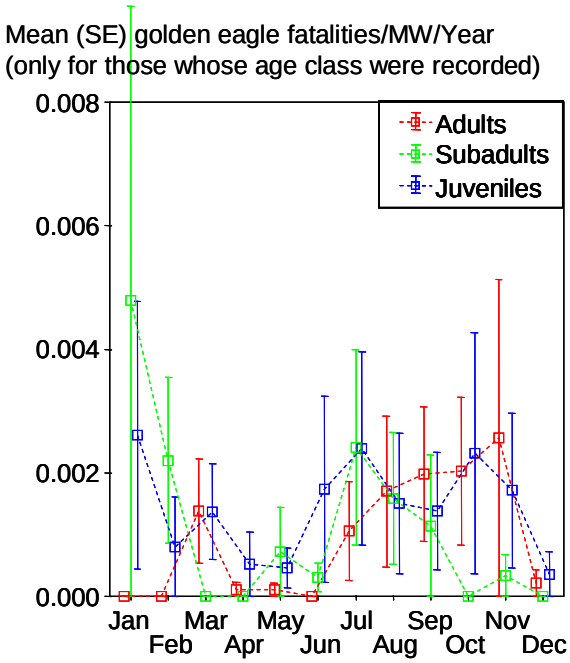

Figure 3. Monthly fatality rates of golden eagles by age class in the Altamont Pass Wind Resource Area, 1998-2009.

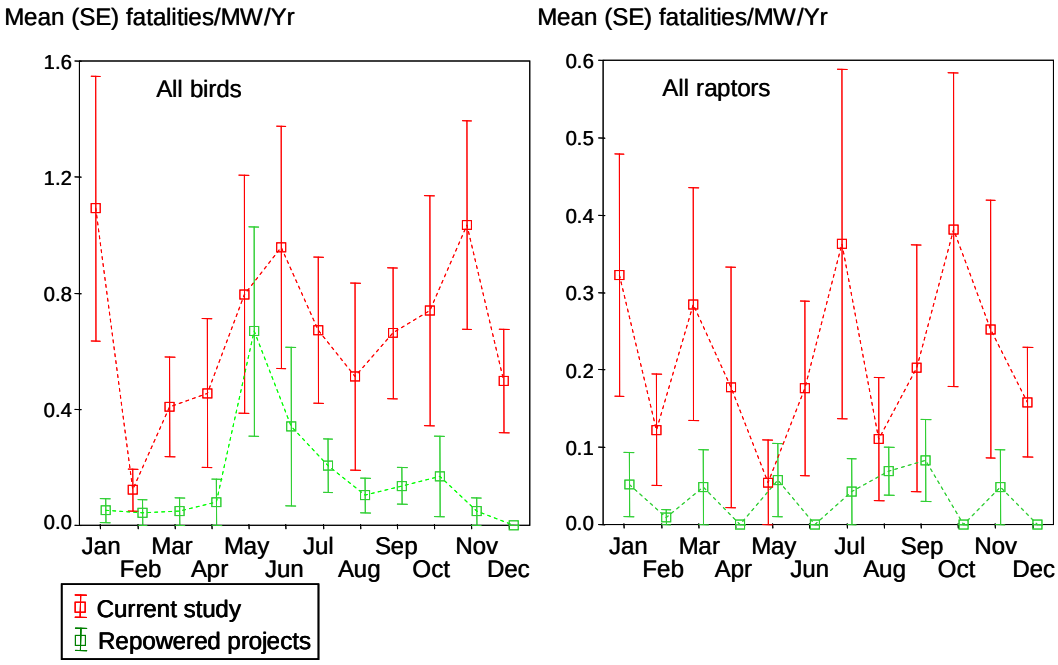

Figure 4. Comparison of monthly fatality rates between Tres Vaqueros turbines over the past 4 years (2005-2009) and both repowering projects at Buena Vista and Diablo Winds.

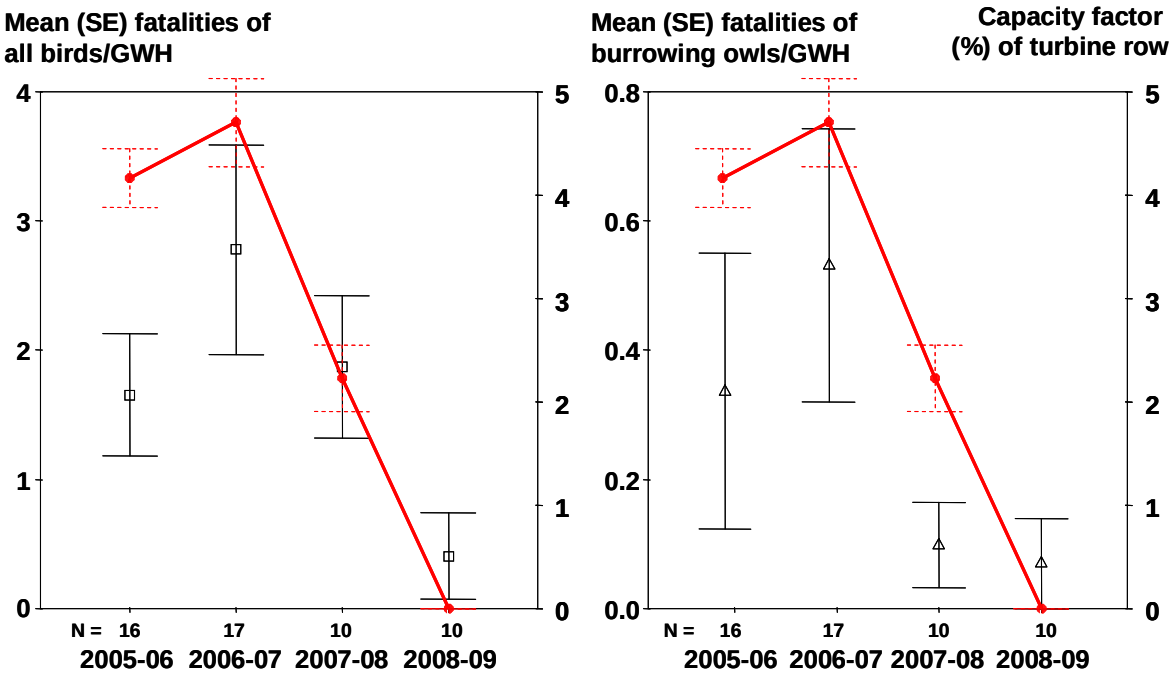

Figure 5. Estimates of mean (and standard error) annual fatalities per GWH at Tres Vaqueros for all birds as a group (left graph, squares) and for burrowing owls (right graph, triangles) compared to mean capacity factor (solid red trend line; SE denoted by dashed bars), where each year spanned November through October.

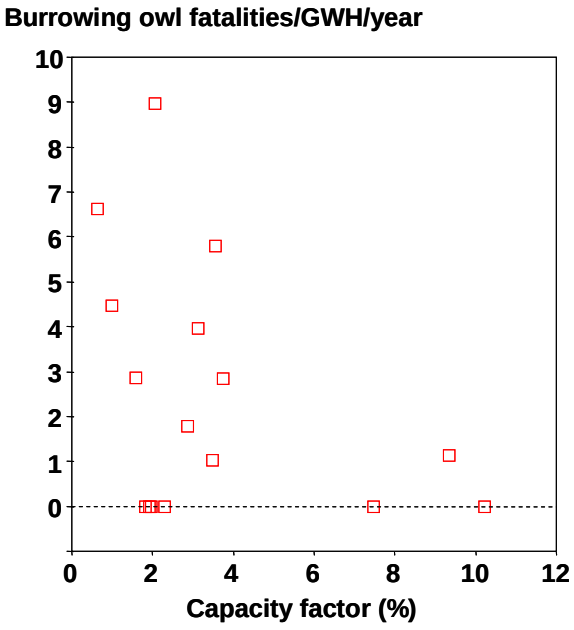

Figure 6. Burrowing owl fatalities per GWH per year declined with increasing capacity factor of the wind turbine row among the Howden turbines at Tres Vaqueros.

Table 2. Estimates of mean (standard error) annual fatalities caused by Howden wind turbines in the Tres Vaqueros wind project, Contra Costa County, California, from 2005 to 2009, calculated as fatalities per MW of rated capacity per year and as fatalities per GWH generated during the study. All estimates were adjusted by scavenger removal trials intended to prevent scavenger swamping (Smallwood et al. 2010). Estimates were from 24.75 MW of rated capacity and 5.19 GWH of average annual energy production at Tres Vaqueros.

	Adjusted annual fatalities					
	Across APWRA's old wind turbines		**At Tres Vaqueros Wind Farm**			
	Per MW		**Per MW**		**Per GWH**	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Red-tailed hawk	0.786	0.106	0.404	0.196	0.460	0.221
Ferruginous hawk	0.008	0.009	0.093	0.090	0.128	0.095
Golden eagle	0.169	0.132	0.029	0.022	0.067	0.046
American kestrel	0.900	0.347	0.086	0.067	0.144	0.100
Barn owl	0.236	0.050	0.437	0.200	0.299	0.193
Burrowing owl	1.337	0.526	1.560	0.863	2.467	0.701
Rock pigeon	2.001	0.387	0.386	0.244	0.357	0.200
Cliff swallow	0.013	0.023	0.173	0.365	0.182	0.181
European starling	3.715	1.329	1.085	0.737	1.630	0.953
Western meadowlark	2.938	1.034	1.900	0.886	3.464	1.660
All raptors	3.660	1.168	2.608	1.437	3.632	0.866
All birds	17.483	6.169	8.743	6.204	10.971	2.857
All bats	0.166	0.135	0.000	0.000	0.000	0.000

Projected fatality rates for normally operating Howden turbines (Baseline estimate #4)

Mean fatality rates declined as an inverse power function with increasing turbine size for all birds as a group, all raptors as a group, and all small endemic birds as a group (Figure 7A, Table 3). Mean fatality rates decreased with increasing turbine size for red-tailed hawk, American kestrel, and burrowing owl (Figure 7B). Golden eagle fatality rates increased with increasing turbine size over two size ranges of turbines, first with turbines ranging in size from 40 KW to 200 KW, and then again with turbines ranging in size from 330 KW to 1 MW (Figure 7B). Due to the sample size available, I also related rock pigeon fatality rates to turbine size, to demonstrate the generality of the pattern between fatality rates and turbine size (Figure 7C). Bat fatality rates increased with increasing turbine size (Figure 7C). Table 4 presents estimates of annual fatalities at Tres Vaqueros derived from the models depicted in Figure 7 and listed in Table 3.

