

COMPARISON OF MORTALITY ESTIMATES IN THE ALTAMONT PASS WIND RESOURCE AREA

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The Alameda County avian fatality monitoring team recently released draft estimates of bird mortality in the Altamont Pass Wind Resource Area (APWRA). As a member of the Scientific Review Committee's subcommittee directed to assist the monitoring team with the timely completion of their report, I met with monitoring team members to agree on methods and assumptions to maximize comparability between their estimates and those from the 1998-2003 monitoring program (Smallwood and Thelander 2004, 2005). I answered questions about the approach I used, and I provided recommendations to the monitoring team. In the course of working with the monitoring team, I requested and obtained the electronic spreadsheets of the data used by the monitoring team to make their estimates. Using these data, along with data I have on the monitoring program from 1998-2003 (the baseline mortality period), I made new mortality estimates. My objectives were to:

1. Provide additional quality control of the data, applying what I have learned about finding errors in these types of data;
2. Estimate APWRA-wide mortality during the last two years as a test of the repeatability of the monitoring team's estimates;
3. Modify the baseline estimates so that they are comparable to the monitoring team's estimates for the last two years;
4. Compare Diablo Winds mortality levels to those of the monitored, old-generation wind turbines; and,
5. Test the effects on mortality due to the long-term shutdown of the Vestas wind turbines in the Santa Clara turbine field.

METHODS

Due to insufficient time, I cannot detail all the methods in this draft report. Smallwood and Thelander (2008) describe most of the field methods and analytical methods that were used, and the monitoring team's report covers other aspects of the field methodology they used. Herein I will explain details of the methods that likely do not appear in these other sources.

I spent a lot of time reviewing the data the monitoring team assembled in their spreadsheets, searching for and correcting errors and identifying fatalities we decided should be excluded from mortality estimates. This type of review is routine, especially for such a large data set, and it is often referred to as *quality control*. Overall, I thought the data set was reasonably well managed, but I will provide constructive criticism where improvements can be made.

One common problem was inconsistent data entry on wind turbine identification numbers associated with the fatality. The naming and numbering systems vary among companies, and sometimes the designations are redundant between companies, so not only did the spelling/numbering of the turbine have to be exact, but an additional identifier was needed, such as plot number or string number. The plot numbers refer to the behavior observation plots, and these differed between the baseline monitoring effort and the current effort, so I relied on string number to confirm the identify of particular wind turbines. However, the monitoring team had not been using string number during their search efforts, so fatality records were not entered with string number. I had to cross-reference data sets to assign string number to each turbine where fatalities were recorded. Complicating this effort were a few errors in string assignments to turbines in the monitoring team's fatality search schedule. Also, utility pole designators were mixed in with the turbine numbers, so these pole numbers had to be identified as such and moved to another data field.

I scanned the data for evidence the fatality was caused by something other than a wind turbine. Electrocutions were commonly suspected by the monitoring team, but these suspicions were inconsistently documented in the data base in terms of where in the data base the documentation was made. Sometimes this information could be found in the data field named 'Likely cause of death,' and sometimes in 'notes,' 'Types of injuries,' 'Body parts,' or 'Evidence of death,' and sometimes it could be inferred from an electrical pole being named under 'Structure.' To find this information in multiple data fields, I relied on keyword searches and methodical review of each record. Based on what was reported for the entire fatality record, I assigned electrocution as the cause of death to each as Unlikely, Possible, Probable, or Certain. I considered electrocution *probable* if WRRS recorded the fatality as "electrocution" or if the monitoring team recorded finding the fatality within several meters of a power pole or overhead lines. I considered electrocution *certain* if the record included evidence of electrocution-caused injury.

I also assigned turbine-caused fatality to each fatality record as unlikely, possible, probable, or certain. Unlikely turbine-caused fatalities were those already regarded as having been caused by electrocution, vehicle collision or predation. Probable turbine-caused fatalities were assigned those other carcasses found near wind turbines. The assignment was 'certain' if evidence suggested a turbine was involved, such as oil or grease on the bird, paint on the bird, or the bird was split in two or dismembered due to blunt force impact. Most of the fatalities found were assigned 'probable' turbine-caused. For estimating turbine-caused mortality, I used only records assigned probable or certain.

Mortality estimates were based on fatalities that were estimated to have been caused within 90 days of discovery. Almost all records used were estimated to have been killed within 45 days of discovery, probably because fatality monitoring had been ongoing prior to the start dates used to calculate mortality at all the turbines included herein. I also searched the data base for fatalities that were of nestling birds. This information was recorded under multiple data fields, similar to the information on electrocutions, so I had to use key word searches and methodical review of each record to identify all fatality records of nestlings. All records of nestling birds were omitted from mortality estimation.

I calculated mortality as the number of dead birds per MW of rated capacity at turbine addresses that were searched by the monitoring team, regardless of whether the address supported a functional turbine or a derelict or vacant tower. If the turbine address was included in the turbine data base maintained by the monitoring team, and if the address was searched, then it was included in my calculations. Thus, removed or non-operational turbines would artificially decrease the mortality calculated at a particular turbine string, but because turbine maintenance is so dynamic in the APWRA, and because the monitoring team has not been regularly updated on turbine functionality, this was the only approach that seemed reasonable. This approach also required that I extrapolate the fatality rates to the permitted capacity of the APWRA.

I assumed mortality is not different between the Buena Vista Wind Energy project and the rest of the APWRA. The fatality rates estimated from the sampled turbines were extrapolated across the Buena Vista turbines. My assumption may be incorrect, but nobody will know until the Buena Vista turbines have been monitored and reports of mortality issued.

The Enertech turbines owned by AES, Inc. were shut down during the winter months, but I made no adjustment for these shutdowns. These winter shutdowns also were practiced during 1998-2003, during the time when data were collected for the baseline mortality estimates. Therefore, the estimates are comparable between the baseline period and the most recent monitoring period.

The monitoring team had no access to the Northwind Energy turbines in Contra Costa County, but the Smallwood et al. (unpublished data) estimates from property owned by East Bay Regional Parks District (EBRPD) included some Northwind Energy turbines. By incorporating the mortality estimates from the EBRPD monitoring effort, the estimates herein include some representation (about 12%) of the Northwind Energy turbines.

I integrated the estimates from the 12.52 MW of rated capacity that operated on the EBRPD property and from the 20.46 MW in the Diablo Winds project. To do this, I extrapolated the fatality rates estimated from the turbines monitored by the monitoring team to the 547.02 MW of rated capacity of the APWRA after subtracting the 12.52 MW on the EBRPD property and the 20.46 MW in the Diablo Winds project. I then summed the mortality estimates from each monitoring project. These separate monitoring projects differed in the number of days between search intervals, which was why I made separate estimates. The EBRPD estimates were based on an average 17-days search interval, whereas the average Diablo Winds interval was 33 days and the average APWRA-wide interval was 41 days.

