Annual Monitoring Report
July 2012 – June 2013

Solano Wind Project – Phase 3 • September 2013

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Executive Summary

This report presents the results of the first year of avian and bat postconstruction monitoring at the Solano Wind Project, Phase 3. Surveys were conducted every 2 weeks at a 34% subset (19 turbines) of the total 55-turbine facility from July 2012 through June 2013. In accordance with the protocol developed for this project, these surveys were conducted by qualified biologists walking concentric rings spaced every 10 meters out to 100 meters from the base of each turbine. Quarterly carcass persistence trials and four searcher efficiency trials were used to estimate the persistence of carcasses over time and searcher efficiency. These trials were used to estimate the ability of the surveyors to detect carcasses in the field. These estimates were then applied to the fatality estimate model to derive an estimate of the total number of facility-related fatalities per year, per turbine, per species, and per megawatt. The Huso estimator was used to estimate the total number of fatalities because this analytical method has been shown to generate more reliable estimates at wind energy facilities (Huso 2010). This method has also become the preferred estimator for wind facilities operating in the Collinsville-Montezuma Hills Wind Resource Area and was recommended during a June 2012 meeting with the Solano County Technical Advisory Committee for avian issues related to wind energy projects (Solano County 2012).

During the first year of surveys, 46 bird and bat carcasses were recorded during standardized fatality surveys. Using the Huso estimator, the overall number of facility-related fatalities at the site was estimated to be 362. This number translates to a rate of 6.56 fatalities per turbine per year, or 2.82 fatalities per megawatt per year. Based on this model, it is estimated that 121 raptors, 206 non-raptors, and 40 bats are taken annually as a result of facility operations. Western meadowlark (*Sturnella neglecta*) had the highest annual estimate of species-specific fatalities (148). American kestrel (*Falco sparverius*) and hoary bat (*Lasiurus cinereus*) had the highest annual raptor estimate (59 individuals) and annual bat estimate (23 individuals), respectively.

The total fatality estimates for the facility are within the range of or below the estimates produced at other wind farms in the Collinsville-Montezuma Hills Wind Resource Area. The estimates for bats were found to be significantly lower than those at other wind farms. Seasonality was found to strongly correlate with searcher efficiency. Because the searcher efficiency trial results varied strongly between seasons, fatality estimates using these variables produced very large confidence intervals. Because seasonal timing introduces such wide confidence intervals into the data, subsequent years of surveys at the site will further analyze the fit of this variable to the model to refine the model used to calculate the final estimates.

Avian and bat postconstruction monitoring will continue at the project site for 2 more years. The addition of data collected in Years 2 and 3 will likely improve the overall accuracy of the estimates produced in subsequent years, and may provide greater clarity on species-specific impacts occurring at the Solano Wind Project, Phase 3.

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Acronyms and Other Abbreviations

AIC	Akaike Information Criterion
CI	confidence interval
CMHWRA	Collinsville-Montezuma Hills Wind Resource Area
DWP	density-weight proportional
MW	megawatt
SMUD	Sacramento Municipal Utility District

Introduction

The Sacramento Municipal Utility District's (SMUD) Solano Wind Project, Phase 3 is a 55 turbine, 128-megawatt (MW) wind energy facility located in the southeastern corner of Solano County, in the Collinsville-Montezuma Hills Wind Resource Area (CMHWRA) (Figure 1). The facility became operational in May 2012 and reached substantial completion by June 2012.

The facility borders include the Sacramento River on the southeast and similar wind energy facilities on the north, east, and west, including the Solano Wind Project, Phases 1 and 2. Lands under easement with the Solano Land Trust border the facility to the east. An overview of the surrounding area is provided in Figure 2. The facility consists of 55 turbines (both 1.8- and 3.0-MW Vestas V90 models) located on approximately 4,244 acres. The landscape of the Montezuma Hills consists of smooth, rolling hills with consistent crest elevations ranging from 150 to 280 feet above sea level. The hills are arid and mostly treeless. Seasonal and ephemeral drainages cross the landscape; most are connected hydrologically to the Sacramento River. The turbines are sited along ridges or hilltops, many in strings or rows, and are relatively evenly spaced across the landscape (Figure 1). The facility is almost entirely composed of ruderal nonnative annual grassland habitats used for grazing and seasonal dryland grain farming, as shown in photographs provided in Appendix A. Small stands of freshwater emergent wetland and *Eucalyptus* spp. are present along the Sacramento River and near the operations and maintenance buildings. A few isolated trees are also scattered throughout the Phase 3 project area, but no trees are located in the turbine survey areas. Scientifically designed postconstruction monitoring programs have become an important tool in determining avian and bat mortality at wind power facilities. The results of these programs can be used to help make future wind farm planning decisions that reduce avian and bat fatalities at these facilities. They also can be used to help understand the greater impact of cumulative wind resource area developments aggregated across multiple wind farms.

To determine avian and bat fatality rates at the Solano Wind Project, Phase 3, a 3-year monitoring program was designed following the guidance in *California Guidelines for Reducing Impacts to Birds and Bats from Wind Energy Development* (California Energy Commission and California Department of Fish and Game 2007). The *U.S. Fish and Wildlife Service Land-Based Wind Energy Guidelines* (2012) were also considered in the development of the monitoring protocol. This monitoring program began in July 2012 and is subdivided into 3 successional years of monitoring. The purpose of this report is to document the results of the first year of monitoring, to provide estimates of avian and bat fatalities occurring at the Solano Wind Project, Phase 3, based on the first year of the study—July 2012 through June 2013—and to compare these values with estimates derived from similar studies in the adjacent operating wind farms of the CMHWRA.

Methods

Avian and bat mortality monitoring was conducted following the *Avian and Bat Mortality Monitoring Program Monitoring Protocol for the Solano Wind Project—Phase 3, Sacramento Municipal Utility District*, a project-specific monitoring protocol prepared in July 2012 (AECOM 2012). Field efforts consisted of carcass surveys aimed at identifying fatalities attributed to turbine strikes, as well as searcher efficiency and carcass persistence trials. Estimations of avian and bat fatality rates at the Solano Wind Project, Phase 3, were calculated through statistical analysis.

