Post-Construction Avian and Bat Mortality Study at the Lower West Wind Energy Project Kern County, California

Final Report for the Fifth Year of Operation
July 2016 – August 2017

Prepared for:
Brookfield Renewable Energy Partners, LP

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EXECUTIVE SUMMARY

In 2012, Western Wind, LLC (WW) contracted Western EcoSystems Technology, Inc. (WEST) to conduct mortality surveys at the Lower West Wind Energy Project (Project) in Kern County, California, during the first, third, and fifth years of operation for the purpose of estimating the impacts of the wind energy facility on birds and bats. In 2013, Brookfield Renewable Energy Partners, LP (BREP) purchased the Project from WW, and it was decided that WEST would continue the monitoring effort on behalf of BREP. The following document contains the results of the third year of mortality monitoring (fifth year of operation) conducted at the Project.

The primary objective of the mortality monitoring study was to determine the level of bird and bat mortality (high, moderate, or low levels compared to other facilities in the region) attributable to collisions with wind turbines for the entire facility on an annual basis. The monitoring study consisted of four components: 1) standardized carcass surveys of selected turbines; 2) searcher efficiency trials to estimate the percentage of carcasses found by searchers; 3) carcass removal trials to estimate the length of time that a carcass remained in the field for possible detection; and 4) adjusted mortality estimates for birds and bats, calculated using the results from searcher efficiency trials and carcass removal trials to estimate the approximate level of bird and bat mortality within the Project.

Avian and bat monitoring at the Project was conducted from July 22, 2016—through August 3, 2017. The original study design for the Project called for monitoring plots surrounding four randomly selected turbines. Each of the four sampled turbine plots was searched approximately twice per month during the monitoring year for a total of 26 visits to each plot and a grand total of 104 turbine plot searches. Search plots consisted of 120-meter (m; 394-foot [ft]) radius circles centered on each sampled turbine. Surveyors walked parallel transects within the search plots while scanning the ground for carcasses or injured birds or bats. During the study, two bird carcasses: a horned lark and common raven were found during the spring period.

To account for factors that may influence carcass detection, results from two types of bias trials, searcher efficiency and carcass removal, were incorporated into the fatality estimate. To determine searcher efficiency and carcass removal rates for the Project, data from Lower West and two other nearby wind facilities (Alta VIII and Mustang Hills) were used. A total of 353 bird carcasses and 75 brown mice carcasses (bat surrogates) were included in the searcher efficiency trials analysis. Overall searcher efficiency rates were 74.9% for small birds, 94.0% for large birds, and 76.7% for bats. For large birds, season had an effect on searcher efficiency and was lowest in spring at 84.9%. Approximately 376 carcass removal trials were conducted which included 106 large birds, 196 small birds, and 74 brown mice; by Day 10, approximately 20% of small birds and 2% of mice remained where they were placed, compared to approximately 55% of large birds. Season affected carcass removal rates for both bats and large birds and was longest in winter for large birds and longest in spring for bats. Compared to winter, removal times in spring, when both fatalities were found, were less than half as long for large birds (x = 16.6 days). Average removal time in spring for small birds was 5.1 days.

Bias trial results were used to calculate the probability that a carcass would remain in the search plot and be found by a searcher (e.g., probability of available and detected) which was then used to adjust the final mortality estimates. In spring, the probability that a carcass would remain in the search plot and be found by a searcher was 0.24 for small birds and 0.59 for large birds. Incorporating these parameters in the Shoenfeld estimator, the adjusted mortality estimate for small birds was 1.04 small birds/turbine/year and 0.42 large birds/turbine/year for a combined estimate of 1.46 birds/turbine/year. On a per MW scale, estimated mortality rates were 0.52 small birds/MW/year and 0.21 large birds/MW/year. No raptors or bats were found during standardized carcass searches, ~~thus~~ therefore mortality estimates were not calculated.

STUDY PARTICIPANTS

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REPORT REFERENCE

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INTRODUCTION

Brookfield Renewable Energy Partners, LP (BREP) purchased the Lower West Wind Energy Project (Project; Figure 1), located in Kern County, California, from Western Wind, LLC (WW), in 2013. Pursuant to a permit requirement to perform three years of post-construction fatality monitoring, Western EcoSystems Technology, Inc. (WEST) was contracted to develop and implement a standardized protocol for the mortality monitoring study with the purpose of estimating the impacts of the wind energy facility on birds and bats. The study protocol developed was similar to those used at other wind energy facilities throughout California and the US. Data collection and analysis followed the recommendations presented in the US Fish and Wildlife Service (USFWS) Wind Turbine Guidelines Advisory Committee (USFWS 2012) and the California Wind Energy Guidelines (California Energy Commission [CEC] and California Department of Fish and Game [CDFG] 2007), and was based on WEST's experience studying wildlife at wind energy projects throughout the US. This report presents the results of avian and bat mortality studies conducted at the Project during the fifth year of operation, from July 2016 to August 2017. Results from this study complement two years of previous fatality monitoring at the Project (Levenstein and Bay 2013, Levenstein and DiDonato 2015).

The primary objective of the mortality monitoring study was to estimate the level of bird and bat mortality attributable to interactions with wind turbines at the Project on an annual basis. Mortality estimates were calculated using the number of carcasses observed during standardized carcass searches and adjusted for biases that influence the detectability of carcasses such as searcher efficiency and carcass persistence. Post-construction mortality monitoring at the Project was conducted from July 22, 2016 through August 3, 2017. In addition to site-specific data, this report presents existing information and results from post-construction studies conducted at other wind energy facilities in California and the Pacific Northwest. Where possible, comparisons with local studies were made.

STUDY AREA

The Project is located in southeastern Kern County at the base of the Tehachapi Mountains in the Western Mojave Desert (Figure 1). The Project is located on approximately 185 acres (0.29 square miles [mi^2]), 7.5 mi (12 kilometers [km]) southwest of the town of Mojave and 9 mi (14.5 km) west of Edwards Airforce Base (Figure 1). The Project is one of many existing wind energy facilities within the Tehachapi Wind Resource Area (TWRA) which are located nearby Lower West and includes, but not limited to: Alta Oak Creek Mojave, Alta VIII, Alta X, Coram, Mustang Hills, Pinyon Pines I and II, Rising Tree, and Windstar.

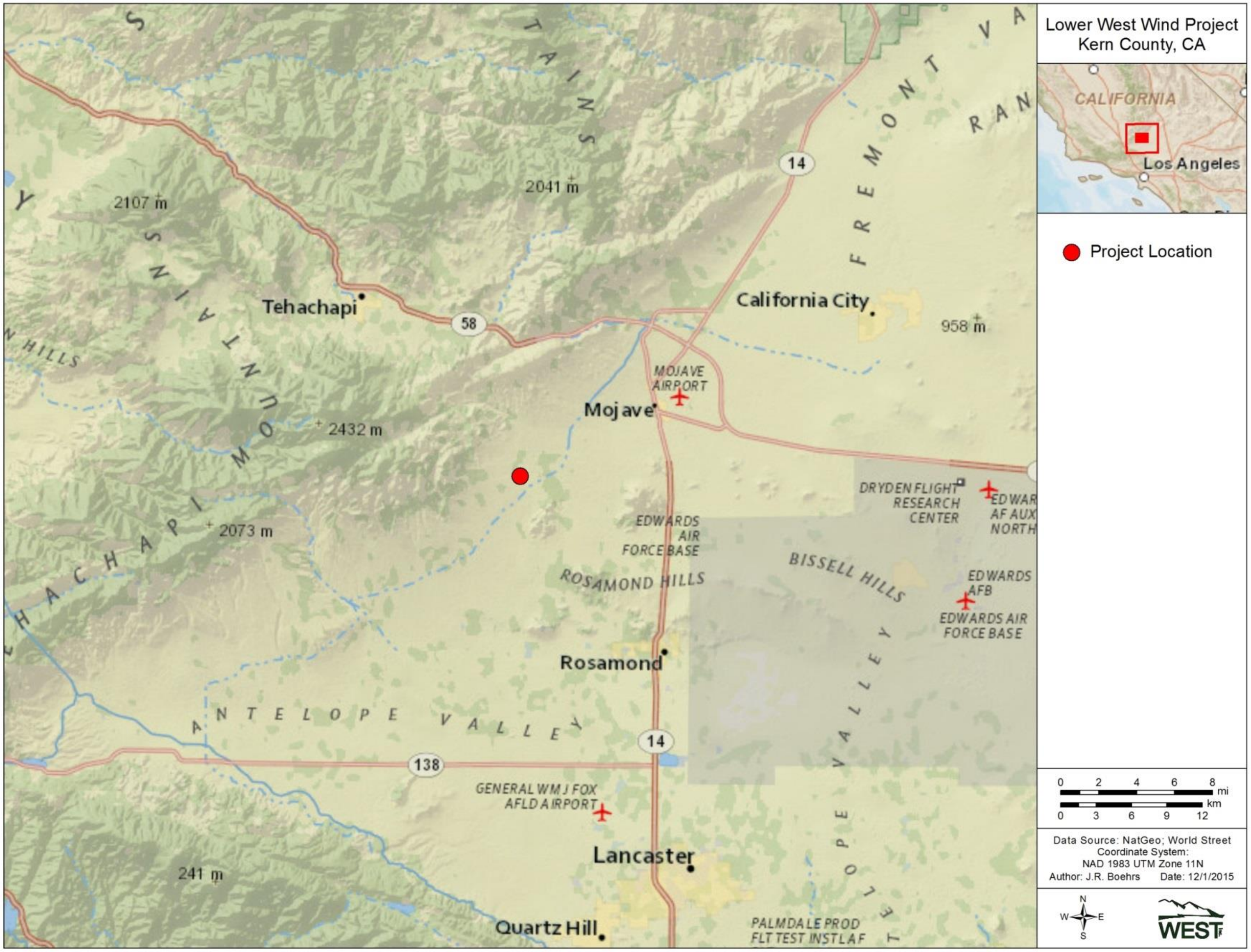

Figure 1. Location of the Lower West Wind Energy Project.

The Project vicinity is generally characterized as sparsely developed and rural. Land uses in and around the Project area consist of open space with scattered residences, off-highway vehicle use, livestock grazing, and numerous wind energy facilities. The nearest populated area is located east of the Project in the outskirts of the unincorporated community of Mojave. Existing developments surrounding the Project area include right-of-ways for underground pipelines, underground portions of the Los Angeles Aqueduct, Southern California Edison electric transmission lines, and a Los Angeles Department of Water and Power electric transmission line easement.

The Project is located at the intersection of two ecological regions; the western Mojave Desert to the southeast, and the Tehachapi Mountains in the southern Sierra Nevada to the northwest (US Environmental Protection Agency [USEPA] 2013). Topography of the Project site consists of nearly level alluvial plains and pediments. The Project site sits at an elevation of about 3,000 feet (ft; 914 meters [m]). Project vegetation is composed of xeric desert scrub with scattered stands of Joshua tree (*Yucca brevifolia*).

METHODS

Avian and Bat Mortality Study

The primary objective of the mortality monitoring study was to estimate the level (high, moderate, or low, relative to other projects) of bird and bat mortality for the entire facility on an annual basis. The methods for the mortality study were broken into four primary components: 1) standardized carcass surveys of selected turbines; 2) searcher efficiency trials to estimate the percentage of carcasses found by searchers; 3) carcass removal trials to estimate the length of time that a carcass remained in the field for possible detection; and 4) adjusted mortality estimates for bird and bat species, calculated using the results from searcher efficiency trials and carcass removal trials to estimate the total number of bird and bat mortalities within the Project.