To decide on which scavenger removal rates to use to adjust the mortality estimates, I examined the fatality search intervals over the two-year period. Unlike the monitoring team, who distinguished the March to September 2007 period as a shorter average search duration compared to the remainder of the two years, I found the shorter-duration searches extended back in time to at least February 2007, but I also found the cut-off date depended on the turbine string. Pre-February 2007, the average search interval was 50 days (SD = 18.4), and post-February 2007 it was 33 days (SD = 9.8). I decided against estimating mortality separately between these periods because the first period was longer than a year, and the second period was shorter than a year. Therefore, I decided to use the average search interval for the entire two years, which was 41 (SD = 16.7) days. From App. 1 in Smallwood (2007), I used the average percentage of

accumulated carcasses remaining at 41 days (these percentages were transformed to proportions for the adjustment calculation). Searcher detection rates were also taken from Smallwood (1997). The error estimates for searcher detection rates and scavenger removal rates were carried through the mortality estimation adjustments using the Delta Method (see Smallwood and Thelander 2008).

Bat mortality was estimated by applying scavenger removal and searcher detection rates estimated for small-bodied bird species (Smallwood 2007), but these rates were probably too conservative for bats. It has already been established in the literature that searchers tend to miss more bats than small birds, and the scavenger removal rate tends to be very high. Therefore, my estimates of bat mortality were likely biased low, but at least they were consistent between estimates reported herein, enabling preliminary comparisons between time periods and turbine fields.

The Vestas 100-KW turbines in the Santa Clara turbine field did not operate during 2006, so I had an opportunity to compare mortality on and off the Santa Clara turbine field during the shutdown and after the shutdown, and over a much longer period than in the winter shutdown experiment. The off site turbines included all the old-generation turbines searched by the monitoring team, except for the approximately 500 turbines that were added to the searches in March 2007, and except for the turbines on property controlled by EBRPD (I excluded fatalities from these two groups of turbines). Whereas the shutdown period was longer than a year at the Santa Clara turbine field, I used monitoring data only from the last nine months of that period, which assured me that any accumulated carcasses at the start of my “shutdown” treatment period had not been killed by operating wind turbines. The months spanning this shutdown treatment period were February through October 2006, or nine months. Therefore, my re-activation treatment period was February through October 2007.

RESULTS

Diablo Winds

I had enough data to estimate mortality over a 2.7-year period, which I used. My decision slightly biased the mortality estimates with the absence of one late winter/early spring period, whereas the other seasons were represented 3 times each. However, I doubt that this bias was very large.

Golden eagle mortality at Diablo Winds, adjusted for searcher detection and scavenger removal rates, averaged only 13% of the rate estimated throughout the rest of the APWRA (Tables 1 and 2). Red-tailed hawk mortality at Diablo Winds was only 36% of the rest of the APWRA, American kestrel mortality was 8%, and burrowing owl mortality was 74%. At Diablo Winds, the estimated adjusted mortality for the four target raptor species pooled together was 50% that of the rest of the APWRA, and most of the mortality of these pooled species was to burrowing owls. Overall raptor mortality at Diablo Winds was 46% of the raptor mortality throughout the rest of the APWRA, and overall bird mortality was 29%.

Bat mortality at Diablo Winds was conservatively estimated at 0.77 deaths/MW/yr, which was 8 times the rate estimated for the old-generation turbines throughout the rest of the APWRA. Assuming the APWRA is repowered, and that the Diablo Winds mortality would typify mortality throughout the repowered APWRA, then at a minimum 448 bats per year could be expected to be killed after repowering, but using more realistic scavenger removal and searcher detection rates would likely mean that thousands of bats will be killed annually.

Table 1. Wind turbine-caused mortality estimates at the Diablo Winds Energy Project, following 2.7 years of fatality monitoring from April 2005 through November 2007, including 33 days before the first fatality search. The average search interval was 33 days.

| Species | Mean mortality per string, deaths/MW/year | | Estimated annual fatalities | | |
|----------------------|---|----------|-----------------------------|-----------|-----------|
| | Unadjusted | Adjusted | Total | LB 80% CI | UB 80% CI |
| Turkey vulture | 0.0144 | 0.015 | 0.3 | -0.1 | 0.7 |
| Golden eagle | 0.0144 | 0.015 | 0.3 | -0.1 | 0.7 |
| Red-tailed hawk | 0.2282 | 0.245 | 5.0 | 2.5 | 7.6 |
| Barn owl | 0.0108 | 0.012 | 0.2 | -0.1 | 0.5 |
| American kestrel | 0.0144 | 0.066 | 1.4 | -0.4 | 3.1 |
| Burrowing owl | 0.3125 | 1.437 | 29.4 | 16.1 | 42.7 |
| Gull spp. | 0.0432 | 0.100 | 2.0 | 0.5 | 3.6 |
| Mallard | 0.0144 | 0.033 | 0.7 | -0.2 | 1.6 |
| Hammond's flycatcher | 0.0144 | 0.088 | 1.8 | -0.8 | 4.4 |
| House finch | 0.0144 | 0.088 | 1.8 | -0.8 | 4.4 |
| Horned lark | 0.0144 | 0.088 | 1.8 | -0.8 | 4.4 |
| Loggerhead shrike | 0.0288 | 0.176 | 3.6 | -0.3 | 7.5 |
| Mourning dove | 0.0252 | 0.154 | 3.2 | -0.3 | 6.6 |
| Pied-billed grebe | 0.0432 | 0.265 | 5.4 | -2.3 | 13.2 |
| Western meadowlark | 0.2830 | 1.734 | 35.5 | 8.1 | 62.9 |
| European starling | 0.0972 | 0.596 | 12.2 | 0.0 | 24.3 |
| Rock pigeon | 0.0720 | 0.114 | 2.3 | 0.4 | 4.3 |
| Unidentified bird | 0.0662 | 0.406 | 8.3 | -0.6 | 17.2 |
| Bats | 0.1260 | 0.772 | 15.8 | -1.6 | 33.2 |
| Target species | 0.5695 | 1.763 | 36.1 | 18.1 | 54.1 |
| Total raptors | 0.5947 | 1.791 | 36.6 | 17.9 | 55.4 |
| Total birds | 1.3111 | 5.634 | 115.3 | 20.9 | 209.7 |

APWRA-wide Mortality

My estimates of avian mortality in the APWRA were close to those produced by the monitoring team (Table 2). Despite correcting errors in the data set and processing the data in a different manner, the estimates were nearly the same.

Red-tailed hawk mortality in the APWRA over the last two years (Table 2) was more than twice the mortality estimated in 1998-2003 (Table 3). Golden eagle mortality was slightly greater than

in 1998-2003, American kestrel mortality was about two-thirds the earlier rate, and burrowing owl mortality was 30% greater than the estimate for the earlier period. Total pooled target species mortality was 13% greater over the last two years compared to the 1998-2003 period, and overall bird mortality was 45% greater.

