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BAT ACOUSTIC SURVEY REPORT

Fountain Wind Project
Shasta County, CA

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EXECUTIVE SUMMARY

In April 2017, Western Ecosystems Technology, Inc. (WEST) initiated bat acoustic surveys at the proposed Fountain Wind Project (Project) in Shasta County, California. WEST designed bat acoustic surveys to evaluate levels of bat activity and species' use of the Project during periods of expected peak activity (i.e., spring through fall). To address the two key study questions posed in the California Wind Energy Guidelines and assess the potential risk the Project may pose to bats, WEST conducted bat acoustic surveys to: 1) determine the bat species present at the Project during the peak bat activity period of spring through fall, and 2) assess the spatial and temporal patterns of bat activity which may influence the risk of collision for bats at the Project.

Bat acoustic surveys were conducted between 30 April and 13 November 2017 at seven stations representative of potential turbine locations ('representative' sampling stations) and at one station with feature(s) thought to be attractive to bats ('feature' sampling station) to assess risk to bats from Project development. Wildlife Acoustics Song Meter (SM3) full-spectrum bat detectors were placed at each of two meteorological (met) towers located in cleared montane coniferous forest. At each met tower, one microphone was placed near the ground ('ground' sampling station) at approximately 5.0 feet (ft; 1.5 meters [m]) above ground level (AGL) and a second microphone was elevated ('raised' sampling station) to approximately 148 ft (45 m) AGL. Raised sampling stations were placed to sample bat activity within the potential rotor-swept zone of commercial wind turbines. In total, there were four representative stations located at the two met towers; two raised stations and two ground stations. Three additional representative ground stations were added to increase spatial coverage at the Project. The one feature station was placed near ground level in a riparian meadow considered attractive to bats to provide an upper reference of bat activity at the Project.

Bat activity was monitored at eight sampling stations for a total of 1,301 detector-nights between 30 April and 13 November 2017. Overall, sampling stations recorded 96,107 bat passes for a mean of 68.18 bat passes per detector-night. Overall mean bat activity levels varied among representative sampling stations, ranging from 25.60 - 87.94 bat passes per detector-night. Ground representative sampling stations averaged 50.25 bat passes per detector-night, whereas raised representative sampling stations, which collected data on bat activity in the rotor-swept zone, averaged 26.07 bat passes per detector-night; roughly half the level of activity recorded at ground stations. The single feature station recorded 49,541 bat passes on 190 detector-nights for a mean of 260.74 bat passes per detector-night; however, the mean activity rate at the single feature station is not representative of activity levels at future turbine locations and should be considered an upper reference for activity in the Project area.

Overall bat activity at all representative sampling stations was greater in summer (45.73 bat passes per detector-night) than in spring (26.98) and fall (41.88), which was consistent with the pattern observed for the high-frequency species group, consisting of mostly smaller species (e.g., Myotis). In contrast, the activity rate of the larger low-frequency (LF) species (e.g., hoary

bat, silver-haired bat, Mexican free-tailed bat) was greater in fall (28.70 bat passes per detector-night) than in spring (20.52) and summer (25.01), with the late summer and early fall (i.e., the fall migration period) having the highest level of LF bat activity (35.83). Bat activity at ground representative sampling stations was higher than at raised representative sampling stations throughout the study period, except in late August to early September and mid to late October, when activity at raised representative sampling stations exceeded activity rates at ground stations.

Fourteen bat species, none of which were unexpected, were documented from acoustic survey data collected within the Project area, including two California species of special concern (SSC): spotted bat, and western mastiff bat. Three species (Townsend's big-eared bat, pallid bat, and western red bat) were identified prior to field studies as having potential to occur, but were not documented from the acoustic survey data. Silver-haired bat and hoary bat were the most commonly recorded species, present on 76% and 75% of operational detector-nights, respectively. Mexican free-tailed bat was the third most frequently identified species, present on 70% of detector-nights. Other commonly detected species included big brown bat (64% of detector nights), and California bat (54%).

Consistent with the California Wind Energy Guidelines' two key study questions: 1) "*which species of bats use the project area and how do their numbers vary throughout the year?"* and 2) "*how much time do these species spend in the risk zone (i.e., rotor-swept area) and does this vary by season*?" WEST conducted bat acoustic surveys to determine the bat species present at the Project and assess the spatial and temporal patterns of bat activity which may influence the risk of collision for bats at the Project. Silver-haired bat, hoary bat, Mexican free-tailed bat, big brown bat, and California bat were the most commonly detected species (documented on more than 50% of operational detector nights), while the two California SSC (spotted bat and western mastiff bat) were documented rarely (seven passes total on three separate nights) during the study period. Hoary bats, silver-haired bats, and Mexican free tailed bats all belong to the LF species group and are among the most commonly documented bat fatalities at wind energy facilities where these species occur.

While activity rates of LF species at paired sample sites (i.e., having both ground and raised stations) were 10-53% greater at ground stations in the spring and summer, activity rates of LF species in the fall were more mixed, with 7% greater activity at the ground station at one paired site and 20% lower activity at the ground station at the other paired site. While the data are not definitive, the temporal pattern of use at raised versus ground stations suggests that LF bats may spend more time at greater heights (and potentially within the rotor-swept zone) during the fall than during spring and summer. Furthermore, while data indicate that LF bats are active at all sampled heights, they clearly represent the majority of bat activity recorded within the rotor-swept zone, accounting for 96% of bat passes recorded at raised sampling stations.

It has been generally presumed that pre-construction bat activity rates are positively related to post-construction bat fatalities; however, to date, the relationship between pre-construction activity rates and post-construction fatality rates has not been established. At European wind energy facilities, risk of collision was higher for bat species that fly at greater heights, and in Canada, a significant positive association was found between pass rates measured at 98 ft (30 m) AGL and fatality rates for hoary and silver-haired bats across five sites in southern Alberta; however, on a continental scale, a similar relationship has not been established. A recent meta-analysis of commercial wind projects in Maine showed no relationship between pre-construction bat activity and post-construction bat fatality rates. Other studies that have estimated both pre-construction activity and post-construction fatalities show results that trend toward a positive association between activity and fatality rates, but lack statistically significant correlations, resulting in the inability to use pre-construction acoustic data to predict post-construction bat fatalities. While researchers continue to investigate the potential utility of pre-construction acoustics in predicting post-construction fatalities, the current science remains consistent with that depicted in the California Wind Energy Guidelines, which state that passive acoustic surveys can provide pre-permitting information useful in establishing baseline patterns of seasonal bat activity, but that a fundamental gap exists regarding links between pre-permitting assessments and operations fatalities.

In other parts of the western US where wind energy facilities are clustered, bat fatality rates have generally been consistent among neighboring facilities; therefore, to evaluate the potential for bat fatalities at the Project, fatality rates documented at nearby facilities were examined to determine if patterns were evident. The only wind energy facility in the western US with publicly available post-construction fatality data and habitat similar to the Project is the Hatchet Ridge facility, located less than two mi (3.2 km) northeast of the Project. The Hatchet Ridge facility is very similar to the Project in terms of geography, topography and habitat, and is in close proximity; therefore, it is likely that bat fatality rates documented at the Hatchet Ridge facility are among the best indicators of potential risk at the Project. Bat fatality rates at the Hatchet Ridge facility were estimated to be 2.23, 5.22, and 4.20 bats/MW/year in the first, second, and third years of operation, respectively. Documented fatalities at the Hatchet Ridge facility were highest from July – September and primarily comprised hoary bats, silver-haired bats, and Mexican free-tailed bats, similar to patterns of bat fatalities throughout the US. The species found as fatalities at the Hatchet Ridge facility are consistent with the species most commonly detected in bat acoustic surveys conducted for the Project, and the timing of the peak fatality rate at the Hatchet Ridge facility aligns with peak bat activity rates documented at the Project.

Given that the species composition and temporal patterns of bat activity documented at the Project align with the results of fatality studies conducted at the nearby Hatchet Ridge facility; pre-construction bat acoustic data suggest that bat fatality patterns at the Project would likely be similar to those documented at the Hatchet Ridge facility. Based on the available data, fatality rates are anticipated to be similar to those documented at the Hatchet Ridge facility (2.23 – 5.22 bats/MW/year) and primarily consist of fatalities of hoary bats, silver-haired bats, and Mexican free-tailed bats during the late summer and fall migration period.