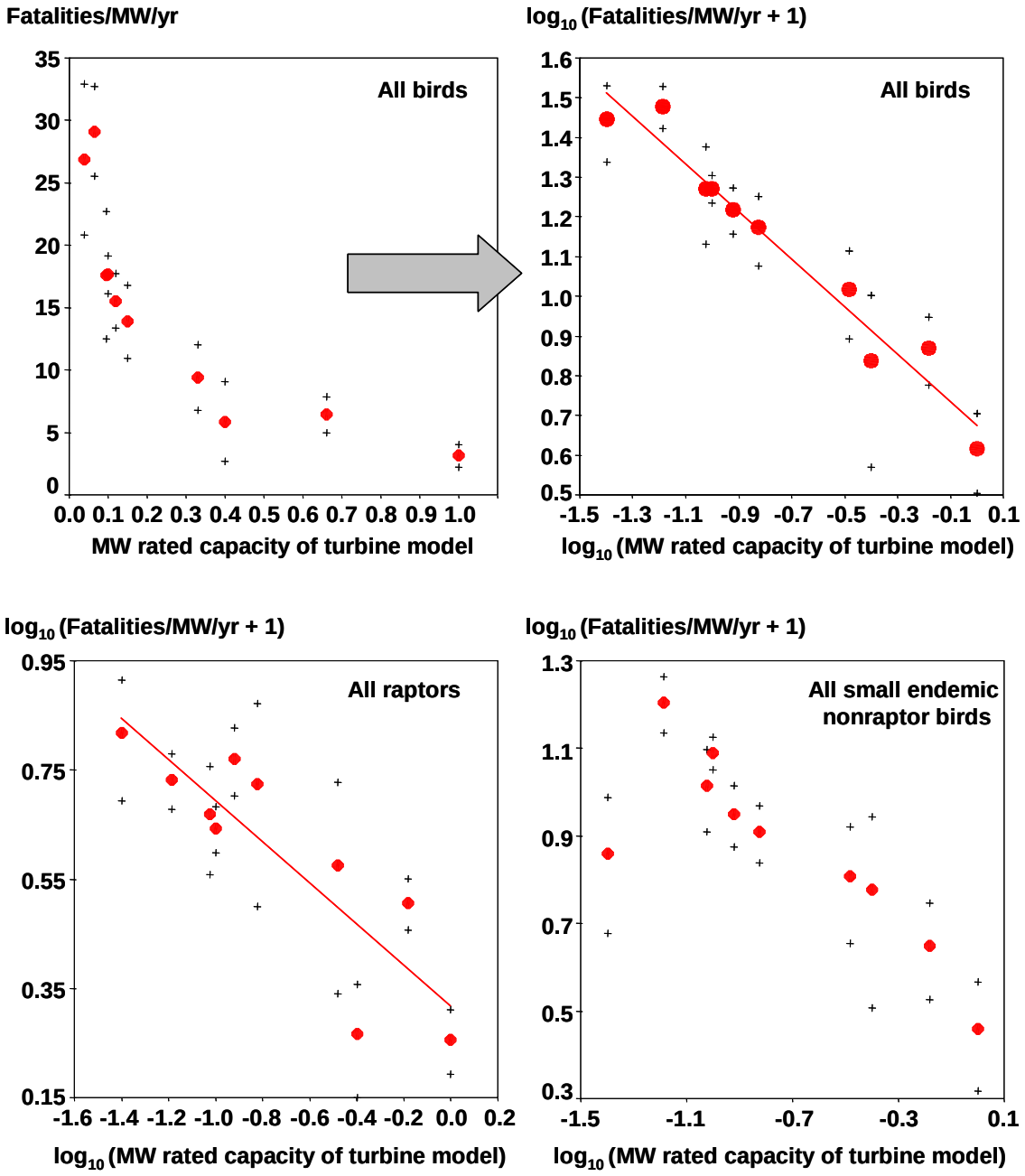

Figure 7A. Mean fatality rates (red circles) and lower and upper bounds of 80% confidence intervals (black crosses) by wind turbine size in the Altamont Pass Wind Resource Area, 2005-2009. Due to small sample size (3 turbine rows), 150-KW turbines were excluded from the comparisons. The arrow between the top graphs shows the transition from untransformed axes to $\log_{10}$-trasnformed axes.

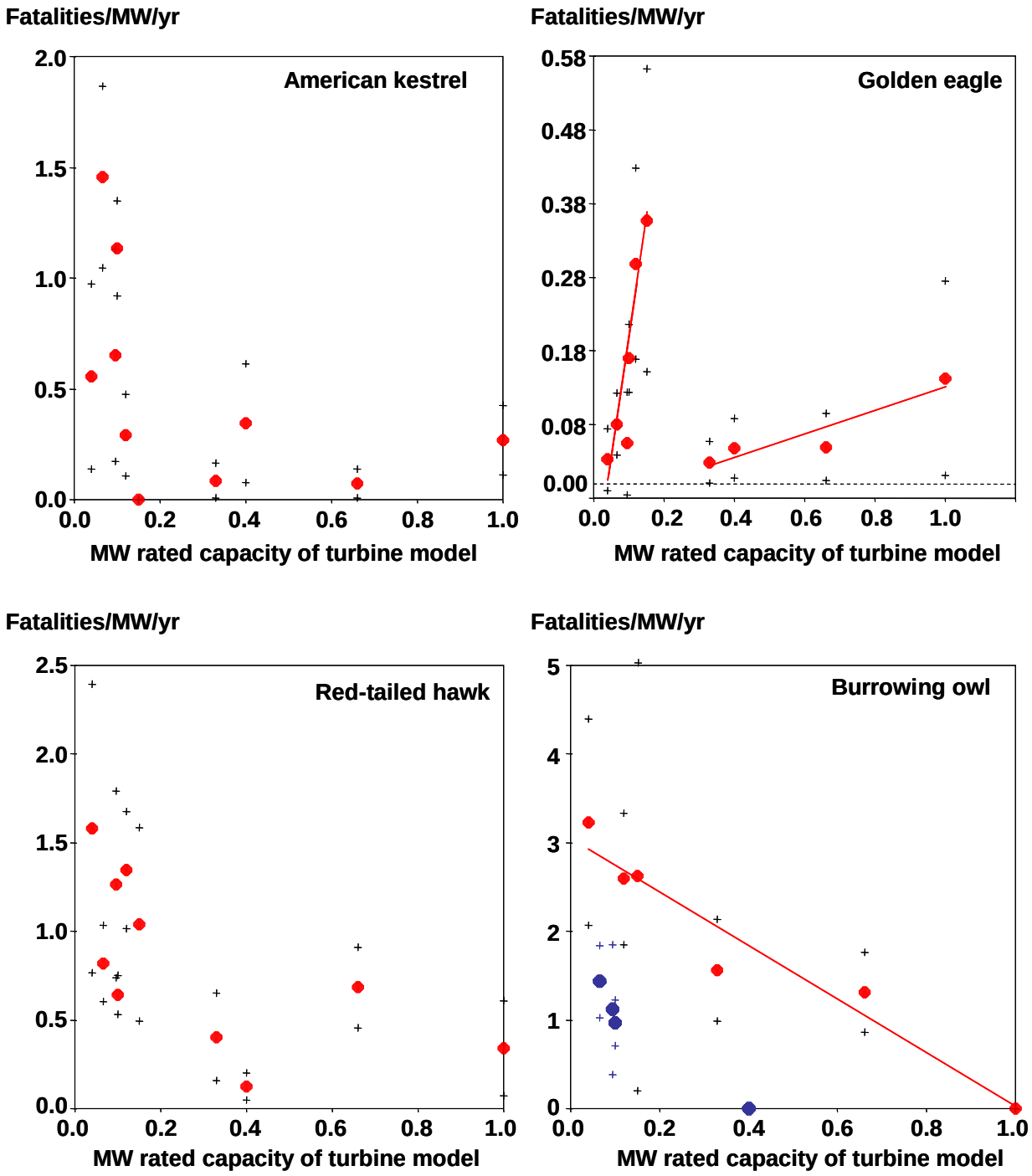

Figure 7B. Mean fatality rates (red circles) and lower and upper bounds of 80% confidence intervals (black crosses) by wind turbine size in the Altamont Pass Wind Resource Area, 2005-2009. Due to small sample size (3 turbine rows), 150-KW turbines were excluded from the comparisons. In the burrowing owl graph, blue circles denote mostly turbines on lattice towers on the west side and extreme east side of the APWRA, and the red circles and regression line represent turbines mostly on tubular towers on the hilly portion of the east side.