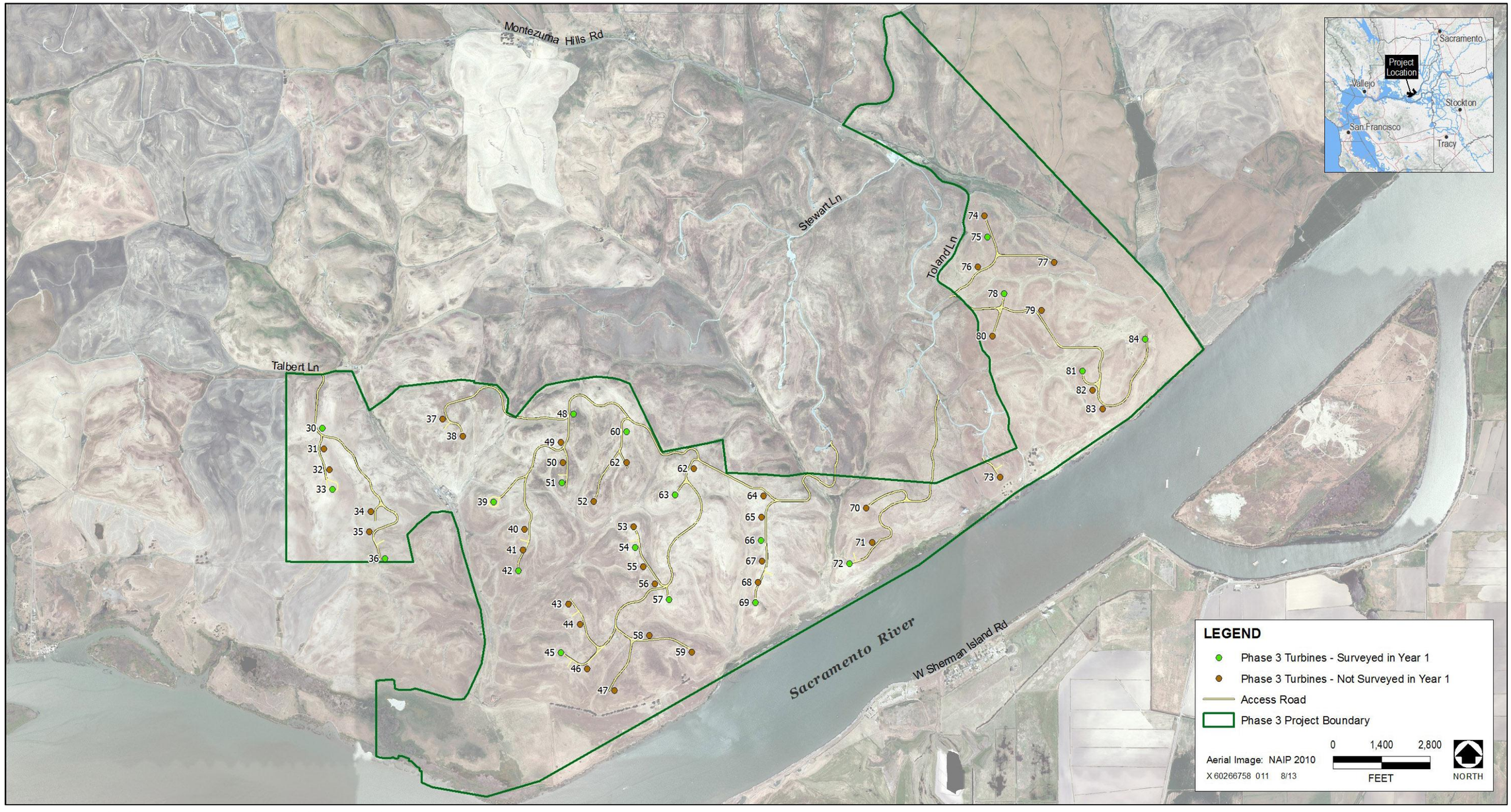
Carcass Surveys

Year 1 surveys were conducted from July 2012 through June 2013. Standardized carcass surveys were conducted twice monthly (approximately every 14 days) by teams of two to four qualified biologists trained to survey for and identify bird and bat carcasses. In accordance with the monitoring protocol, a minimum of 33% of the turbines are required to be surveyed each year for 3 years. During Year 1, the areas around 19 turbines—a 34% subset of the 55 total turbines—were surveyed. The individual turbines in the subset were selected from across the site to ensure that even coverage of the entire wind farm was accomplished during each monitoring event. The areas surveyed during the 2012/2013 season were around turbines 30, 33, 36, 39, 42, 45, 48, 51, 54, 57, 60, 63, 66, 69, 72, 75, 78, 81, and 84 (Figure 1). Areas around turbines in each of the remaining two subsets will be surveyed in Year 2, and Year 3.

Survey Design

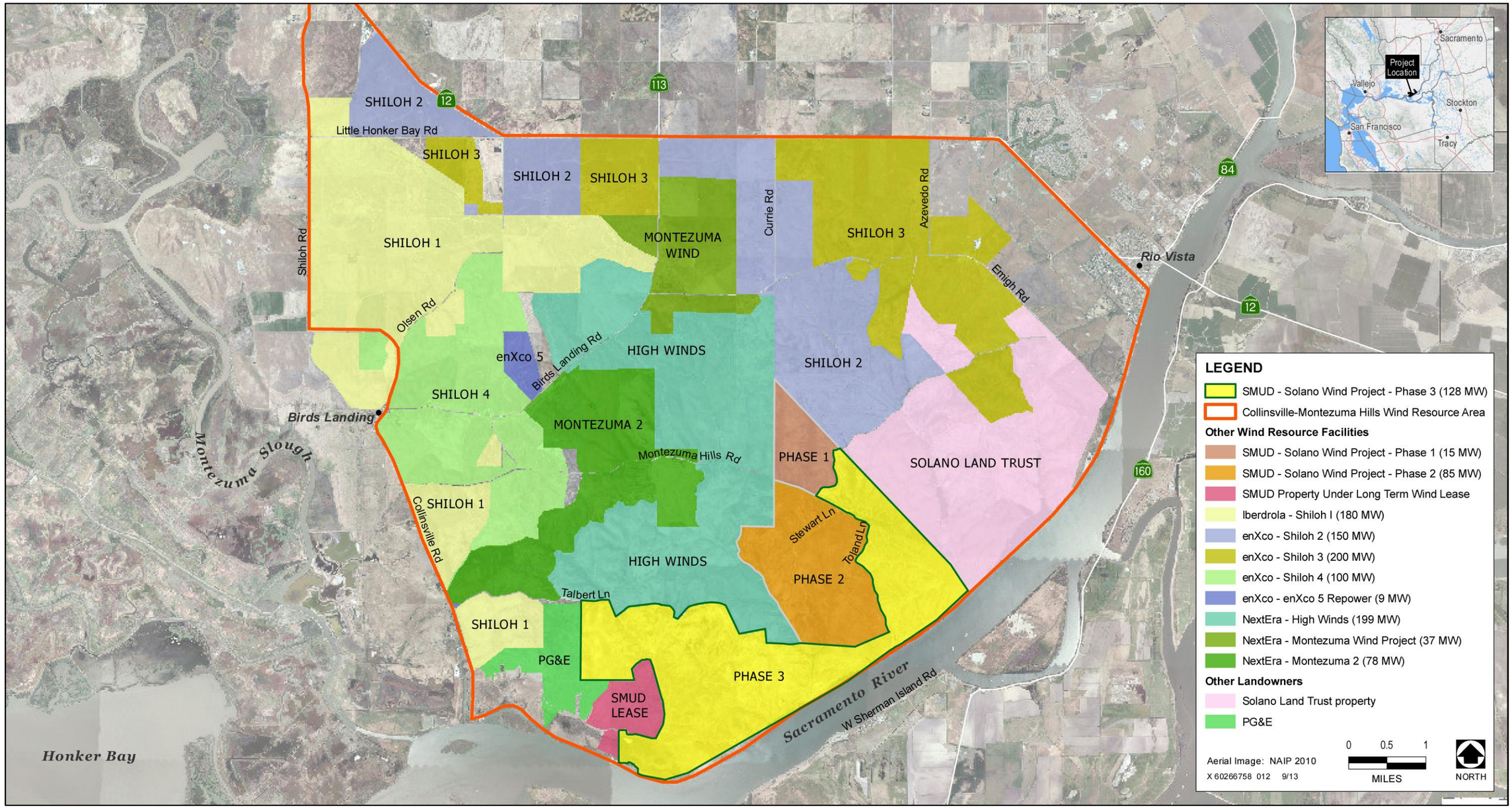
Each turbine area was surveyed along transects arranged in concentric rings around the base of each tower. Although State guidelines recommend the search area have a radius equal to the maximum rotor tip height (e.g., 62.5 meters from the base of each turbine based on a rotor tip height of 125 meters), SMUD chose to follow recommendations provided in June 2012 during a meeting of the Solano County Technical Advisory Committee and extend the survey radius to 100 meters from each turbine (Solano County 2012). Survey transects were spaced 10 meters apart, extending from 10 meters to 100 meters from the base of each turbine.