STUDY PARTICIPANTS

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REPORT REFERENCE

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INTRODUCTION

Pacific Wind Development LLC (Pacific Wind) is considering development of a wind energy facility in Shasta County, California, referred to as the Fountain Wind Project (Project). Pacific Wind contracted Western EcoSystems Technology, Inc. (WEST) to complete a study of bat activity based on recommendations in the US Fish and Wildlife Service (USFWS) *Land-Based Wind Energy Guidelines* (USFWS 2012a), the *California Guidelines for Reducing Impacts to Birds and Bats from Wind Development* (California Energy Commission [CEC] and California Department of Fish and Game [CDFG] 2007), and Kunz et al. (2007a). The initial study plan was modified based on consultation with the USFWS and the California Department of Fish and Wildlife (CDFW), which occurred 15 June 2017. The CEC Guidelines (CEC and CDFG 2007) identify two key study questions that need to be addressed in order to assess risk to bats: 1) "*which species of bats use the project area and how do their numbers vary throughout the yea?"* and 2) *how much time do these species spend in the risk zone (i.e., rotor-swept area) and does this vary by season?".* To address these two key study questions and assess the potential risk the Project may pose to bats, WEST conducted bat acoustic surveys to: 1) determine the bat species present at the Project during the peak bat activity period of spring through fall, and 2) assess the spatial and temporal patterns of bat activity which may influence the risk of collision for bats at the Project. This report describes the bat acoustic surveys conducted at the Project in 2017, summarizes the results, and provides a qualitative risk assessment for the Project based on regional patterns in bat activity and fatalities.

STUDY AREA

The Project area currently encompasses approximately 32,000 acres (ac; 12,950 hectares [ha]) within Shasta County in northern California west of the community of Burney and northeast of the larger community of Redding (Figure 1). The east-west running California State Route 299 bisects the northern portion of the Project area, and the Hatchet Ridge Wind Energy Facility (Hatchet Ridge), in operation since 2010, is located approximately 1.48 miles (mi; 2.38 kilometers [km]) northeast of the Project. The Lassen National Forest is located to the southeast of the Project and the Shasta-Trinity National Forest is located to the north and east.

The Project area is entirely privately owned and actively managed for timber production, with recent and ongoing timber harvest operations occurring primarily within the southern half of the Project area. A large portion of the Project is early seral forest resulting from the Fountain Fire, which burned approximately 64,000 ac (24,900 ha) in 1992, including the north-central half of the Project area. Post-fire management included salvage logging, site preparation, and planting of conifer seedlings in the year following the fire to enhance forest regeneration for future timber harvesting.

The vegetation communities within the Project area are predominantly coniferous forest (54.7%) and harvested areas classified as shrub/scrub (38.3%; Figure 2, Table 1). The shrub/scrub classification is primarily the result of a temporary change in vegetation in recently harvested coniferous forests that persists until the replanted conifer trees become established and reclaim dominance in the site. These shrub/scrub areas may also be actively treated with herbicides to enhance conifer seedling establishment. Small areas of mixed montane chaparral and herbaceous vegetation (i.e., grassland) are scattered throughout the Project area (Figure 2, Table 1). Wetlands are present within the Project area, occurring primarily as riverine habitats, with much smaller areas of wet montane meadow and open water (Figure 2, Table 1). Cliffs and rocky outcrops are present in addition to several bridges, culverts, and other manufactured structures that offer habitat for bats. While some of the cover types should remain relatively consistent over time, the spatial distribution and amount of coniferous forest and shrub/scrub cover types within the Project area are likely to change substantially over time due to ongoing timber management activities.

Table 1. Land cover types within the Fountain Wind Project area according to National Land Cover Data (US Geological Survey [USGS] National Land Cover Database [NLCD] 2011, Homer et al. 2015).

Land Cover	Acres	% Composition
Coniferous Forest	17,786.16	54.7
Shrub/Scrub	12,430.51	38.3
Herbaceous	1,516.25	4.7
Deciduous Forest	344.15	1.1
Barren Land	205.18	0.6
Mixed Forest	95.09	0.3
Developed, Open Space	74.90	0.2
Emergent Herbaceous Wetlands	21.26	0.1
Developed, Low Intensity	8.13	<0.01
Cultivated Crops	5.71	<0.01
Total	**32,487.34**	**100**

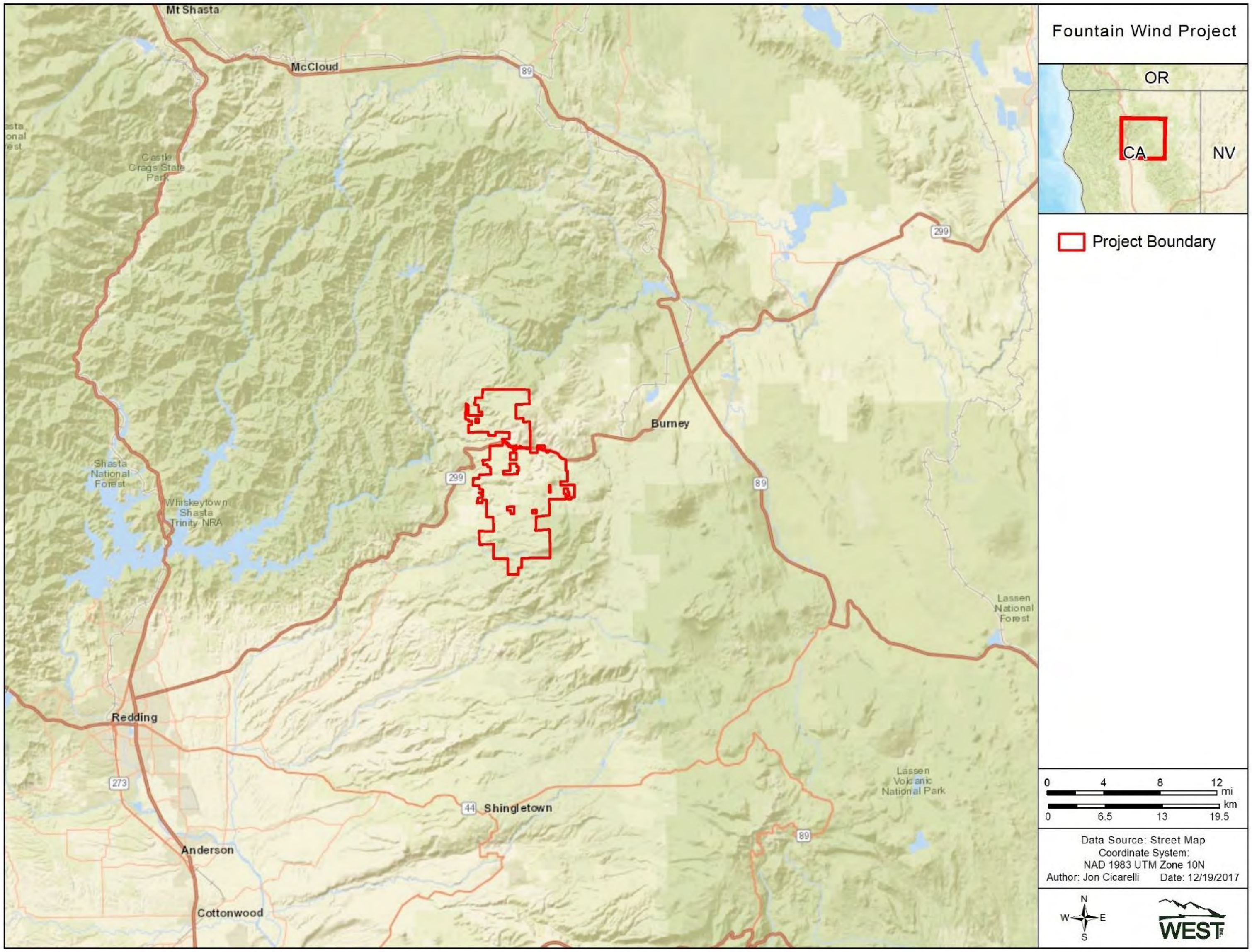

Figure 1. Location of the proposed Fountain Wind Project, Shasta County, California.