Comparing mortality estimates only from turbines that were monitored during both programs (i.e., during 1998-2003 and 2005-2007), the point estimate of mortality during the last two years was lower than the baseline for golden eagles, red-tailed hawks, and American kestrels (Table 4). However, the point estimates from both monitoring programs were well the other's 80% confidence intervals. I do not believe these estimates differed significantly between monitoring periods. For perspective, the point estimates of mortality multiplied against the 82.63 MW of rated capacity used to make them yields a reduction of 2 golden eagle fatalities, 5 red-tailed hawk fatalities, and 105 American kestrel fatalities, but an increase of 55 burrowing owl fatalities. Overall bird mortality was the same.

I suspect that the reason mortality appeared different between the APWRA-wide estimates during the baseline and on-going monitoring efforts, while it appeared essentially the same between the consistently surveyed turbines, was because the baseline estimates included only two fatality searches over winter and spring months at more than 2,500 turbines. During the baseline monitoring effort, permission to access these turbines was not granted until the last year or so of the study, and our monitoring team did not deploy until the last few months of the study. We had always suspected that mortality of some species was likely greater where we were last granted access to perform fatality searches. Also, certain species are killed more often in the summer (e.g., golden eagle), and some are killed more often in the fall (e.g., burrowing owl and red-tailed hawk), so because the surveys at >2,500 turbines were performed during winter and spring months, mortality estimates used by the settling parties as the baseline may have been biased low (also see the note about this potential bias in Smallwood and Thelander 2008). Many of the mortality estimates in Table 3 are likely biased low. The comparisons in Table 4 are probably more reliable, but they are based on a smaller portion of the APWRA.

Table 2. Wind turbine-caused mortality estimates in the Altamont Pass Wind Resource Area, following slightly more than 2 years of fatality monitoring from 1 October 2005 through October 2007, including 45 days before the first fatality search. The average search interval was 41 days.

| Species | Mean mortality per string, deaths/MW/year | | Estimated annual fatalities, based on sum of separate estimates for EBRPD, Diablo Winds, and the stratified random sample of turbines | | |
|------------------------|---|----------|---|-----------|-----------|
| | Unadjusted | Adjusted | Total | LB 80% CI | UB 80% CI |
| Turkey vulture | 0.0166 | 0.0180 | 10.2 | 0.8 | 19.6 |
| Golden eagle | 0.1082 | 0.1176 | 64.7 | 42.3 | 87.0 |
| Red-tailed hawk | 0.6328 | 0.6878 | 391.7 | 302.8 | 480.6 |
| Ferruginous hawk | 0.0012 | 0.0013 | 4.0 | -1.0 | 8.9 |
| Swainson's hawk | 0.0009 | 0.0010 | 0.5 | -0.2 | 1.2 |
| Red-shouldered hawk | 0.0005 | 0.0006 | 0.3 | -0.1 | 0.7 |
| Buteo spp. | 0.0280 | 0.0304 | 16.6 | 6.4 | 26.9 |
| Northern harrier | 0.0055 | 0.0060 | 3.3 | 0.7 | 5.9 |
| White-tailed kite | 0.0006 | 0.0007 | 0.4 | -0.1 | 0.8 |
| Hawk spp. | 0.0016 | 0.0018 | 1.0 | -0.3 | 2.2 |
| Raptor spp. | 0.0039 | 0.0042 | 2.3 | 0.2 | 4.4 |
| Large raptor spp. | 0.0022 | 0.0024 | 1.3 | 0.1 | 2.6 |
| Prairie falcon | 0.0023 | 0.0025 | 1.3 | 0.3 | 2.4 |
| Great horned owl | 0.0535 | 0.0581 | 31.8 | 18.6 | 45.0 |
| Barn owl | 0.2354 | 0.2558 | 150.2 | 103.6 | 196.8 |
| Owl spp. | 0.0002 | 0.0002 | 0.1 | 0.0 | 0.3 |
| American kestrel | 0.1383 | 0.8017 | 439.9 | 285.3 | 594.5 |
| Burrowing owl | 0.3333 | 1.9322 | 1112.4 | 736.8 | 1487.9 |
| Great blue heron | 0.0005 | 0.0013 | 0.7 | -0.2 | 1.7 |
| Great egret | 0.0210 | 0.0514 | 28.1 | -9.1 | 65.3 |
| Sandhill crane | 0.0011 | 0.0028 | 1.5 | -0.5 | 3.5 |
| Wild turkey | 0.0007 | 0.0017 | 0.9 | -0.3 | 2.1 |
| Medium non-raptor spp. | 0.0620 | 0.1519 | 83.1 | 31.8 | 134.4 |
| Mallard | 0.0499 | 0.1222 | 67.5 | 17.3 | 117.7 |
| Gull spp. | 0.0469 | 0.1150 | 65.0 | 31.0 | 98.9 |
| Duck spp. | 0.0073 | 0.0178 | 9.8 | 1.8 | 17.7 |
| Common raven | 0.0662 | 0.1624 | 88.8 | 40.1 | 137.6 |
| California gull | 0.0047 | 0.0116 | 6.4 | -2.1 | 14.8 |
| American crow | 0.0227 | 0.0557 | 30.5 | 12.1 | 48.9 |
| Large non-raptor spp. | 0.0295 | 0.0723 | 39.5 | 15.2 | 63.9 |
| Pied-billed grebe | 0.0000 | | 5.4 | -2.3 | 13.2 |
| Black-necked stilt | 0.0058 | 0.0420 | 23.0 | -11.2 | 57.1 |
| Killdeer | 0.0016 | 0.0115 | 6.3 | -1.3 | 13.9 |
| White-throated swift | 0.0074 | 0.0537 | 40.9 | -10.1 | 91.9 |
| Western tanager | 0.0006 | 0.0040 | 2.2 | -1.1 | 5.5 |
| Tree swallow | 0.0006 | 0.0043 | 2.3 | -1.1 | 5.8 |
| Cliff swallow | 0.0049 | 0.0354 | 27.0 | -4.9 | 59.0 |
| American pipit | 0.0008 | 0.0060 | 3.3 | -1.6 | 8.1 |