While surveying along each transect, the surveyors scanned an area that extended approximately 5 meters on either side of the transect line, yielding a total of 105 meters surveyed out from each turbine. Surveyors used rangefinders to periodically confirm their distance from the turbine and ensure that they were surveying along the appropriate transect. They randomized the order in which they surveyed the turbine areas to ensure that individual turbine areas were surveyed at different times of day throughout the course of the year. During each survey day, the surveyors completed a field day summary form in which they recorded general weather conditions, turbine areas surveyed, times surveyed, and any fatalities observed (included in Appendix B).



Source: Data provided by SMUD in 2012 and compiled by AECOM in 2013

Figure 1. Project Site Map



Source: Data provided by SMUD in 2012 and compiled by AECOM in 2013

Figure 2. Project Overview Map

On June 26 and 27, 2012, before the first carcass survey was conducted, “clean sweep surveys” were conducted at the Year 1 subset of turbine areas to remove any avian and bat carcasses from the survey area. These surveys were conducted to allow the presumption that carcasses found during the formal carcass surveys could be attributed to the preceding 14-day period of turbine operation. Following the completion of the clean sweep surveys, regularly scheduled carcass surveys began.

Bird and Bat Processing

During carcass surveys, only birds and bats identified during standardized turbine surveys were considered “recordable fatalities.” Carcasses or injured wildlife found at times and locations outside of the standardized survey times and locations of this study, such as during surveys of a different subset, during travel between sites, or outside of the 105-meter survey area around each turbine, were classified as “incidental” finds. If the carcass was in an area that was scheduled to be surveyed on another day, it was marked with black electrical tape and left in place. If a carcass was left in place and was still present during later regularly scheduled surveys, it was processed as a recordable fatality.

Carcasses found were evaluated for the presence of scavenging and age, as well as any evidence regarding the cause of death. To be considered an avian turbine-related fatality, a feather spot was required to have at least five tail feathers or two primary feathers within at least 5 meters of each other or a total of 10 feathers. When partial remains were found (e.g., single wings), the data collected were cross-referenced with data collected for finds at adjacent turbine areas to avoid double-counting the remains from birds found during other surveys.

For each dead bird or bat found, a surveyor completed an Incident Data Form (included in Appendix C), documenting the condition and location of the find. Incidental finds were processed in the same manner as recordable finds.

All carcasses collected on-site were stored in an on-site freezer. These carcasses were held for a minimum of 1 month in case cross-comparison with other finds was necessary. In some instances, these carcasses were used in the carcass persistence trials and searcher efficiency trials. No eagle carcasses were found; however, had any been found, they would have been shipped to the National Eagle Repository.

Estimating Detection Probability

Variables such as scavengers removing carcasses in between surveys and surveyors missing carcasses affect the number of recordable fatalities detected during surveys. Carcass persistence is the probability of a carcass being removed by scavengers or other factors and are therefore not be detected by searchers. Carcasses can be removed from the search area in between surveys by scavengers, and are therefore not

be detected by searchers. Searcher efficiency is a metric referring to the proportion of carcasses detected by the surveyor. Searcher efficiency may be influenced by inherent individual differences (visual acuity, physical vigor, motivation, experience, and training) and differences in field conditions (weather, vegetation density, and height). To estimate these two probabilities, carcass persistence and searcher efficiency trials were performed.

Carcass Persistence Trials

Four seasonal carcass persistence trials were conducted during the first year of monitoring to estimate the proportion of carcasses removed by scavengers during the 14-day interval in between surveys. During each of these trials, 10 carcasses—including five medium to large birds and five small birds and/or bats—were placed in the field and monitored to determine the average rate of removal in days. Medium to large birds were represented by carcasses of medium to large raptors, waterfowl, and/or corvids. Small birds were represented primarily by carcasses of small passerines or small raptors. Small raptors were those that were the same size or smaller than a mourning dove (*Zenaida macroura*), such as western screech owl (*Megascops kennicottii*) or American kestrel (*Falco sparverius*). Carcasses were obtained from local rescue organizations and raptor rehabilitation facilities; others were collected during carcass surveys on-site.

Carcass persistence trials were conducted for 14 consecutive days per season. Seasons were divided as follows:

- summer: July through September,
- fall: October through December,
- winter: January through March, and
- spring: April through June.

On the first day of a trial—Day 0—the carcasses were placed in randomly selected locations in the 105 meter search area of turbines surveyed in Year 1. To select the locations for each carcass, combinations of turbines (30–84), distances from the turbines (0–105 meters), and bearings from the turbine (0–360 degrees) were selected at random. Each carcass was marked with green electrical tape around one leg and dropped from chest height at the randomized locations. The carcasses were checked daily for the first 3 days following placement in the field (Days 1–3). The carcasses were then checked every other day for the remainder of the trial (Days 4, 6, 8, 10, 12, and 14). Every time they were checked, each carcass was classified into one of four categories:

- intact—a carcass that is not badly decomposed and shows no sign of scavenging;

- scavenged—an entire carcass that shows signs of being fed on by a scavenger, or a partial carcass that has been scavenged, with portions of it (e.g., wings, skeletal remains, legs, pieces of skin) found in more than one location;

- feather spot—at least five tail feathers or two primary feathers within at least 5 meters of each other or a total of 10 feathers, indicating predation or scavenging; or

- removed—the carcass has been removed and/or evidence remaining would not classify as a facility-related fatality during standardized carcass surveys.

Searcher Efficiency Trials

Four seasonal searcher efficiency trials were conducted during the first year of monitoring to estimate the proportion of carcasses missed by surveyors. To reduce surveyor bias, carcasses were placed in the field without the knowledge of survey staff members in the morning before their arrival on-site. During the course of each season, a total of 12 carcasses—including a minimum of five medium to large birds and five small birds and/or bats—were placed in the field. A list of random turbine numbers, distances from the turbines (0–105 meters), and bearings from the turbine (0–360 degrees) were selected at random to determine the placement location for each carcass used in the trial. Birds were marked with brown electrical tape so they would not be confused with facility-related fatalities.

Analytical Methods

Estimates of facility-related fatalities were calculated using the Huso estimator, which was run using R statistical software (Huso 2010). The estimator was used to calculate the total number of facility-related fatalities. The number of fatalities per species encountered, as well as the number of bat-, raptor-, and nonraptor-fatalities was also calculated. Only "recordable fatalities" were included in statistical estimates; incidental finds were not included in the models. When this model was run, bootstrap[1] resampling was used to generate a 95% confidence interval for all estimates. The Huso estimator recommends running a minimum of 1,000 resampling replicates. For this study, confidence intervals were calculated using 3,000 bootstrapping replicates.

To fit the best model to the fatality estimates, carcass size, ground visibility, and season were evaluated as variables of the searcher efficiency and carcass persistence. Models were also run in which no variables were evaluated. The best models were selected by comparing their Akaike Information Criterion (AIC) values, of which the lowest values indicate the best fitting models. To fit the models to carcass persistence data, four distributions commonly used to represent survival or persistence times were compared (White and Garrott 1990): Weibull, exponential, lognormal, and loglogistic.