There were three scenarios under which carcasses were found in the Project: 1) during the standardized carcass searches for the study; 2) while study personnel were on site, but not conducting a standardized search (i.e., an incidental find); and 3) by facility personnel or others on site for other purposes. Carcasses found by study personnel, regardless of timing (i.e., during a standardized survey or not), were recorded by the methods described below. All carcasses found within a search plot, even if found outside of a standard plot search, were included in the dataset under the broad assumption that they would have been found during standardized surveys.

The total number of bird and bat fatalities was estimated by adjusting for search frequency, carcass removal bias (length of stay in the field), and searcher efficiency bias (percent found).

Field Methods

Standardized carcass searches were conducted at the Project from July 22, 2016, through August 3, 2017. Turbines were selected for sampling using a systematic design with a random start and represented the same turbines that were searched during the first and third years of operation (Levenstein and Bay 2013, Levenstein and DiDonato 2015).

The study plan called for systematic carcass searches of 120-m (394-ft) radius circular plots centered around four randomly selected turbines, which resulted in 57% coverage of the Project's seven turbines (Figure 2). The CEC Wind Energy Guidelines for fatality monitoring specifies a minimum plot width equal to the maximum height of the rotor tip height (CEC and CDFW 2007). The plot size at the Project exceeded CEC guidance, as all sampled turbines were 110.5-m (362.5-ft) tall Gamesa G-87 2.0-megawatt [MW]) turbines (Figure 3). The 120 m radius circular plot (11.18 ac) surrounding each of the four sample turbines included 100 percent of the anticipated carcass distribution for bat and bird fatalities as modeled by Hull and Muir (2010).

Per CEC guidance, standardized carcass surveys were conducted approximately every two weeks during the spring (March 1 to May 31), summer (June 1 to September 2), fall (September 3 to November 15), and winter (November 16 to February 28) at each of the sampled turbines.

Standardized Carcass Surveys

The objective of the standardized carcass surveys was to systematically search the wind energy facility for bird and bat carcasses. Each carcass found was recorded using the following categories:

- Intact - a carcass that was completely intact, was not badly decomposed, and showed no sign of being fed upon by a predator or scavenger.
- Scavenged - an entire carcass, which showed signs of being fed upon by a predator or scavenger, or a portion(s) of a carcass in one location (e.g., wings, skeletal remains, portion of a carcass, etc.), or a carcass that was heavily infested by insects.
- Feather Spot - 10 or more feathers or two or more primaries at one location, indicating a bird carcass had been there.

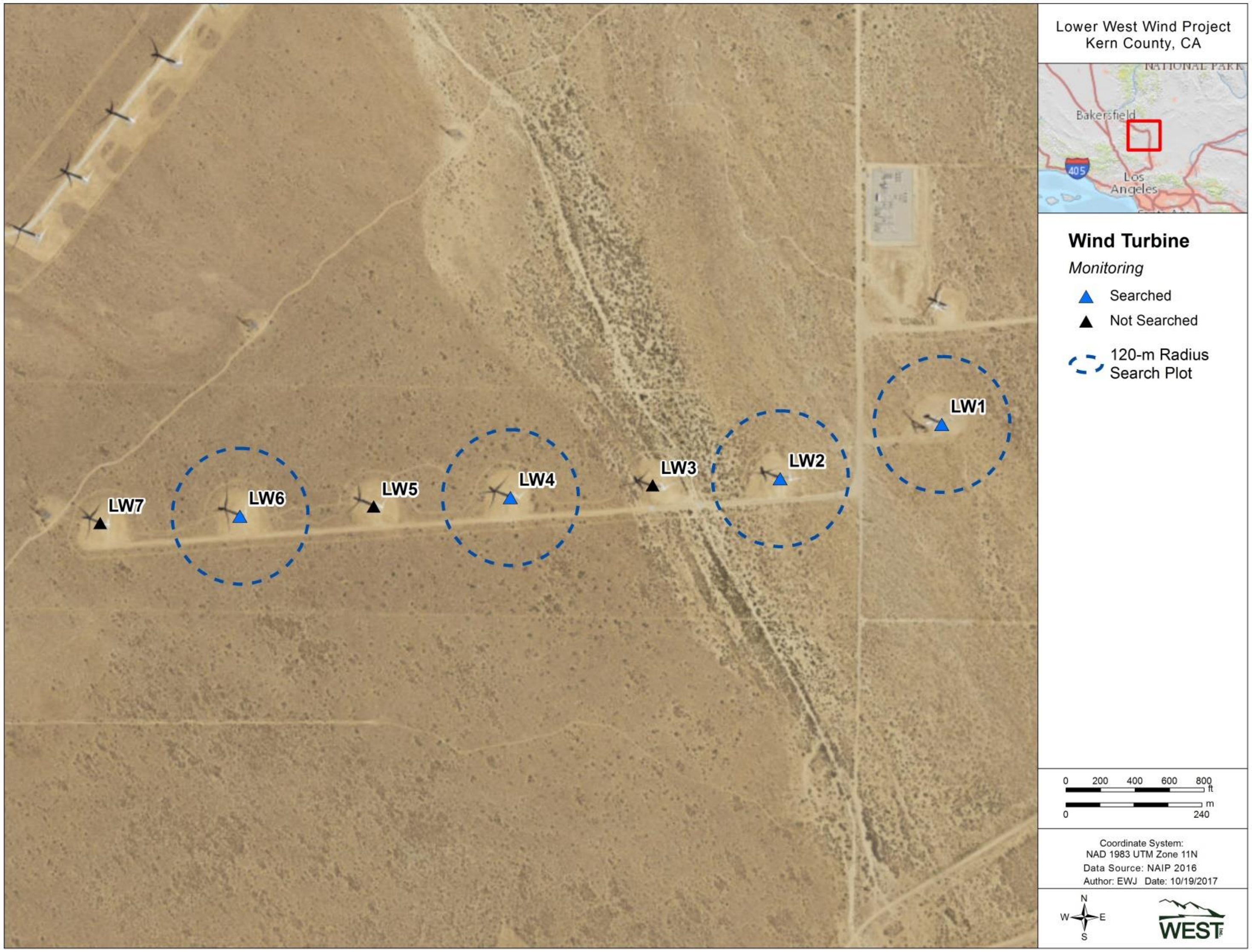

Figure 2. Lower West Wind Energy Project turbine layout and post-construction fatality monitoring plots. Additional turbines in the aerial photo represent other operations in the surrounding TWRA, Kern County, California.

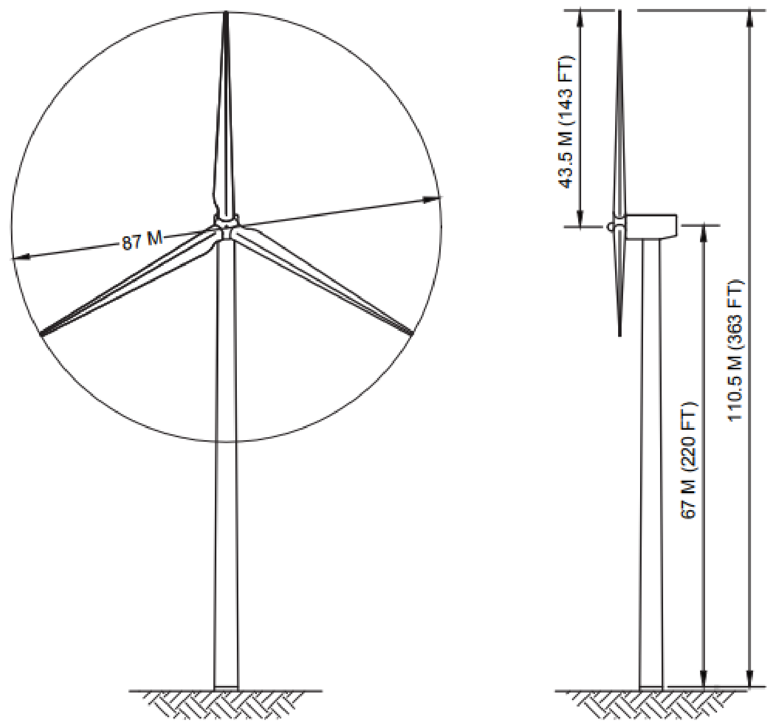

Figure 3. Physical specifications of the Gamesa G-87 2MW wind turbine at Lower West Wind Energy Project (Kern County Planning and Community Development Department 2011).

Data was recorded for all carcasses found and included: species, sex and age when possible, date and time encountered, Global Positioning System (GPS) location, condition (intact, scavenged, feather spot), and any comments that indicated possible cause of death. All carcasses were photographed as found, including detailed close-up photos of the carcass for identification purposes, as well as photos showing location of the carcass in relation to the closest wind turbine or other Project infrastructure, such as overhead power lines or meteorological towers. In addition to carcasses, any injured bird or bat observed in the search plots was recorded and treated as a fatality.

The Project does not have a Special Purpose Utility Permit from the USFWS, nor does it have a Scientific Collecting Permit from the California Department of Fish and Wildlife. As a result, study personnel were not permitted to possess any carcasses of native migratory birds encountered during searches, and all bird and bat carcasses were left in the field as found. Because of this, care was taken in photographing carcasses for purposes of identification and in accurately recording the condition and location of all carcasses so as to avoid double-counting in the event that a carcass' appearance changed or it was moved by a scavenger.

Searcher Efficiency Trials

The objective of the searcher efficiency trials was to estimate the percentage of carcasses found by searchers. Carcasses used for searcher efficiency trials were primarily non-native/non-protected and/or commercially available species (Coturnix quail [*Coturnix* spp.], mallard [*Anas* *platyrhynchos*], rock pigeon [*Columba livia*], chukar [*Alectoris chukar*], and house sparrow [*Passer domesticus*]). Brown mice (*Mus musculus*) were used as surrogates for bats due to a lack of availability of bat carcasses.

Searcher efficiency trials were conducted in the same areas as standardized carcass surveys. Personnel conducting carcass surveys did not know when searcher efficiency trials were being conducted or the location of the trial carcasses. To determine searcher efficiency rates for the Project, an aggregated dataset from Lower West and two other nearby wind facilities, Alta Vlll and Mustang Hills, were used. Searcher efficiency was estimated by the size of carcass (large bird, small bird or bat), and season. Estimates of searcher efficiency were used to adjust the total number of carcasses found for those missed by searchers, correcting for detection bias.

All searcher efficiency trial carcasses were placed at random locations within search areas prior to a day's scheduled carcass survey. Each trial carcass was discreetly marked with electrical tape so that it could be identified as a study carcass after it was found. The number and location of searcher efficiency carcasses found during the carcass survey were recorded. The number of carcasses available for detection during each trial was determined immediately after the trial by the person responsible for distributing the carcasses. Carcasses determined to have been scavenged before a searcher had a chance to locate them were excluded from the analysis.

Carcass Removal Trials

The objective of carcass removal trials was to estimate the average length of time a carcass remained in the study area and was potentially detectable. Carcasses used for carcass removal trials were non-native/non-protected or commercially available species, similar to those species used for searcher efficiency trials. Carcass removal may include removal by predation or scavenging, or could include removal by other less likely means, such as burial by wind-blown sand. Turbines, including searched and non-searched turbines, were randomly selected for inclusion in the removal trials. Estimates of carcass removal were used to adjust the total number of carcasses found for those removed from the study area, correcting for removal bias. Trials were spread throughout the year to address the confounding effects of varying weather conditions and scavenger densities.