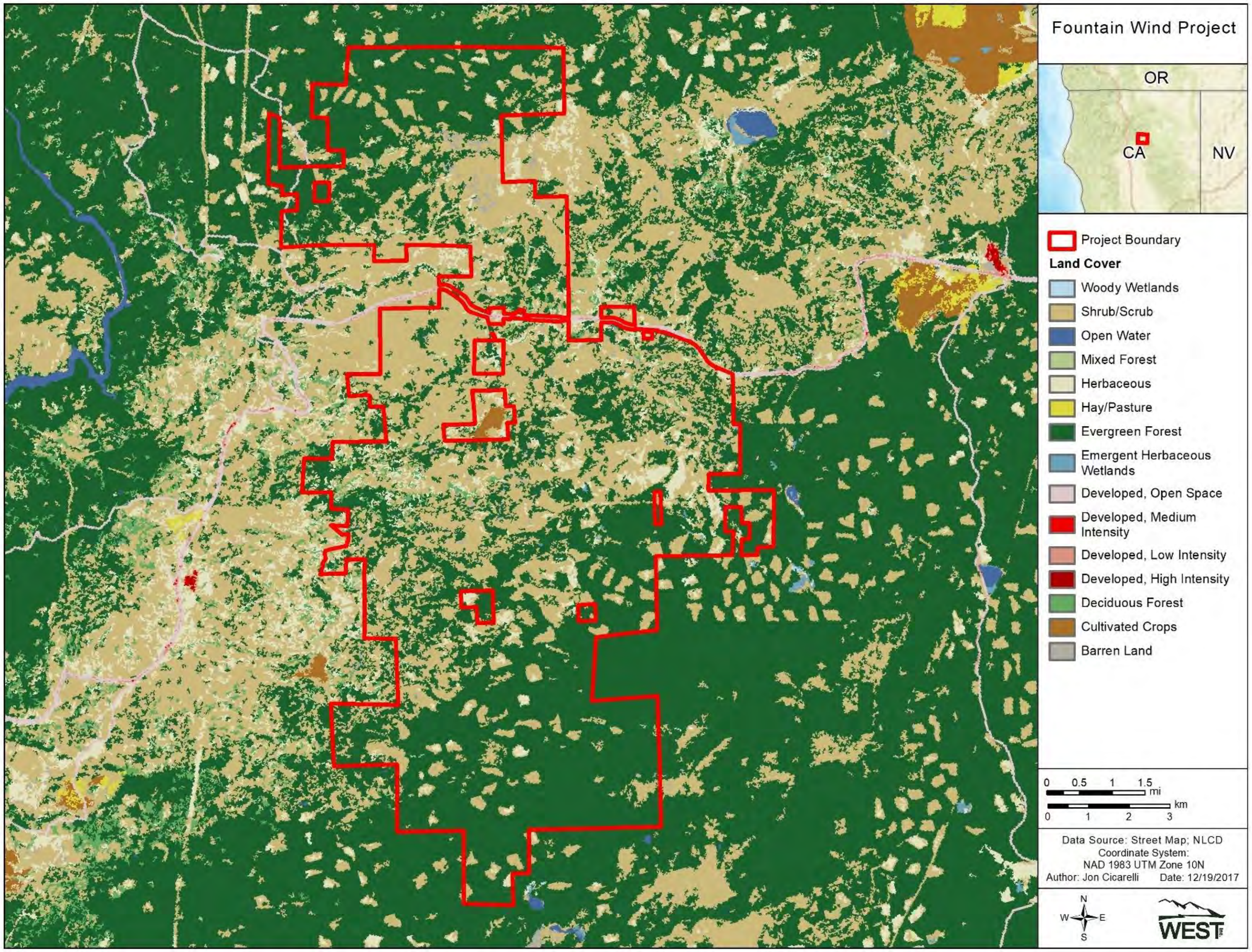

Figure 2. Land cover types within the proposed Fountain Wind Project (US Geological Survey [USGS] National Land Cover Database [NLCD] 2011, Homer et al. 2015).

Overview of Bat Diversity

Seventeen species of bats potentially occur at the Project (Table 2, International Union for Conservation of Nature [IUCN] 2016), none of which are federally protected. Eleven of the potentially occurring bat species have been documented as fatalities at wind energy facilities and five are considered Species of Special Concern (SSC) by the CDFW (Table 2).

Table 2. Bat species with the potential to occur within the Fountain Wind Project area categorized by echolocation call frequency.

Common Name	Scientific Name
High-Frequency (> 30 kilohertz [kHz])	
California bat	*Myotis californicus*
canyon bat[1, 4]	*Parastrellus hesperus*
little brown bat[1]	*Myotis lucifugus*
long-legged bat[1]	*Myotis volans*
western long-eared bat[1]	*Myotis evotis*
western red bat[1,2]	*Lasiurus blossevillii*
western small-footed bat [3]	*Myotis ciliolabrum*
Yuma bat	*Myotis yumanensis*
Low-Frequency (15 – 30 kHz)	
big brown bat[1]	*Eptesicus fuscus*
fringed bat	*Myotis thysanodes*
hoary bat[1]	*Lasiurus cinereus*
Mexican free-tailed bat[1]	*Tadarida brasiliensis*
pallid bat[3]	*Antrozous pallidus*
silver-haired bat[1]	*Lasionycteris noctivagans*
Townsend's big-eared bat[2]	*Corynorhinus townsendii*
Very Low-Frequency (< 15 kHz)	
spotted bat[2]	*Euderma maculatum*
western mastiff bat[2]	*Eumops perotis*

[1] Species known to have been killed at wind energy facilities (species reported by: Anderson et al. 2004, Kunz et al. 2007b, Baerwald 2008, Miller 2008, Arnett and Baerwald 2013, Barclay et al. 2017, AWWI 2018);
[2] California Species of Special Concern (CDFW 2018);
[3] Species not known to occur within the Project based on IUCN 2016 or BCI 2018 range maps but included in review due to proximity to known range and habitat suitability within the Project.

METHODS

Bat Acoustic Surveys

Sampling Stations

Bat activity levels and composition can vary with height above ground level (AGL; Baerwald and Barclay 2009, Collins and Jones 2009, Müeller et al. 2013), and high-flying bat species are at greater risk of collision with turbines (Roemer et al. 2017). Therefore, it is useful to monitor activity at different heights (Kunz et al. 2007b). Because most bat species spend at least some time flying at low flight heights, microphones near the ground may detect a more complete sample of the bat species present within a given area; however, elevated microphones may provide a more accurate assessment of bat species flying at rotor-swept heights (Kunz et al. 2007b, Müeller et al. 2013; but see Amorim et al. 2012).

Six Song Meter (SM3) full-spectrum ultrasonic bat detectors (Wildlife Acoustics, Inc., Concord, Massachusetts) were used to record bat echolocation and social calls during the study. Each SM3 detector is equipped with two microphone ports; each operational microphone was considered a sampling station. Biologists placed a single SM3 detector at each of two meteorological (met) towers, with one sampling station placed near the ground (g), and a second sampling station raised (r) to approximately 148 ft (45 m) AGL. Sampling stations are named by project, order of deployment, and type (e.g., MF1g = McCloud-Fountain, first-deployed, ground sampling station). Met towers are considered representative of future turbine locations; detectors at met towers comprise 'representative sampling stations'. Raised representative sampling stations monitored bat activity near the proposed rotor-swept zone.

During initiation of the bat acoustic surveys, WEST placed two additional detectors at other locations within the Project area. One detector was deployed in an area representative of future turbine locations (i.e., a forest opening); another detector was deployed in an area with features possibly attractive to bats (i.e., a riparian meadow), but not representative of future turbine locations. Data collected by the bat detector deployed near a habitat feature possibly attractive to bats served to provide an upper reference for bat activity at the Project and to increase the likelihood of detecting all species that may be present within the Project area. The detector at the bat habitat feature is considered a 'feature sampling station' while the detector placed in the forest opening is a representative sampling station; both additional detectors comprised ground sampling stations only. Finally, following the 15 June meeting with CDFW and USFWS, two additional ground sampling stations were added in areas representative of future turbine locations to increase the spatial coverage of the Project area.

Microphones at all ground sampling stations were elevated slightly on 5-ft (1.5-m) masts to enhance the quality of sound recordings (e.g., to reduce recordings of insect calls) for improved species identification. Microphones at raised sampling stations were positioned on met towers using pulley systems and oriented at 75 degrees relative to the ground to maximize the amount of air space sampled. Large weatherproof boxes housed the SM3 units and external deep-cycle batteries for protection from weather and wildlife.

Survey Schedule

Acoustic monitoring surveys were conducted at the Project from 30 April to 13 November 2017. Detectors were programmed to turn on approximately 30 minutes (min) before sunset and turn off approximately 30 min after sunrise each day. To highlight seasonal activity patterns, the study was divided into three survey periods: spring (30 April – 31 May), summer (1 June – 14 August), and fall (15 August – 13 November).