| Species | Mean mortality per string, deaths/MW/year | | Estimated annual fatalities, based on sum of separate estimates for EBRPD, Diablo Winds, and the stratified random sample of turbines | | |
|------------------------------|---|---------------|---|---------------|---------------|
| | Unadjusted | Adjusted | Total | LB 80% CI | UB 80% CI |
| Bluebird spp. | 0.0128 | 0.0932 | 51.0 | -6.1 | 108.1 |
| House wren | 0.0012 | 0.0086 | 4.7 | -2.3 | 11.7 |
| Mountain bluebird | 0.0085 | 0.0619 | 33.8 | 2.6 | 65.1 |
| Rock wren | 0.0022 | 0.0163 | 8.9 | -4.3 | 22.2 |
| Swainson's thrush | 0.0021 | 0.0154 | 8.4 | -4.1 | 20.9 |
| Western meadowlark | 0.4336 | 3.1487 | 1761.7 | 411.2 | 3112.3 |
| Loggerhead shrike | 0.0448 | 0.3251 | 181.4 | 21.6 | 341.2 |
| Sparrow spp. | 0.0020 | 0.0143 | 7.8 | -3.8 | 19.4 |
| Lincoln sparrow | 0.0007 | 0.0053 | 2.9 | -1.4 | 7.3 |
| Northern flicker | 0.0039 | 0.0280 | 15.3 | -7.5 | 38.1 |
| Hammond's flycatcher | 0.0007 | 0.0053 | 4.7 | -2.2 | 11.7 |
| Mourning dove | 0.0780 | 0.5668 | 313.2 | 59.3 | 567.1 |
| Dove spp. | 0.0090 | 0.0651 | 35.6 | 1.4 | 69.9 |
| Say's phoebe | 0.0028 | 0.0206 | 11.3 | -5.5 | 28.0 |
| Brown-headed cowbird | 0.0072 | 0.0526 | 28.8 | -14.0 | 71.6 |
| Scrub jay | 0.0002 | 0.0016 | 0.9 | -0.4 | 2.2 |
| Blackbird spp. | 0.0530 | 0.3848 | 210.5 | 10.4 | 410.6 |
| Northern mockingbird | 0.0024 | 0.0171 | 9.3 | -4.5 | 23.2 |
| Brewer's blackbird | 0.0488 | 0.3542 | 193.8 | 26.1 | 361.4 |
| Horned lark | 0.0732 | 0.5315 | 292.5 | 34.5 | 550.5 |
| Cockatiel | 0.0031 | 0.0223 | 12.2 | -5.9 | 30.4 |
| Red-winged blackbird | 0.0352 | 0.2553 | 139.6 | 20.2 | 259.1 |
| House finch | 0.0000 | | 1.8 | -0.8 | 4.4 |
| Rock pigeon | 0.8788 | 4.1729 | 2292.5 | 1266.6 | 3318.3 |
| European starling | 0.4673 | 3.3933 | 1882.9 | 421.5 | 3344.4 |
| Small non-raptor | 0.0856 | 0.6214 | 339.9 | 65.8 | 614.0 |
| Unidentified bird spp. | 0.0406 | 0.2947 | 169.5 | 18.0 | 321.0 |
| Bats | 0.0132 | 0.0961 | 68.4 | -5.4 | 142.1 |
| Target raptor species | 1.2125 | 3.5393 | 2008.6 | 1367.1 | 2650.0 |
| Total raptors | 1.5649 | 3.9223 | 2232.0 | 1496.1 | 2967.9 |
| Total birds | 4.1967 | 19.3214 | 10779.3 | 3896.0 | 17662.6 |

Table 3. Revised baseline mortality estimates, after adding WRRS data omitted from Smallwood and Thelander (2008) and using similar assumptions to the current program's estimates for selecting fatalities to use in mortality estimates. Specifically, compared to the earlier estimates I made, this time I excluded more golden eagles and red-tailed hawks to be more consistent with the treatment of age-since-death estimates applied by the current monitoring program.

| Species | Mean mortality per string, deaths/MW/year | | Estimated annual fatalities | | |
|---------------------------|--|----------|-----------------------------|-----------|-----------|
| | Unadjusted | Adjusted | Total | LB 80% CI | UB 80% CI |
| Turkey vulture | 0.0040 | 0.0044 | 2.5 | 0.6 | 4.5 |
| White-tailed kite | 0.0000 | 0.0000 | 0.0 | 0.0 | 0.0 |
| Northern harrier | 0.0011 | 0.0012 | 0.7 | 0.1 | 1.2 |
| Red-tailed hawk | 0.2723 | 0.3057 | 177.3 | 114.5 | 240.2 |
| Ferruginous hawk | 0.0000 | 0.0000 | 0.0 | 0.0 | 0.0 |
| Golden eagle | 0.0844 | 0.0953 | 55.3 | 24.3 | 86.3 |
| Prairie falcon | 0.0017 | 0.0019 | 1.1 | 0.2 | 2.0 |
| Barn owl | 0.0704 | 0.0792 | 46.0 | 19.2 | 72.7 |
| Great horned owl | 0.0113 | 0.0125 | 7.3 | 3.3 | 11.2 |
| Raptor spp. | 0.0004 | 0.0004 | 0.2 | -0.1 | 0.5 |
| American kestrel | 0.1131 | 1.2606 | 731.2 | 286.0 | 1176.3 |
| Burrowing owl | 0.1472 | 1.4798 | 858.3 | 241.2 | 1475.4 |
| Double-breasted cormorant | 0.0014 | 0.0036 | 2.1 | -0.7 | 4.8 |
| Cattle egret | 0.0017 | 0.0054 | 3.1 | -1.1 | 7.3 |
| Black-crowned night heron | 0.0007 | 0.0019 | 1.1 | 0.0 | 2.2 |
| Mallard | 0.0351 | 0.0959 | 55.6 | 13.0 | 98.2 |
| Ring-necked duck | 0.0023 | 0.0072 | 4.2 | -1.5 | 9.9 |
| Wild turkey | 0.0010 | 0.0026 | 1.5 | -0.5 | 3.6 |
| American avocet | 0.0044 | 0.0116 | 6.7 | -0.9 | 14.3 |
| Ring-billed gull | 0.0057 | 0.0148 | 8.6 | 1.2 | 16.0 |
| California gull | 0.0058 | 0.0151 | 8.8 | 2.8 | 14.8 |
| American crow | 0.0104 | 0.0272 | 15.8 | 2.5 | 29.0 |
| Common raven | 0.0238 | 0.0703 | 40.8 | 1.0 | 80.6 |
| Gull spp. | 0.0606 | 0.1883 | 109.2 | 38.0 | 180.4 |
| Lesser yellowlegs | 0.0004 | 0.0032 | 1.9 | -1.1 | 4.9 |
| Rock pigeon | 0.2833 | 0.5602 | 324.9 | 197.8 | 452.1 |
| Mourning dove | 0.0779 | 0.8068 | 468.0 | -112.0 | 1047.9 |
| Northern flicker | 0.0186 | 0.2540 | 147.3 | -116.9 | 411.5 |
| Pacific-slope flycatcher | 0.0012 | 0.0110 | 6.4 | -3.8 | 16.6 |
| Western kingbird | 0.0005 | 0.0043 | 2.5 | -1.5 | 6.5 |
| Horned lark | 0.0197 | 0.1965 | 114.0 | -24.9 | 252.9 |
| Violet-green swallow | 0.0005 | 0.0041 | 2.4 | -1.4 | 6.2 |
| Cliff swallow | 0.0056 | 0.0514 | 29.8 | -4.6 | 64.3 |
| Mountain bluebird | 0.0170 | 0.2527 | 146.5 | -117.7 | 410.8 |
| Northern mockingbird | 0.0018 | 0.0160 | 9.3 | -5.5 | 24.0 |
| Loggerhead shrike | 0.0169 | 0.2118 | 122.8 | -97.7 | 343.4 |