Trial carcasses were randomly placed at selected turbines within a plot of similar size to the actual search plots. Personnel conducting carcass searches monitored the trial birds over a 40-day period, checking the carcasses every day for the first four days of the trial, and then again on days seven, 10, 14, 21, 30, and 40. This schedule varied somewhat depending on weather and coordination with the other survey work. Removal trial carcasses were marked discreetly (e.g., with dark electrical tape around one or both legs) for recognition by searchers and other personnel, and left at the location until the end of the carcass removal trial. At the end of the 40-day period, any remaining evidence of the carcass was removed.

Statistical Analysis

Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) measures were implemented at all stages of the study, including in the field, during data entry and analysis, and report writing. Following field surveys, observers were responsible for inspecting data forms for completeness, accuracy, and legibility. A sample of records from an electronic database was compared to the raw data forms and any errors detected were corrected. Irregular codes or data suspected as questionable were discussed with the observer. Errors, omissions, or problems identified in later stages of analysis were traced back to the raw data forms, and appropriate changes in all steps were made.

Data Compilation and Storage

A Microsoft® SQL Server database was developed to store, organize, and retrieve survey data. Data were keyed into the electronic database using a pre-defined format to facilitate subsequent QA/QC and data analysis. All data forms, field notebooks, and electronic data files were retained for reference.

Standardized Carcass Surveys

Estimates of mortality are based on:

(1) Observed number of carcasses found on search plots during the monitoring year, for which the cause of death was either unknown or was probably facility-related;

(2) Non-removal rates, expressed as the estimated average probability a carcass was expected to remain in the study area and be available for detection by the searchers during removal trials; and

(3) Searcher efficiency, expressed as the proportion of planted carcasses found by searchers during searcher efficiency trials.

Necropsies were not performed so causes of mortality were not conclusive; however, we included the conservative assumption that all fatalities found within the search plots were attributable to operation of the wind energy facility. Mortality rate of bird carcasses was estimated by adjusting for removal and searcher efficiency biases.

Because of the low number of fatalities, overall mortality estimates are provided for two categories: small birds and large birds. Seasonal mortality estimates were calculated when possible. To calculate the annual project-wide mortality rate for each category, the seasonal average, weighted by the number of turbine searches was calculated and summed across seasons.

Definition of Variables

The following variables are used in the equations below:

- c_i the number of carcasses detected at plot *i* for the study period of interest (e.g., one monitoring year), for which the cause of death was either unknown or was attributed to the facility
- n the number of search plots
- k the number of turbines searched (including the turbines centered within each search plot)
- $\bar{c}$ the average number of carcasses observed per turbine per monitoring year
- t_i the time (in days) a carcass remained in the study area before it was removed, as determined by the removal trials
- $\bar{t}$ the average time (in days) a carcass remained in the study area before it was removed, as determined by the removal trials
- d the total number of carcasses placed in searcher efficiency trials
- p the estimated proportion of detectable carcasses found by searchers, as determined by the searcher efficiency trials
- I the average interval between standardized carcass searches, in days
- A proportion of the search area of a turbine actually searched
- $\hat{\pi}$ the estimated probability that a carcass was both available to be found during a search and was found, as determined by the removal trials and the searcher efficiency trials
- m the estimated annual average number of mortalities per turbine per year, adjusted for removal and searcher efficiency bias

Observed Number of Carcasses

The estimated average number of carcasses ($\bar{c}$) observed per turbine per monitoring year is:

$$\bar{c} = \frac{\sum_{i=1}^{n} c_i}{k \cdot A} \quad (1)$$

Estimation of Carcass Non-Removal Rates

Estimates of carcass removal rates were used to adjust carcass counts for removal bias. Carcass removals were modeled for each size class (i.e., large bird, small bird, or bat) as a function of season. Models with different underlying distributions can be examined, but since the Shoenfeld estimator (see below) was used, all models used only the exponential distribution. Models were fit and the best model was selected using the corrected Akaike Information Criteria

(AIC_c; Burnham and Anderson 2002). In the case where the AIC_c rank was within 2 points on the top model, the most parsimonious model (intercept only) was selected. The average probability of persistence of a carcass was estimated from the interval censored carcass persistence model and $\bar{t}$ was determined and used to calculate $\hat{\pi}$.

Estimation of Searcher Efficiency Rates

Searcher efficiency rates, *p*, were estimated for each size class (i.e., large bird, small bird, or bat) using a logistic regression model. Potential covariates for this logistic model included season. The logistic regression models the natural logarithm of the odds of finding an available carcass as a function of the above covariates. The model assumes that searchers have a single opportunity to discover a carcass. Similar to non-removal rates, the best model was selected using AIC_c (Burnham and Anderson 2002). Estimated searcher efficiency rates were then generated using the best supported model.

Estimation of Facility-Related Mortality Rates

The estimated per turbine annual mortality rate (*m*) was calculated by:

$$m = \frac{\bar{c}}{\hat{\pi}} \qquad (2)$$

where $\hat{\pi}$ includes adjustments for both carcass removal (from scavenging and other means) and searcher efficiency biases. Data for carcass removal and searcher efficiency were pooled across the study to estimate $\hat{\pi}$ as:

$$\hat{\pi} = \frac{\bar{t} \cdot p}{I} \cdot \left[\frac{\exp\left(I / \bar{t} \right) - 1}{\exp\left(I / \bar{t} \right) - 1 + p} \right] \qquad (3)$$

This formula has been independently verified by Shoenfeld (2004). The final reported estimates of *m* and associated standard errors and 90% confidence intervals were calculated using bootstrapping (Manly 1997). Bootstrapping is a computer simulation technique that is useful for calculating point estimates, variances, and confidence intervals for complicated test statistics. For each bootstrap sample, $\bar{c}$, $\bar{t}$, *p*, $\hat{\pi}$, and *m* were calculated. A total of 1,000 bootstrap samples were used. The reported estimates are the mathematical means of the 1,000 bootstrap estimates. The standard deviation of the bootstrap estimates is the estimated standard error. The lower 5^{th} and upper 95^{th} percentiles of the 1,000 bootstrap estimates are estimates of the lower limit and upper limit of 90% confidence intervals. Confidence intervals were not calculated for fatality rates (observed or adjusted) due to high variability with low sample sized (less than 5 individuals).

RESULTS

Avian and Bat Mortality Surveys

A sample of four of the seven turbines at the Project was searched during the study. Each of the sampled turbines was searched approximately every two weeks for a full year (26 visits over the course of 12 consecutive months), for a total of 104 plot searches.

Two birds were found during standardized carcass surveys; no carcasses were found incidentally (Table 1). No bats were found during standardized searches or incidentally during the study. The number, species, location, other characteristics of the bird carcasses, and the mortality estimates adjusted for searcher efficiency and carcass removal biases are discussed below.

Table 1. Bird carcasses discovered at the Lower West Wind Energy Project from July 22, 2016 – August 3, 2017.

	Fatalities during Scheduled Searches		Incidental Fatalities at Search Plots		Other Incidentals		Total	
Species	**Total**	**% Comp.**	**Total**	**% Comp.**	**Total**	**% Comp.**	**Total**	**% Comp.**
common raven	1	50	0	0	0	0	1	50
horned lark	1	50	0	0	0	0	1	50

Bird Mortalities

Two birds were found during scheduled carcass searches and included one common raven (*Corvus corax*) and one horned lark (*Eremophila alpestris*; Table 1, Figure 4). The common raven carcass was found in grass vegetation on April 25, 2017, approximately 17 m (55 ft) from Turbine LW2 (Figure 4). Time since death was estimated to be between four and seven days and the carcass was heavily scavenged. The horned lark carcass was found on bare ground on May 11, 2017, approximately 12 m (39 ft) from Turbine LW6 (Figure 4). Time since death was estimated to be between two and three days and the carcass was intact.

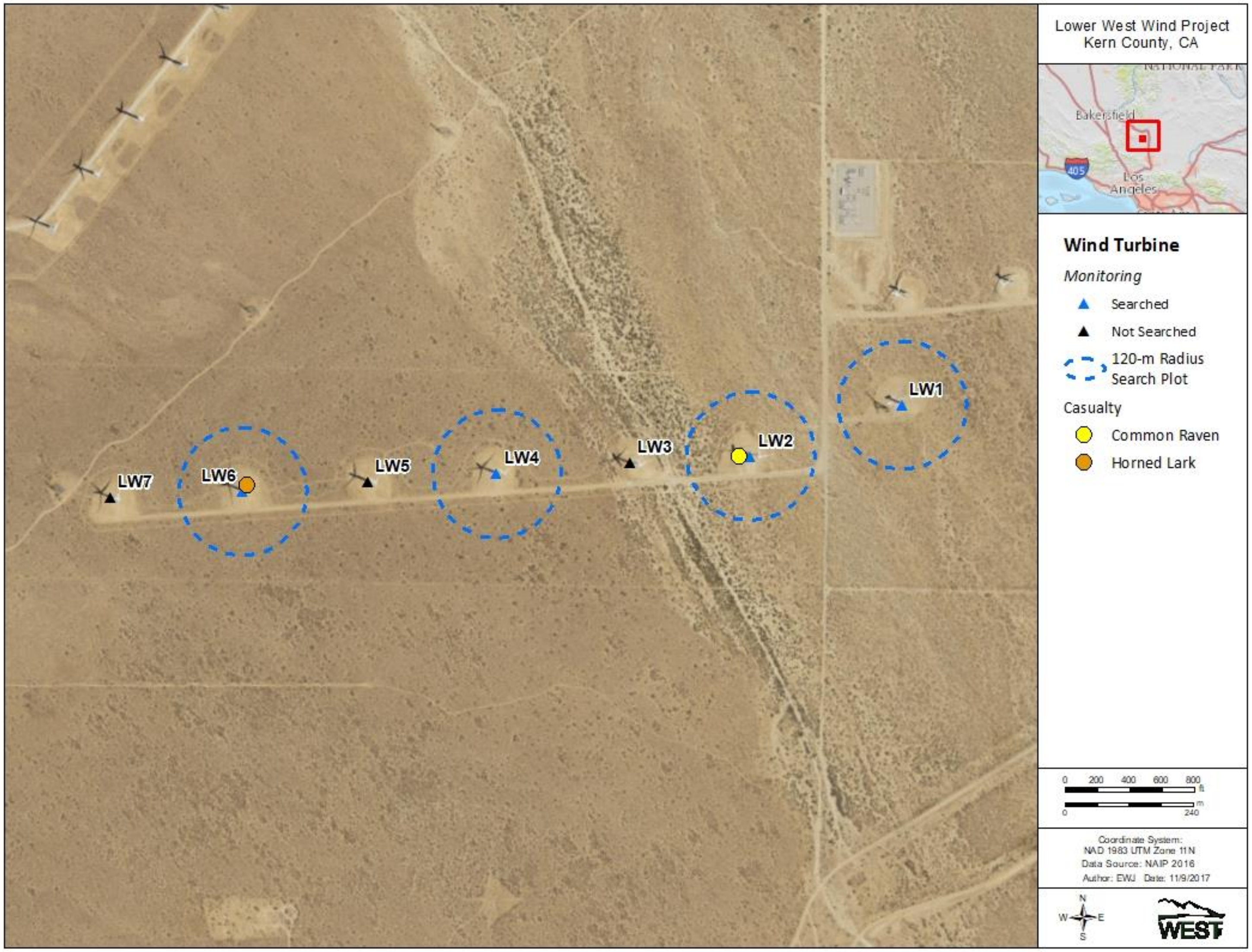

Figure 4. Location of bird carcass found during standardized carcass searches within the Lower West Wind Energy Project, July 2016 – August 2017. No carcasses were found incidentally.