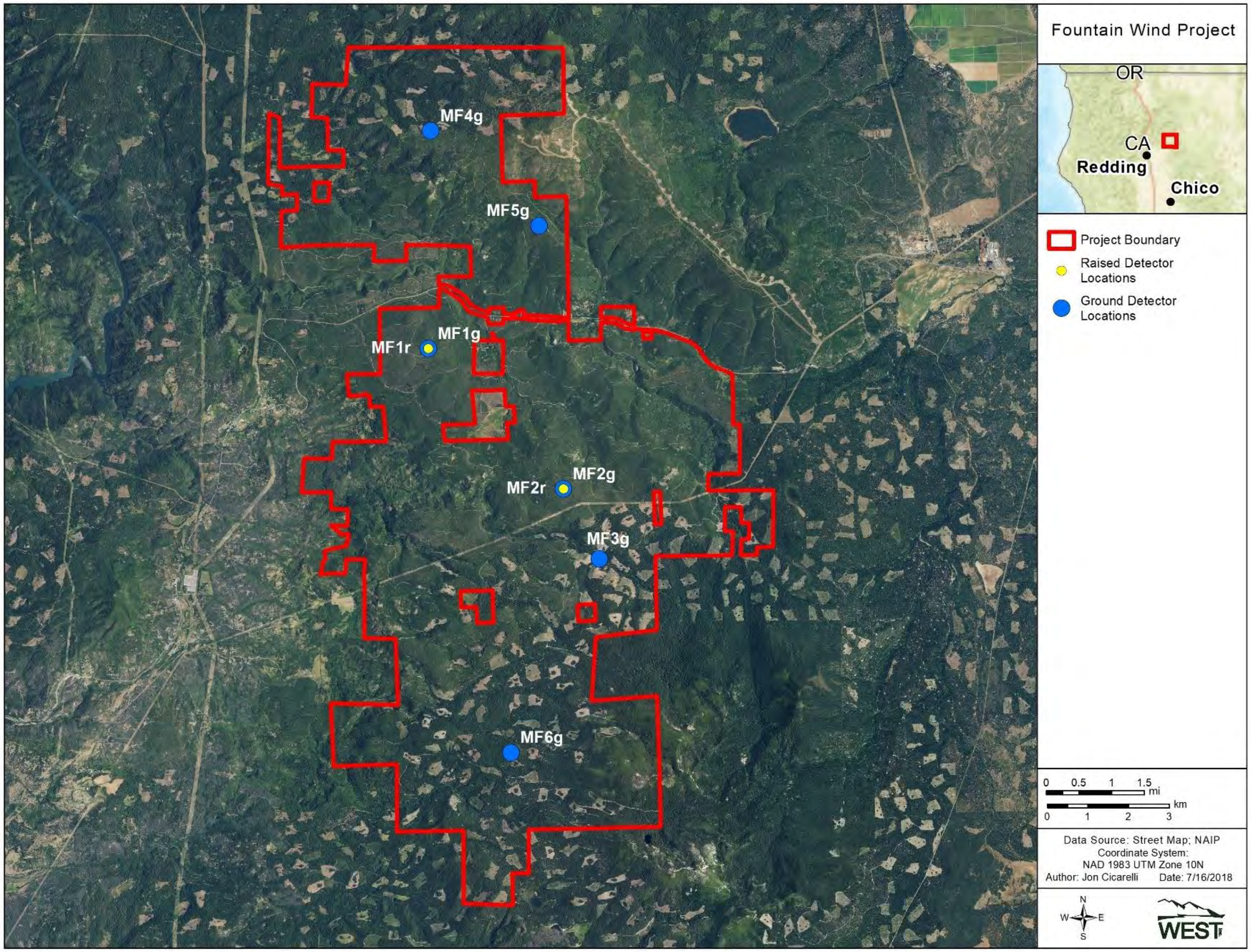

Figure 3. Location of sampling stations used during the bat acoustic surveys at the proposed Fountain Wind Project.

Data Collection and Call Analysis

The Song Meter SM3 is a highly reliable full-spectrum bat detector that records complete acoustic waveforms by sampling sound waves at 192 kilohertz (kHz). The high sampling rate enables the detector to record sound amplitude data at all frequencies up to 96 kHz and to make high resolution recordings. The high-quality recordings produced by the SM3 detector provide more information for making accurate species identifications at the cost of higher data storage requirements. SM3 detectors use an omnidirectional microphone to detect and record bat echolocation calls that are stored as files on Secure Digital (SD) cards.

All recorded files were converted from full-spectrum to zero-cross (division ratio 8) using the software program Kaleidoscope Pro (version 4.2.0; Wildlife Acoustics, Concord, Massachusetts). Noise files (i.e., files typically produced by wind or insects) were automatically filtered by Kaleidoscope into a Noise subfolder and not reviewed or included in results. All remaining ultrasonic files were viewed by a biologist as digital sonograms that show changes in echolocation call frequency over time in the bat call analysis software Analook©. Frequency versus time displays were used to separate bat calls from other types of ultrasonic noise (e.g., wind, insects) to determine the call frequency category, and when possible, identify the species of bat that generated the call.

For each sampling station, bat passes were grouped into three categories based on minimum frequency to aid in data sorting and because some species cannot be individually discerned through acoustic analysis. High-frequency (HF) bats such as *Myotis* species have minimum frequencies greater than 30 kHz. Low-frequency (LF) bats, such as big brown bat (*Eptesicus fuscus*), Mexican free-tailed bat (*Tadarida brasiliensis*), silver-haired bat (*Lasionycteris noctivagans*) and hoary bat (*Lasiurus cinereus*) typically emit echolocation calls with minimum frequencies between 15 and 30 kHz. Very low-frequency (VLF) bats, such as the western mastiff bat (*Eumops perotis*) and spotted bat (*Euderma maculatum*), have minimum echolocation frequencies below 15 kHz. Table 2 lists HF, LF, and VLF species that may occur in the Project area.

Files labeled as HF, LF, or VLF were then run through Kaleidoscope Pro again using the Bats of North America classifier (version 4.2.0) on the neutral (zero) setting to further define calls with sufficient call data (e.g., multiple pulses) to the species level, selecting for the 17 bat species that potentially occur in the Project area (Table 2). A qualified bat biologist reviewed all calls identified by Kaleidoscope Pro as spotted bat, western mastiff bat, pallid bat (*Antrozous pallidus*), Townsend's big-eared bat (*Corynorhinus townsendii)*, and western red bat (*Lasiurus blossevillii*) to verify species-level identification because these five species are all listed as SSC. A qualified bat biologist also reviewed passes identified by Kaleidoscope Pro as western small-footed bat (*Myotis ciliolabrum*) or canyon bat (*Parastrellus hesperus*) until species presence was confirmed or all calls were reviewed, as the Project area includes potentially suitable habitat but is just outside the known range for these species. Calls of the remaining species, which have ranges that overlap with the Project area and are not considered SSC, were not reviewed by a bat biologist but assumed present based on the classification by Kaleidoscope Pro.

Statistical Analysis

The standard metric used for measuring bat activity, the number of bat passes per detector-night, was used as an index of bat activity at the Project. A bat pass was defined as a sequence of at least two echolocation calls (pulses) produced by an individual bat with no pause between calls of more than one second (Fenton 1980, White and Gehrt 2001, Gannon et al. 2003). A detector-night was defined as one sampling station (i.e., detector) operating for one entire night. The terms bat pass and bat call are used interchangeably in this report. Bat passes per detector-night were calculated for all bats, and for HF, LF, and VLF bats. Bat pass rates represent indices of bat activity and do not represent numbers of individuals.

Mean bat activity was calculated by sampling station, season, fall migration period (FMP), and overall (overall averages were calculated as unweighted averages of total activity at each individual detector station). The FMP, defined here as 30 July – 14 October 2017 is a known period of increased landscape-scale movement and reproductive behavior that occurs in late summer and early fall (Cryan 2008), and is often associated with increased levels of bat fatalities at operational wind energy facilities (Arnett et al. 2008, Arnett and Baerwald 2013). The defined FMP may vary among projects across the county, as the FMP may differ depending on latitude or regional climate patterns.

Using detector-nights as a metric for calculating bat activity controls for differences in sampling effort among individual sampling stations and provides unbiased estimates for the nights that were surveyed. The period of peak sustained bat activity was defined as the 7-day period with the highest average bat activity. If multiple 7-day periods equaled the peak sustained bat activity rate, all dates in these 7-day periods were reported. This and all multi-station averages reported here were calculated as unweighted averages of total activity at each sampling station.

Risk Assessment

Collision with wind turbine blades is the primary risk to bats at operating wind energy facilities (Arnett et al. 2008). The intent of the risk assessment is to use pre-construction bat activity data and other relevant information to describe the potential for bat fatalities at the Project. The intent of the risk assessment is not to predict the number of fatalities, but rather provide context for data collected at the Project. To assess the potential risk to bats, bat activity in the Project area was compared to existing publicly available pre- and post-construction data from other wind energy facilities in the California, Southwestern, and Pacific Northwest regions.