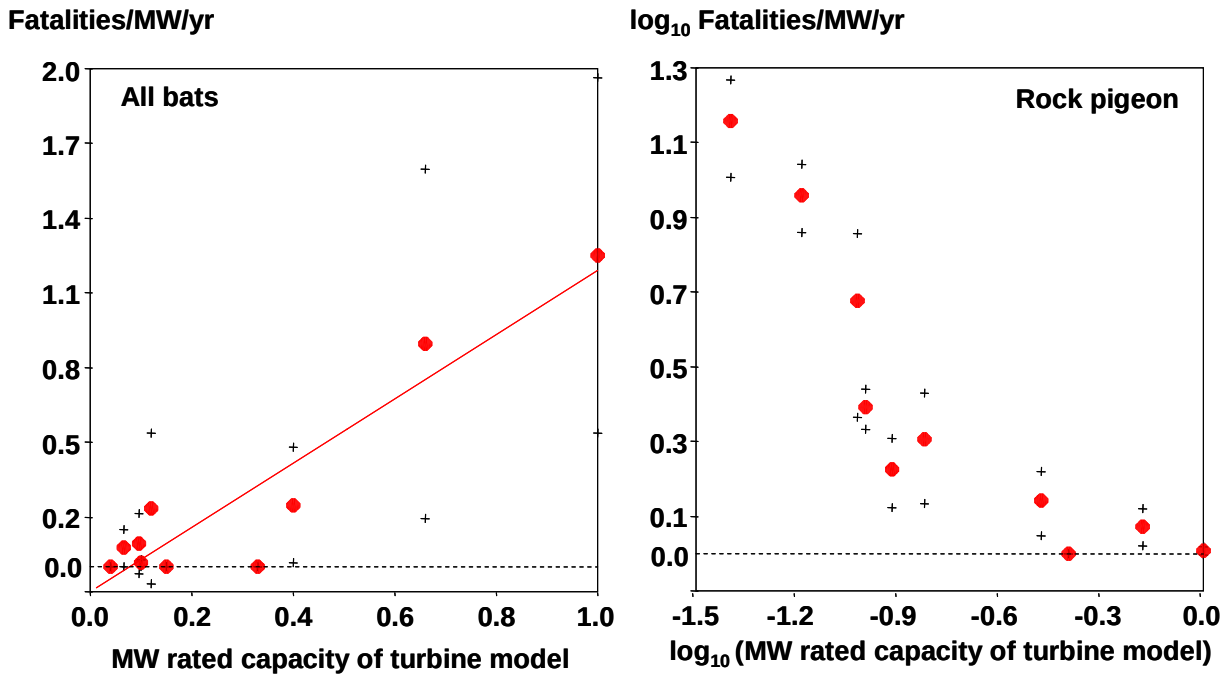

Figure 7C. Mean fatality rates (red circles) and lower and upper bounds of 80% confidence intervals (black crosses) by wind turbine size in the Altamont Pass Wind Resource Area, 2005-2009. Due to small sample size (3 turbine rows), 150-KW turbines were excluded from the comparisons.

Table 3. Least-squares regression models fit to relationships between fatality rates and wind turbine size in the Altamont Pass Wind Resource Area and used to project fatality rates at the 330-KW turbines comprising the Tres Vaqueros Wind Farm before the turbines declined to the low capacity factors observed over the past four years (2005-2009). Fatality rates were presented as means and lower (LB) and upper (UB) bounds of an 80% confidence interval. The LB and UB values were also projected from regression models fit to the data, though the model parameters for these regressions are not shown in the Table.

		Model fit parameters					**Fatalities/MW/year**		
Species	**Model**	**a**	**b**	**r^2**	**SE**	**P**	**Mean**	**LB**	**UB**
Golden eagle	Y = a + b×MW for MW = 0.04-0.20	-0.131	3.122	0.81	0.07	0.015	---	---	---
Golden eagle	Y = a + b×MW for MW = 0.25-1.00	-0.034	0.166	0.90	0.02	0.014	0.021	0.002	0.039
Red-tailed hawk	Y = a + b/MW	0.332	0.052	0.53	0.37	0.011	0.490	0.294	0.687
American kestrel	Y = a + b/MW	0.283	0.031	0.21	0.44	0.152	0.375	0.129	0.623
Burrowing owl	Y = a + b×MW for mid-east slope	3.047	-3.028	0.94	0.32	0.001	2.048	1.074	3.020
All raptors	Y = a + b×ln(MW)	0.718	-1.424	0.74	0.88	0.001	2.296	1.521	3.072
All small endemic nonraptors	$Log_{10}(Y + 1) = a + b \times log_{10}(MW)$ excluding 40 KW and 250 KW turbines (outliers)	0.515	-0.536	0.95	0.05	0.001	4.930	3.342	6.451
All birds	$Log_{10}(Y + 1) = a + b \times log_{10}(MW)$ excluding 250 KW turbines (outlier)	0.677	-0.598	0.95	0.06	0.001	8.224	5.942	10.350
All bats	Y = a + b×MW	-0.125	1.303	0.85	0.17	0.001	0.305	0.080	0.531

Table 4. Estimated annual fatalities at Tres Vaqueros Wind Farm prior to the decline in capacity factors of the Howden 330 KW wind turbines, based on regressions models fit to relationships between fatality rates and turbine size (see Table 2).

	Fatalities per year and 80% CI		
Species/Group	**Mean**	**LB**	**UB**
Golden eagle	0.525	0.050	0.975
Red-tailed hawk	12.250	7.350	17.175
American kestrel	9.375	3.225	15.575
Burrowing owl	51.200	26.850	75.500
All raptors	57.400	38.025	76.800
All small endemic nonraptors	123.250	83.550	161.275
All birds	205.600	148.550	258.750
All bats	7.625	2.000	13.275

Patterns of fatalities at Buena Vista

Mean fatality rates of all birds as a group and all raptors as a group were highest at wind turbines located in notches of ridges at the Buena Vista Wind Energy project (Figure 8A). Mean fatality rates of all bats as a group were highest amongst wind turbines on ridgelines and ridge saddles (Figure 8A). All golden eagle fatalities were at turbines located on ridge saddles and notches, and red-tailed hawk fatality rates were highest on notches, plateaus, and hill peaks (Figure 8B). American kestrel fatalities occurred on ridgelines, ridge crests, and ridge saddles (Figure 8B).

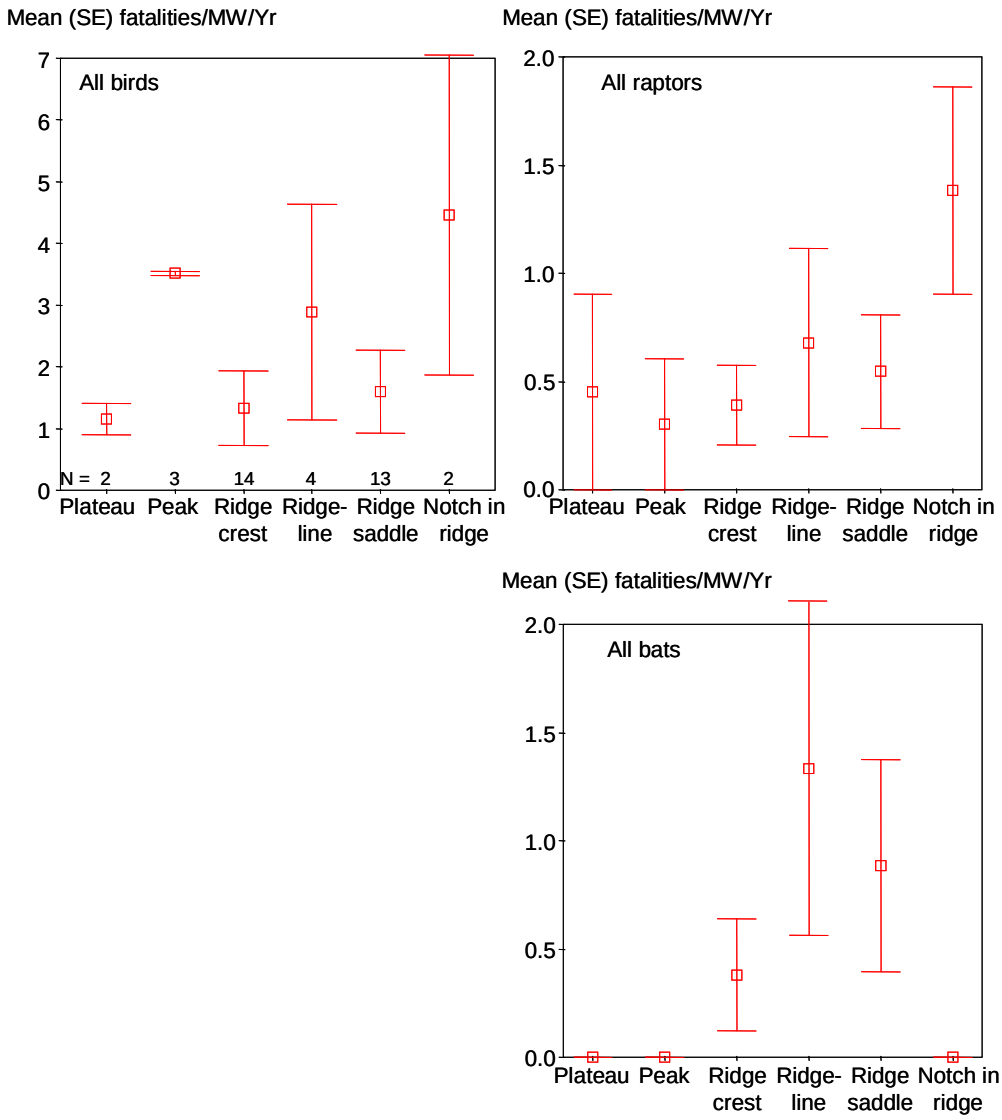

Figure 8A. Adjusted mean fatalities/MW/year among topographic features where 1-MW Mitsubishi wind turbines were sited at the Buena Vista Wind Energy project, where the adjustments were for scavenger removal and searcher detection rates (Smallwood et al. 2010).