Searcher Efficiency Trials

One hundred seven searcher efficiency trials were conducted between October 2014 and August 2017 and included 428 carcasses (117 large birds, 236 small birds, and 75 mice) (Table 2). The average searcher efficiency rate was 74.9% for small birds (90% CI: 70.3–79.2%), 94.0% for large birds (variable CI due to seasonal effect), and 76.7% for bats/mice (90% CI: 69.1–84.9%; Table 2). Searcher efficiency varied by season within each carcass size class and was generally lowest during spring; although spring and winter efficiency rates were nearly equal for small birds and bats (Table 2). Season had a strong influence on searcher efficiency for large birds, but did not account for the variability observed in searcher efficiency rates for small birds and bats (Table 3). Searcher efficiency for large birds varied between 84.9% and 100% across seasons (Table 3). Because of the variability between seasons, a single searcher efficiency rate was calculated for small birds and bats while large birds were calculated by season.

Table 2. Searcher efficiency trials by season used for the Lower West Wind Energy Project. Includes data from trails conducted October 2014 – August 2017.

Size Class/Type	Season[1]	Placed	Available	Found	% Found
Small Bird	Spring	70	64	44	68.8
	Summer	57	57	48	84.2
	Fall	51	48	38	79.2
	Winter	58	54	37	68.5
	Total	236	223	167	74.9
Large Bird	Spring	33	33	28	84.9
	Summer	31	31	29	93.6
	Fall	25	25	25	100
	Winter	28	28	28	100
	Total	117	117	110	94.0
Bat	Spring	14	14	9	64.3
	Summer	30	30	22	73.3
	Fall	31	29	25	86.2
	Total	75	73	56	76.7

[1] Summer (June 1 to August 31), Fall (September 1 to November 15), Winter (November 16 to February 28), and Spring (March 1 to May 31). No bat trials occurred during winter.

Table 3. Model selection results of seasonal effects on searcher efficiency during trials conducted October 2014 – August 2017.

Carcass Size	Model	AIC_c	ΔAIC_c	Top Model
Small Bird	response ~ intercept	253.37	0.00	*
Small Bird	response ~ season	253.81	0.44	
Large Bird	response ~ season	51.26	0.00	*
Large Bird	response ~ intercept	55.04	3.78	
Bat	response ~ intercept	81.29	0.00	*
Bat	response ~ season	82.66	1.37	

Carcass Removal Trials

Carcass removal trials were conducted 376 times from August 2014 through July 2017 and consisted of 106 large birds, 196 small birds, and 74 brown mice (bat surrogates). The trial carcasses were of similar composition to those used for searcher efficiency trials. By Day 10, approximately 20% of small birds and 2% of bats (mouse surrogates) remained where they were placed, compared to approximately 55% of large birds (Figure 5). By Day 20, approximately 4% of small birds and no bats (mouse surrogates) remained, while approximately 43% of large bird carcasses remained (Figure 5).

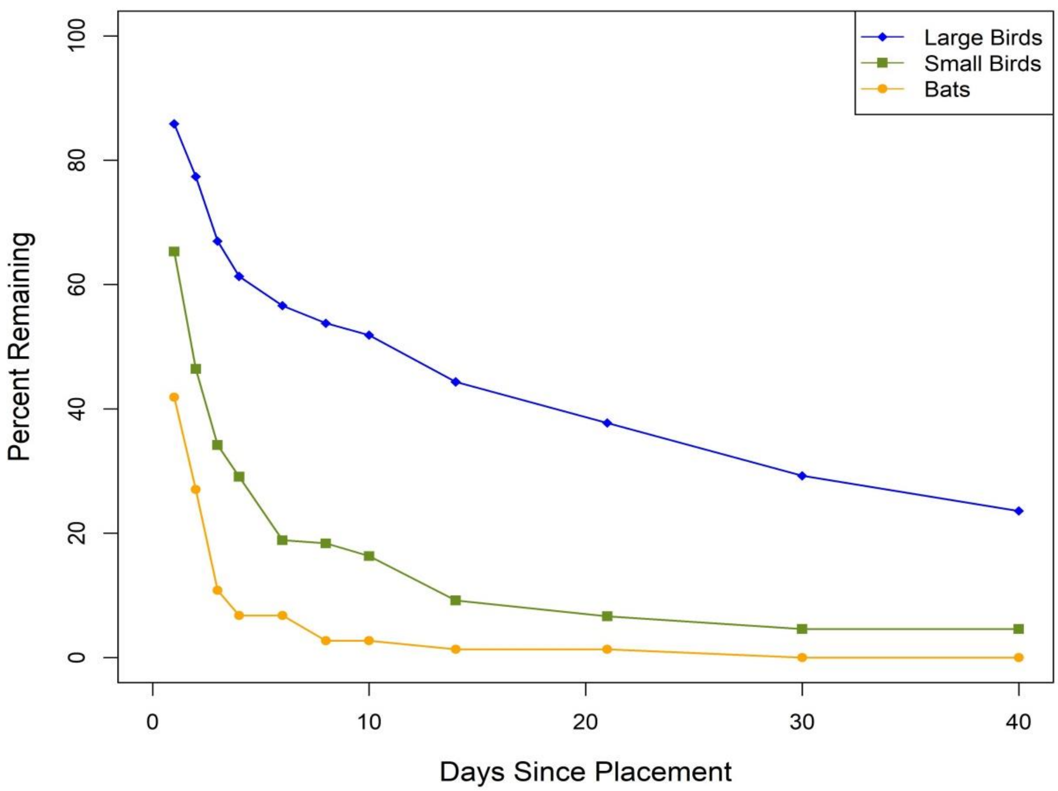

Figure 5. Carcass removal rates at the Lower West Wind Energy Project.

Model results that compared removal time by season suggested a strong seasonal influence on carcass removal rates for large birds and bats, but not small birds (Table 4). Average carcass removal time was longest in winter for large birds ($\bar{t}$ = 40.3 days) and in spring for bats ($\bar{t}$ = 2.3 days; Table 5). The average carcass removal time in spring, when both fatalities were found, was approximately half as long for large birds ($\bar{t}$ = 16.6 days).

Table 4. Model selection results of seasonal effects on carcass removal during trials conducted August 2014 – July 2017.

Carcass Size	Model	AICc	∆AICc	Top Model
Small Bird	response ~ season	838.22	0.00	
Small Bird	response ~ intercept	839.06	0.84	*
Large Bird	response ~ season	502.63	0.00	*
Large Bird	response ~ intercept	507.48	4.85	
Bat	response ~ season	190.19	0.00	*
Bat	response ~ intercept	192.64	2.45	

Table 5. Average carcass removal days by carcass type based on trials that used 279 carcasses, conducted August 2014 – July 2017.

Carcass Size	Season[1]	Avg. Removal Time (*days*)	90% Confidence Interval
Small Bird	Spring	5.1	4.0–6.2
	Summer	5.1	4.0–6.2
	Fall	5.1	4.0–6.2
	Winter	5.1	4.0–6.2
Large Bird	Spring	16.6	11.9–22.8
	Summer	14.5	8.7–23.4
	Fall	18.7	9.9–33.1
	Winter	40.3	23.2–71.0
Bat	Spring	2.3	1.1–4.0
	Summer	1.2	0.8–1.6
	Fall	1.2	0.7–1.8

[1] Summer (June 1 to September 2), Fall (September 3 to November 15), Winter (November 16 to February 28), and Spring (March 1 to May 31). Carcass removal trials were not conducted in winter.

Adjusted Mortality Estimates

Overall project-wide mortality estimates were calculated for each bird category on a per turbine and per MW basis. Because of the uncertainty when calculating variance in situations with low sample sizes (e.g., < 5 carcasses), 90% confidence intervals are not reported. Mortality estimates were calculated for the spring study period as no mortalities were encountered during any other season (Appendix A). As discussed, mortality estimates were adjusted based on the corrections for carcass removal, observer detection bias, and searcher detection probability (Appendix A). Bias trail results are reported previously; each plot was 100% searchable and did not need an area correction factor applied. The probability that a carcass would remain in the search plot and be found by a searcher (e.g., probability of being available and detected) was 0.24 for small birds, and 0.59 for large birds (Appendix A). Incorporating these parameters in the Shoenfeld estimator, the adjusted mortality estimate for small birds was 1.04 small birds/turbine/year and 0.42 large birds/turbine/year for a combined estimate of 1.46 birds/turbine/year (Appendix A). On a per MW scale, estimated mortality rates was 0.52 small birds/MW/year and 0.21 large birds/MW/year. No raptors or bats were found during standardized carcass searches, thus mortality estimates were not calculated.

DISCUSSION AND IMPACT ASSESSMENT

Sources of Bias

The approach used for calculating adjusted mortality estimates is consistent with the approach outlined by Shoenfeld (2004) and Erickson et al. (2005a), and accounted for search interval, searcher efficiency rates, and carcass removal rates. While other estimators (E.g., Huso) are available for calculating adjusted mortality rates, the Shoenfeld estimator was used to ensure comparability with past survey data at the Project, as the Shoenfeld (2004) estimator was used to estimate mortality at the Project during the two prior mortality studies conducted in Year 1 (Levenstein and Bay 2013) and Year 3 (Levenstein and DiDonato 2015) at the Project. It is hypothesized that scavenging could change through time at a given site and must be accounted for when attempting to estimate mortality rates. We accounted for this bias by incorporating regional and project-specific scavenger removal rates and searcher efficiency rates to obtain a more robust sample size to account for any biases associated with changes in conditions.

There are numerous factors that could contribute to both positive and negative biases in estimating mortality rates (Erickson 2006). The overall design of this study incorporates assumptions or factors that affect the results of the mortality estimates. First, we assumed that carcasses found during the study were due to collision with wind turbines, while cause of death is unconfirmed for most carcasses. It is possible that a bird carcass encountered was the result of predation or some other natural cause (background mortality). This factor would lead to an overestimate of avian mortality rates.

Other potential biases are associated with the experimental carcasses used in searcher efficiency and carcass removal trials and whether or not they were representative of actual carcasses. This may occur if the types of birds used were larger or smaller than the carcasses of turbine-related casualties, or more or less cryptic in color than the actual casualties, etc. Mallard hens, rock pigeons, *Coturnix* quail, chukar, and house sparrows were used to represent the range of bird carcasses expected and brown mice were used as surrogates for bats. It is believed that this range captures the range of sizes and other characteristics of actual casualties and should be a reasonable representation of scavenging and detection rates of birds and bats as a group. It is generally not practical or feasible to obtain many of the native bird and bat species in fresh condition for these trials.

Concern has also been raised regarding how the number of carcasses placed in the field for carcass removal trials on a given day could lead to biased estimates of scavenging rates (e.g., Smallwood et al. 2010). Hypothetically, this would lead to underestimating true scavenging rates if the scavenger densities are low enough such that scavenging rates for these placed carcasses are lower than for actual casualties. The logic is that if the trials are based on too many carcasses on a given day, scavengers are unable to access all trial carcasses, whereas they could access all wind turbine-related casualties. If this is the case, and the trial- carcass density is much greater than actual turbine-related carcass density, the trials would underestimate scavenging rates compared to rates on actual casualties. The contrary is also possible, where placing carcasses may draw in more scavengers and carcasses could be removed more quickly than normal. In this study, carcass removal times for small birds and bats were much shorter than the average search interval and may underestimate the number of mortalities, particularly for species groups where few or no fatalities were found (e.g., small birds, bats, raptors).