Forecasting collision risk for bats at the Project is challenging for several reasons. First, there are relatively few publicly available studies presenting both pre-construction bat activity and post-construction fatality data, and the ecological differences among geographically dispersed facilities could limit the strength of inference. Further, as explained in detail below, there is no clear correlation between pre-construction bat activity and post-construction fatality data. Second, among studies with both pre-construction bat activity and post-construction fatality data, most pre-construction data were collected during the fall (i.e., the period of greatest risk) using Anabat™ zero-cross detectors (Titley Scientific™, Columbia, Missouri) placed near the ground. In contrast, this study used SM3 full-spectrum detectors near the ground and elevated near the rotor-swept area. Finally, the primary limitation of conducting a qualitative risk assessment for the Project is the difference in data collected by Anabat (used at most other projects) and SM3 detectors (used at the Project). Full-spectrum detectors, such as the SM3 units used at the Project, may record more bat passes per detector-night on average than the Anabat (zero-cross) units used for data collection at the majority of wind farms. Full-spectrum detectors have more sensitive microphones that sample more airspace, as well as different data processing algorithms (Solick et al. 2011, Adams et al. 2012), which may combine to result in higher activity rates than those measured by Anabat detectors. For this reason, activity levels recorded by SM3 detectors are not directly comparable to activity levels recorded by Anabat detectors, though trends in spatial and temporal activity rates collected by Anabat detectors can serve to contextualize trends in data collected using SM3 detectors. Differences in data collection technology (i.e., full-spectrum versus zero-cross detectors), and the resultant possibility that use of SM3 detectors rather than Anabat units at the Project led to increased collection of bat acoustic data should be considered. Inclusion of Anabat data in this report is for general discussion purposes only.

It has been generally presumed that pre-construction bat activity rates are positively related to post-construction bat fatalities (Kunz et al. 2007b). However, to date, the relationship between pre-construction activity rates and post-construction fatality rates has not been definitively established. At European wind energy facilities, Roemer et al. (2017) determined risk of collision was higher for bat species that fly at greater heights. In Canada, Baerwald and Barclay (2009) found a significant positive association between pass rates measured at 98 ft (30 m) AGL and fatality rates for hoary and silver-haired bats across five sites in southern Alberta; however, on a continental scale, a similar relationship has not been established. A recent meta-analysis of commercial wind projects in Maine showed no relationship between pre-construction bat activity and post-construction bat fatality rates (Peterson 2017). Hein et al. (2013) analyzed studies at 12 wind projects that included both pre- and post-construction data to assess if pre-construction acoustic activity predicted post-construction fatality rates. Based on data from the 12 projects, the authors did not find a statistically significant relationship ($p=0.07$) between pre-construction activity and post-construction mortality; and although the results suggested a positive relationship only a small portion of the variation in fatalities was explained by the pre-construction activity (adj. R^2= 21.8%; Hein et al. 2013). Hein et al. (2013) went on to conclude that the analysis results indicated the inability to use pre-construction acoustic data to predict post-construction bat fatalities. While researchers continue to investigate the potential utility of pre-construction acoustics in predicting post-construction fatalities, the current science remains consistent with that depicted in the CEC Guidelines, which state that passive acoustic surveys can provide pre-permitting information useful in establishing baseline patterns of seasonal bat activity, but that a fundamental gap exists regarding links between pre-permitting assessments and operations fatalities (CEC and CDFW 2007).

RESULTS

Bat Acoustic Surveys

Bat activity was monitored at eight sampling stations for a total of 1,301 detector-nights between 30 April and 13 November 2017; sampling stations were operational 95.4% of the study period. All sampling stations, with the exception of MF4g, occasionally failed to collect data due to wildlife interference with equipment (e.g., small mammals chewing cables, bears disturbing detectors). Overall, sampling stations recorded 96,107 bat passes for a mean (± standard error) of 68.18 ± 4.08 bat passes per detector-night (Table 3).

Spatial Variation

Overall bat activity varied among representative sampling stations (Table 3), ranging from a mean of (± standard error) 25.60 ± 2.64 bat passes per detector-night at sampling station MF2r, to 87.94 ± 5.32 bat passes per detector-night at sampling station MF4g (Table 3, Figure 4). Ground representative sampling stations recorded 36,582 bat passes on 728 detector-nights for a mean of 50.25 ± 4.33 bat passes per detector-night (Table 3; Figure 4a). In contrast, raised representative sampling stations, which collected data on bat activity in the rotor-swept zone, recorded 9,984 bat passes on 383 detector-nights for a mean of 26.07 ± 2.76 bat passes per detector-night; roughly half the level of activity recorded at ground stations (Table 3).

The single feature sampling station recorded 49,541 bat passes on 190 detector-nights for a mean of 260.74 ± 18.75 bat passes per detector-night (Table 3). The mean activity rate at the single feature station is not representative of activity levels at future turbine locations and should be considered an upper reference for bat activity in the Project area.

Table 3. Results of bat acoustic surveys by sampling station in the Fountain Wind Project area from 30 April – 13 November 2017. Passes are separated by call frequency: high frequency (HF), low frequency (LF), and very low frequency (VLF).

Sampling Station	Type	Habitat	# of HF Bat Passes	# of LF Bat Passes	# of VLF Bat Passes	Total Bat Passes	Detector-Nights	Mean Bat Passes/Night (± Standard Error)*†
MF1g	Ground representative	Representative of future turbine locations	1,114	5,756	1	6,871	189	36.35 ± 3.32
MF1r	Raised representative		132	4,885	1	5,018	189	26.55 ± 3.18
MF2g	Ground representative	Representative of future turbine locations	2,151	4,324	1	6,476	194	33.38 ± 3.31
MF2r	Raised representative		284	4,681	1	4,966	194	25.60 ± 2.64
MF3g	Ground feature	Includes features possibly attractive to bats	23,031	26,508	2**	49,541	190	260.74 ±18.75
MF4g	Ground representative	Representative of future turbine locations	9,913	7,498	1	17,412	198	87.94 ± 5.32
MF5g**	Ground representative	Representative of future turbine locations	2,539	1,719	0	4,258	88	48.39 ± 5.72
MF6g**	Ground representative	Representative of future turbine locations	566	999	0	1,565	59	26.53 ± 3.99
Total: Ground Representative Sampling Stations			16,283	12,798	3	36,582	728	50.25 ± 4.33
Total: Raised Representative Sampling Stations			416	9,566	2	9,984	383	26.07 ± 2.76
Total: Feature Sampling Stations			23,031	26,508	2	49,541	190	260.74 ±18.75
Total			**39,730**	**56,370**	**7**	**96,107**	**1,301**	**68.18 ± 4.08**

*± bootstrapped standard error.
†Sums may not total the values shows due to rounding.
**Sampling stations added 17 August

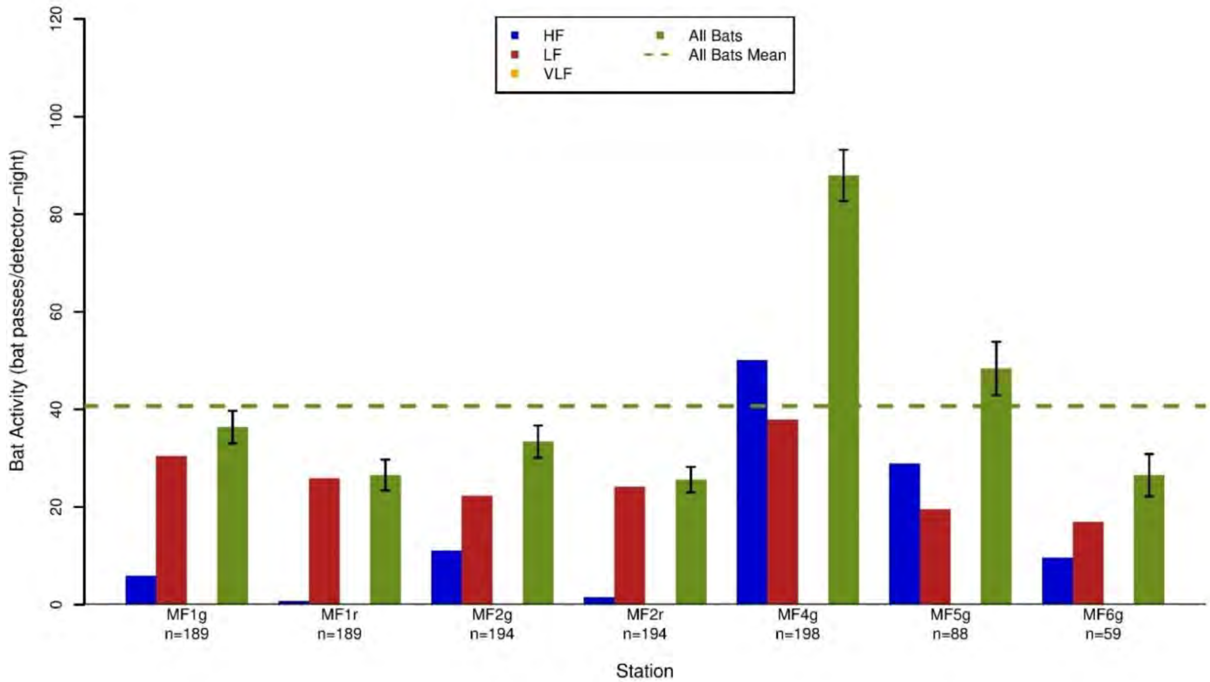

Figure 4. Number of high-frequency (HF), low-frequency (LF), and very low-frequency (VLF) bat passes per detector-night recorded at SM3 representative stations in the Fountain Wind Project area from 30 April – 13 November 2017. The bootstrapped standard errors are represented by the black error bars on the "All Bats" columns. VLF bat passes per detector night were very low at all stations and are thus not discernable here.