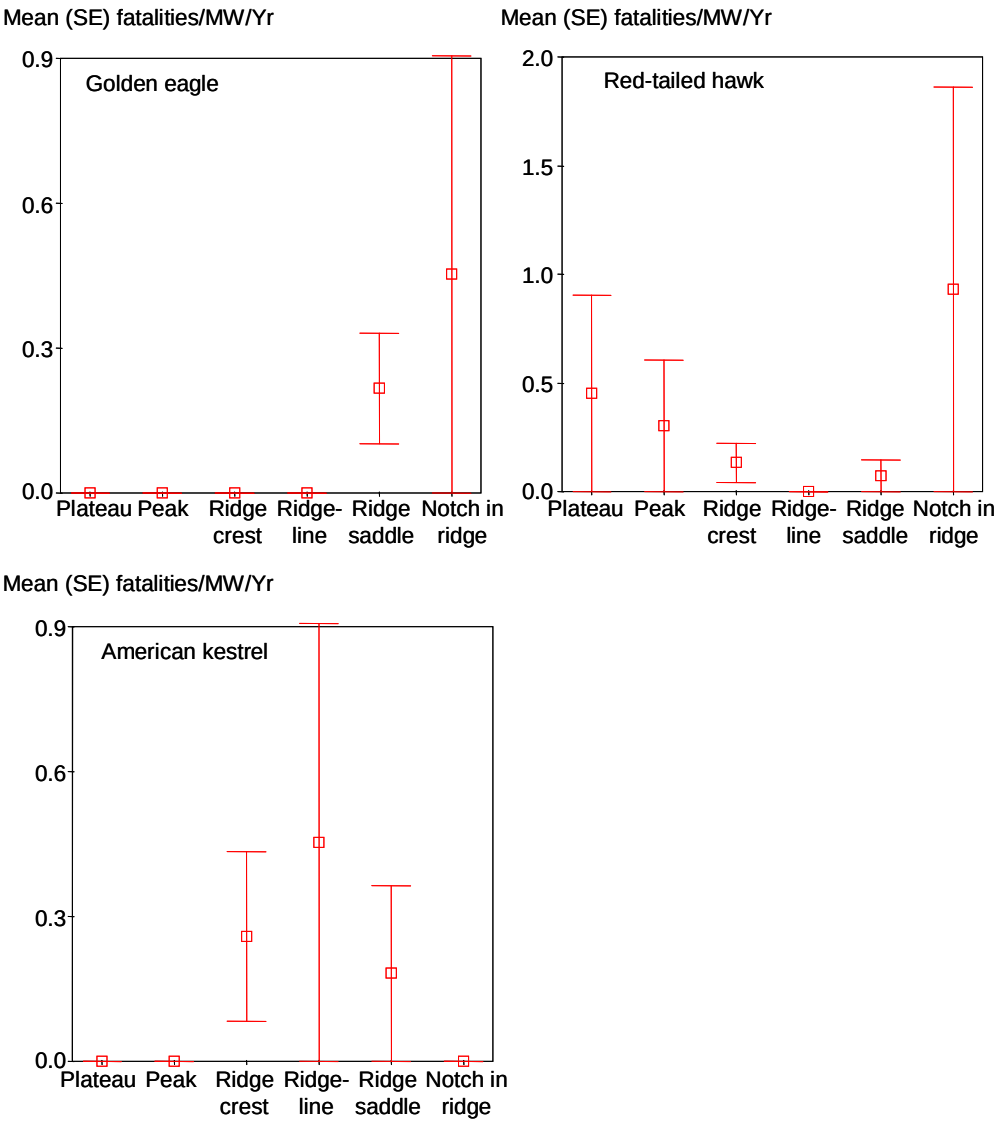

Figure 8B. Adjusted mean fatalities/MW/year among topographic features where 1-MW Mitsubishi wind turbines were sited at the Buena Vista Wind Energy project, where the adjustments were for scavenger removal and searcher detection rates (Smallwood et al. 2010).

DISCUSSION

I recommend the fatality rates in Tables 3 and 4 should be considered the baseline fatality rates for the Tres Vaqueros repowering project. These rates more robustly represent fatality rates at Tres Vaqueros before the turbines declined in capacity factor. Of course, it will be useful to compare post-repowered fatality rates to the actual fatality rates at Tres Vaqueros during 2005-2009, as well as to the fatality rates at the repowered Buena Vista Wind Energy project and all of the other projects in the APWRA, so all of those rates are reported herein.

Although the estimates of fatality rates presented herein were more comprehensive and better prepared than any previous estimates in the APWRA (see Smallwood and Thelander 2004, 2005, 2008; Smallwood et al. 2007; Smallwood and Karas 2009; Smallwood et al. 2010), I nevertheless regard them as conservative. I still cannot account for the effects of crippling bias (Smallwood 2007, Smallwood et al. 2010), and I suspect that scavenger removal rates have been faster than characterized so far. The estimates are especially conservative for bats, for which I have used small birds as the surrogate species group when calculating scavenger removal and searcher detection rates. Bats are likely removed faster than small birds and are likely more often missed by searchers when they are still present.

Estimating baseline fatality rates expressed as fatalities per GWH proved to be complicated, perhaps due to small sample size and very low energy production amongst the Howden turbines during the fatality monitoring period. For example, 0-values are obtained if no power was produced by a turbine, even if a bird or bat was found dead at that turbine. Also, GWH can vary substantially from turbine to turbine, whereas the range of variation in numbers of fatalities within a four-year period will barely affect the metric unless the fatalities fall to 0. Therefore, dividing a relatively constant value (fatalities) by a highly variable value (GWH) will force an inverse relationship between fatality rates and GWH generated per turbine or per turbine row. This relationship can be misleading, especially if the sample size is relatively small, as was the case at Tres Vaqueros. Using GWH as the basis of a fatality rate metric would make sense if the fatality rates measured this way related positively to power generation, but the reverse pattern was apparent for at least some species (Figure 6). For these reasons, fatalities per GWH may be of limited usefulness in predicting future fatality rates or for establishing baseline rates, at least among wind turbines that achieve very low capacity factors. The capacity factors of modern wind turbines will likely be much greater, however, and their relationship to fatality rates may also differ.

Opportunities to minimize or reduce fatalities

Because monthly patterns of fatality rates vary among species, no particular seasonal shutdown of turbines will uniformly benefit all species. However, August and September is when wind turbines in the APWRA kill larger numbers of bats, disproportionately more golden eagles, and most raptors. The downside to shutting down wind turbines at this time of the year is that wind power generation is near to its annual peak, so much more wind energy would need to be sacrificed to minimize bird and bat fatalities. Also, compared to previous years of monitoring (i.e., 1998-2002), red-tailed hawk fatalities were reduced during APWRA turbine shutdowns over the past four years, only to increase during the several months following the shutdown,

indicating that red-tailed hawks tend to stay long enough in the APWRA to get killed after periods of shutdown (unpublished data). In other words, the shutdowns may not have resulted in a net reduction of red-tailed hawk fatalities.

Fatality rates related strongly to wind turbine size, which declined with increasing turbine size for most species. The exceptions to this trend were for golden eagle and bats, which increased with turbine size. Thus, repowering may pose equal or greater threats to golden eagles and bats, unless effective mitigation measures can be formulated. For golden eagles, a scientific basis exists to more safely site the wind turbines by avoiding favored golden eagle flight paths. The same is true for bats (see Fig. 7A), though the more hazardous terrain for bats at Buena Vista was generally where turbine siting would minimize impacts to raptors (Figure 7A).

The first nearly two years of fatality monitoring at Buena Vista Wind Energy project revealed ridge saddles and notches in ridges or slopes to be the most hazardous turbine locations for golden eagle and most raptors. On the other hand, bats were more vulnerable to modern turbines on ridgelines and ridge saddles. It appears that no siting guidelines will uniformly benefit all bird and bat species, so tradeoffs will be necessary when making siting decisions at Tres Vaqueros. However, I only crudely categorized topographic features at wind turbine locations in the Buena Vista project, so a more refined study of topography and wind patterns at Buena Vista might reveal different patterns.

Immediate research needs

There is an urgent need for additional data and analysis of golden eagle flight patterns and for burrowing owl spatial distribution and fatality patterns. An analysis is underway, as Lee Neher and I are working under contract to EBRPD to relate golden eagle flight data and burrowing owl burrow location data to slope and wind data obtained in a portion of the Tres Vaqueros project area. Additional data are being processed APWRA-wide, but no results are anticipated from that effort within the next year. Flight behavior data can be more informative than fatality data (Smallwood et al. 2009c), especially when replacing old-generation turbines with much larger modern turbines. A result of this type of research should be species-specific collision hazard maps for the purpose of guiding wind turbine siting, similar to the maps produced for burrowing owl (Smallwood and Neher 2004, 2009; Smallwood et al. 2009a).

There is a need to direct research toward bat fatalities, as well as toward local bat ecology so that wind turbine-caused impacts can be assessed. Furthermore, research needs to be directed toward on-site scavenger removal and searcher detection errors. Scavenger removal and searcher detection trials should be sufficient to detect seasonal differences, since the last study performed at Tres Vaqueros hinted at slow removal rates during winter and fast removal rates during summer (Smallwood et al. 2009b, Smallwood et al. 2010).

Additional research should be directed toward avoidance effects, which can result in habitat loss to some species. The most effective way to perform this research would be to obtain data on behavior and distribution patterns prior to the installation of the proposed new wind turbines. Standardized observation data should be obtained as early as possible before project construction is underway, along with mapping of prey distributions of raptor species, so that pre-construction

use patterns can be characterized robustly and later compared to post-construction use patterns. The opportunity to learn from this type of research is especially great in the case of Tres Vaqueros because the rest of the APWRA will likely soon begin repowering. What is learned at Tres Vaqueros can benefit the rest of the APWRA as well as wind power development worldwide.

Finally, there is need for formulating offsite compensatory mitigation measures for the adverse project impacts that cannot be avoided. Fatality rates have been so high prior to repowering that there has been little hope of finding a nexus between fatalities and benefits gained through compensatory mitigation. Repowering should lessen collision-caused impacts of most bird species, and as a result the remaining collision-caused impacts might be more reasonably compensated. As repowering progresses in the APWRA, there is urgent need to establish the biological basis for compensatory mitigation measures.