Bird Mortality

The range of overall bird mortality estimates at wind energy facilities across California and the Pacific Northwest with publicly available data ranges from 0.16 to 17.44 birds/MW/year (Appendix B1). The estimated annual bird mortality rate for the Project in 2016–2017 (0.73 birds/MW/year) is relatively low compared to other wind energy facilities in California and the Pacific Northwest (Figure 6). The two bird carcasses were encountered at two different turbines during the spring period. Given the low number of documented fatalities, combined with the fact that the seven project turbines occur on a generally east-west axis at the same elevation, in the same habitat, and within a distance of one mile, it is unlikely that any single project turbine presents a significantly higher risk to birds than other project turbines. There were no raptor or sensitive species fatalities documented at the Project, but raptor fatality rates across California are generally low (Appendix B2). While there is some potential that one or more raptor fatalities may have occurred and gone undetected at the Project in 2016–2017, the lack of any documented raptor fatalities suggests raptor mortality at the Project was low.

Adjusted bird mortality was lower than the previous two monitoring studies conducted at the Project (Levenstein and Bay 2013, Levenstein and DiDonato 2015). Annual variation of bird fatalities are observed in the TWRA and other Regions (Appendix B1). Bird and bat fatalities found at the Project during this study were consistent with results from studies conducted during the third year of operation (one small bird and one bat; Levenstein and DiDonato 2015), but lower than that documented during the first year of operation (three small birds, one large bird, and two bats; Levenstein and Bay 2013). The number of fatalities (adjusted and unadjusted) observed over the 3-year monitoring effort are consistent, and within the range of other facilities within the TWRA.

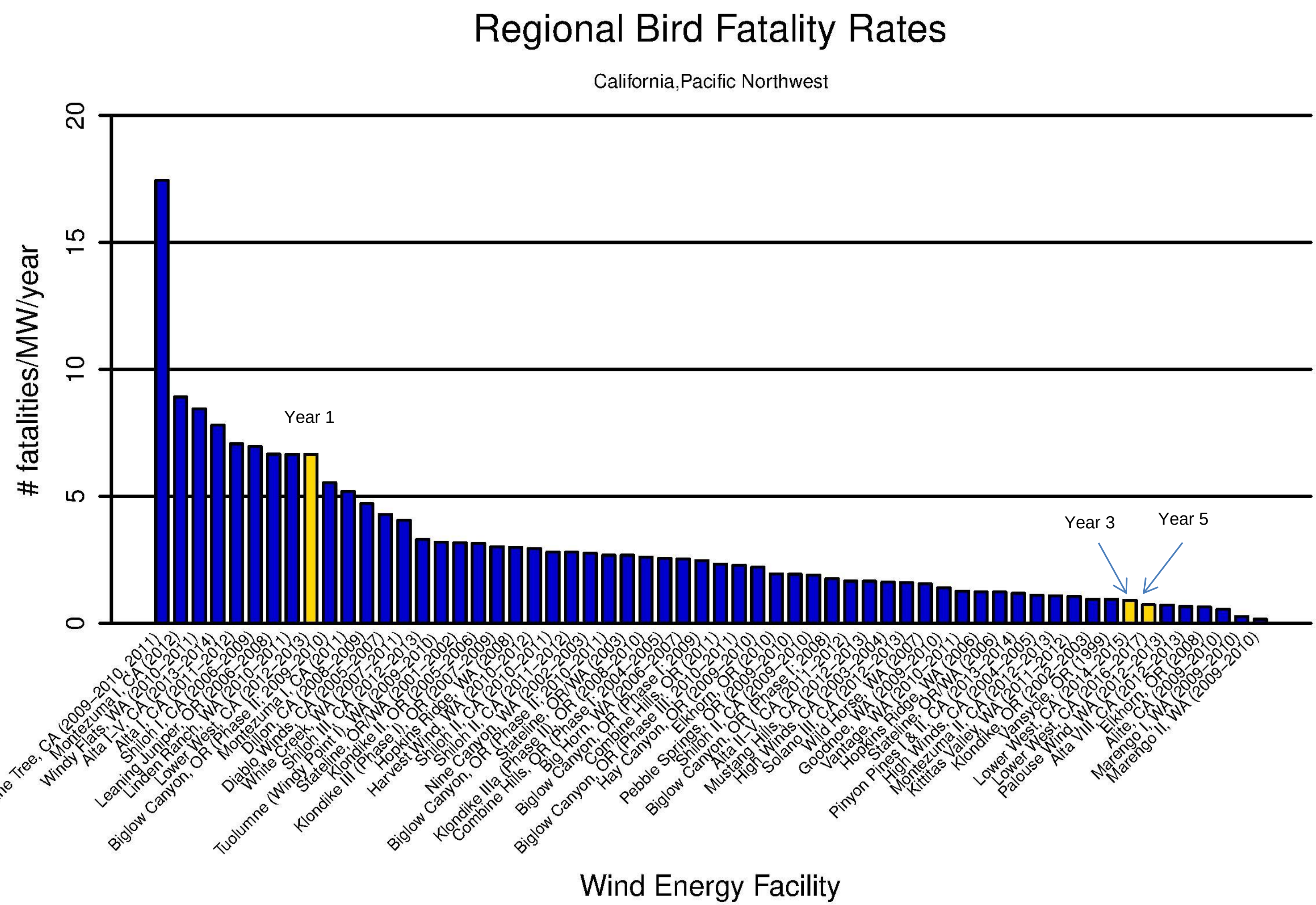

Figure 6. Mortality rates for birds (number of birds per megawatt per year) at the Lower West Wind Energy Project (shown in yellow) compared with mortality rates from publicly available studies at wind energy facilities in California, Oregon, and Washington.

Figure 6 (*continued*). Mortality rates for birds (number of birds per megawatt per year) at the Lower West Wind Energy Project compared with mortality rates from publicly available studies at wind energy facilities in California, Oregon, and Washington.

Data from the following sources:

Wind Energy Facility	Reference	Wind Energy Facility	Reference	Wind Energy Facility	Reference
Pine Tree, CA (09-11)	BioResource Consultants 2012	Harvest Wind, WA (10-12)	Downes and Gristki 2012a	High Winds, CA (03-04)	Kerlinger et al. 2006
Montezuma I, CA (12)	ICF International 2013	Shiloh II, CA (10-12)	Kerlinger et al. 2013	Solano III, CA (12-13)	AECOM 2013
Windy Flats, WA (10-11)	Enz et al. 2011	Nine Canyon, WA (02-03)	Erickson et al. 2003	Wild Horse, WA (07)	Erickson et al. 2008
Alta I-V, CA (13-14)	Chatfield et al 2014	Biglow Canyon, OR (10-11)	Enk et al. 2012b	Goodnoe, WA (09-10)	URS 2010a
Alta I, CA (11-12)	Chatfield et al. 2012	Stateline, OR/WA (2003)	Erickson et al. 2004	Vantage, WA (10-11)	Ventus Environmental Solutions 2012
Shiloh I, CA (06-09)	Kerlinger et al. 2010	Klondike III, OR (08-10)	Gritski et al. 2011	Hopkins Ridge, WA (06)	Young et al. 2007
Leaning Juniper, OR (06-08)	Gritski et al. 2008	Combine Hills, OR (04-05)	Young et al. 2006	Stateline, OR/WA (06)	Erickson et al. 2007
Linden Ranch, WA (10-11)	Enz and Bay 2011	Big Horn, WA (06-07)	Kronner et al. 2008	Pinyon Pines I & II, CA (13-14)	Chatfield and Russo 2014
Lower West, CA (12-13)	Levenstein and Bay 2013	Biglow Canyon, OR (09)	Enk et al. 2010	High Winds, CA (04-05)	Kerlinger et al. 2006
Biglow Canyon II, OR (09-10)	Enk et al. 2011a	Combine Hills, OR (11)	Enz et al. 2012a	Montezuma II, CA (12-13)	Harvey & Associates 2013
Montezuma I, CA (11)	ICF International 2012	Biglow Canyon, OR; (10-11)	Enk et al. 2012b	Kittitas Valley, WA (11-12)	Stantec 2012
Dillon, CA (08-09)	Chatfield et al. 2009	Hay Canyon, OR (09-10)	Gritski and Kronner 2010a	Klondike, OR (02-03)	Johnson et al. 2003
Diablo Winds, CA (05-07)	WEST 2006, WEST 2008	Elkhorn, OR (10)	Enk et al. 2011b	Vansycle, OR (99)	Erickson et al. 2000
White Creek, WA (07-11)	Downes and Gristki 2012b	Lower West, CA (16-17)	Gritski and Kronner 2010b	Lower West, CA (14-15)	Levenstein and DiDonato 2015
Shiloh III, CA (12-13)	Kerlinger et al. 2013	Pebble Springs, OR (09-10)	WEST 2017	Palouse Wind, WA (12-13)	Stantec Consulting 2013
Tuolumne, WA (09-10)	Enz and Bay 2010	Shiloh II, CA (09-10)	Kerlinger et al. 2013	Alta VIII, CA (12-13)	Chatfield and Bay 2014
Stateline, OR/WA (01-02)	Erickson et al. 2004	Shiloh II, CA (09-10)	Kerlinger et al. 2013	Elkhorn, OR (08)	Jeffery et al. 2009b
Klondike II, OR (05-06)	NWC and WEST 2007	Biglow Canyon, OR (08)	Jeffrey et al. 2009a	Alite, CA (09-10)	Chatfield et al. 2010
Klondike III OR (07-09)	Gritski et al. 2010	Mustang Hills, CA (12-13)	Chatfield and Bay 2014	Marengo I, WA (09-10)	URS 2010b
Hopkins Ridge, WA (08)	Young et al. 2009	Alta II-V, CA (11-12)	Chatfield et al. 2012	Marengo II, WA (09-10)	URS 2010c

CONCLUSIONS

Results of mortality monitoring at the Project further contribute to our understanding of the effects of wind energy on birds and bats, particularly in the TWRA. The level of avian mortality observed during the third year of monitoring at the Project was similar to the level of mortality during the second year of monitoring and relatively low compared to other wind energy projects in California and the Pacific Northwest. However, the first year of monitoring (2012–2013) had a relatively higher mortality rate compared to the most recent efforts (2014–2017). The monitoring design, associated bias rates and statistical methods have remained relatively constant during the three-year study period which suggests additional factors (e.g., weather, migration patterns, foraging habitat, or avoidance) may influence fatality patterns at the Project. Nevertheless, given the relatively low bird and bat mortality rates documented during the three years of mortality monitoring, especially when considered in light of the small size of the Project (only seven turbines / 14 MW), it is unlikely that the Project would result in significant impacts to bird populations in the region. We did not observe any site conditions or data that suggested the results were atypical of mortality patterns of a low-risk site. These factors along with the mortality patterns observed across seasons (two birds found during the spring), the species composition of very common bird species, the distribution of carcasses within search plots and across the site, and the high percentage of turbine plots searched support the conclusion that the risk from this Project to significantly reduce bird populations is relatively low.

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Appendix A. Correction Factors and Bird Fatality Rates by Season and Turbine Type for Studies Conducted within the Lower West Wind Energy Project from July 2016 – August 2017

Appendix A. Correction factors and bird and bat fatality rates by season and turbine type for studies conducted within the Lower West Wind Energy Project from July 22, 2016 to August 3, 2017.