| Species | Mean mortality per string, deaths/MW/year | | Estimated annual fatalities | | |
|------------------------|--|---------------|-----------------------------|--------------|---------------|
| | Unadjusted | Adjusted | Total | LB 80% CI | UB 80% CI |
| European starling | 0.1673 | 2.2741 | 1319.0 | -712.7 | 3350.7 |
| Yellow warbler | 0.0007 | 0.0062 | 3.6 | -2.1 | 9.3 |
| Savanna sparrow | 0.0043 | 0.0569 | 33.0 | -31.1 | 97.1 |
| Red-winged blackbird | 0.0146 | 0.1333 | 77.3 | -3.1 | 157.7 |
| Tricolored blackbird | 0.0007 | 0.0067 | 3.9 | -2.3 | 10.1 |
| Western meadowlark | 0.2094 | 2.7486 | 1594.2 | -796.5 | 3984.9 |
| Brewer's blackbird | 0.0411 | 0.5871 | 340.5 | -249.7 | 930.7 |
| Brown-headed cowbird | 0.0166 | 0.2515 | 145.9 | -151.8 | 443.6 |
| House finch | 0.0189 | 0.1722 | 99.9 | -6.5 | 206.3 |
| House sparrow | 0.0051 | 0.0802 | 46.5 | -49.3 | 142.3 |
| Cockatiel | 0.0006 | 0.0051 | 3.0 | -1.8 | 7.7 |
| Unidentified bird spp. | 0.0364 | 0.4929 | 285.9 | -168.8 | 740.6 |
| Songbird spp. | 0.0141 | 0.1287 | 74.7 | -4.4 | 153.7 |
| Blackbird spp. | 0.0018 | 0.0165 | 9.5 | -5.7 | 24.8 |
| Hoary bat | 0.0027 | 0.0248 | 14.4 | -3.5 | 32.3 |
| Target raptors | 0.6170 | 3.1415 | 1822.1 | 666.0 | 2978.2 |
| All raptors | 0.7058 | 3.2410 | 1879.8 | 689.3 | 3070.3 |
| All birds | 1.8339 | 13.0171 | 7549.9 | -1731.9 | 16831.8 |

Table 4. Comparison of mortality estimates at wind turbines searched during both monitoring programs, in 1998-2002 and in 2005-2007. These turbines totaled 82.63 MW of rated capacity, and occurred in various portions of the APWRA, but mostly in the central, eastern, and southern aspects of the APWRA. The duration of the baseline effort ranged from 1.5 to 4.5 years, with the majority more than 2 years.

| Species | Adjusted mean mortality per string, deaths/MW/year | | | | | | Change in mean mortality |
|--------------------------|--|--------------|--------------|--------------|--------------|--------------|--------------------------|
| | 1998-03 mean | LB 80% CI | UB 80% CI | 2005-07 mean | LB 80% CI | UB 80% CI | |
| Turkey vulture | 0.010 | -0.003 | 0.023 | 0.003 | -0.001 | 0.006 | -74 |
| Northern harrier | 0.031 | 0.008 | 0.054 | 0.015 | 0.001 | 0.029 | -50 |
| Red-tailed hawk | 0.839 | 0.599 | 1.079 | 0.778 | 0.566 | 0.991 | -7 |
| Golden eagle | 0.123 | 0.073 | 0.172 | 0.091 | 0.045 | 0.137 | -26 |
| Prairie falcon | 0.010 | -0.003 | 0.023 | 0.006 | 0.000 | 0.011 | -45 |
| Barn owl | 0.256 | 0.165 | 0.346 | 0.267 | 0.178 | 0.356 | 4 |
| Great horned owl | 0.061 | 0.024 | 0.099 | 0.048 | 0.014 | 0.082 | -22 |
| Buteo spp. | 0.000 | 0.000 | 0.000 | 0.016 | -0.003 | 0.035 | |
| American kestrel | 1.804 | 0.945 | 2.663 | 0.538 | 0.298 | 0.779 | -70 |
| Burrowing owl | 2.406 | 1.378 | 3.434 | 3.071 | 1.989 | 4.153 | 28 |
| Double-crested cormorant | 0.024 | -0.008 | 0.056 | 0.000 | 0.000 | 0.000 | |
| Great blue heron | 0.000 | 0.000 | 0.000 | 0.004 | -0.001 | 0.009 | |
| Great egret | 0.000 | 0.000 | 0.000 | 0.156 | -0.050 | 0.362 | |
| Mallard | 0.460 | 0.206 | 0.713 | 0.137 | 0.014 | 0.260 | -70 |
| Wild turkey | 0.024 | -0.008 | 0.056 | 0.000 | 0.000 | 0.000 | |
| American avocet | 0.073 | -0.001 | 0.146 | 0.000 | 0.000 | 0.000 | |
| Ring-billed gull | 0.048 | 0.002 | 0.095 | 0.000 | 0.000 | 0.000 | |
| California gull | 0.097 | 0.027 | 0.167 | 0.035 | -0.011 | 0.082 | -64 |
| American crow | 0.073 | 0.014 | 0.132 | 0.048 | 0.006 | 0.089 | -35 |
| Common raven | 0.121 | 0.030 | 0.212 | 0.148 | 0.062 | 0.233 | 22 |
| Medium non-raptor spp. | 0.000 | 0.000 | 0.000 | 0.200 | 0.067 | 0.334 | |
| Large non-raptor spp. | 0.000 | 0.000 | 0.000 | 0.128 | 0.022 | 0.233 | |
| Duck spp. | 0.000 | 0.000 | 0.000 | 0.018 | -0.006 | 0.041 | |
| Gull spp. | 0.073 | 0.014 | 0.132 | 0.124 | 0.048 | 0.200 | 71 |
| Killdeer | 0.000 | 0.000 | 0.000 | 0.004 | -0.001 | 0.009 | |
| Black-necked stilt | 0.000 | 0.000 | 0.000 | 0.127 | -0.062 | 0.316 | |
| Rock pigeon | 2.122 | 1.332 | 2.913 | 5.378 | 3.463 | 7.293 | 153 |
| Mourning dove | 2.028 | 0.037 | 4.020 | 1.029 | 0.166 | 1.893 | -49 |
| White-throated swift | 0.000 | 0.000 | 0.000 | 0.028 | -0.013 | 0.069 | |
| Northern flicker | 0.254 | -0.050 | 0.557 | 0.085 | -0.041 | 0.211 | -67 |
| Pacific-slope flycatcher | 0.085 | -0.050 | 0.219 | 0.000 | 0.000 | 0.000 | |
| Western kingbird | 0.085 | -0.050 | 0.219 | 0.000 | 0.000 | 0.000 | |
| Horned lark | 0.930 | -0.013 | 1.872 | 0.493 | -0.140 | 1.125 | -47 |
| Tree swallow | 0.000 | 0.000 | 0.000 | 0.013 | -0.006 | 0.032 | |
| Cliff swallow | 0.085 | -0.050 | 0.219 | 0.045 | -0.011 | 0.102 | -47 |
| Mountain bluebird | 0.000 | 0.000 | 0.000 | 0.080 | -0.008 | 0.168 | |
| Northern mockingbird | 0.085 | -0.050 | 0.219 | 0.000 | 0.000 | 0.000 | |