Acknowledgments

I thank Douglas Bell and East Bay Regional Park District for funding this report. I also thank George Hardie and Rick Greiner of Pattern Energy for provision of the Howden wind turbine energy generation data. I also thank Brian Karas and Levin Nason for answering my many questions about the fatality data collected by the Alameda County Avian Monitoring Team.

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Appendix 1. Mean and upper and lower bounds of 80% confidence interval (LB, UB) of estimated fatalities per year of birds and bats in the Altamont Pass Wind Resource Area and in the Tres Vaqueros project in particular, adjusted for searcher detection and scavenger removal rates based on Smallwood (2007) and Smallwood et al. (2010).

	Fatalities/year and 80% CI, 2005-2009											
	Adjusted by Smallwood (2007)						Adjusted by Smallwood et al. (2010)					
	APWRA-wide			Tres Vaqueros			APWRA-wide			Tres Vaqueros		
Species	**Mean**	**LB**	**UB**	**Mean**	**LB**	**UB**	**Mean**	**LB**	**UB**	**Mean**	**LB**	**UB**
Mallard	37.9	11.2	64.6	0.0	0.0	0.0	55.3	19.0	91.6	0.0	0.0	0.0
Ring-necked duck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Puddle duck	0.9	-0.3	2.1	0.0	0.0	0.0	1.3	-0.4	3.1	0.0	0.0	0.0
Duck spp.	4.8	0.6	9.0	0.0	0.0	0.0	7.0	1.1	12.8	0.0	0.0	0.0
Wild turkey	0.6	-0.2	1.5	0.0	0.0	0.0	0.9	-0.3	2.1	0.0	0.0	0.0
Pied-billed grebe	3.4	-1.9	8.6	0.0	0.0	0.0	3.8	-1.5	9.1	0.0	0.0	0.0
Brown pelican	5.7	1.6	9.9	0.0	0.0	0.0	4.7	-1.3	10.7	0.0	0.0	0.0
Double-crested cormorant	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Great blue heron	0.5	-0.2	1.3	0.0	0.0	0.0	0.8	-0.2	1.8	0.0	0.0	0.0
Great egret	3.2	-1.0	7.4	0.0	0.0	0.0	4.7	-1.3	10.7	0.0	0.0	0.0
Cattle egret	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Black-crowned night-heron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Turkey vulture	8.9	2.8	14.9	0.0	0.0	0.0	15.2	5.0	25.4	0.0	0.0	0.0
White-tailed kite	0.3	-0.1	0.6	0.0	0.0	0.0	0.5	-0.1	1.0	0.0	0.0	0.0
Northern harrier	5.0	2.0	8.1	0.0	0.0	0.0	8.6	3.4	13.7	0.0	0.0	0.0
Red-shouldered hawk	0.3	-0.1	0.6	0.0	0.0	0.0	0.5	-0.1	1.1	0.0	0.0	0.0
Swainson's hawk	0.4	-0.1	0.9	0.0	0.0	0.0	0.7	-0.2	1.6	0.0	0.0	0.0
Red-tailed hawk	253.4	195.9	310.9	6.1	2.2	9.9	433.4	347.4	519.4	10.4	3.9	16.9
Ferruginous hawk	2.8	-0.6	6.1	1.4	-0.3	3.2	4.7	-1.0	10.3	2.4	-0.6	5.4
Buteo spp.	16.8	9.5	24.1	0.0	0.0	0.0	28.7	16.6	40.7	0.0	0.0	0.0
Hawk spp.	0.1	0.0	0.3	0.0	0.0	0.0	0.2	-0.1	0.5	0.0	0.0	0.0
Golden eagle	55.0	37.8	72.2	0.4	0.0	0.9	94.0	66.5	121.5	0.7	0.0	1.5
American kestrel	475.3	315.8	634.9	2.2	0.1	4.3	477.2	239.0	715.3	2.2	0.0	4.4
Peregrine falcon	1.2	-0.4	2.8	0.0	0.0	0.0	2.1	-0.6	4.8	0.0	0.0	0.0
Prairie falcon	1.3	0.3	2.2	0.0	0.0	0.0	2.2	0.5	3.8	0.0	0.0	0.0

Species	Fatalities/year and 80% CI, 2005-2009											
	Adjusted by Smallwood (2007)						Adjusted by Smallwood et al. (2010)					
	APWRA-wide			Tres Vaqueros			APWRA-wide			Tres Vaqueros		
	Mean	LB	UB	Mean	LB	UB	Mean	LB	UB	Mean	LB	UB
Falcon spp.	7.9	-3.6	19.3	0.0	0.0	0.0	8.3	-3.4	20.0	0.0	0.0	0.0
Raptor	9.0	5.3	12.8	0.0	0.0	0.0	15.4	9.2	21.6	0.0	0.0	0.0
Large raptor	1.0	0.1	1.9	0.0	0.0	0.0	1.6	0.1	3.2	0.0	0.0	0.0
Small raptor	0.6	-0.2	1.4	0.0	0.0	0.0	0.6	-0.2	1.4	0.0	0.0	0.0
American coot	0.4	0.1	0.8	0.0	0.0	0.0	0.4	-0.1	0.8	0.0	0.0	0.0
Sandhill crane	0.4	-0.1	0.9	0.0	0.0	0.0	0.6	-0.2	1.4	0.0	0.0	0.0
Killdeer	9.7	-0.3	19.7	0.0	0.0	0.0	10.6	1.3	20.0	0.0	0.0	0.0
Black-necked stilt	5.5	-1.6	12.7	0.0	0.0	0.0	8.1	-2.3	18.5	0.0	0.0	0.0
American avocet	2.9	1.4	4.5	0.0	0.0	0.0	2.4	0.2	4.6	0.0	0.0	0.0
Lesser yellowlegs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bonaparte's gull	0.4	-0.1	0.9	0.0	0.0	0.0	0.6	-0.2	1.4	0.0	0.0	0.0
Ring-billed gull	0.8	-0.2	1.7	0.0	0.0	0.0	1.1	-0.3	2.5	0.0	0.0	0.0
Western gull	1.2	-0.4	2.7	0.0	0.0	0.0	1.7	-0.5	3.9	0.0	0.0	0.0
California gull	44.2	10.9	77.4	0.0	0.0	0.0	64.2	18.6	109.9	0.0	0.0	0.0
Herring gull	1.2	-0.4	2.7	0.0	0.0	0.0	1.7	-0.5	3.9	0.0	0.0	0.0
Gull spp.	116.1	62.5	169.8	2.9	0.0	5.8	169.5	106.3	232.8	4.2	0.1	8.3
Rock pigeon	475.6	359.3	591.8	4.8	1.1	8.5	1039.7	779.0	1300.3	9.9	1.9	18.0
Mourning dove	186.9	41.6	332.3	1.5	-0.7	3.7	206.4	92.7	320.0	1.6	-0.6	3.9
Dove spp.	87.1	14.8	159.4	3.3	-0.7	7.2	96.4	36.8	156.1	3.6	-0.3	7.5
Cockatiel	1.3	-0.6	3.1	0.0	0.0	0.0	1.4	-0.5	3.3	0.0	0.0	0.0
Barn owl	72.6	50.0	95.2	6.6	2.7	10.5	124.1	88.0	160.2	11.2	4.7	17.8
Great-horned owl	19.0	11.1	26.9	0.0	0.0	0.0	32.5	19.5	45.6	0.0	0.0	0.0
Burrowing owl	713.9	467.4	960.3	35.1	12.5	57.7	718.3	354.0	1082.6	40.2	11.7	68.6
Common poorwill	1.0	-0.4	2.4	0.0	0.0	0.0	1.1	-0.4	2.5	0.0	0.0	0.0
White-throated swift	7.5	-1.9	16.9	0.0	0.0	0.0	8.3	-1.0	17.6	0.0	0.0	0.0
Northern flicker	18.2	-1.8	38.2	0.0	0.0	0.0	19.9	0.8	39.1	0.0	0.0	0.0
Hammond's flycatcher	1.8	-0.9	4.6	0.0	0.0	0.0	2.1	-0.8	4.9	0.0	0.0	0.0
Pacific-slope flycatcher	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Say's phoebe	8.5	-4.1	21.1	0.0	0.0	0.0	9.4	-3.4	22.2	0.0	0.0	0.0