	Spring (4 turbines searched)		Summer (4 turbines searched)		Winter (4 turbines searched)		Fall (4 turbines searched)	
Parameter	**Mean**	**CI**	**Mean**	**CI**	**Mean**	**CI**	**Mean**	**CI**
Search Area Adjustment								
A (small birds)	1	--	1	--	1	--	1	--
A (large birds)	1	--	1	--	1	--	1	--
A (bats)	1	--	1	--	1	--	1	--
Searcher Efficiency Rate								
p (small birds)	0.75	0.70 – 0.79	0.75	0.70 – 0.79	0.75	0.70 – 0.79	0.75	0.70 – 0.79
p (large birds)	0.85	0.74 – 0.94	0.94	0.86 – 1.0	1.0	--	1.0	--
p (bats)	0.77	0.69 – 0.85	0.77	0.69 – 0.85	0.77	0.69 – 0.85	0.77	0.69 – 0.85
Mean Carcass Removal Time (Days)								
$\bar{t}$ (small birds)	5.1	4.0 – 6.2	5.1	4.0 – 6.2	5.1	4.0 – 6.2	5.1	4.0 – 6.2
$\bar{t}$ (large birds)	16.6	11.9 – 22.8	14.5	8.7 – 23.4	40.3	23.2 – 71.0	18.7	9.9 – 33.1
$\bar{t}$ (bats)	2.3	1.1 – 4.0	1.2	0.8 – 1.6	--	--	1.2	0.7 – 1.8
Observed Fatality Rates (Fatalities/Turbine/Season[s])								
small birds	0.25	--	0	--	0	--	0	--
large birds	0.25	--	0	--	0	--	0	--
raptors	0	--	0	--	0	--	0	--
bats	0	--	0	--	0	--	0	--
Average Probability of Carcass Availability and Detected								
small birds	0.24	0.19 – 0.29	0.24	0.19 – 0.29	0.24	0.19 – 0.29	0.24	0.19 – 0.29
large birds	0.59	0.49 – 0.68	0.59	0.45 – 0.72	0.83	0.74 – 0.90	0.69	0.51 – 0.80
bats	0.12	0.06 – 0.20	0.06	0.04 – 0.80	--	--	0.06	0.03 – 0.09
Observed Adjusted Fatality Rates (Fatalities/Turbine/Seasons[s])								
small birds	1.04	--	0	--	0	--	0	--
large birds	0.42	--	0	--	0	--	0	--
all birds	1.46	--	0	--	0	--	0	--

Appendix B. North American Mortality Summary Tables

Appendix B1. Wind energy facilities in California and the Pacific Northwest with mortality data for all bird species. Mortality estimate is number of mortalities per megawatt (MW) per year.

Wind Energy Facility	Mortality Estimate	No. of Turbines	Total MW
Lower West, CA (2016-2017)	**0.73**	**7**	**14**
Lower West, CA (2014-2015)	**0.90**	**7**	**14**
Lower West, CA (2013-2014)	**6.65**	**7**	**14**
California			
Pine Tree, CA (2009-2010, 2011)	17.44	90	135
Montezuma I, CA (2012)	8.91	16	36.8
Alta Wind I-V, CA (2013-2014)	7.80	290	720 (150 GE, 570 Vestas)
Alta Wind I, CA (2011-2012)	7.07	100	150
Shiloh I, CA (2006-2009)	6.96	100	150
Montezuma I, CA (2011)	5.19	16	36.8
Dillon, CA (2008-2009)	4.71	45	45
Diablo Winds, CA (2005-2007)	4.29	31	20.46
Shiloh III, CA (2012-2013)	3.30	50	102.5
Shiloh II, CA (2010-2011)	2.80	75	150
Shiloh II, CA (2009-2010)	1.90	75	150
Mustang Hills, CA (2012-2013)	1.66	50	150
Alta Wind II-V, CA (2011-2012)	1.66	190	570
High Winds, CA (2003-2004)	1.62	90	162
Solano III, CA (2012-2013)	1.60	55	128
Pinyon Pines I & II, CA (2013-2014)	1.18	100	NA
High Winds, CA (2004-2005)	1.10	90	162
Montezuma II, CA (2012-2013)	1.08	34	78.2
Alta VIII, CA (2012-2013)	0.66	50	150
Alite, CA (2009-2010)	0.55	8	24
Pacific Northwest			
Windy Flats, WA (2010-2011)	8.45	114	262.2
Leaning Juniper, OR (2006-2008)	6.66	67	100.5
Linden Ranch, WA (2010-2011)	6.65	25	50
Biglow Canyon, OR (Phase II; 2009-2010)	5.53	65	150
White Creek, WA (2007-2011)	4.05	89	204.7
Tuolumne (Windy Point I), WA (2009-2010)	3.2	62	136.6
Stateline, OR/WA (2001-2002)	3.17	454	299
Klondike II, OR (2005-2006)	3.14	50	75
Klondike III (Phase I), OR (2007-2009)	3.02	125	223.6
Hopkins Ridge, WA (2008)	2.99	87	156.6
Harvest Wind, WA (2010-2012)	2.94	43	98.9
Nine Canyon, WA (2002-2003)	2.76	37	48.1
Biglow Canyon, OR (Phase II; 2010-2011)	2.68	65	150
Stateline, OR/WA (2003)	2.68	454	299
Klondike IIIa (Phase II), OR (2008-2010)	2.61	51	76.5
Combine Hills, OR (Phase I; 2004-2005)	2.56	41	41
Big Horn, WA (2006-2007)	2.54	133	199.5
Biglow Canyon, OR (Phase I; 2009)	2.47	76	125.4
Combine Hills, OR (2011)	2.33	104	104
Biglow Canyon, OR (Phase III; 2010-2011)	2.28	76	174.8
Hay Canyon, OR (2009-2010)	2.21	48	100.8
Elkhorn, OR (2010)	1.95	61	101
Pebble Springs, OR (2009-2010)	1.93	47	98.7
Biglow Canyon, OR (Phase I; 2008)	1.76	76	125.4
Wild Horse, WA (2007)	1.55	127	229
Goodnoe, WA (2009-2010)	1.4	47	94

Appendix B1. Wind energy facilities in California and the Pacific Northwest with mortality data for all bird species. Mortality estimate is number of mortalities per megawatt (MW) per year.

Wind Energy Facility	Mortality Estimate	No. of Turbines	Total MW
Vantage, WA (2010-2011)	1.27	60	90
Hopkins Ridge, WA (2006)	1.23	83	150
Stateline, OR/WA (2006)	1.23	454	299
Kittitas Valley, WA (2011-2012)	1.06	48	100.8
Klondike, OR (2002-2003)	0.95	16	24
Vansycle, OR (1999)	0.95	38	24.9
Palouse Wind, WA (2012-2013)	0.72	58	104.4
Elkhorn, OR (2008)	0.64	61	101
Marengo I, WA (2009-2010)	0.27	78	140.4
Marengo II, WA (2009-2010)	0.16	39	70.2

Appendix B1 (*continued*). Wind energy facilities in California and the Pacific Northwest with mortality data for all bird species.

Data from the following sources:

Wind Energy Facility	Estimate Reference	Wind Energy Facility	Estimate Reference
Lower West, CA (16-17)	This Study		
Lower West, CA (14-15)	Levenstein and DiDonato 2015		
Lower West, CA (13-14)	Levenstein and Bay 2013		
Alite, CA (09-10)	Chatfield et al. 2010	Klondike IIIa (Phase II), OR (08-10)	Gritski et al. 2011
Alta Wind I, CA (11-12)	Chatfield et al. 2012	Leaning Juniper, OR (06-08)	Gritski et al. 2008
Alta Wind I-V, CA (13-14)	Chatfield and Bay 2014	Linden Ranch, WA (10-11)	Enz and Bay 2011
Alta Wind II-V, CA (11-12)	Chatfield et al. 2012	Marengo I, WA (09-10)	URS Corporation 2010b
Alta VIII, CA (12-13)	Chatfield and Bay 2014	Marengo II, WA (09-10)	URS Corporation 2010c
Big Horn, WA (06-07)	Kronner et al. 2008	Montezuma I, CA (11)	ICF International 2012
Biglow Canyon, OR (Phase I; 08)	Jeffrey et al. 2009a	Montezuma I, CA (12)	ICF International 2013
Biglow Canyon, OR (Phase I; 09)	Enk et al. 2010	Montezuma II, CA (12-13)	H.T. Harvey & Associates 2013
Biglow Canyon, OR (Phase II; 09-10)	Enk et al. 2011a	Mustang Hills, CA (12-13)	Chatfield and Bay 2014
Biglow Canyon, OR (Phase II; 10-11)	Enk et al. 2012b	Nine Canyon, WA (02-03)	Erickson et al. 2003
Biglow Canyon, OR (Phase III; 10-11)	Enk et al. 2012a	Palouse Wind, WA (12-13)	Stantec 2013
Combine Hills, OR (Phase I; 04-05)	Young et al. 2006	Pebble Springs, OR (09-10)	Gritski and Kronner 2010b
Combine Hills, OR (11)	Enz et al. 2012	Pine Tree, CA (09-10, 11)	BioResource Consultants 2012
Diablo Winds, CA (05-07)	WEST 2006, 2008	Pinyon Pines I&II, CA (13-14)	Chatfield and Russo 2014
Dillon, CA (08-09)	Chatfield et al. 2009	Shiloh I, CA (06-09)	Kerlinger et al. 2009
Elkhorn, OR (08)	Jeffrey et a. 2009b	Shiloh II, CA (09-10)	Kerlinger et al. 2010, 2013a
Elkhorn, OR (10)	Enk et al. 2011b	Shiloh II, CA (10-11)	Kerlinger et al. 2013a
Goodnoe, WA (09-10)	URS Corporation 2010a	Shiloh III, CA (12-13)	Kerlinger et al. 2013b
Harvest Wind, WA (10-12)	Downes and Gritski 2012a	Solano III, CA (12-13)	AECOM 2013
Hay Canyon, OR (09-10)	Gritski and Kronner 2010a	Stateline, OR/WA (01-02)	Erickson et al. 2004
High Winds, CA (03-04)	Kerlinger et al. 2006	Stateline, OR/WA (03)	Erickson et al. 2004
High Winds, CA (04-05)	Kerlinger et al. 2006	Stateline, OR/WA (06)	Erickson et al. 2007
Hopkins Ridge, WA (06)	Young et al. 2007	Tuolumne (Windy Point I), WA (09-10)	Enz and Bay 2010
Hopkins Ridge, WA (08)	Young et al. 2009	Vansycle, OR (99)	Erickson et al. 2000
Kittitas Valley, WA (11-12)	Stantec Consulting 2012	Vantage, WA (10-11)	Ventus Environmental Solutions 2012
Klondike, OR (02-03)	Johnson et al. 2003	White Creek, WA (07-11)	Downes and Gritski 2012b
Klondike II, OR (05-06)	NWC and WEST 2007	Wild Horse, WA (07)	Erickson et al. 2008
Klondike III (Phase I), OR (07-09)	Gritski et al. 2010	Windy Flats, WA (10-11)	Enz et al. 2011

Appendix B2. Mortality estimates for California and Pacific Northwest wind energy facilities.