[1] Bootstrapping is a statistical resampling process of calculating repeated scenarios of the model in order to generate a summary outcome.

The Huso estimator allows for the incorporation of density-weight proportional (DWP) factors to be applied to the model using a spatial polynomial analysis. As a simplified alternative approach, the Huso estimation package also states that a factor of 1 can be applied to this variable in the model, which assumes complete surveying of the turbine area. Four turbines on-site (numbers 36, 69, 72, and 84) had survey areas that exceeded SMUD's rights-of-way or property lines. These areas were not accessible to biologists conducting the carcass surveys. To account for this reduction in the searchable area, the fraction of the area accessible was calculated and used as the DWP variable for those specific turbines.

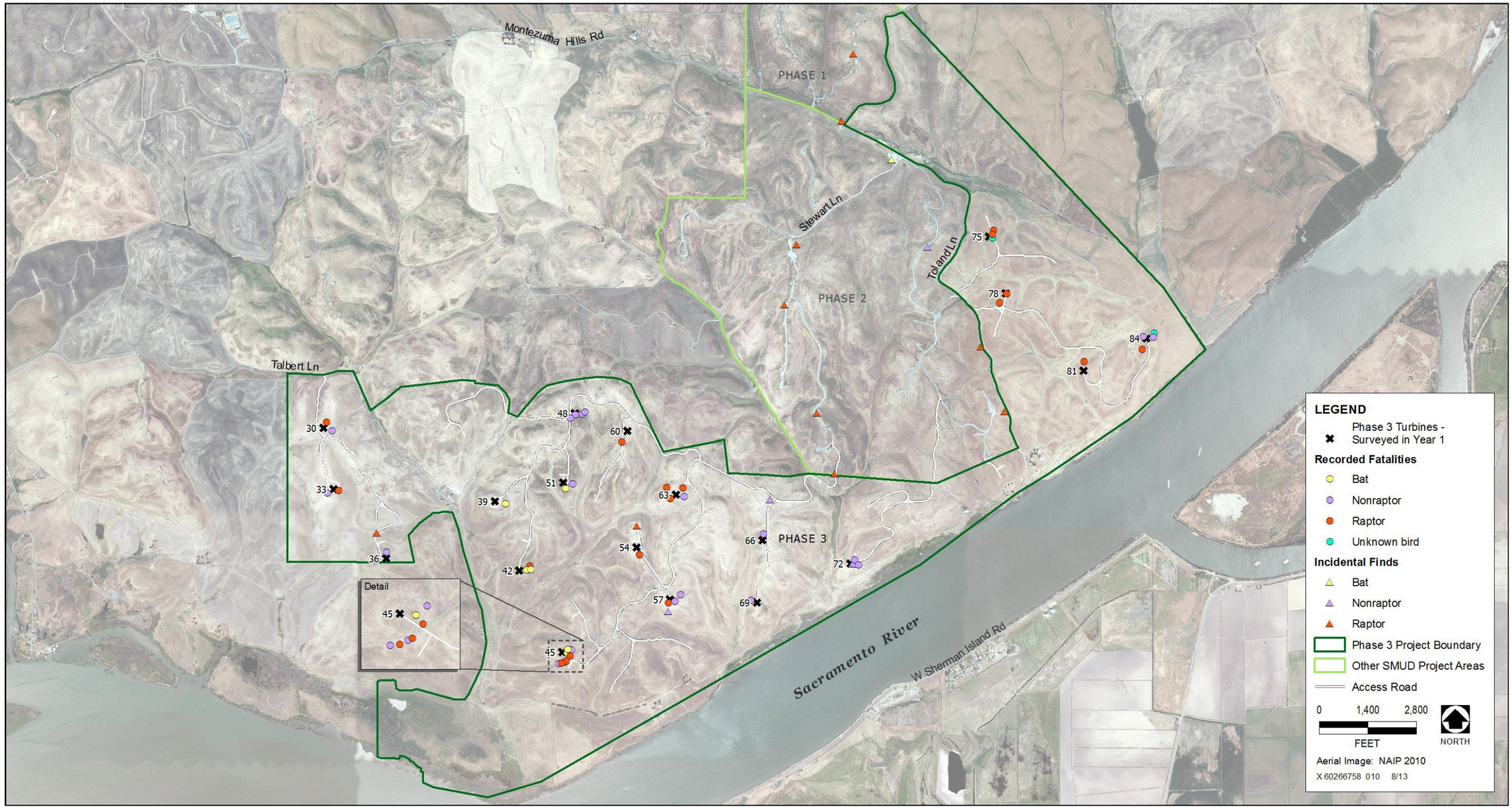
Because four birds could not be identified to genus level, they could not be classified as either large or small birds. For this reason, species-specific fatality estimates excluded these fatalities. Models were run that included these carcasses but that did not evaluate carcass size as a variable.

Results

During the first year of surveys, a total of 46 bird and bat recordable fatalities were recorded on site during regularly scheduled turbine surveys (Figure 3). Of these recordable fatalities, 41 were bird species (18 raptors and 23 nonraptors) and five were bat species. Feather spots, rather than complete or partial carcasses, accounted for 29 of these fatalities. These were conservatively attributed to turbine strikes but could also have been a result of predation or other causes. Western meadowlark (*Sturnella neglecta*) (12 recorded fatalities), American kestrel (eight recorded fatalities), barn owl (*Tyto alba*) (five recorded fatalities), and red-tailed hawk (*Buteo jamaicensis*) (three recorded fatalities) were the most commonly found bird species. Fewer than three fatalities were recorded for each of the other species detected. Hoary bat (*Lasiurus cinereus*) was the most common bat species recorded (three recorded fatalities). The locations of these carcasses are shown in Figure 3.

No fatalities of eagles or species listed under the federal Endangered Species Act or California Endangered Species Act were recorded. One fatality was recorded for a state species of special concern (northern harrier [*Circus cyaneus*]).

In addition to the 46 recordable fatalities, an additional 15 incidental finds were recorded either outside the turbine survey area or outside of regularly scheduled turbine surveys (Figure 3). Many of these incidental finds were recorded in the Solano Wind Project, Phases 1 or 2, by surveyors driving through portions of the Phase 3 turbine area. Details regarding each of the recordable fatalities and incidental finds are provided in Appendix D. Red-tailed hawk was the most commonly found species recorded as an incidental find (eight individuals). These incidental finds were excluded from statistical analysis. No carcasses were found during the clean sweep surveys. The recordable fatalities and incidental finds were represented by at least 16 different species; four bird



Sources: Data provided by SMUD in 2012 and compiled by AECOM in 2013; data collected by AECOM in 2012 and 2013

Figure 3. Distribution of Fatality Detections, Year 1

carcasses could not be identified to genus level, and one bat could not be identified to species level. A breakdown of the number of recordable fatalities and incidental finds per species is provided in Table 1. Table 2 summarizes the number of fatalities recorded per species at each turbine.