| Species | Adjusted mean mortality per string, deaths/MW/year | | | | | | Change in mean mortality |
|------------------------------|--|--------------|--------------|--------------|--------------|--------------|--------------------------|
| | 1998-03 mean | LB 80% CI | UB 80% CI | 2005-07 mean | LB 80% CI | UB 80% CI | |
| Loggerhead shrike | 0.169 | -0.052 | 0.390 | 0.431 | 0.032 | 0.830 | 155 |
| European starling | 2.704 | 0.047 | 5.361 | 3.226 | 0.606 | 5.846 | 19 |
| Savanna sparrow | 0.085 | -0.050 | 0.219 | 0.000 | 0.000 | 0.000 | |
| Red-winged blackbird | 0.592 | -0.033 | 1.216 | 0.322 | 0.017 | 0.627 | -46 |
| Tricolored blackbird | 0.085 | -0.050 | 0.219 | 0.000 | 0.000 | 0.000 | |
| Western meadowlark | 4.310 | 0.124 | 8.496 | 3.795 | 0.805 | 6.785 | -12 |
| Brewer's blackbird | 0.592 | -0.088 | 1.271 | 0.224 | -0.004 | 0.452 | -62 |
| Brown-headed cowbird | 0.085 | -0.050 | 0.219 | 0.000 | 0.000 | 0.000 | |
| House finch | 0.676 | -0.045 | 1.397 | 0.000 | 0.000 | 0.000 | |
| Cockatiel | 0.000 | 0.000 | 0.000 | 0.068 | -0.033 | 0.168 | |
| Unidentified bird spp. | 1.099 | -0.066 | 2.263 | 0.262 | 0.009 | 0.515 | -76 |
| Songbird spp. | 0.676 | -0.028 | 1.380 | 1.166 | 0.171 | 2.161 | 72 |
| Sparrow spp. | 0.000 | 0.000 | 0.000 | 0.043 | -0.021 | 0.108 | |
| Blackbird spp. | 0.000 | 0.000 | 0.000 | 0.708 | -0.111 | 1.527 | |
| Dove spp. | 0.000 | 0.000 | 0.000 | 0.101 | 0.000 | 0.202 | |
| Bats | 0.338 | -0.046 | 0.722 | 0.260 | -0.033 | 0.553 | -23 |
| Target raptor species | 5.172 | 2.996 | 7.348 | 4.479 | 2.897 | 6.060 | -13 |
| Total raptors | 5.541 | 3.188 | 7.894 | 4.834 | 3.087 | 6.581 | -13 |
| Total birds | 23.276 | 4.278 | 42.274 | 23.457 | 8.053 | 38.862 | 1 |

Santa Clara Shutdown

While the Santa Clara turbines were not operating, red-tailed hawk fatalities were found at the turbines at 19% of the rate they were found at the rest of the monitored turbines in the APWRA (Table 5). However, after the turbines were activated, red-tailed hawk mortality at the Santa Clara turbines increased 786% while it decreased 42% in the rest of the APWRA. While the Santa Clara turbines operated in 2007, they killed red-tailed hawks at nearly three times the rate of the rest of the APWRA. Overall, the Santa Clara site appeared more hazardous to red-tailed hawks than the rest of the APWRA, but the hazard was much greater when the turbines were operating.

While the Santa Clara turbines were not operating, American kestrels were not found dead on site, but their mortality offsite was nearly 0.7/MW/yr. After the Santa Clara turbines were turned on, American kestrel mortality jumped to 0.168/MW/yr on site, but this rate was still only 20% of the rate estimated off-site. The Santa Clara site was safer for American kestrels than the rest of the APWRA, but the hazard it posed to American kestrels appeared to be a function of turbine operations.

While the Santa Clara turbines were not operating, burrowing owl mortality on site was estimated to be 17% of that measured off site. At a rate of 0.27 deaths/MW/yr, burrowing owl mortality amongst non-operational turbines was still substantial. At this rate, 156 burrowing owls would be killed per year if all the turbines in the APWRA were shut down (and their towers left in place). Nevertheless, after the Santa Clara turbines were activated, burrowing owl mortality increased 260% on site while it increased 150% off site. After activation, burrowing owl mortality on site was 29% that estimated off site. The Santa Clara site was relatively safer to burrowing owls than the rest of the APWRA, although it was much more dangerous after the turbines were re-activated.

Golden eagles were not found dead at the Santa Clara site, so no comparison of golden eagle mortality could be made between the times the turbines were operating and not operating.

While the Santa Clara turbines were off, no horned larks were found dead on site, while off site estimated mortality was 0.13 deaths/MW/yr. When the Santa Clara turbines operated the next year, horned lark mortality jumped to 0.62 deaths/MW/yr on site, which was nearly the same level of mortality off site during that time. The Santa Clara turbines appeared to be hazardous to horned larks while the turbines operated.

Western meadowlark mortality was estimated to be 1.24 deaths/MW/yr on the Santa Clara site during the shutdown, which was substantial. But after re-activation of these turbines, western meadowlark mortality doubled on site, while it decreased 20% off site. Similar patterns were observed for multiple other Passerine species, including American crow, common raven, red-winged blackbird, rock pigeon, and European starling.

For all raptors combined, I estimated mortality was 0.74 deaths/MW/yr within the Santa Clara turbine field during the shutdown, which would extrapolate to 429 raptors per year throughout the APWRA if all turbines were shut down. During the shutdown at Santa Clara, an unknown

but potentially large number of the fatalities were likely linked to the occurrence of the turbines and their towers on the landscape. Some raptors may collide with the structures, even when no blades are moving. Some raptors may be killed by others using the towers as perches, launching attacks from concealed locations on the lattice towers or from behind the turbine. The exact mechanisms of these fatalities, and their relative contribution to the toll, remain speculative, but if the mere occurrence of the towers caused most of the estimated mortality at the shutdown Santa Clara turbines, then turbine shutdowns alone may just barely achieve the 50% mortality reduction goal. Of course, in this scenario, no wind power would be generated, so a more balanced approach would be to also remove as many derelict or poorly performing turbines and their towers as possible.

After the Santa Clara turbines were re-activated, raptor mortality increased 303% on site, while it increased 120% off site. The mortality of all birds pooled together increased 248% on site, while it increased 140% off site. The wind turbines were definitely more hazardous to birds while operating than while shut down. The birds that contributed most to the mortality estimated during the shutdown were smaller-bodied bird species that are prey species to the larger-bodied raptors using the APWRA, including blackbirds, western meadowlark, rock pigeon, and burrowing owl. Exceptions were barn owl and great horned owl, which are relatively large in size, but were killed during the shutdown. Still, these owls can also be killed by Buteo hawks perched on the turbine towers at the edge of darkness. Alternatively, these owls may collide with the towers or with the unmoving turbine blades.