Species	Fatalities/year and 80% CI, 2005-2009											
	Adjusted by Smallwood (2007)						Adjusted by Smallwood et al. (2010)					
	APWRA-wide			Tres Vaqueros			APWRA-wide			Tres Vaqueros		
	Mean	LB	UB	Mean	LB	UB	Mean	LB	UB	Mean	LB	UB
Western kingbird	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flycatcher spp.	10.1	-2.7	22.8	0.0	0.0	0.0	11.1	-1.6	23.7	0.0	0.0	0.0
Loggerhead shrike	94.5	15.2	173.7	0.0	0.0	0.0	104.5	38.6	170.4	0.0	0.0	0.0
Warbling vireo	6.7	-3.1	16.5	0.0	0.0	0.0	7.4	-2.6	17.4	0.0	0.0	0.0
Vireo spp.	1.2	-0.5	2.9	0.0	0.0	0.0	1.4	-0.6	3.4	0.0	0.0	0.0
Western scrub-jay	4.1	-2.2	10.5	3.7	-2.0	9.4	4.7	-1.8	11.1	4.2	-1.6	10.0
American crow	38.9	21.4	56.3	0.0	0.0	0.0	34.9	11.1	58.7	0.0	0.0	0.0
Common raven	95.4	53.1	137.7	2.5	-0.2	5.3	139.4	91.0	187.8	3.7	-0.2	7.6
Horned lark	225.1	44.5	405.7	0.0	0.0	0.0	251.0	97.4	404.7	0.0	0.0	0.0
Corvid spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tree swallow	0.5	-0.2	1.1	0.0	0.0	0.0	0.5	-0.2	1.2	0.0	0.0	0.0
Violet-green swallow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cliff swallow	8.8	-8.0	25.6	5.2	-6.6	17.1	8.2	-8.6	25.1	4.5	-7.6	16.5
Barn swallow	2.3	-1.0	5.7	0.0	0.0	0.0	2.6	-0.9	6.0	0.0	0.0	0.0
Swallow spp.	2.5	-1.1	6.1	0.0	0.0	0.0	2.7	-0.9	6.4	0.0	0.0	0.0
Rock wren	6.1	-2.7	14.8	0.0	0.0	0.0	6.6	-2.2	15.5	0.0	0.0	0.0
House wren	5.2	-0.8	11.1	0.0	0.0	0.0	5.7	-0.1	11.4	0.0	0.0	0.0
Western bluebird	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mountain bluebird	19.6	1.5	37.7	0.0	0.0	0.0	21.6	5.5	37.7	0.0	0.0	0.0
Bluebird spp.	26.1	-3.4	55.6	0.0	0.0	0.0	29.0	0.9	57.1	0.0	0.0	0.0
Swainson's thrush	3.2	-1.6	8.0	0.0	0.0	0.0	3.6	-1.3	8.4	0.0	0.0	0.0
Northern mockingbird	9.1	-1.6	19.7	0.0	0.0	0.0	9.9	-0.5	20.3	0.0	0.0	0.0
European starling	1742.5	487.5	2997.5	25.7	-0.8	52.3	1933.9	1040.4	2827.4	27.9	3.6	52.2
American pipit	11.1	-3.1	25.3	0.0	0.0	0.0	12.4	-1.6	26.3	0.0	0.0	0.0
Yellow warbler	2.7	-1.1	6.6	0.0	0.0	0.0	3.2	-1.4	7.8	0.0	0.0	0.0
Black-throated gray warbler	1.2	-0.5	2.9	0.0	0.0	0.0	1.4	-0.6	3.4	0.0	0.0	0.0
Wilson's warbler	5.6	-2.6	13.8	0.0	0.0	0.0	6.2	-2.2	14.5	0.0	0.0	0.0
Western tanager	18.3	-5.3	41.9	0.0	0.0	0.0	20.7	-5.3	46.6	0.0	0.0	0.0
Spotted towhee	0.7	-0.4	1.7	0.0	0.0	0.0	0.8	-0.3	1.8	0.0	0.0	0.0

Species	Fatalities/year and 80% CI, 2005-2009											
	Adjusted by Smallwood (2007)						Adjusted by Smallwood et al. (2010)					
	APWRA-wide			Tres Vaqueros			APWRA-wide			Tres Vaqueros		
	Mean	LB	UB	Mean	LB	UB	Mean	LB	UB	Mean	LB	UB
Savannah sparrow	0.6	-0.2	1.4	0.0	0.0	0.0	0.6	-0.2	1.4	0.0	0.0	0.0
Fox sparrow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lincoln sparrow	0.7	-0.3	1.8	0.0	0.0	0.0	0.8	-0.3	1.8	0.0	0.0	0.0
Golden-crowned sparrow	3.3	-1.3	8.0	0.0	0.0	0.0	3.8	-1.5	9.2	0.0	0.0	0.0
Sparrow spp.	3.5	-1.5	8.5	0.0	0.0	0.0	4.0	-1.7	9.8	0.0	0.0	0.0
Red-winged blackbird	60.8	7.2	114.5	5.0	-2.2	12.2	66.7	20.4	113.1	5.5	-1.8	12.8
Tricolored blackbird	3.4	-1.5	8.2	0.0	0.0	0.0	3.7	-1.2	8.6	0.0	0.0	0.0
Western meadowlark	1412.1	410.5	2413.6	45.3	8.9	81.6	1559.0	847.0	2271.0	48.9	19.7	78.1
Brewer's blackbird	51.9	3.1	100.7	0.0	0.0	0.0	57.4	12.2	102.5	0.0	0.0	0.0
Brown-headed cowbird	3.0	-1.3	7.3	0.0	0.0	0.0	3.3	-1.1	7.6	0.0	0.0	0.0
Blackbird spp.	148.7	26.3	271.2	6.1	-2.4	14.6	164.7	65.0	264.4	6.9	-1.6	15.4
House finch	1.1	-0.6	2.9	0.0	0.0	0.0	1.3	-0.5	3.0	0.0	0.0	0.0
Lesser goldfinch	1.2	-0.5	2.9	0.0	0.0	0.0	1.4	-0.6	3.4	0.0	0.0	0.0
House sparrow	0.3	-0.2	0.8	0.0	0.0	0.0	0.4	-0.1	0.9	0.0	0.0	0.0
Unknown bird	938.9	296.2	1581.6	29.7	-11.6	70.9	1115.4	591.0	1639.7	37.0	-11.0	85.0
Mexican free-tailed bat	18.1	-2.5	38.7	0.0	0.0	0.0	20.9	-1.0	42.8	0.0	0.0	0.0
Hoary bat	41.4	0.9	81.9	0.0	0.0	0.0	48.8	0.6	97.0	0.0	0.0	0.0
Western red bat	21.2	-5.7	48.1	0.0	0.0	0.0	23.2	-3.4	49.9	0.0	0.0	0.0
Unknown bat	3.1	-0.6	6.8	0.0	0.0	0.0	3.5	-0.1	7.1	0.0	0.0	0.0
All bats	83.9	-7.8	175.6	0.0	0.0	0.0	96.5	-3.9	196.8	0.0	0.0	0.0
All native small birds	3201.1	683.7	5718.5	88.1	-14.3	190.6	3538.7	1562.2	5515.2	95.1	-1.0	191.2
All native medium/large birds	577.0	275.0	879.0	17.1	-3.0	37.2	814.8	440.6	1189.0	25.0	-3.8	53.8
All native nonraptors	3778.1	958.7	6597.6	105.3	-17.3	227.8	4353.5	2002.8	6704.2	120.1	-4.8	245.0
All exotic birds	2220.3	845.9	3594.7	30.6	0.3	60.8	2976.3	1818.5	4134.1	37.9	5.5	70.2
All target raptors	1497.6	1016.9	1978.3	43.9	14.9	72.8	1722.9	1006.9	2438.8	53.5	15.6	91.4
All raptors	1644.6	1092.9	2196.4	51.9	17.3	86.5	1968.6	1143.5	2793.7	67.1	19.7	114.6
All birds	7643.1	2897.5	12388.7	187.8	0.3	375.2	9298.4	4964.8	13632.0	225.1	20.3	429.8

Appendix 2. Mean (SE) fatality rates of birds and bats in the Altamont Pass Wind Resource Area, and in the Tres Vaqueros project in particular, adjusted for searcher detection and scavenger removal errors based on Smallwood (2007).