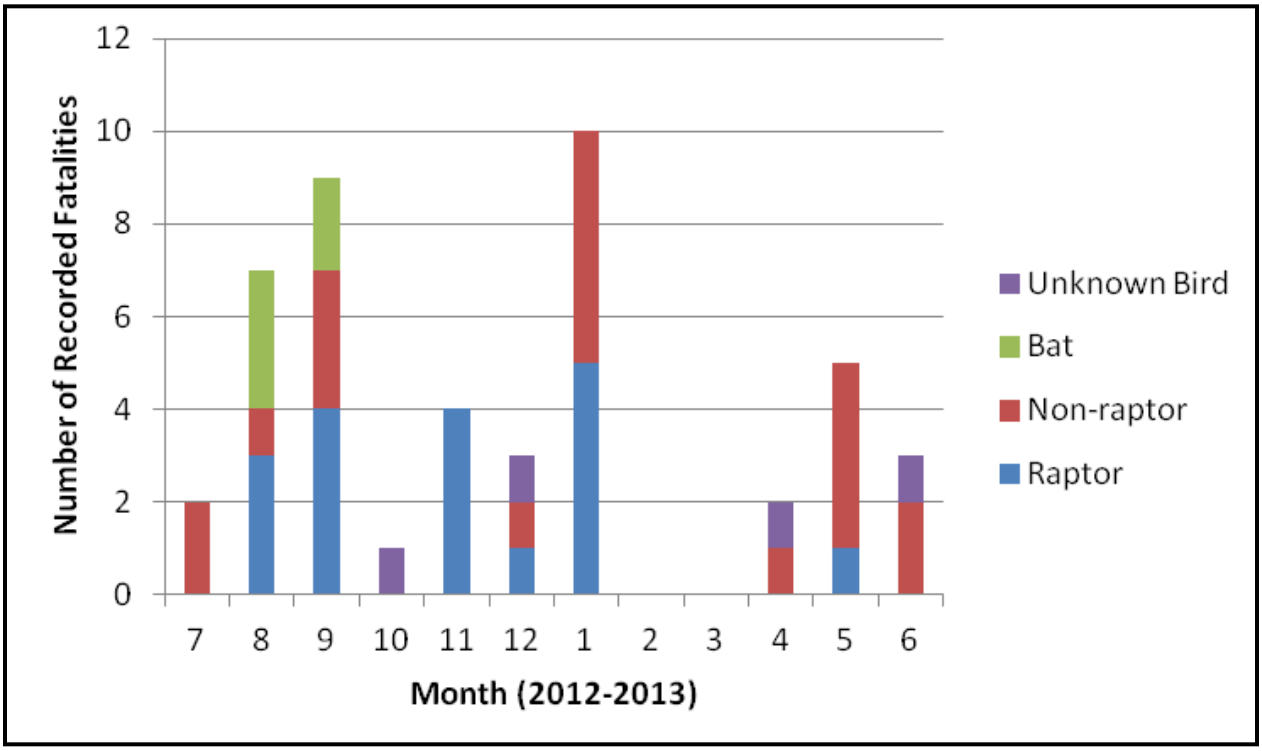
Table 1. Fatalities Detected, Year 1

Species	Recorded Fatality (included in analysis)	Incidental Finds
Birds		
American kestrel (*Falco sparverius*)	8	0
Barn owl (*Tyto alba*)	5	2
Black-headed grosbeak (*Pheucticus melanocephalus*)	1	0
Brown-headed cowbird (*Molothrus ater*)	2	0
Brown pelican (*Pelecanus occidentalis*)	0	1
Horned lark (*Eremophila alpestris*)	1	0
Northern harrier (*Circus cyaneus*)	1	0
Unknown grebe (Family Podicipedidae)	0	1
Red-tailed hawk (*Buteo jamaicensis*)	3	8
Rough-legged hawk (*Buteo lagopus*)	1	0
Red-winged blackbird (*Agelaius phoeniceus*)	1	0
Ring-necked pheasant (*Phasianus colchicus*)	1	1
Western meadowlark (*Sturnella neglecta*)	12	1
Wilson's warbler (*Wilsonia pusilla*)	1	0
Unknown bird	4	0
Total Birds	**41**	**14**
Bats		
Hoary bat (*Lasiurus cinereus*)	3	0
Mexican free-tailed bat (*Tadarida brasiliensis*)	0	1
Unknown free-tailed bat (*Tadarida* sp.)	1	0
Unknown bat	1	0
Total Bats	**5**	**1**

Source: Data collected by AECOM in 2012 and 2013

Spatial and Temporal Variation in Fatalities

Recorded fatalities were distributed throughout the year, with the highest numbers of fatalities recorded in August, September, and January. February, March, and October had the lowest number of fatalities recorded. All bat fatalities were recorded in August and September. A graph displaying the breakdown of fatalities per month is shown in Figure 4.



Source: Data collected by AECOM in 2012 and 2013

Figure 4. Monthly Distribution of Fatalities

Fatalities were recorded at all 19 turbine areas surveyed during Year 1, with the highest number of fatalities recorded (seven) at Turbine 45—the southernmost turbine surveyed. Raptor and nonraptor bird fatalities were distributed across the wind farm, with raptor fatalities recorded at 12 different turbines and nonraptor fatalities recorded at 12 different turbines; however, clusters of nonraptors were recorded along the Sacramento River. All bat fatalities were recorded at four turbines located close to each other in the west-central portion of the wind farm (Figure 3).

Detection Probability Modeling

Several models were fit to the searcher efficiency data to determine which fit the data best, according to their AIC values. After models applying ground cover visibility, season, and carcass size class, as well as a model with no variables, were evaluated, it was determined that the model considering season was most significantly aligned with the data, as indicated by the lowest AIC value (Table 3). Searcher efficiency estimates for each size class are shown in Table 4.

Table 2. Summary of Recorded Fatalities by Turbine

Turbine Number	American Kestrel	Northern Harrier	Red-Tailed Hawk	White-Tailed Kite	Cooper's Hawk	Western Screech Owl	Barn Owl	Brown Pelican	Ring-Necked Pheasant	Western Meadowlark	Brewer's Blackbird	Red-Winged Blackbird	Brown-Headed Cowbird	Wilson's Warbler	Black-Headed Grosbeak	Horned Lark	*Podiceps* spp.	Unknown Dove	Unknown Bird	Hoary Bat	Mexican Free-Tailed Bat	Unknown Bat	Unknown Free-Tailed Bat	TOTAL
30	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2
33	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	2
36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
42	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	3
45	2	1	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	1	-	-	-	7
48	-	-	-	-	-	-	-	-	-	1	1	-	-	-	1	-	-	-	1	-	-	-	-	4
51	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	2
54	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
57	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	3
60	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
63	-	-	1	-	-	-	2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	4
66	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
69	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
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81	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
84	1	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	1	-	-	-	-	4

Source: Data compiled by AECOM in 2013

Table 3. Searcher Efficiency Models Evaluated

Model	AIC Value
No explanatory variables	65.6
Carcass size	66.35
Visibility	67.47
Season	**62.67**

Note: AIC = Akaike Information Criterion. Bolded results indicate those models used in adjusted fatality estimates.
Source: Data compiled by AECOM in 2013

Table 4. Searcher Efficiency Estimate by Size Class

Carcass Size	Carcasses Placed	Carcasses Found	Searcher Efficiency Estimate
Small birds	24	13	0.54
Large birds	24	17	0.71
Total	48	30	0.63 (average)

Source: Data compiled by AECOM in 2012 and 2013

When the carcass persistence rate was being calculated, models evaluating no variables, evaluating size class as a variable, and evaluating size class and season as variables were run and compared. The models were fit to all four distribution types included in the Huso estimator package, and their AIC values were compared to identify the best fit, as shown in Table 5. The model evaluating size class and following the exponential distribution was selected for use in fatality estimates because it had the lowest AIC value. The estimated carcass persistence rates for each size class are shown in Table 6.