Temporal Variation

Overall bat activity at all representative sampling stations was lowest in spring (26.98 ± 3.38 bat passes per detector-night), highest in summer (45.73 ± 2.73), and slightly decreased numerically during fall (41.88 ± 5.37), which was consistent with the pattern observed for the HF species group (Table 4; Figure 5). In contrast, activity rates of LF species were greater in fall (28.70 ± 3.59 bat passes per detector-night) than in spring (20.52 ± 2.66) and summer (25.01 ± 1.52), with activity during the FMP (35.83 ± 2.74), which overlaps late summer and early fall, having the highest levels of LF bat activity (Table 4). The week of peak activity for all bats and HF bats at representative sampling stations was 29 July to 4 August (90.57 and 46.71 bat passes per detector night, respectively), while LF bat activity peaked the week of 3-9 October.

Bat activity at ground representative sampling stations was higher than at raised representative sampling stations throughout the study period, except in late August/early September and mid to late October, when activity at raised representative sampling stations exceeded activity rates at ground stations (Figure 5). Activity by VLF species was documented only in the spring and fall, consisting of a spotted bat pass recorded simultaneously at stations MF1g and MF1r in the spring and western mastiff bat calls detected in mid-October at multiple representative sampling stations (Table 3).

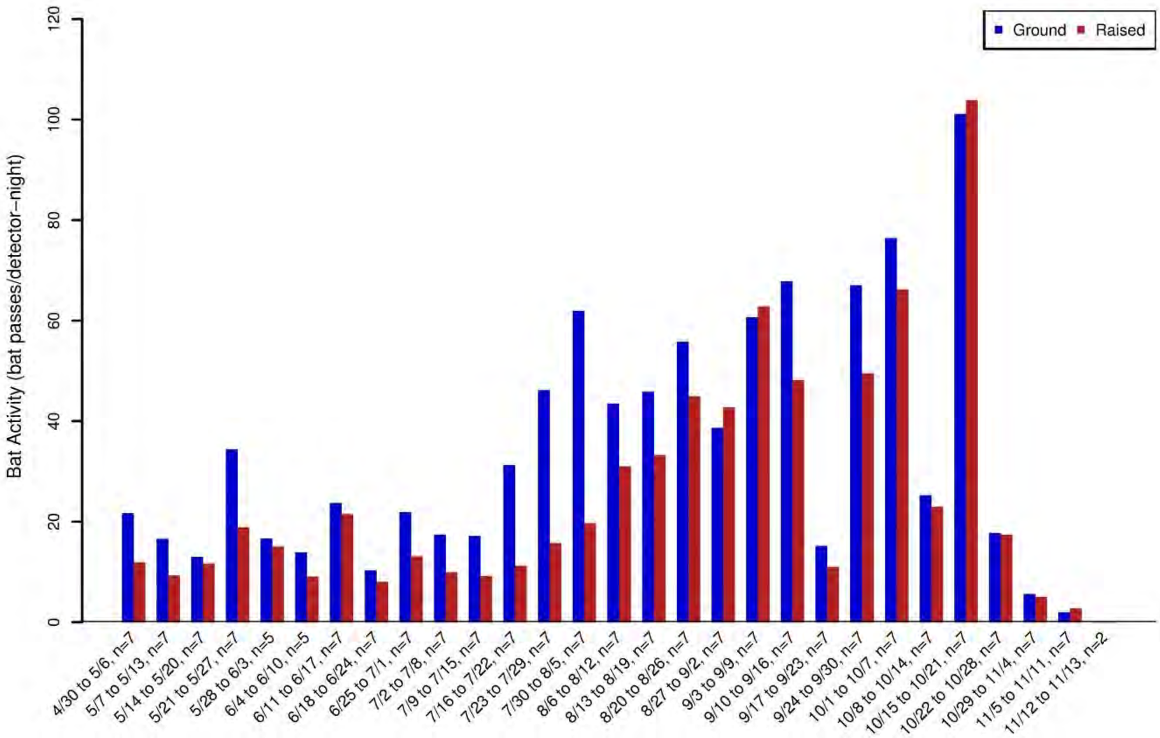

Figure 5. Number of bat passes per detector-night recorded at raised and ground level stations considered representative of future turbine locations in the Fountain Wind Project area from 30 April – 13 November 2017.

Species Composition

Calls of 17 bat species were identified by Kaleidoscope Pro from bat acoustic survey data collected in the Project area, including five California SSC: western red bat, pallid bat, Townsend's big-eared bat, spotted bat, and western mastiff bat (Table 5). However, calls for three (western red bat, Townsend's big-eared bat, and pallid bat) of the five SSC could not be verified upon review by an experienced bat biologist. A bat biologist also reviewed and verified the calls of western small-footed bat and canyon bat during review because the Project is located at the edge of the range of these species. The remaining 10 species were assumed present based on the Kaleidoscope Pro classifications because the calls were numerous and all 10 species were expected based on species ranges and habitats; thus 14 species were documented from acoustic survey data collected within the Project area. Silver-haired bat and hoary bat were the most commonly recorded species, present on 76% and 75% of operational detector-nights, respectively. Mexican free-tailed bat was the third most frequently recorded species, present on 70% of detector-nights. Other commonly detected species included big brown bat (64%), California bat (*Myotis californicus*; 54%), and Yuma bat (*Myotis yumanensis;* 41%). All other species were detected on less than 30% of operational detector-nights (Table 5).

Table 4. Number of bat passes per detector-night recorded at representative sampling stations in the Fountain Wind Project area during each season and during the standardized Fall Migration Period, separated by call frequency: high-frequency (HF), low-frequency (LF), very low-frequency (VLF), and all bats (AB).

Station	Call Frequency	Spring 30 April – 31 May	Summer 1 June – 14 August	Fall 15 August – 13 November	Fall Migration Period 30 July – 14 October
MF1g	VLF	0.04	0	0	0
	LF	22.11	22.23	39.35	44.75
	HF	2.75	6.96	6.04	8.86
	AB	24.89	29.19	45.4	53.61
MF1r	VLF	0.04	0	0	0
	LF	16.39	15.73	36.54	37.51
	LF	0.14	0.09	1.34	0.35
	AB	16.57	15.81	37.88	37.86
MF2g	VLF	0	0	0.01	0
	LF	14.59	18.23	28.16	34.36
	HF	3.22	12.70	12.59	13.47
	AB	17.81	30.93	40.77	47.83
MF2r	VLF	0	0	0.01	0
	LF	9.53	16.58	35.15	40.13
	HF	0.16	0.04	3.03	0.57
	AB	9.69	16.62	38.20	40.70
MF4g	VLF	0.03	0	0	0
	LF	40	52.29	25.23	43.53
	HF	25.91	83.8	30.76	55.88
	AB	65.94	136.09	55.99	99.42
MF5g*	VLF	-	-	0	0
	LF	-	-	19.53	25.59
	HF	-	-	28.85	38.37
	AB	-	-	48.39	63.97
MF6g*	VLF	-	-	0	0
	LF	-	-	16.93	24.97
	HF	-	-	9.59	12.55
	AB	-	-	26.53	37.52
Ground Station Totals	**VLF**	**0.02±0.02**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
	LF	**25.57±3.57**	**30.92±1.88**	**25.84±2.89**	**34.64±2.62**
	HF	**10.62±2.06**	**34.49±2.63**	**17.57±2.26**	**25.83±2.44**
	AB	**36.21±4.71**	**65.40±4.06**	**43.41±4.76**	**60.47±4.18**
Raised Station Totals	**VLF**	**0.02±0.02**	**0.00±0.00**	**0.01±0.01**	**0.00±0.00**
	LF	**12.96±2.19**	**16.15±1.37**	**35.85±5.08**	**38.82±3.95**
	HF	**0.15±0.07**	**0.06±0.03**	**2.19±1.39**	**0.46±0.14**
	AB	**13.13±2.21**	**16.22±1.37**	**38.04±6.10**	**39.28±4.00**
Representative Sampling Station Overall	**VLF**	**0.02±0.02**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
	LF	**20.52±2.66**	**25.01±1.52**	**28.70±3.59**	**35.83±2.74**
	HF	**6.43±1.42**	**20.72±1.53**	**13.17±2.11**	**18.58±1.97**
	AB	**26.98±3.38**	**45.73±2.73**	**41.88±5.37**	**54.41±3.89**

*Sampling stations added on 17 August

Table 5. The number and percent (in parentheses) of detector-nights that bat species were detected using Kaleidoscope Pro 4.2.0 and verified by a bat biologist at the proposed Fountain Wind Project from 30 April – 13 November 2017.