Table 5. Mortality estimates on and off the Santa Clara turbine field during a long shutdown period (2006) and after the turbines were re-activated (2007).

| Species | Year | Estimated mortality (deaths/MW/yr) | | | | | |
|---------------------|------|------------------------------------|--------------|--------------|------------------------------|--------------|--------------|
| | | Outside Santa Clara turbine field | | | In Santa Clara turbine field | | |
| | | Mean | LB 80% CI | UB 80% CI | Mean | LB 80% CI | UB 80% CI |
| Turkey vulture | 2006 | 0.0052 | 0.0000 | 0.0105 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0114 | 0.0011 | 0.0217 | 0.0000 | 0.0000 | 0.0000 |
| Golden eagle | 2006 | 0.0802 | 0.0488 | 0.1117 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0753 | 0.0438 | 0.1069 | 0.0000 | 0.0000 | 0.0000 |
| Red-tailed hawk | 2006 | 0.5628 | 0.4112 | 0.7144 | 0.1085 | -0.0313 | 0.2484 |
| | 2007 | 0.3283 | 0.2300 | 0.4267 | 0.9613 | 0.2143 | 1.7082 |
| Ferruginous hawk | 2006 | 0.0014 | -0.0004 | 0.0032 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Swainson's hawk | 2006 | 0.0031 | -0.0009 | 0.0070 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Red-shouldered hawk | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0016 | -0.0005 | 0.0037 | 0.0000 | 0.0000 | 0.0000 |
| Buteo spp. | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0238 | 0.0025 | 0.0451 | 0.0383 | -0.0110 | 0.0877 |
| Northern harrier | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0101 | -0.0001 | 0.0203 | 0.0000 | 0.0000 | 0.0000 |
| Prairie falcon | 2006 | 0.0038 | -0.0011 | 0.0088 | 0.0000 | 0.0000 | 0.0000 |

| Species | Year | Estimated mortality (deaths/MW/yr) | | | | | |
|----------------------|------|------------------------------------|--------------|--------------|------------------------------|--------------|--------------|
| | | Outside Santa Clara turbine field | | | In Santa Clara turbine field | | |
| | | Mean | LB 80% CI | UB 80% CI | Mean | LB 80% CI | UB 80% CI |
| American kestrel | 2007 | 0.0034 | 0.0003 | 0.0066 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.6982 | 0.3467 | 1.0497 | 0.0000 | 0.0000 | 0.0000 |
| Barn owl | 2007 | 0.8398 | 0.4598 | 1.2198 | 0.1680 | -0.0512 | 0.3871 |
| | 2006 | 0.3115 | 0.1536 | 0.4694 | 0.1764 | -0.0508 | 0.4036 |
| Great horned owl | 2007 | 0.1698 | 0.0995 | 0.2401 | 0.3554 | 0.1049 | 0.6059 |
| | 2006 | 0.0207 | 0.0035 | 0.0380 | 0.1764 | -0.0508 | 0.4036 |
| Burrowing owl | 2007 | 0.0673 | 0.0193 | 0.1153 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 1.6525 | 0.8442 | 2.4608 | 0.2767 | -0.0905 | 0.6438 |
| Owl spp. | 2007 | 2.4714 | 1.5570 | 3.3858 | 0.7199 | 0.0273 | 1.4124 |
| | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Large raptor spp. | 2007 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Small raptor spp. | 2007 | 0.0069 | 0.0005 | 0.0133 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Pied-billed grebe | 2007 | 0.0275 | -0.0084 | 0.0633 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Great blue heron | 2007 | 0.0395 | -0.0174 | 0.0965 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.0044 | -0.0014 | 0.0102 | 0.0000 | 0.0000 | 0.0000 |
| Great egret | 2007 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.1700 | -0.0561 | 0.3962 | 0.0000 | 0.0000 | 0.0000 |
| Mallard | 2007 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.0336 | -0.0010 | 0.0683 | 0.0000 | 0.0000 | 0.0000 |
| Wild turkey | 2007 | 0.2283 | 0.0182 | 0.4384 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Sandhill crane | 2007 | 0.0044 | -0.0014 | 0.0103 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Killdeer | 2007 | 0.0077 | -0.0025 | 0.0179 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| California gull | 2007 | 0.0301 | -0.0048 | 0.0650 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Gull spp. | 2007 | 0.0318 | -0.0101 | 0.0738 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.0217 | 0.0032 | 0.0401 | 0.0000 | 0.0000 | 0.0000 |
| Rock pigeon | 2007 | 0.0940 | 0.0366 | 0.1514 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.8485 | 0.5658 | 1.1313 | 0.2953 | 0.0368 | 0.5538 |
| Mourning dove | 2007 | 2.5555 | 1.7573 | 3.3537 | 0.8534 | -0.0025 | 1.7093 |
| | 2006 | 0.3402 | -0.0616 | 0.7421 | 0.0000 | 0.0000 | 0.0000 |
| Dove spp. | 2007 | 0.6380 | 0.1317 | 1.1444 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| White-throated swift | 2007 | 0.1677 | 0.0180 | 0.3175 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Northern flicker | 2007 | 0.0372 | -0.0056 | 0.0800 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.1132 | -0.0719 | 0.2982 | 0.0000 | 0.0000 | 0.0000 |