Table 5. Carcass Persistence Models Evaluated

Distribution Type	AIC Value (no variable)	AIC Value (size class variable)	AIC Value (season variable)
Weibull	115.95	114.24	121.29
Exponential	114.77	**112.82**	119.54
Loglogistic	116.29	114.58	121.86
Lognormal	116.88	114.4	122.91

Note: AIC = Akaike Information Criterion. Bolded results indicate those models used in adjusted fatality estimates.
Source: Data compiled by AECOM in 2013

Table 6. Carcass Persistence Rate Estimates

Carcass Size	Carcasses Placed	Carcass Persistence Rate (95% confidence interval)
Small birds	20	0.85 (0.71–0.96)
Large birds	20	0.63 (0.47–0.79)

Source: Data compiled by AECOM in 2012 and 2013

Estimation of Total Fatalities

The estimates of the number of fatalities per species using the Huso estimator, as well as the annual per turbine and per megawatt fatality rates per species, are shown in Table 7.

The fatality estimates per species were run using season as a variable for searcher efficiency and with size as a variable for carcass persistence (shown in Table 8). As a simplified approach to the DWP analysis, all turbines were assigned a DWP value of 1. Because portions of the total survey area at four turbines were inaccessible to biologists in the field, the surveyable fractions at these turbines were included in the DWP variable of the model. The fractions used were:

- Turbine 84: DWP Value = 0.9415,
- Turbine 36: DWP Value = 0.6747,
- Turbine 72: DWP Value = 0.5846, and
- Turbine 69: DWP Value = 0.9928.

All other turbines were assigned a DWP value of 1. Four bird fatalities were recorded in which the species could not be identified to genus level. For this reason, these four carcasses could not be assigned a size classification. Because models including size as a variable were determined to fit the data most significantly based on their AIC values, these four fatalities were excluded from models that were used to calculate species-specific fatality estimates. To evaluate the effect of these four additional recorded fatalities on the estimates of total facility-related fatalities, models were also run in which size class was not used as a variable. These estimates were calculated per turbine, per megawatt, and for the entire facility. The comparison of these estimates with other wind energy projects in the CMHWRA is provided in Table 9.

Table 7. Estimation of Annual Facility-Related Fatalities Using Huso Method

Species	Unadjusted Fatalities	Estimated Facility-Related Fatalities (95% CI)	Estimated Fatalities per Megawatt	Estimated Fatalities per Turbine (95% CI)
Raptors				
American kestrel	8	59 (26–514)	0.46	1.06 (0.46–9.34)
Barn owl	5	34 (8–317)	0.27	0.61 (0.13–5.75)
Northern harrier	1	6 (5–33)	0.05	0.1 (0.08–0.59)
Red-tailed hawk	3	18 (4–280)	0.14	0.32 (0.07–5.08)
Rough-legged hawk	1	4 (4–24)	0.03	0.07 (0.06–3.89)
Total Raptors[a]	**18**	**121**	**0.95**	**2.16**
Nonraptors				
Black-headed grosbeak	1	7 (6–58)	0.05	0.13 (0.09–1.05)
Brown-headed cowbird	2	16 (6–77)	0.13	0.27 (0.1–1.39)
Horned lark	1	14 (9–86)	0.11	0.24 (0.16–1.55)
Red-winged blackbird	1	7 (6–61)	0.05	0.13 (0.09–1.11)
Ring-necked pheasant	1	7 (5–33)	0.05	0.11 (0.08–0.58)
Western meadowlark	12	148 (59–517)	1.16	2.68 (10.7–9.4)
Wilson's warbler	1	7 (5–62)	0.05	0.13 (0.09–1.12)
Total Nonraptors[a]	**19**	**206**	**1.6**	**3.69**
Bats				
Hoary bat	3	23 (7–105)	0.18	0.42 (0.12–1.91)
Unknown free-tailed bat	1	9 (6–46)	0.07	0.15 (0.11–0.83)
Unknown bat	1	8 (6–51)	0.06	0.14 (0.1–0.93)
Total Bats[a]	**5**	**40**	**0.31**	**0.71**

Note: Carcasses that could not be assigned a size classification have been excluded from this model.
CI = confidence interval.
[a] These estimates were generated by the sums of the respective data; no bootstrapping analysis was conducted for these subsets.
Source: Data compiled by AECOM in 2012 and 2013

Table 8. Total Facility-Related Fatality Estimates

Model	Total Carcasses Included	Total Annual Facility-Related Fatality Estimate (95% CI)	Annual Estimate per Turbine (95% CI)	Estimate per Megawatt
Best Fit Model (season and carcass size variables)	42	362 (243–1541)	6.56 (4.42–28.01)	2.82
No Variable Model	46	310 (209–462)	5.63 (3.79–8.4)	2.42

Note: CI = confidence interval.
Source: Data compiled by AECOM in 2012 and 2013

Table 9. Comparison of per-Megawatt Fatality Estimates

Fatality Type	Solano Wind Project, Phase 3, Year 1	Montezuma I, Year 1	Shiloh II, Year 1
All raptors	0.95	1.06	0.12
All nonraptors	1.6	4.13	1.39
All birds	2.55	5.19	1.51
All bats	0.31	1.90	2.72
Total	**2.86 (2.82)[a]**	**7.09**	**4.23**

Note:
[a] 2.86 fatalities per megawatt is reflective of the sum of the species-specific estimates; 2.82 fatalities per megawatt is reflective of the total facility estimate. These numbers vary slightly because of the bootstrapping methodology.
Sources: Compiled by AECOM in 2013; ICF International 2012; Curry and Kerlinger 2010, 2012

Comparison to Other Facilities

The adjusted fatality estimates for the Solano Wind Project, Phase 3, were compared to the rates calculated at two other nearby wind energy facilities in the Montezuma Hills: Montezuma Wind, Year 1 (prepared in 2011; ICF International 2012) and Shiloh II, Year 1 (prepared in 2010; Curry and Kerlinger 2010). These wind energy facilities were selected for comparison because reports on these CMHWRA facilities had been prepared relatively recently and used similar study design. Montezuma Wind, Year 1, was the only other facility that could be identified in the CMHWRA with published estimates obtained using the Huso statistical methodology. Both wind energy facilities are located within 5 miles of Solano Wind Project, Phase 3. These rates are compared on a per megawatt basis, as shown in Table 9.

Discussion

Based on Year 1 data, adjusted fatality estimates recorded at the Solano Wind Project, Phase 3, fall within the range of or are lower than fatality estimates for other projects in the CMHWRA (Table 9). There is a fairly broad range of estimates from different

projects in the CMHWRA, which is partly explained by the use of different field methods (e.g., survey radius, transect width), different methods for conducting carcass detection trials, and different analytical formulas to estimate fatality rates (Montezuma Wind used the Huso estimator, whereas Shiloh II used an estimator considered less accurate); the range is also likely attributable to variable use of the CMHWRA by different species. The estimated bird and bat fatality rates at Solano Wind Project, Phase 3, were lower than those at Montezuma Wind. Bat fatality rates at Solano Wind Project, Phase 3, were considerably lower than those recorded at other wind energy facilities in the CMHWRA.

Recorded fatalities were distributed throughout the year; however, a slightly higher proportion of the fatalities occurred in the late summer through early winter months, possibly corresponding to seasonal southward migration patterns. Similarly, all bat fatalities were recorded over a 2-month period in August and September, which corresponds to the fall bat migration in the CMHWRA and the period of greatest reported bat fatalities at most facilities operating in the CMHWRA.