Common Name	MF1g	MF1r	MF2g	MF2r	MF3g	MF4g	MF5g	MF6g	Total
High-Frequency (> 30 kHz)									
California bat	122 (65)	10 (5)	134 (69)	9 (5)	163 (86)	171 (86)	60 (68)	35 (59)	704 (54)
canyon bat*	22 (12)	5 (3)	27 (14)	0 (0)	54 (28)	104 (53)	12 (14)	3 (5)	227 (17)
little brown bat	20 (11)	3 (2)	44 (23)	2 (1)	134 (71)	107 (54)	7 (8)	9 (15)	326 (25)
long-legged bat	11 (6)	0 (0)	14 (7)	0 (0)	112 (59)	85 (43)	8 (9)	12 (20)	242 (19)
western long-eared bat	16 (8)	0 (0)	76 (39)	0 (0)	118 (62)	114 (58)	31 (35)	19 (32)	374 (29)
western small-footed bat	13 (7)	0 (0)	15 (8)	0 (0)	66 (35)	85 (43)	21 (24)	4 (7)	204 (16)
Yuma bat	78 (41)	6 (3)	82 (42)	9 (5)	140 (74)	141 (71)	48 (55)	30 (51)	534 (41)
Low-Frequency (15 – 30 kHz)									
big brown bat	135 (71)	97 (51)	145 (75)	89 (46)	145 (76)	149 (75)	51 (58)	27 (46)	838 (64)
fringed bat	22 (12)	3 (2)	24 (12)	2 (1)	50 (26)	85 (43)	32 (36)	9 (15)	227 (17)
hoary bat	137 (72)	144 (76)	135 (70)	158 (81)	163 (86)	148 (75)	51 (58)	42 (71)	978 (75)
Mexican free-tailed bat	124 (66)	139 (74)	138 (71)	141 (73)	164 (86)	114 (58)	54 (61)	39 (66)	913 (70)
silver-haired bat	147 (78)	142 (75)	150 (77)	140 (72)	169 (89)	159 (80)	51 (58)	37 (63)	995 (76)

*Species presence verified by a bat biologist

**Very low-frequency bats (i.e., spotted bat and western mastiff bat) are not included in this table

***Kaleidoscope also identified calls by pallid bat, Townsend’s big-eared bat, and western red bat; these calls were reviewed by a bat biologist and could not be confirmed

DISCUSSION AND RISK ASSESSMENT

Consistent with the California Wind Energy Guidelines' two key study questions: 1) *which species of bats use the project area and how do their numbers vary throughout the year?*, and 2) *how much time do these species spend in the risk zone (i.e., rotor-swept area) and does this vary by season?*, WEST conducted bat acoustic surveys to: 1) determine the bat species present at the Project during the peak bat activity period of spring – fall and 2) assess the spatial and temporal patterns of bat activity which may influence the risk of collision for bats at the Project.

Fourteen species of bat were confirmed as occurring at the Project during the bat activity study, none of which were unexpected. Three species (Townsend's big-eared bat, pallid bat, and western red bat) identified prior to field studies as having potential to occur were not documented from the acoustic survey data. Silver-haired bat, hoary bat, Mexican free-tailed bat, big brown bat, and California bat were the most commonly detected species, with calls of all five species documented on more than 50% of operational detector nights (see Table 5). Among the 14 identified species, two (spotted bat and western mastiff bat) are designated as California SSC. Calls of both SSC were documented in low numbers (seven passes total) on three separate nights during the study period. Hoary bats, silver-haired bats, and Mexican free-tailed bats all belong to the LF species group and were the three most commonly detected of the five LF bats identified, therefore, it is presumed in this discussion that the LF bat data is highly indicative of the amount of use and spatial and temporal patterns of use exhibited by these three species, while recognizing that there may be some variability among the three species. These three species are also among the most commonly documented bat fatalities at wind energy facilities where these species occur (Cryan and Barclay 2009, Arnett and Baerwald 2013, Tetra Tech 2013, Thompson et al. 2017, AWWI 2018).

Overall bat activity measured at representative stations was greater in the summer and fall, compared to spring; however the variability in temporal patterns was largely due to patterns within the HF species group, which varied up to about 70% across seasons and peaked in the summer. In contrast, LF bat activity was more consistent, varying only about 30% across seasons and peaking in the fall. LF species accounted for a larger proportion of overall bat activity in the spring and fall (76 and 66%, respectively) compared to the summer (55%), when HF bat activity was at its peak.

Based on the 2017 bat acoustic surveys at the Project, activity rates of LF species (inclusive of the three migratory species) were 10-53% greater at ground stations compared to raised stations at paired sample sites in the spring and summer. However, activity rates of LF species in the fall were more mixed, with 7% greater activity at the ground station at one paired site (MF1) and 20% lower activity at the ground station at the other paired site (MF2; see Table 4). While the data are not definitive, the temporal pattern of use at raised versus ground stations suggests that LF bats may spend more time at greater heights (and potentially within the rotor-swept zone) during the fall than during spring and summer. Furthermore, while data indicate that LF bats are active at all sampled heights, LF bats accounted for 96% of bat passes recorded at raised sampling stations within the rotor-swept zone compared to only 35% of bat passes at representative ground stations.

As the relationship between pre-construction activity rates and post-construction fatality rates has not been definitively established (Hein et al. 2013; see Risk Assessment in Methods section p. 9-10), fatality rates documented at nearby facilities were used to evaluate the potential for bat fatalities at the Project. In other parts of the western US where wind energy facilities are clustered, bat fatality rates have generally been consistent among neighboring facilities. For example, in the Tehachapi Wind Resource Area in southern California, bat fatality rates range from zero to 1.28 bats/MW/year, and at the Shiloh and Montezuma projects located in close proximity to each other in the Montezuma Hills, bat fatality rates are consistently less than 4.0 bats/MW/year (Appendix A). Similar patterns are evident in the Pacific Northwest, where a majority of wind projects are located along the Columbia Plateau and bat fatality rates have been consistently less than 3.0 bats/MW/year (Appendix A).

The only wind energy facility in the western US with publicly available post-construction fatality data and habitat similar to the Project is the Hatchet Ridge facility, located less than two mi (3.2 km) northeast of the Project. Given the proximity of the Hatchet Ridge facility to the Project and similarities in geography, topography and habitat, it is likely that bat fatality rates documented at the Hatchet Ridge facility are among the best indicators of potential risk at the Project. For the three years of fatality monitoring conducted at the Hatchet Ridge facility, bat fatality rates were estimated to be 2.23, 5.22, and 4.20 bats/MW/year in years 1, 2, and 3, respectively (Tetra Tech 2014). Although the three years of data at Hatchet Ridge suggest some annual variability in fatality rates, 90% confidence intervals for all three years of estimates overlapped, indicating no statistical difference among years. Documented fatalities at the Hatchet Ridge facility were highest from July – September and primarily comprised hoary bats, silver-haired bats, and Mexican free-tailed bats, similar to patterns of bat fatalities throughout the US (Cryan and Barclay 2009, Arnett and Baerwald 2013, Tetra Tech 2014, Thompson et al. 2017, AWWI 2018). The species found as fatalities at the Hatchet Ridge facility are consistent with the species most commonly detected in bat acoustic surveys conducted for the Project, and the timing of peak fatalities at Hatchet Ridge aligns with peak activity rates documented at the Project.