Project	Bird Mortality (birds/MW/ year)	Raptor Mortality (raptors/MW/ year)	Bat Mortality (bats/MW/ year)	Predominant Habitat Type	Citation
Alite, CA (2009-2010)	0.55	0.12	0.24	Shrub/scrub & grassland	Chatfield et al. 2010
Alta Wind I, CA (2011-2012)	7.07	0.27	1.28	Woodland, grassland, shrubland	Chatfield et al. 2012
Alta Wind I-V, CA (2013-2014)	7.8	0.08	0.2	Desert scrub	Chatfield and Bay 2014
Alta Wind II-V, CA (2011-2012)	1.66	0.05	0.08	Desert scrub	Chatfield et al. 2012
Alta VIII, CA (2012-2013)	0.66	0.02	0	Grassland and riparian	Chatfield and Bay 2014
Big Horn, WA (2006-2007)	2.54	0.11	1.9	Agriculture/grassland	Kronner et al. 2008
Biglow Canyon, OR (Phase I; 2008)	1.76	0.03	1.99	Agriculture/grassland	Jeffrey et al. 2009a
Biglow Canyon, OR (Phase I; 2009)	2.47	0	0.58	Agriculture/grassland	Enk et al. 2010
Biglow Canyon, OR (Phase II; 2009-2010)	5.53	0.14	2.71	Agriculture	Enk et al. 2011a
Biglow Canyon, OR (Phase II; 2010-2011)	2.68	0.03	0.57	Grassland/shrub-steppe, agriculture	Enk et al. 2012b
Biglow Canyon, OR (Phase III; 2010-2011)	2.28	0.05	0.22	Grassland/shrub-steppe, agriculture	Enk et al. 2012a
Combine Hills, OR (Phase I; 2004-2005)	2.56	0	1.88	Agriculture/grassland	Young et al. 2006
Combine Hills, OR (2011)	2.33	0.05	0.73	Grassland/shrub-steppe, agriculture	Enz et al. 2012
Diablo Winds, CA (2005-2007)	4.29	0.4	0.82	Agriculture/grassland	WEST 2006, 2008
Dillon, CA (2008-2009)	4.71	0	2.17	Desert	Chatfield et al. 2009
Elkhorn, OR (2008)	0.64	0.06	1.26	Shrub/scrub & agriculture	Jeffrey et a. 2009b
Elkhorn, OR (2010)	1.95	0.08	2.14	Shrub/scrub & agriculture	Enk et al. 2011b

Appendix B2. Mortality estimates for California and Pacific Northwest wind energy facilities.

Project	Bird Mortality (birds/MW/ year)	Raptor Mortality (raptors/MW/ year)	Bat Mortality (bats/MW/ year)	Predominant Habitat Type	Citation
Goodnoe, WA (2009-2010)	1.4	0.17	0.34	Grassland and shrub-steppe	URS Corporation 2010a
Harvest Wind, WA (2010-2012)	2.94	0.23	1.27	Grassland/shrub-steppe	Downes and Gritski 2012a
Hay Canyon, OR (2009-2010)	2.21	0	0.53	Agriculture	Gritski and Kronner 2010a
High Winds, CA (2003-2004)	1.62	0.5	2.51	Agriculture/grassland	Kerlinger et al. 2006
High Winds, CA (2004-2005)	1.1	0.28	1.52	Agriculture/grassland	Kerlinger et al. 2006
Hopkins Ridge, WA (2006)	1.23	0.14	0.63	Agriculture/grassland	Young et al. 2007
Hopkins Ridge, WA (2008)	2.99	0.07	1.39	Agriculture/grassland	Young et al. 2009
Kittitas Valley, WA (2011-2012)	1.06	0.09	0.12	Sagebrush-steppe, grassland	Stantec Consulting 2012
Klondike, OR (2002-2003)	0.95	0	0.77	Agriculture/grassland	Johnson et al. 2003
Klondike II, OR (2005-2006)	3.14	0.06	0.41	Agriculture/grassland	NWC and WEST 2007
Klondike III (Phase I), OR (2007-2009)	3.02	0.15	1.11	Agriculture/grassland	Gritski et al. 2010
Klondike IIIa (Phase II), OR (2008-2010)	2.61	0.06	0.14	Grassland/shrub-steppe and agriculture	Gritski et al. 2011
Leaning Juniper, OR (2006-2008)	6.66	0.16	1.98	Agriculture	Gritski et al. 2008
Linden Ranch, WA (2010-2011)	6.65	0.27	1.68	Grassland/shrub-steppe, agriculture	Enz and Bay 2011
Lower West, CA (2016-2017)	0.73	0	0	Desert scrub	This Study
Lower West, CA (2014-2015)	0.90	0	1.13	Desert scrub	Levenstein and DiDonato 2015
Lower West, CA (2013-2014)	6.65	0	2.17	Desert scrub.	Levenstein and Bay 2013

Appendix B2. Mortality estimates for California and Pacific Northwest wind energy facilities.

Project	Bird Mortality (birds/MW/ year)	Raptor Mortality (raptors/MW/ year)	Bat Mortality (bats/MW/ year)	Predominant Habitat Type	Citation
Marengo I, WA (2009-2010)	0.27	0	0.17	Agriculture	URS Corporation 2010b
Marengo II, WA (2009-2010)	0.16	0.05	0.27	Agriculture	URS Corporation 2010c
Montezuma I, CA (2011)	5.19	1.06	1.9	Agriculture and grasslands	ICF International 2012
Montezuma I, CA (2012)	8.91	0.79	0.84	Agriculture and grasslands	ICF International 2013
Montezuma II, CA (2012-2013)	1.08	0.46	0.91	Agriculture	H.T. Harvey & Associates 2013
Mustang Hills, CA (2012-2013)	1.66	0.08	0.1	Grasslands and riparian	Chatfield and Bay 2014
Nine Canyon, WA (2002-2003)	2.76	0.03	2.47	Agriculture/grassland	Erickson et al. 2003
Palouse Wind, WA (2012-2013)	0.72	NA	4.23	Agriculture and grasslands	Stantec 2013
Pebble Springs, OR (2009-2010)	1.93	0.04	1.55	Grassland	Gritski and Kronner 2010b
Pine Tree, CA (2009-2010, 2011)	17.44	NA	NA	Grassland	BioResource Consultants 2012
Pinyon Pines I & II, CA (2013-2014)	1.18	NA	0.04	Desert scrub	Chatfield and Russo 2014
Shiloh I, CA (2006-2009)	6.96	0.42	3.92	Agriculture/grassland	Kerlinger et al. 2009
Shiloh II, CA (2009-2010)	1.9	0.11	2.6	Agriculture	Kerlinger et al. 2010, Kerlinger et al. 2013a
Shiloh II, CA (2010-2011)	2.8	0.44	3.8	Agriculture	Kerlinger et al. 2013a
Shiloh III, CA (2012-2013)	3.3	NA	0.4	Agriculture/grassland	Kerlinger et al. 2013b
Solano III, CA (2012-2013)	1.6	0.95	0.31	Agriculture/grassland	AECOM 2013
Stateline, OR/WA (2001-2002)	3.17	0.09	1.09	Agriculture/grassland	Erickson et al. 2004

Appendix B2. Mortality estimates for California and Pacific Northwest wind energy facilities.

Project	Bird Mortality (birds/MW/ year)	Raptor Mortality (raptors/MW/ year)	Bat Mortality (bats/MW/ year)	Predominant Habitat Type	Citation
Stateline, OR/WA (2003)	2.68	0.09	2.29	Agriculture/grassland	Erickson et al. 2004
Stateline, OR/WA (2006)	1.23	0.11	0.95	Agriculture/grassland	Erickson et al. 2007
Tuolumne (Windy Point I), WA (2009-2010)	3.2	0.29	0.94	Grassland/shrub-steppe, agriculture and forest	Enz and Bay 2010
Vansycle, OR (1999)	0.95	0	1.12	Agriculture/grassland	Erickson et al. 2000
Vantage, WA (2010-2011)	1.27	0.29	0.4	Shrub-steppe, grassland	Ventus Environmental Solutions 2012
White Creek, WA (2007-2011)	4.05	0.47	2.04	Grassland/shrub-steppe, agriculture	Downes and Gritski 2012b
Wild Horse, WA (2007)	1.55	0.09	0.39	Grassland	Erickson et al. 2008
Windy Flats, WA (2010-2011)	8.45	0.04	0.41	Grassland/shrub-steppe, agriculture	Enz et al. 2011

Appendix B3. All post-construction monitoring studies, project characteristics, and select study methodology for California and Pacific Northwest wind energy facilities.

Project Name	Total # of Turbines	Total MW	Tower Size (m)	Number Turbines Searched	Plot Size	Length of Study	Survey Frequency
Alite, CA (2009-2010)	8	24	80	8	200 m x 200 m	1 year	Weekly (spring, fall), bi-monthly (summer, winter)
Alta Wind I, CA (2011-2012)	100	150	80	25	120-m radius circle	12.5 months	Every two weeks
Alta Wind I-V, CA (2013-2014)	290	720 (150 GE, 570 vestas)	80	55 (25 at Alta I, 30 at Alta II-V)	120 m radius circles	NA	Monthly or bi-weekly
Alta Wind II-V, CA (2011-2012)	190	570	80	41	120-m radius circle	14.5 months	Every two weeks
Alta VIII, CA (2012-2013)	50	150	90	12 plots (equal to 15 turbines	240 x 240 m	1 year	Bi-weekly
Big Horn, WA (2006-2007)	133	199.5	80	133	180 m x 180 m	1 year	Bi-monthly (spring, fall), monthly (winter, summer)
Biglow Canyon, OR (Phase I; 2008)	76	125.4	80	50	110 m x 110 m	1 year	Bi-monthly (spring, fall), monthly (winter, summer)
Biglow Canyon, OR (Phase I; 2009)	76)	125.4	80	50	110 m x 110 m	1 year	Bi-monthly (spring, fall), monthly (winter, summer)
Biglow Canyon, OR (Phase II; 2009-2010)	65	150	80	50	250 m x 250 m	1 year	Bi-monthly (spring, fall), monthly (winter, summer)
Biglow Canyon, OR (Phase II; 2010-2011)	65	150	80	50	252 m x 252 m	1 year	Bi-weekly(spring, fall), monthly (summer, winter)
Biglow Canyon, OR (Phase III; 2010-2011)	76	174.8	80	50	252 m x 252 m	1 year	Bi-weekly(spring, fall), monthly (summer, winter)
Buena Vista, CA (2008-2009)	38	38	45-55	38	75-m radius	1 year	Monthly to bi-monthly starting in September 2008

Appendix B3. All post-construction monitoring studies, project characteristics, and select study methodology for California and Pacific Northwest wind energy facilities.

Project Name	Total # of Turbines	Total MW	Tower Size (m)	Number Turbines Searched	Plot Size	Length of Study	Survey Frequency
Combine Hills, OR (Phase I; 2004-2005)	41	41	53	41	90-m radius	1 year	Monthly
Combine Hills, OR (2011)	104	104	53	52 (plus 1 MET tower)	180 m x 180 m	1 year	Bi-weekly(spring, fall), monthly (summer, winter)
Condon, OR	84	NA	NA	NA	NA	NA	N/a
Diablo Winds, CA (2005-2007)	31	20.46	50 and 55	31	75 m x 75 m	2 years	Monthly
Dillon, CA (2008-2009)	45	45	69	15	200 m x 200 m	1 year	Weekly, bi-monthly in winter
Elkhorn, OR (2008)	61	101	80	61	220 m x 220 m	1 year	Monthly
Elkhorn, OR (2010)	61	101	80	31	220 m x 220 m	1 year	Bi-monthly (spring, fall), monthly (winter, summer)
Goodnoe, WA (2009-2010)	47	94	80	24	180 m x 180 m	1 year	14 days during migration periods, 28 days during non-migration periods
Harvest Wind, WA (2010-2012)	43	98.9	80	32	180 m x 180 m & 240 m x 240 m	2 years	Twice a week, weekly and monthly
Hay Canyon, OR (2009-2010)	48	100.8	79	20	180 m x 180 m	1 year	Bi-monthly (spring, fall), monthly (winter, summer)
High Winds, CA (2003-2004)	90	162	60	90	75-m radius	1 year	Bi-monthly
High Winds, CA (2004-2005)	90	162	60	90	75-m radius	1 year	Bi-monthly
Hopkins Ridge, WA (2006)	83	150	67	41	180 m x 180 m	1 year	Monthly, weekly (subset of 22 turbines spring and fall migration)

Appendix B3. All post-construction monitoring studies, project characteristics, and select study methodology for California and Pacific Northwest wind energy facilities.