Although recorded fatalities were widely distributed across the Solano Wind Project, Phase 3, area, few clear spatial patterns or species-specific patterns were detected, with two possible exceptions. Bat fatalities were concentrated among four relatively closely spaced turbines in the west-central portion of the study area, suggesting localized use of the area by migrating bats. There was also a concentration of nonraptor fatalities near the turbines nearest the Sacramento River, suggesting passerine movement along that corridor. Eight widely spaced turbines were responsible for multiple (more than three) fatalities, suggesting that more subtle topographic conditions that influence bird movement may also have been a factor in the spatial distribution of fatalities. Because this report describes the data collected from only 1 year, spatial patterns may shift or become more apparent as the amount of collected data grows during the second and third year of surveys.

This report assumed a standardized survey area for each turbine, rather than a spatial polynomial-based weighted estimate. This method can slightly overestimate the turbine fatality rate by assuming that the likelihood of finding a carcass is equal in all portions of the survey area. Further, four turbines surveyed in Year 1 had survey areas that were partially excluded from the study because of landowner access restrictions. To accommodate for this limitation, a fraction of that survey area was used in the model to bolster the fatality estimates at these turbines proportionate to the areas that could not be surveyed. The areas that could not be surveyed generally lie at the outermost survey transects around the turbine, where the likelihood of finding a carcass is reduced compared to the more central transect rings. For this reason, applying a fraction to the DWP value likely slightly overestimates the fatality rates of these unsurveyed portions. Because these areas constitute only a small component of the overall Solano Wind Project, Phase 3, survey area, this adjustment is not expected to result in significant changes to the estimates; however, more accurate estimates could be generated from

using truly density-weighted proportions at these four turbines. For subsequent annual reports, density-weighted proportions will be calculated and used in the DWP formulations.

It should be noted that although the seasonal timing of the searcher efficiency trials was found to correlate most closely with the data, it resulted in large confidence intervals, likely attributable to the high variation in search efficiency between seasons. For this reason, it was observed that the use of models excluding additional covariates (run for the purposes of analyzing birds without a size classification) actually resulted in a lower total facility-related fatality estimate. Because seasonal timing introduces such wide confidence intervals into the data, subsequent years of surveys at the site will further analyze the fit of this variable to the model to refine the model used to calculate the final estimates.

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APPENDIX A:
REPRESENTATIVE PHOTOGRAPHS

Photograph 1: A representative photograph of dryland farming landscapes found on the wind farm

Photograph 2: A representative photograph of dryland farming landscapes found on the wind farm

Photograph 3: An example of a raptor fatality; this particular photograph depicts a rough-legged hawk

Photograph 4: An example of a bat found on site; this particular photograph depicts a hoary bat

Photograph 5: An example of a feather spot; this particular photograph depicts a bird that was not identified to species level.

APPENDIX B:
SAMPLE TURBINE SURVEY LOG

AECOM

Sacramento Municipal Utility District
Solano Wind Project – Phase 3

Turbine Survey Data Log

Date: ______________ Surveyors: ____

Temperature (F): ____________ Wind Speed/Direction: ____________/____________ Cloud Cover: ________%

Turbine Number	Time		Fatality Recorded?	Height Visibility Categories (circle one)
	Start	Finish		
			☐ No ☐ Yes Inc. #:	Low ☐ Medium ☐ High ☐
			☐ No ☐ Yes Inc. #:	Low ☐ Medium ☐ High ☐
			☐ No ☐ Yes Inc. #:	Low ☐ Medium ☐ High ☐
			☐ No ☐ Yes Inc. #:	Low ☐ Medium ☐ High ☐
			☐ No ☐ Yes Inc. #:	Low ☐ Medium ☐ High ☐
			☐ No ☐ Yes Inc. #:	Low ☐ Medium ☐ High ☐
			☐ No ☐ Yes Inc. #:	Low ☐ Medium ☐ High ☐
			☐ No ☐ Yes Inc. #:	Low ☐ Medium ☐ High ☐

Notes:

Instructions

- Fatality Recorded:
  If yes, include Incident Form number (e.g., 20120726-01)
  Processing Protocol: Green = scavenger trial ➔ do not process. Brown = surveyor efficiency trial ➔ process and return to freezer. Black = found during non-survey event ➔ process and return to freezer.

- Vegetation Height Visibility Categories:

  Circle the category that is the dominant visibility, i.e., if 60% of the area surveyed is high visibility and 40% is low visibility, circle "high."

  1. High Visibility: Includes gravel areas around the base of the turbine, roads, recently cut or mowed vegetation, recently prepared for planting or recently planted agricultural fields, actively grazed grasslands with low vegetation.
  2. Moderate Visibility: Includes ungrazed grasslands, moderate growth and development of wheat and other crops.
  3. Low Visibility: Disked fields with large clods, crops with maximum growth and development, tall, dense ruderal vegetation (e.g., mustard plants that are > 3 feet tall).

APPENDIX C:
SAMPLE INCIDENT DATA FORM

AECOM

Sacramento Municipal Utility District
Solano Wind Project – Phase 3

Incident Data Form

Incident Number:		☐ **Fatality**	☐ **Injury**
Species:		**Date:**	
Surveyor(s):			
Location Data			
Turbine Number:	**Degree**:	**Distance**:	
Nearest Structure:	**Northing**:	**Easting**:	
Photograph Numbers:			
Carcass Information			
Age: ☐ Juvenile ☐ Adult	**Sex**:	**Band**: ☐ No ☐ Yes ☐ Legs Missing	
Estimated Cause of Death:			
Method of Species ID:			
Estimated Time Since Death: ☐ Fresh	☐ <1 Week	☐ < 1 Month	☐ > 1 Month
Body Parts Present:			
Scavenging: ☐ Vertebrate:		☐ Invertebrate:	
Condition of Carcass: ☐ Intact	☐ Scavenged	☐ Feather Spot	
Habitat Conditions			
Cover Type(s): ☐ Gravel ☐ Tilled ☐ Grain ☐ Ruderal ☐ Other:			
Vegetation Height: Low Medium High			
Prey Species Present:			
Notes			