Given that the species composition and temporal patterns of bat activity documented at the Project align with the results of fatality studies conducted at the nearby Hatchet Ridge facility; pre-construction bat acoustic data suggest that bat fatality patterns at the Project would likely be similar to those documented at the Hatchet Ridge facility. Based on the available data, fatality rates are anticipated to be similar to those documented at the Hatchet Ridge facility (2.23 – 5.22 bats/MW/year) and primarily consist of fatalities of hoary bats, silver-haired bats, and Mexican free-tailed bats during the late summer and fall migration period.

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Appendix A: Western US Bat Fatality Table

Appendix A1. Wind energy facilities in the western US with comparable fatality data for bats, separated by geographic region.

Wind Energy Facility	Fatality Estimate	No. of Turbines	Total MW
California			
Hatchet Ridge, CA (2010-2011)	2.23	44	101.2
Hatchet Ridge, CA (2011-2012)	5.22	44	101.2
Hatchet Ridge, CA (2012-2013)	4.20	44	101.2
Shiloh I, CA (2006-2009)	3.92	100	150
Shiloh II, CA (2010-2011)	3.8	75	150
Shiloh II, CA (2011-2012)	3.4	75	150
Shiloh II, CA (2009-2010)	2.6	75	150
High Winds, CA (2003-2004)	2.51	90	162
Dillon, CA (2008-2009)	2.17	45	45
Montezuma I, CA (2011)	1.9	16	36.8
High Winds, CA (2004-2005)	1.52	90	162
Alta I, CA (2011-2012)	1.28	100	150
Montezuma II, CA (2012-2013)	0.91	34	78.2
Montezuma I, CA (2012)	0.84	16	36.8
Diablo Winds, CA (2005-2007)	0.82	31	20.46
Shiloh III, CA (2012-2013)	0.4	50	102.5
Solano III, CA (2012-2013)	0.31	55	128
Alite, CA (2009-2010)	0.24	8	24
Alta I-V, CA (2013-2014)	0.2	290	720 (150 GE, 570 vestas)
Mustang Hills, CA (2012-2013)	0.1	50	150
Alta II-V, CA (2011-2012)	0.08	190	570
Pinyon Pines I & II, CA (2013-2014)	0.04	100	NA
Alta VIII, CA (2012-2013)	0	50	150
Southwest			
Dry Lake I, AZ (2009-2010)	3.43	30	63
Dry Lake II, AZ (2011-2012)	1.66	31	65
Pacific Northwest			
Palouse Wind, WA (2012-2013)	4.23	58	104.4
Biglow Canyon, OR (Phase II; 2009-2010)	2.71	65	150
Nine Canyon, WA (2002-2003)	2.47	37	48.1
Stateline, OR/WA (2003)	2.29	454	299
Elkhorn, OR (2010)	2.14	61	101
White Creek, WA (2007-2011)	2.04	89	204.7
Biglow Canyon, OR (Phase I; 2008)	1.99	76	125.4
Leaning Juniper, OR (2006-2008)	1.98	67	100.5
Big Horn, WA (2006-2007)	1.9	133	199.5
Combine Hills, OR (Phase I; 2004-2005)	1.88	41	41
Linden Ranch, WA (2010-2011)	1.68	25	50
Pebble Springs, OR (2009-2010)	1.55	47	98.7
Hopkins Ridge, WA (2008)	1.39	87	156.6
Harvest Wind, WA (2010-2012)	1.27	43	98.9
Elkhorn, OR (2008)	1.26	61	101
Vansycle, OR (1999)	1.12	38	24.9
Klondike III (Phase I), OR (2007-2009)	1.11	125	223.6
Stateline, OR/WA (2001-2002)	1.09	454	299
Stateline, OR/WA (2006)	0.95	454	299
Tuolumne (Windy Point I), WA (2009-2010)	0.94	62	136.6
Klondike, OR (2002-2003)	0.77	16	24
Combine Hills, OR (2011)	0.73	104	104
Hopkins Ridge, WA (2006)	0.63	83	150

Appendix A1. Wind energy facilities in the western US with comparable fatality data for bats, separated by geographic region.

Wind Energy Facility	Fatality Estimate	No. of Turbines	Total MW
Biglow Canyon, OR (Phase I; 2009)	0.58	76	125.4
Biglow Canyon, OR (Phase II; 2010-2011)	0.57	65	150
Hay Canyon, OR (2009-2010)	0.53	48	100.8
Windy Flats, WA (2010-2011)	0.41	114	262.2
Klondike II, OR (2005-2006)	0.41	50	75
Vantage, WA (2010-2011)	0.4	60	90
Wild Horse, WA (2007)	0.39	127	229
Goodnoe, WA (2009-2010)	0.34	47	94
Marengo II, WA (2009-2010)	0.27	39	70.2
Biglow Canyon, OR (Phase III; 2010-2011)	0.22	76	174.8
Marengo I, WA (2009-2010)	0.17	78	140.4
Klondike IIIa (Phase II), OR (2008-2010)	0.14	51	76.5
Kittitas Valley, WA (2011-2012)	0.12	48	100.8

Facility	Fatality Estimate	Facility	Fatality Estimate
Alite, CA (09-10)	Chatfield et al. 2010	Klondike III (Phase I), OR (07-09)	Gritski et al. 2010
Alta Wind I, CA (11-12)	Chatfield et al. 2012	Klondike IIIa (Phase II), OR (08-10)	Gritski et al. 2011
Alta Wind I-V, CA (13-14)	Chatfield et al. 2014	Leaning Juniper, OR (06-08)	Gritski et al. 2008
Alta Wind II-V, CA (11-12)	Chatfield et al. 2012	Linden Ranch, WA (10-11)	Enz and Bay 2011
Alta VIII, CA (12-13)	Chatfield and Bay 2014	Marengo I, WA (09-10)	URS Corporation 2010b
Big Horn, WA (06-07)	Kronner et al. 2008	Marengo II, WA (09-10)	URS Corporation 2010c
Biglow Canyon, OR (Phase I; 08)	Jeffrey et al. 2009b	Montezuma I, CA (11)	ICF International 2012
Biglow Canyon, OR (Phase I; 09)	Enk et al. 2010	Montezuma I, CA (12)	ICF International 2013
Biglow Canyon, OR (Phase II; 09-10)	Enk et al. 2011b	Montezuma II, CA (12-13)	Harvey & Associates 2013
Biglow Canyon, OR (Phase II; 10-11)	Enk et al. 2012b	Mustang Hills, CA (12-13)	Chatfield and Bay 2014
Biglow Canyon, OR (Phase III; 10-11)	Enk et al. 2012a	Nine Canyon, WA (02-03)	Erickson et al. 2003
Combine Hills, OR (Phase I; 04-05)	Young et al. 2006	Palouse Wind, WA (12-13)	Stantec 2013
Combine Hills, OR (11)	Enz et al. 2012	Pebble Springs, OR (09-10)	Gritski and Kronner 2010b
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
Dry Lake I, AZ (09-10)	Thompson et al. 2011	Shiloh II, CA (09-10)	Kerlinger et al. 2010, 2013a
Dry Lake II, AZ (11-12)	Thompson and Bay 2012	Shiloh II, CA (10-11)	Kerlinger et al. 2013a
Elkhorn, OR (08)	Jeffrey et a. 2009a	Shiloh II, CA (11-12)	Kerlinger et al. 2013a
Elkhorn, OR (10)	Enk et al. 2011a	Shiloh III, CA (12-13)	Kerlinger et al. 2013b
Goodnoe, WA (09-10)	URS Corporation 2010a	Solano III, CA (12-13)	AECOM 2013
Harvest Wind, WA (10-12)	Downes and Gritski 2012a	Stateline, OR/WA (01-02)	Erickson et al. 2004
Hatchet Ridge	Tetra Tech 2014	Stateline, OR/WA (03)	Erickson et al. 2004
Hay Canyon, OR (09-10)	Gritski and Kronner 2010a	Stateline, OR/WA (06)	Erickson et al. 2007
High Winds, CA (03-04)	Kerlinger et al. 2006	Tuolumne (Windy Point I), WA (09-10)	Enz and Bay 2010
High Winds, CA (04-05)	Kerlinger et al. 2006	Vansycle, OR (99)	Erickson et al. 2000
Hopkins Ridge, WA (06)	Young et al. 2007a	Vantage, WA (10-11)	Ventus 2012
Hopkins Ridge, WA (08)	Young et al. 2009b	White Creek, WA (07-11)	Downes and Gritski 2012b
Kittitas Valley, WA (11-12)	Stantec Consulting Services 2012	Wild Horse, WA (07)	Erickson et al. 2008
Klondike, OR (02-03)	Johnson et al. 2003	Windy Flats, WA (10-11)	Enz et al. 2011
Klondike II, OR (05-06)	NWC and WEST 2007		