	Fatalities/MW/year, 2005-2009 (2008-2009 at Buena Vista), adjusted based on Smallwood (2007)											
	All small turbines, 40-65 KW		Randomly selected turbines, 95-200 KW		All large old-generation turbines, 250-400 KW		Diablo Winds, 660 KW		Buena Vista 1 MW		Tres Vaqueros old-generation turbines, 330 KW	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Mallard	0.164	0.116	0.069	0.034	0.000	0.000	0.041	0.043	0.000	0.000	0.000	0.000
Ring-necked duck	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Puddle duck	0.000	0.000	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Duck spp.	0.000	0.000	0.011	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Wild turkey	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pied-billed grebe	0.000	0.000	0.000	0.000	0.000	0.000	0.164	0.200	0.000	0.000	0.000	0.000
Brown pelican	0.127	0.072	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Double-crested cormorant	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Great blue heron	0.003	0.003	0.000	0.000	0.000	0.000	0.020	0.021	0.000	0.000	0.000	0.000
Great egret	0.071	0.072	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cattle egret	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Black-crowned night-heron	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Turkey vulture	0.001	0.001	0.019	0.009	0.004	0.004	0.029	0.030	0.000	0.000	0.000	0.000
White-tailed kite	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Northern harrier	0.009	0.007	0.011	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Red-shouldered hawk	0.003	0.003	0.000	0.000	0.004	0.004	0.000	0.000	0.000	0.000	0.000	0.000
Swainson's hawk	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Red-tailed hawk	0.547	0.114	0.477	0.068	0.168	0.076	0.400	0.111	0.200	0.126	0.237	0.116
Ferruginous hawk	0.011	0.011	0.001	0.001	0.035	0.033	0.010	0.010	0.000	0.000	0.056	0.053
Buteo spp.	0.016	0.014	0.037	0.011	0.004	0.004	0.000	0.000	0.000	0.000	0.000	0.000
Hawk spp.	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Golden eagle	0.043	0.017	0.112	0.022	0.018	0.009	0.029	0.021	0.084	0.063	0.017	0.013
American kestrel	1.340	0.380	0.913	0.224	0.249	0.119	0.069	0.055	0.228	0.112	0.087	0.064
Peregrine falcon	0.000	0.000	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	Fatalities/MW/year, 2005-2009 (2008-2009 at Buena Vista), adjusted based on Smallwood (2007)											
	All small turbines, 40-65 KW		Randomly selected turbines, 95-200 KW		All large old-generation turbines, 250-400 KW		Diablo Winds, 660 KW		Buena Vista 1 MW		Tres Vaqueros old-generation turbines, 330 KW	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Prairie falcon	0.000	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.006	0.006	0.000	0.000
Falcon spp.	0.000	0.000	0.018	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Raptor	0.000	0.000	0.021	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Large raptor	0.000	0.000	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Small raptor	0.014	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
American coot	0.000	0.000	0.000	0.000	0.000	0.000	0.021	0.013	0.000	0.000	0.000	0.000
Sandhill crane	0.009	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Killdeer	0.012	0.014	0.021	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Black-necked stilt	0.000	0.000	0.013	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
American avocet	0.000	0.000	0.007	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lesser yellowlegs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bonaparte's gull	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ring-billed gull	0.000	0.000	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Western gull	0.000	0.000	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
California gull	0.004	0.005	0.085	0.042	0.000	0.000	0.021	0.022	0.180	0.185	0.000	0.000
Herring gull	0.000	0.000	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gull spp.	0.028	0.021	0.253	0.086	0.071	0.056	0.130	0.065	0.000	0.000	0.113	0.088
Rock pigeon	4.067	0.749	0.661	0.121	0.118	0.072	0.084	0.051	0.008	0.008	0.187	0.111
Mourning dove	0.752	0.435	0.327	0.191	0.185	0.182	0.178	0.147	0.000	0.000	0.059	0.066
Dove spp.	0.131	0.088	0.180	0.114	0.080	0.076	0.000	0.000	0.000	0.000	0.127	0.120
Cockatiel	0.028	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Barn owl	0.227	0.065	0.123	0.023	0.174	0.078	0.014	0.015	0.026	0.026	0.256	0.119
Great-horned owl	0.047	0.021	0.036	0.010	0.033	0.019	0.000	0.000	0.000	0.000	0.000	0.000
Burrowing owl	1.734	0.455	1.322	0.328	0.891	0.465	1.247	0.457	0.000	0.000	1.364	0.685
Common poorwill	0.022	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
White-throated swift	0.050	0.056	0.012	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Northern flicker	0.018	0.021	0.040	0.034	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	Fatalities/MW/year, 2005-2009 (2008-2009 at Buena Vista), adjusted based on Smallwood (2007)											
	All small turbines, 40-65 KW		Randomly selected turbines, 95-200 KW		All large old-generation turbines, 250-400 KW		Diablo Winds, 660 KW		Buena Vista 1 MW		Tres Vaqueros old-generation turbines, 330 KW	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Hammond's flycatcher	0.000	0.000	0.002	0.002	0.000	0.000	0.055	0.067	0.000	0.000	0.000	0.000
Pacific-slope flycatcher	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Say's phoebe	0.000	0.000	0.017	0.020	0.000	0.000	0.055	0.067	0.000	0.000	0.000	0.000
Western kingbird	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Flycatcher spp.	0.000	0.000	0.023	0.023	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Loggerhead shrike	0.199	0.136	0.189	0.120	0.037	0.042	0.109	0.101	0.000	0.000	0.000	0.000
Warbling vireo	0.000	0.000	0.000	0.000	0.147	0.168	0.000	0.000	0.000	0.000	0.000	0.000
Vireo spp.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.031	0.035	0.000	0.000
Western scrub-jay	0.000	0.000	0.000	0.000	0.091	0.109	0.000	0.000	0.000	0.000	0.145	0.173
American crow	0.074	0.027	0.072	0.018	0.000	0.000	0.000	0.000	0.120	0.123	0.000	0.000
Common raven	0.224	0.088	0.186	0.058	0.062	0.053	0.123	0.090	0.000	0.000	0.099	0.083
Horned lark	0.618	0.371	0.396	0.242	0.000	0.000	0.109	0.101	0.642	0.472	0.000	0.000
Corvid spp.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tree swallow	0.010	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Violet-green swallow	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cliff swallow	0.041	0.032	0.000	0.000	0.128	0.226	0.054	0.066	0.000	0.000	0.204	0.359
Barn swallow	0.036	0.040	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Swallow spp.	0.000	0.000	0.006	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rock wren	0.135	0.151	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
House wren	0.000	0.000	0.012	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Western bluebird	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mountain bluebird	0.018	0.020	0.044	0.031	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bluebird spp.	0.101	0.092	0.042	0.035	0.074	0.085	0.000	0.000	0.000	0.000	0.000	0.000
Swainson's thrush	0.000	0.000	0.006	0.007	0.000	0.000	0.033	0.039	0.000	0.000	0.000	0.000
Northern mockingbird	0.000	0.000	0.021	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
European starling	3.855	2.132	3.527	1.963	0.829	0.594	0.534	0.487	0.000	0.000	1.000	0.805
American pipit	0.033	0.037	0.022	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	Fatalities/MW/year, 2005-2009 (2008-2009 at Buena Vista), adjusted based on Smallwood (2007)											
	All small turbines, 40-65 KW		Randomly selected turbines, 95-200 KW		All large old-generation turbines, 250-400 KW		Diablo Winds, 660 KW		Buena Vista 1 MW		Tres Vaqueros old-generation turbines, 330 KW	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Yellow warbler	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.072	0.079	0.000	0.000
Black-throated gray warbler	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.031	0.035	0.000	0.000
Wilson's warbler	0.000	0.000	0.013	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Western tanager	0.000	0.000	0.020	0.018	0.000	0.000	0.000	0.000	0.250	0.276	0.000	0.000
Spotted towhee	0.000	0.000	0.000	0.000	0.000	0.000	0.033	0.039	0.000	0.000	0.000	0.000
Savannah sparrow	0.012	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fox sparrow	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lincoln sparrow	0.000	0.000	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Golden-crowned sparrow	0.028	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.053	0.058	0.000	0.000
Sparrow spp.	0.018	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.072	0.079	0.000	0.000
Red-winged blackbird	0.310	0.200	0.096	0.062	0.123	0.137	0.000	0.000	0.000	0.000	0.195	0.218
Tricolored blackbird	0.049	0.055	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Western meadowlark	3.401	1.905	2.682	1.462	1.509	0.910	1.485	0.943	0.107	0.116	1.760	1.101
Brewer's blackbird	0.380	0.240	0.070	0.052	0.000	0.000	0.000	0.000	0.122	0.132	0.000	0.000
Brown-headed cowbird	0.066	0.074	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Blackbird spp.	0.406	0.300	0.287	0.173	0.150	0.162	0.000	0.000	0.000	0.000	0.239	0.257
House finch	0.000	0.000	0.000	0.000	0.000	0.000	0.055	0.067	0.000	0.000	0.000	0.000
Lesser goldfinch	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.031	0.035	0.000	0.000
House sparrow	0.008	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Unknown bird	2.219	1.177	1.807	0.908	0.980	0.909	0.298	0.278	0.244	0.265	1.152	1.249
Mexican free-tailed bat	0.037	0.033	0.000	0.000	0.000	0.000	0.479	0.448	0.176	0.143	0.000	0.000
Hoary bat	0.000	0.000	0.000	0.000	0.042	0.048	0.312	0.255	0.872	0.636	0.000	0.000
Western red bat	0.022	0.024	0.045	0.044	0.016	0.019	0.000	0.000	0.000	0.000	0.000	0.000
Unknown bat	0.000	0.000	0.007	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
All bats	0.059	0.057	0.053	0.051	0.058	0.067	0.791	0.703	1.048	0.779	0.000	0.000
All native small birds	8.586	5.368	5.925	3.470	3.210	2.730	2.525	2.044	1.656	1.580	3.424	3.105
All native medium and large birds	1.183	0.589	1.122	0.402	0.426	0.385	0.458	0.323	0.301	0.308	0.666	0.609

	Fatalities/MW/year, 2005-2009 (2008-2009 at Buena Vista), adjusted based on Smallwood (2007)											
	All small turbines, 40-65 KW		Randomly selected turbines, 95-200 KW		All large old-generation turbines, 250-400 KW		Diablo Winds, 660 KW		Buena Vista 1 MW		Tres Vaqueros old-generation turbines, 330 KW	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
All native nonraptors	9.769	5.957	7.047	3.872	3.636	3.115	2.983	2.367	1.957	1.888	4.090	3.714
All exotic birds	7.958	2.922	4.190	2.086	0.946	0.666	0.618	0.537	0.008	0.008	1.187	0.917
All target raptors	3.664	0.965	2.824	0.641	1.326	0.669	1.745	0.645	0.512	0.301	1.705	0.877
All raptors	3.994	1.103	3.098	0.735	1.579	0.811	1.798	0.699	0.544	0.333	2.017	1.049
All birds	21.721	9.982	14.335	6.693	6.162	4.592	5.399	3.603	2.509	2.230	7.294	5.680

Appendix 3. Mean (SE) fatality rates of birds and bats in the Altamont Pass Wind Resource Area, and in the Tres Vaqueros project in particular, adjusted for searcher detection and scavenger removal errors based on Smallwood et al. (2010).