| | | Estimated mortality (deaths/MW/yr) | | | | | |
|------------------------|------|------------------------------------|--------------|--------------|------------------------------|--------------|--------------|
| | | Outside Santa Clara turbine field | | | In Santa Clara turbine field | | |
| Species | Year | Mean | LB 80% CI | UB 80% CI | Mean | LB 80% CI | UB 80% CI |
| | 2007 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Hammond's flycatcher | 2006 | 0.0206 | -0.0131 | 0.0542 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0130 | -0.0057 | 0.0318 | 0.0000 | 0.0000 | 0.0000 |
| California horned lark | 2006 | 0.1303 | -0.0523 | 0.3129 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.6597 | 0.1086 | 1.2108 | 0.6178 | -0.2719 | 1.5076 |
| Tree swallow | 2006 | 0.0174 | -0.0111 | 0.0459 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Cliff swallow | 2006 | 0.0608 | -0.0259 | 0.1476 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| American crow | 2006 | 0.0123 | -0.0041 | 0.0286 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0627 | 0.0072 | 0.1182 | 0.2100 | -0.0669 | 0.4868 |
| Common raven | 2006 | 0.0353 | 0.0071 | 0.0635 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.1240 | -0.0082 | 0.2563 | 0.3078 | -0.0028 | 0.6183 |
| Rock wren | 2006 | 0.0660 | -0.0419 | 0.1739 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| House wren | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0217 | -0.0096 | 0.0531 | 0.0000 | 0.0000 | 0.0000 |
| Mountain bluebird | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0348 | -0.0049 | 0.0745 | 0.0000 | 0.0000 | 0.0000 |
| Bluebird spp. | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0373 | -0.0164 | 0.0910 | 0.0000 | 0.0000 | 0.0000 |
| Northern mockingbird | 2006 | 0.0679 | -0.0431 | 0.1789 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Loggerhead shrike | 2006 | 0.1554 | -0.0552 | 0.3660 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.3482 | 0.0446 | 0.6519 | 0.0000 | 0.0000 | 0.0000 |
| European starling | 2006 | 3.6907 | -0.2642 | 7.6455 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 2.6135 | 0.6851 | 4.5418 | 3.2436 | 0.2497 | 6.2376 |
| Western tanager | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0100 | -0.0044 | 0.0245 | 0.0000 | 0.0000 | 0.0000 |
| Lincoln's sparrow | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0130 | -0.0057 | 0.0318 | 0.0000 | 0.0000 | 0.0000 |
| Sparrow spp. | 2006 | 0.0570 | -0.0362 | 0.1502 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Red-winged blackbird | 2006 | 0.2425 | -0.0669 | 0.5519 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.3537 | 0.0444 | 0.6631 | 0.2231 | -0.0982 | 0.5444 |
| Western meadowlark | 2006 | 3.1873 | -0.1970 | 6.5717 | 1.2351 | -0.4799 | 2.9500 |
| | 2007 | 2.5582 | 0.7401 | 4.3763 | 2.4542 | -0.5753 | 5.4837 |
| Brewer's blackbird | 2006 | 0.1867 | -0.0496 | 0.4230 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.6312 | 0.0872 | 1.1752 | 0.0000 | 0.0000 | 0.0000 |
| Brown-headed cowbird | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 2007 | 0.1338 | -0.0589 | 0.3266 | 0.0000 | 0.0000 | 0.0000 |
| Blackbird spp. | 2006 | 0.0815 | -0.0518 | 0.2147 | 1.5562 | -0.9883 | 4.1007 |

| | | Estimated mortality (deaths/MW/yr) | | | | | |
|------------------------|-------------|---|----------------------|----------------------|-------------------------------------|----------------------|----------------------|
| | | Outside Santa Clara turbine field | | | In Santa Clara turbine field | | |
| Species | Year | Mean | LB 80% CI | UB 80% CI | Mean | LB 80% CI | UB 80% CI |
| Cockatiel | 2007 | 0.6848 | -0.0151 | 1.3848 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.0895 | -0.0569 | 0.2360 | 0.0000 | 0.0000 | 0.0000 |
| Unidentified bird spp. | 2007 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.3261 | -0.1946 | 0.8469 | 0.0000 | 0.0000 | 0.0000 |
| small non-raptor spp. | 2007 | 0.5645 | 0.1217 | 1.0073 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.0000 | 0.0000 | 0.0000 | 0.3458 | -0.2196 | 0.9113 |
| Medium non-raptor spp. | 2007 | 1.9262 | 0.2559 | 3.5965 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 0.0155 | -0.0051 | 0.0360 | 0.0000 | 0.0000 | 0.0000 |
| Large non-raptor spp. | 2007 | 0.1595 | 0.0397 | 0.2793 | 0.2100 | -0.0669 | 0.4868 |
| | 2006 | 0.0340 | -0.0112 | 0.0792 | 0.0000 | 0.0000 | 0.0000 |
| All raptors | 2007 | 0.0603 | 0.0151 | 0.1055 | 0.0000 | 0.0000 | 0.0000 |
| | 2006 | 3.3396 | 1.8057 | 4.8735 | 0.7379 | -0.2235 | 1.6993 |
| All birds | 2007 | 4.0367 | 2.4048 | 5.6687 | 2.2428 | 0.2842 | 4.2014 |
| | 2006 | 13.3481 | 1.0095 | 25.6867 | 4.1703 | -1.8745 | 10.2151 |
| | 2007 | 18.8815 | 6.3453 | 31.4176 | 10.3627 | -0.5507 | 21.2761 |

DISCUSSION

The monitoring team's mortality estimates were repeatable and robust to methods and assumptions used. I have to conclude that the monitoring team's estimates were sound, and that they would change little with changes in assumptions and analytical methods, for the most part. They would likely increase, however, by using more realistic scavenger removal rates, which have been recently estimated by a study in a portion of the APWRA controlled by East Bay Regional Parks District (the report has yet to be published). In this study, bird carcasses were placed at rates more consistent with wind turbine deposition, rather than had been the convention of placing 20 to 40 carcasses at once. By not swamping the scavengers of carcasses, the removal rates were much faster.

The revised "baseline" mortality estimates were more comparable to the monitoring team's estimates for the last two years, but the limited searches at >2,500 turbines likely introduced substantial bias into the comparison. The increase in mortality between survey periods was probably more apparent than real. Nevertheless, after comparing mortality estimates in two different ways, it appears wind turbine-caused mortality has not lessened since 1998-2003.

The year-long Vestas shutdown served to demonstrate the relative impacts of operating wind turbines. The wind turbines are much more dangerous to birds while they are operating. Some bird species continue to die amongst non-operating turbines, and these appear to be nocturnal owls and small-bodied birds regularly predated by larger raptors. It may be that the mere existence of turbines and their towers pose inherent hazards to certain bird species. Turbine shutdowns will not eliminate mortality caused by wind turbines in all cases.

The mortality estimates from Diablo Winds indicate that repowering can substantially lessen bird mortality in the APWRA. Mortality could probably be reduced further by more carefully siting the new turbines to minimize hazards posed by landscape and wind conditions we have been learning to associate with avian fatalities. Additionally, the timing of operations might be controlled to further reduce bird mortality. An important downside to repowering, however, appears to be increased bat mortality. The Diablo Winds project killed bats at a higher rate than the old-generation turbines. After using more appropriate scavenger removal and searcher detection adjustment coefficients, it is likely that a complete repowering of wind turbines in the APWRA would kill thousands of bats per year.

REFERENCES

- Orloff, S., and A. Flannery. 1992. Wind turbine effects on avian activity, habitat use, and mortality in Altamont Pass and Solano County Wind Resource Areas: 1989-1991. Report to California Energy Commission, Sacramento, California.
- Smallwood, K.S. 2007. Estimating wind turbine-caused bird mortality. *Journal of Wildlife Management* 71:2781-2791.

Smallwood, K. S. and C. Thelander. 2004. Developing methods to reduce bird mortality in the Altamont Pass Wind Resource Area. Final Report to the California Energy Commission, Public Interest Energy Research – Environmental Area, Contract No. 500-01-019. Sacramento, California. 531 pp.

Smallwood, K. S. and C. Thelander. 2005. Bird mortality in the Altamont Pass Wind Resource Area, March 1998 – September 2001 Final Report. National Renewable Energy Laboratory, NREL/SR-500-36973. Golden, Colorado. 410 pp.

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