Project Name	Total # of Turbines	Total MW	Tower Size (m)	Number Turbines Searched	Plot Size	Length of Study	Survey Frequency
Hopkins Ridge, WA (2008)	87	156.6	67	41 - 43	180 m x 180 m	1 year	Bi-monthly (spring, fall), monthly (winter, summer)
Kittitas Valley, WA (2011-2012)	48	100.8	80	48	100 m x 102 m	1 year	Bi-weekly from Aug 15 - Oct 31 and March 16 - May 15; every 4 weeks from Nov 1 - March 15 and May 16 - Aug 14
Klondike, OR (2002-2003)	16	24	80	16	140 m x 140 m	1 year	Monthly
Klondike II, OR (2005-2006)	50	75	80	25	180 m x 180 m	1 year	Bi-monthly (spring, fall), monthly (summer, winter)
Klondike III (Phase I), OR (2007-2009)	125	223.6	GE = 80; Siemens = 80, Mitsubishi = 80	46	240 m x 240 m (1.5MW) 252 m x 252 m (2.3MW)	2 year	Bi-monthly (spring, fall migration), monthly (summer, winter)
Klondike IIIa (Phase II), OR (2008-2010)	51	76.5	GE = 80	34	240 m x 240 m	2 years	Bi-monthly (spring, fall), monthly (summer, winter)
Leaning Juniper, OR (2006-2008)	67	100.5	80	17	240 m x 240 m	2 years	Bi-monthly (spring, fall), monthly (winter, summer)
Linden Ranch, WA (2010-2011)	25	50	80	25	110 m x 110 m	1 year	Bi-weekly(spring, fall), monthly (summer, winter)
Lower West, CA (2013-2017)	7	14	67	4	120 m radius	3 years	Bi-weekly
Marengo I, WA (2009-2010)	78	140.4	67	39	180 m x 180 m	1 year	Bi-monthly (spring, fall), monthly (winter, summer)
Marengo II, WA (2009-2010)	39	70.2	67	20	180 m x 180 m	1 year	Bi-monthly (spring, fall), monthly (winter, summer)

Appendix B3. All post-construction monitoring studies, project characteristics, and select study methodology for California and Pacific Northwest wind energy facilities.

Project Name	Total # of Turbines	Total MW	Tower Size (m)	Number Turbines Searched	Plot Size	Length of Study	Survey Frequency
Montezuma I, CA (2011)	16	36.8	80	16	105 m radius	1 year	Weekly and bi-Weekly
Montezuma I, CA (2012)	16	36.8	80	16	105 m radius	1 year	Weekly and bi-Weekly
Montezuma II, CA (2012-2013)	34	78.2	80	17	105 m radius	1 year	Weekly
Mustang Hills, CA (2012-2013)	50	150	90	13 plots (equal to 15 turbines)	240 x 240 m	1 year	Bi-weekly
Nine Canyon, WA (2002-2003)	37	48.1	60	37	90-m radius	1 year	Bi-monthly (spring, summer, fall), monthly (winter)
Nine Canyon II, WA (2004)	12	15.6	60	12	90 m x 90 m	3 months	Once every two weeks
Pacific, CA (2012-2013)	70	140	78.5	20	126 m radius	NA	Twice weekly (fall), and biweekly
Palouse Wind, WA (2012-2013)	58	104.4	80, 90, or 105 M (according to the Vestas website)	19	120m x 120m	1 year	Monthly (Winter) and Weekly (Spring-Fall)
Pebble Springs, OR (2009-2010)	47	98.7	79	20	180 m x 180 m	1 year	Bi-monthly (spring, fall), monthly (winter, summer)
Pine Tree, CA (2009-2010, 2011)	90	135	65	40	100 m radius	1.5 year	Bi-weekly, weekly
Pinyon Pines I & II, CA (2013-2014)	100	NA	90	25 plots (approx. 31 turbines)	240x240 m	NA	Bi-weekly
San Gorgonio, CA (1997-1998; 1999-2000)	3000	n/a	24.4-42.7	NA	50-m radius	2 years	Quarterly

Appendix B3. All post-construction monitoring studies, project characteristics, and select study methodology for California and Pacific Northwest wind energy facilities.

Project Name	Total # of Turbines	Total MW	Tower Size (m)	Number Turbines Searched	Plot Size	Length of Study	Survey Frequency
Shiloh I, CA (2006-2009)	100	150	65	100	105-m radius	3 years	Weekly
Shiloh II, CA (2009-2010)	75	150	80	25	100m radius	1 year	Weekly
Shiloh II, CA (2010-2011)	75	150	80	25	100 m radius	1 year	Weekly
Shiloh III, CA (2012-2013)	50	102.5	78.5	25	100 m radius	Na	Weekly
SMUD Solano, CA (2004-2005)	22	15	65	22	60-m radius	1 year	Bi-monthly
Solano III, CA (2012-2013)	55	128	80	19	100 m radius	NA	Bi-Weekly
Stateline, OR/WA (2001-2002)	454	299	50	124	minimum 126 m x 126 m	17 months	Bi-weekly, monthly
Stateline, OR/WA (2003)	454	299	50	153	minimum 126 m x 126 m	1 year	Bi-weekly, monthly
Stateline, OR/WA (2006)	454	299	50	39	variable turbine strings	1 year	Bi-weekly
Tehachapi, CA (1996-1998)	3300	NA	14.7 to 57.6	201	50-m radius	20 months	Quarterly
Tuolumne (Windy Point I), WA (2009-2010)	62	136.6	80	21	180 m x 180 m	1 year	Monthly throughout the year, a sub-set of 10 turbines were also searched weekly during the spring, summer, and fall
Vansycle, OR (1999)	38	24.9	50	38	126 m x 126 m	1 year	Monthly

Appendix B3. All post-construction monitoring studies, project characteristics, and select study methodology for California and Pacific Northwest wind energy facilities.

Project Name	Total # of Turbines	Total MW	Tower Size (m)	Number Turbines Searched	Plot Size	Length of Study	Survey Frequency
Vantage, WA (2010-2011)	60	90	80	30	240 m x 240 m	1 year	Monthly, a subset of 10 searched weekly during migration
Vasco, CA (2012-2013)	34	78.2	80	34	105 m radius	1 year	Weekly, monthly
White Creek, WA (2007-2011)	89	204.7	80	89	180 m x 180 m & 240 m x 240 m	4 years	Twice a week, weekly and monthly
Wild Horse, WA (2007)	127	229	67	64	110 m from two turbines in plot	1 year	Monthly, weekly (fall, spring migration at 16 turbines)
Windy Flats, WA (2010-2011)	114	262.2	80	36 (plus 1 MET tower)	180 m x 180 m (120m at MET tower)	1 year	Monthly (spring, summer, fall, and winter), weekly (spring and fall migration)

Appendix B3 (*continued*). All post-construction monitoring studies, project characteristics, and select study methodology for California and Pacific Northwest wind energy facilities.

Data from the following sources:

Project, Location	Reference	Project, Location	Reference
Alite, CA (09-10)	Chatfield et al. 2010	Linden Ranch, WA (10-11)	Enz and Bay 2011
Alta Wind I, CA (11-12)	Chatfield et al. 2012	Marengo I, WA (09-10)	URS Corporation 2010b
Alta Wind I-V, CA (13-14)	Chatfield and Bay 2014	Marengo II, WA (09-10)	URS Corporation 2010c
Alta Wind II-V, CA (11-12)	Chatfield et al. 2012	Montezuma I, CA (11)	ICF International 2012
Alta VIII, CA (12-13)	Chatfield and Bay 2014	Montezuma I, CA (12)	ICF International 2013
Big Horn, WA (06-07)	Kronner et al. 2008	Montezuma II, CA (12-13)	H.T. Harvey & Associates 2013
Biglow Canyon, OR (Phase I; 08)	Jeffrey et al. 2009a	Mustang Hills, CA (12-13)	Chatfield and Bay 2014
Biglow Canyon, OR (Phase I; 09)	Enk et al. 2010	Nine Canyon, WA (02-03)	Erickson et al. 2003
Biglow Canyon, OR (Phase II; 09-10)	Enk et al. 2011a	Nine Canyon II, WA (04)	Erickson et al. 2005b
Biglow Canyon, OR (Phase II; 10-11)	Enk et al. 2012b	Pacific, CA (12-13)	Sapphos Environmental 2014
Biglow Canyon, OR (Phase III; 10-11)	Enk et al. 2012a	Palouse Wind, WA (12-13)	Stantec 2013
Buena Vista, CA (08-09)	Insignia Environmental 2009	Pebble Springs, OR (09-10)	Gritski and Kronner 2010b
Combine Hills, OR (Phase I; 04-05)	Young et al. 2006	Pine Tree, CA (09-10, 11)	BioResource Consultants 2012
Combine Hills, OR (11)	Enz et al. 2012	Pinyon Pines I&II, CA (13-14)	Chatfield and Russo 2014
Condon, OR	Fishman Ecological Services 2003	San Gorgonio, CA (97-98; 99-00)	Anderson et al. 2005
Diablo Winds, CA (05-07)	WEST 2006, 2008	Shiloh I, CA (06-09)	Kerlinger et al. 2009
Dillon, CA (08-09)	Chatfield et al. 2009	Shiloh II, CA (09-10)	Kerlinger et al. 2010, 2013a
Elkhorn, OR (08)	Jeffrey et a. 2009b	Shiloh II, CA (10-11)	Kerlinger et al. 2013a
Elkhorn, OR (10)	Enk et al. 2011b	Shiloh III, CA (12-13)	Kerlinger et al. 2013b
Goodnoe, WA (09-10)	URS Corporation 2010a	SMUD Solano, CA (04-05)	Erickson and Sharp 2005
Harvest Wind, WA (10-12)	Downes and Gritski 2012a	Solano III, CA (12-13)	AECOM 2013
Hay Canyon, OR (09-10)	Gritski and Kronner 2010a	Stateline, OR/WA (01-02)	Erickson et al. 2004
High Winds, CA (03-04)	Kerlinger et al. 2006	Stateline, OR/WA (03)	Erickson et al. 2004
High Winds, CA (04-05)	Kerlinger et al. 2006	Stateline, OR/WA (06)	Erickson et al. 2007
Hopkins Ridge, WA (06)	Young et al. 2007	Tehachapi, CA (96-98)	Anderson et al. 2004
Hopkins Ridge, WA (08)	Young et al. 2009	Tuolumne (Windy Point I), WA (09-10)	Enz and Bay 2010
Kittitas Valley, WA (11-12)	Stantec Consulting 2012	Vansycle, OR (99)	Erickson et al. 2000
Klondike, OR (02-03)	Johnson et al. 2003a	Vantage, WA (10-11)	Ventus Environmental Solutions 2012
Klondike II, OR (05-06)	NWC and WEST 2007	Vasco, CA (12-13)	Brown et al. 2013
Klondike III (Phase I), OR (07-09)	Gritski et al. 2010	White Creek, WA (07-11)	Downes and Gritski 2012b
Klondike IIIa (Phase II), OR (08-10)	Gritski et al. 2011	Wild Horse, WA (07)	Erickson et al. 2008
Leaning Juniper, OR (06-08)	Gritski et al. 2008	Windy Flats, WA (10-11)	Enz et al. 2011