	Fatalities/MW/year, 2005-2009 (2008-2009 at Buena Vista), adjusted based on Smallwood et al. (2010)											
	All small turbines, 40-65 KW		Randomly selected turbines, 95-200 KW		All large old-generation turbines, 250-400 KW		Diablo Winds, 660 KW		Buena Vista, 1 MW		Tres Vaqueros old-generation turbines, 330 KW	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Mallard	0.239	0.163	0.101	0.046	0.000	0.000	0.059	0.061	0.000	0.000	0.000	0.000
Ring-necked duck	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Puddle duck	0.000	0.000	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Duck spp.	0.000	0.000	0.016	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Wild turkey	0.000	0.000	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pied-billed grebe	0.000	0.000	0.000	0.000	0.000	0.000	0.186	0.203	0.000	0.000	0.000	0.000
Brown pelican	0.104	0.104	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Double-crested cormorant	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Great blue heron	0.004	0.004	0.000	0.000	0.000	0.000	0.030	0.031	0.000	0.000	0.000	0.000
Great egret	0.104	0.104	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cattle egret	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Black-crowned night-heron	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Turkey vulture	0.002	0.002	0.032	0.015	0.006	0.006	0.050	0.050	0.000	0.000	0.000	0.000
White-tailed kite	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Northern harrier	0.016	0.011	0.018	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Red-shouldered hawk	0.004	0.004	0.000	0.000	0.006	0.006	0.000	0.000	0.000	0.000	0.000	0.000
Swainson's hawk	0.000	0.000	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Red-tailed hawk	0.936	0.179	0.815	0.096	0.286	0.127	0.683	0.182	0.338	0.218	0.404	0.196
Ferruginous hawk	0.019	0.019	0.002	0.001	0.059	0.057	0.016	0.017	0.000	0.000	0.093	0.090
Buteo spp.	0.028	0.023	0.063	0.019	0.007	0.007	0.000	0.000	0.000	0.000	0.000	0.000
Hawk spp.	0.004	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Golden eagle	0.073	0.028	0.192	0.034	0.031	0.016	0.050	0.036	0.143	0.107	0.029	0.022
American kestrel	1.320	0.533	0.916	0.346	0.248	0.137	0.073	0.058	0.267	0.133	0.086	0.067
Peregrine falcon	0.000	0.000	0.005	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	Fatalities/MW/year, 2005-2009 (2008-2009 at Buena Vista), adjusted based on Smallwood et al. (2010)											
	All small turbines, 40-65 KW		Randomly selected turbines, 95-200 KW		All large old-generation turbines, 250-400 KW		Diablo Winds, 660 KW		Buena Vista, 1 MW		Tres Vaqueros old-generation turbines, 330 KW	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Prairie falcon	0.000	0.000	0.004	0.002	0.000	0.000	0.000	0.000	0.010	0.010	0.000	0.000
Falcon spp.	0.000	0.000	0.019	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Raptor	0.000	0.000	0.036	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Large raptor	0.000	0.000	0.004	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Small raptor	0.013	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
American coot	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.018	0.000	0.000	0.000	0.000
Sandhill crane	0.013	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Killdeer	0.014	0.014	0.023	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Black-necked stilt	0.000	0.000	0.019	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
American avocet	0.000	0.000	0.006	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lesser yellowlegs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bonaparte's gull	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ring-billed gull	0.000	0.000	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Western gull	0.000	0.000	0.004	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
California gull	0.007	0.007	0.124	0.057	0.000	0.000	0.030	0.031	0.259	0.272	0.000	0.000
Herring gull	0.000	0.000	0.004	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gull spp.	0.041	0.030	0.369	0.099	0.103	0.079	0.189	0.086	0.000	0.000	0.164	0.124
Rock pigeon	8.916	1.681	1.444	0.272	0.243	0.158	0.183	0.111	0.018	0.019	0.386	0.244
Mourning dove	0.822	0.335	0.362	0.145	0.204	0.180	0.201	0.135	0.000	0.000	0.064	0.067
Dove spp.	0.143	0.076	0.200	0.092	0.087	0.074	0.000	0.000	0.000	0.000	0.139	0.118
Cockatiel	0.031	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Barn owl	0.388	0.107	0.211	0.035	0.296	0.131	0.025	0.025	0.044	0.045	0.437	0.200
Great-horned owl	0.080	0.035	0.061	0.017	0.057	0.032	0.000	0.000	0.000	0.000	0.000	0.000
Burrowing owl	1.707	0.664	1.319	0.501	1.014	0.575	1.311	0.598	0.000	0.000	1.560	0.863
Common poorwill	0.024	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
White-throated swift	0.054	0.056	0.014	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Northern flicker	0.020	0.021	0.044	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	Fatalities/MW/year, 2005-2009 (2008-2009 at Buena Vista), adjusted based on Smallwood et al. (2010)											
	All small turbines, 40-65 KW		Randomly selected turbines, 95-200 KW		All large old-generation turbines, 250-400 KW		Diablo Winds, 660 KW		Buena Vista, 1 MW		Tres Vaqueros old-generation turbines, 330 KW	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Hammond's flycatcher	0.000	0.000	0.002	0.002	0.000	0.000	0.062	0.068	0.000	0.000	0.000	0.000
Pacific-slope flycatcher	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Say's phoebe	0.000	0.000	0.019	0.020	0.000	0.000	0.062	0.068	0.000	0.000	0.000	0.000
Western kingbird	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Flycatcher spp.	0.000	0.000	0.026	0.023	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Loggerhead shrike	0.217	0.119	0.210	0.098	0.041	0.043	0.123	0.097	0.000	0.000	0.000	0.000
Warbling vireo	0.000	0.000	0.000	0.000	0.162	0.171	0.000	0.000	0.000	0.000	0.000	0.000
Vireo spp.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.036	0.041	0.000	0.000
Western scrub-jay	0.000	0.000	0.000	0.000	0.102	0.110	0.000	0.000	0.000	0.000	0.162	0.175
American crow	0.061	0.038	0.059	0.023	0.000	0.000	0.000	0.000	0.173	0.181	0.000	0.000
Common raven	0.327	0.110	0.271	0.062	0.091	0.075	0.179	0.126	0.000	0.000	0.144	0.119
Horned lark	0.677	0.295	0.439	0.190	0.000	0.000	0.123	0.096	0.760	0.596	0.000	0.000
Corvid spp.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tree swallow	0.011	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Violet-green swallow	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cliff swallow	0.045	0.030	0.000	0.000	0.109	0.230	0.061	0.067	0.000	0.000	0.173	0.365
Barn swallow	0.039	0.041	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Swallow spp.	0.000	0.000	0.006	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rock wren	0.147	0.153	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
House wren	0.000	0.000	0.013	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Western bluebird	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mountain bluebird	0.019	0.020	0.048	0.027	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bluebird spp.	0.111	0.089	0.047	0.032	0.082	0.086	0.000	0.000	0.000	0.000	0.000	0.000
Swainson's thrush	0.000	0.000	0.006	0.007	0.000	0.000	0.037	0.040	0.000	0.000	0.000	0.000
Northern mockingbird	0.000	0.000	0.023	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
European starling	4.214	1.567	3.923	1.377	0.902	0.516	0.604	0.463	0.000	0.000	1.085	0.737
American pipit	0.036	0.038	0.025	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	Fatalities/MW/year, 2005-2009 (2008-2009 at Buena Vista), adjusted based on Smallwood et al. (2010)											
	All small turbines, 40-65 KW		Randomly selected turbines, 95-200 KW		All large old-generation turbines, 250-400 KW		Diablo Winds, 660 KW		Buena Vista, 1 MW		Tres Vaqueros old-generation turbines, 330 KW	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Yellow warbler	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.083	0.094	0.000	0.000
Black-throated gray warbler	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.036	0.041	0.000	0.000
Wilson's warbler	0.000	0.000	0.014	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Western tanager	0.000	0.000	0.022	0.018	0.000	0.000	0.000	0.000	0.290	0.330	0.000	0.000
Spotted towhee	0.000	0.000	0.000	0.000	0.000	0.000	0.037	0.040	0.000	0.000	0.000	0.000
Savannah sparrow	0.014	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fox sparrow	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lincoln sparrow	0.000	0.000	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Golden-crowned sparrow	0.031	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.064	0.071	0.000	0.000
Sparrow spp.	0.020	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.083	0.094	0.000	0.000
Red-winged blackbird	0.339	0.169	0.105	0.051	0.134	0.140	0.000	0.000	0.000	0.000	0.213	0.222
Tricolored blackbird	0.053	0.055	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Western meadowlark	3.726	1.412	2.964	1.019	1.639	0.710	1.680	0.735	0.128	0.143	1.900	0.886
Brewer's blackbird	0.416	0.199	0.077	0.047	0.000	0.000	0.000	0.000	0.146	0.163	0.000	0.000
Brown-headed cowbird	0.072	0.075	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Blackbird spp.	0.444	0.272	0.318	0.135	0.168	0.162	0.000	0.000	0.000	0.000	0.267	0.257
House finch	0.000	0.000	0.000	0.000	0.000	0.000	0.062	0.068	0.000	0.000	0.000	0.000
Lesser goldfinch	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.036	0.041	0.000	0.000
House sparrow	0.008	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Unknown bird	2.604	0.971	2.147	0.698	1.188	1.007	0.371	0.304	0.293	0.326	1.438	1.454
Mexican free-tailed bat	0.041	0.032	0.000	0.000	0.000	0.000	0.541	0.430	0.211	0.180	0.000	0.000
Hoary bat	0.000	0.000	0.000	0.000	0.046	0.049	0.354	0.233	1.039	0.805	0.000	0.000
Western red bat	0.024	0.025	0.050	0.044	0.018	0.019	0.000	0.000	0.000	0.000	0.000	0.000
Unknown bat	0.000	0.000	0.008	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
All bats	0.064	0.056	0.058	0.050	0.064	0.068	0.895	0.663	1.249	0.985	0.000	0.000
All native small birds	9.400	4.331	6.551	2.601	3.489	2.515	2.857	1.823	1.957	1.942	3.693	2.912
All native medium and large birds	1.601	0.786	1.589	0.475	0.621	0.552	0.655	0.452	0.432	0.453	0.972	0.873

	Fatalities/MW/year, 2005-2009 (2008-2009 at Buena Vista), adjusted based on Smallwood et al. (2010)											
	All small turbines, 40-65 KW		Randomly selected turbines, 95-200 KW		All large old-generation turbines, 250-400 KW		Diablo Winds, 660 KW		Buena Vista, 1 MW		Tres Vaqueros old-generation turbines, 330 KW	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
All native nonraptors	11.000	5.117	8.140	3.077	4.111	3.067	3.512	2.275	2.389	2.395	4.665	3.786
All exotic birds	13.169	3.289	5.369	1.651	1.145	0.674	0.788	0.575	0.018	0.019	1.471	0.981
All target raptors	4.035	1.404	3.243	0.977	1.579	0.855	2.117	0.875	0.748	0.459	2.078	1.147
All raptors	4.591	1.625	3.700	1.117	2.010	1.095	2.208	0.967	0.803	0.513	2.608	1.437
All birds	28.760	10.032	17.209	5.845	7.266	4.835	6.507	3.816	3.210	2.927	8.743	6.204