Sacramento Municipal Utility District
Solano Wind Project - Phase 3

Instructions
• Incident Number – A unique number for all birds/bats collected, regardless of cause of death/injury, that includes the year, month, date, and a number corresponding to the number found each day. For example, the third bird found October 10, 2012, would be #20121010-03). • Species – Identified as accurately as possible (red-tailed hawk, unknown *Buteo*, unknown hawk, California myotis). If unknown, it is listed as "unknown small bird" (smaller than a mourning dove), "unknown medium bird" (between a mourning dove and raven), "unknown large bird" (red-tail hawk-sized or larger) or "unknown bat." • Age and Sex – if known. Classify age by adult or juvenile. • Photo Number – at least four photographs are taken with a digital camera: two of the fatality before it is disturbed and two of indicators used to determine species, age, or sex, as applicable. The photo numbers will be recorded on the data form and regularly downloaded from the camera. • Turbine Number – the nearest turbine. If the nearest turbine is not within the Solano Wind Project Phase 3, it will be noted. • Degree – the compass bearing from the nearest intact turbine to the remains. • Distance – the distance (in meters) from the nearest turbine to the remains. • Nearest Structure (if closer to fatality than a turbine) – the nearest structure to the fatality (meteorological tower, power pole, building, other). • GPS Location – in Universal Transverse Mercator (datum NAD83). • Body Parts – all body parts found (for example, "whole bird" or "right wing" or "flight feathers only" or "skull, vertebrae, and sternum"). • Estimated Cause of Death – probable cause of death as determined by carcass location and condition (turbine blade collision, electrocution, predation, overhead lines, hit by car, etc.). Include a reason for determination of cause of death when cause other than unknown is circled (e.g., fatality has broken right humerus, <10 m from turbine). • Estimated Time Since Death – age of fatality (fresh, <1 week, <1 month, >1 month) based on the presence and type of insects, condition of flesh and eyes, whether or not leg scales or bones are bleached, etc. Due to difficulty of determining age after approximately 1 week, categories are quite large. • Scavenging – record the carcass condition in one of the following categories: • Intact – a carcass that is not badly decomposed and shows no sign of having been fed upon by a predator or scavenger, although it may show signs of traumatic injury such as amputation from a turbine collision • Scavenged – an entire carcass that shows signs of having been fed upon by a predator or scavenger, or a partial carcass that has been scavenged, with portions of it (for example, wings, skeletal remains, legs, pieces of skin) found in more than one location • Feather spot – 10 or more feathers at one location, indicating predation or scavenging • Notes – additional information such as carcass condition and location, details for identification of rare species, band number if banded (see the Monitoring Protocol regarding banded bird procedures), obvious injuries, and potential cause of death if other than those listed above. • Vegetation characteristics – cover type, vegetation height (either low, medium, or high), etc. • Presence of Raptor Prey Species – evidence of ground squirrels, pocket gophers, other rodents, etc. • Surveyor – first and last initials of all present, in case of future questions. The surveyor recording the data lists his/her initials first.

APPENDIX D:
SUMMARY OF CARCASSES DETECTED, JULY 2012 – JUNE 2013

Table D-1
Data Summary for Carcasses Detected during SMUD Solano Wind Project Phase 3 Mortality Monitoring, July 2012 – June 2013

Date	Species	Turbine Number	Estimated Cause of Death
July 19, 2012	Western meadowlark	84	Turbine blade collision
July 19, 2012	Horned lark	36	Turbine blade collision
August 28, 2012	Ring-necked pheasant	84	Unknown
August 29, 2012	Hoary bat	42	Turbine blade collision
August 29, 2012	Hoary bat	42	Turbine blade collision
August 29, 2012	Hoary bat	45	Turbine blade collision
August 29, 2012	Northern harrier	45	Unknown
August 29, 2012	American kestrel	45	Unknown
August 30, 2012	American kestrel	60	Unknown
September 11, 2012	Barn owl	81	Turbine blade collision
September 11, 2012	American kestrel	84	Turbine blade collision
September 11, 2012	Brown-headed cowbird	33	Turbine blade collision
September 12, 2012	Unknown free-tailed bat	39	Turbine blade collision
September 12, 2012	American kestrel	45	Predation
September 12, 2012	Western meadowlark	48	Turbine blade collision
September 12, 2012	Unknown bat	51	Turbine blade collision
September 12, 2012	Western meadowlark	51	Turbine blade collision
September 25, 2012	American kestrel	30	Turbine blade collision
October 9, 2012	Unknown small nonraptor	48	Unknown
November 7, 2012	Barn owl	78	Turbine blade collision
November 7, 2012	Red-tailed hawk	33	Turbine blade collision
November 8, 2012	American kestrel	54	Turbine blade collision
November 19, 2012	American kestrel	75	Turbine blade collision
December 20, 2012	Western meadowlark	45	Turbine blade collision
December 21, 2012	Unknown dove	72	Unknown
December 21, 2012	Rough-legged hawk	75	Turbine blade collision
January 2, 2013	Red-tailed hawk	42	Turbine blade collision
January 2, 2013	Barn owl	63	Turbine blade collision
January 15, 2013	Western meadowlark	45	Turbine blade collision

Table D-1
Data Summary for Carcasses Detected during SMUD Solano Wind Project Phase 3 Mortality Monitoring, July 2012 – June 2013

Date	Species	Turbine Number	Estimated Cause of Death
January 15, 2013	Western meadowlark	63	Turbine blade collision
January 15, 2013	Barn owl	63	Turbine blade collision
January 15, 2013	Western meadowlark	66	Turbine blade collision
January 16, 2013	Western meadowlark	72	Turbine blade collision
January 16, 2013	Barn owl	78	Turbine blade collision
January 29, 2013	Western meadowlark	57	Unknown
January 29, 2013	Red-tailed hawk	63	Turbine blade collision
April 10, 2013	Western meadowlark	72	Unknown
April 10, 2013	Unknown bird	84	Unknown
May 8, 2013	Brewer's blackbird	48	Turbine blade collision
May 8, 2013	Black-headed grosbeak	48	Unknown
May 21, 2013	Wilson's warbler	30	Turbine blade collision
May 22, 2013	American kestrel	57	Turbine blade collision
May 22, 2013	Western meadowlark	57	Turbine blade collision
June 6, 2013	Unknown bird	75	Unknown
June 18, 2013	Red-winged blackbird	45	Predation
June 19, 2013	Western meadowlark	69	Turbine blade collision

Source: Data collected by AECOM in 2012 and 2013

Table D-2
Data Summary for Carcasses and Injured Wildlife Detected Incidentally at SMUD Solano Wind Project Phase 3 Site, July 2012 – June 2013

Date	Species	Turbine Number	Estimated Cause of Death	Fatality/ Injury
July 26, 2012	Brown pelican	72	Turbine blade collision	Fatality
September 13, 2012	Western meadowlark	57	Unknown	Fatality
September 21, 2012	Barn owl	Not within Phase 3 facility	Collision with overhead transmission line	Fatality
October 10, 2012	Ring-necked	Not within Phase 3 facility	Unknown	Fatality

Table D-2
Data Summary for Carcasses and Injured Wildlife Detected Incidentally at SMUD Solano Wind Project Phase 3 Site, July 2012 – June 2013

Date	Species	Turbine Number	Estimated Cause of Death	Fatality/ Injury
	pheasant			
October 15, 2012	Red-tailed hawk	Not within Phase 3 facility	Turbine blade collision	Fatality
October 24, 2012	Red-tailed hawk	Not within Phase 3 facility	Turbine blade collision	Fatality
November 1, 2012	Mexican free-tailed bat	Found at tank storage building	Unknown	Fatality
December 11, 2012	Red-tailed hawk	53	Turbine blade collision	Fatality
January 29, 2013	Red-tailed hawk	Not within Phase 3 facility	Turbine blade collision	Fatality
January 29, 2013	Barn owl	80	Unknown	Fatality
February 4, 2013	Red-tailed hawk	Found at intersection of Montezuma Hills Road and Toland Lane	NA (injured bird; cause unknown)	Injury
March 28, 2013	Red-tailed hawk	Not within Phase 3 facility	Turbine blade collision	Fatality
April 12, 2013	Red-tailed hawk	Not within Phase 3 facility	Turbine blade collision	Fatality
May 30, 2013	*Podiceps* species	64	Turbine blade collision	Fatality
June 20, 2013	Red-tailed hawk	35	Turbine blade collision	Fatality

Notes:
"Incidental" finds are carcasses or injured wildlife found at times and locations outside of the standardized surveys conducted as part of this study. These include carcasses incidentally detected at turbines that were not part of the 19-turbine subset that were surveyed during this first monitoring year and carcasses found elsewhere on the SMUD Solano Wind Project Phase 3 site.
NA = not applicable.
Source: Data collected by AECOM in 2012 and 2013