Appendix 3.4-3
Acoustical Study of Bat Activity

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An Acoustic Study of Bat Activity At the Proposed Skookumchuck Wind Energy Project, Washington, 2015

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AN ACOUSTIC STUDY OF BAT ACTIVITY AT THE PROPOSED SKOOKUMCHUCK WIND ENERGY PROJECT, WASHINGTON, 2015

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March 2016

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EXECUTIVE SUMMARY

- The primary goal of the study was to collect acoustic information on activity levels of bats during nocturnal hours of spring migration, summer, and fall migration. Specifically, our objectives were to: (1) collect baseline information on levels of bat activity (bat passes/detector-night) for migratory bats (e.g., hoary, big brown, and silver-haired bats); non-migratory species (e.g., Myotis spp.); and species of concern; and (2) examine spatial (height and location) and temporal (within and among nights) variations in bat activity.
- We conducted bat acoustic monitoring for 1,284 potential detector-nights between 3 April 2015 and 2 November 2015 at the proposed Skookumchuck wind energy project, Washington. Each night we conducted bat acoustic monitoring for ~8–14 h/night (~1h < sunset to ~1h > sunrise).
- We recorded bat activity from Wildlife Acoustics SM2BAT+ detectors positioned at 2 altitudes (~3 m and ~45 m agl) at 2 meteorological towers (Towers 1 and 2) and 2 ground-based stations (~3 m agl) at G1 and G2 for a total of 1,284 potential detector nights (# detectors * # nights) in spring, summer, and fall. We obtained useable data for the majority 97.6% (*n* = 1,253) of detector-nights throughout the study.
- Total bat passes from all detectors across the entire study was 5,787.
- Activity (mean passes/detector-night ± SE) for all bats was (6.83 ± 0.82) across the entire study.
- Activity (mean passes/detector-night ± SE) for migratory tree-roosting bats was high (5.75 ± 0.74) across the entire study.
- Activity (mean passes/detector-night ± SE) across all sites appeared higher at 3 m (6.78 ± 0.79) than at 45 m (0.13 ± 0.03).
- Landscape variability (e.g., proximity to roosting or foraging habitat) between stations likely resulted in differences in mean activity

(passes/detector-night). The highest activity for All bats was recorded at G2 (17.77 ± 2.57).

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ACKNOWLEDGMENTS

Funding for this study was provided by RES America Developments, Inc. (RES). We thank Sean Bell and Theresa Webber at RES for assistance with project coordination and logistics. Weyerhaeuser Corporation provided site access. At ABR, Peter Sanzenbacher, Delee Spiesschaert, and Susan Cooper provided logistical support; Matt Apling, Mike Davis, and Michael Medina installed or maintained field equipment and Pam Odom provided assistance with report production.

INTRODUCTION

The increasing global energy demand has led most countries to seek ways to reduce fossil fuel consumption and generate energy using alternative sources. Wind energy has been produced commercially in North America for nearly four decades and is one of the fastest growing forms of renewable energy both nationally and globally (Arnett et al. 2007, AWEA 2015). In recent years, the United States (US) has led the world in wind capacity additions and at the end of the fourth quarter 2015 had an overall installed capacity totaling over 67,000 MW (AWEA 2015). The state of Washington currently ranks eighth in the US with an installed wind capacity of 3,075 MW. Wind-generated energy does not produce emissions of carbon and other greenhouse gasses associated with global warming and wind energy is generally considered an environmentally sound alternative to fossil fuels; however, wildlife and habitats can be impacted by wind development (Arnett et al. 2007).

Bat fatalities at wind-energy facilities have been documented since the early 1970s (Hall and Richards 1972). Studies have documented high fatality rates (>30 bats/MW/year) within the Appalachian region in the eastern U.S. (Fiedler 2004, Kerns et al. 2005, Fiedler et al. 2007, Hein et al. 2013, AWWI 2014) and data from the Midwest and Canada suggest high fatality rates (6.5–24.5 bats/MW/year) across a variety of landscapes; including agricultural, grassland prairies, and deciduous or coniferous forest landscapes (Jain 2005, Barclay et al. 2007, Kunz et al. 2007a, Arnett et al. 2008, Gruver et al. 2009). In the Great Basin/Southwest Open Range-Desert region, Arnett and Baerwald (2013) found low fatality rates (mean of 1.39 bats/MW/year) from 24 studies in this region. Fatality estimates for some facilities in central and southern California were also relatively low (0.24–3.92 bats/MW/year; Kerlinger et al. 2006, Chatfield et al. 2009). Across the U.S., bat fatalities were the highest in Northeastern deciduous forest (8.30 bats/MW/year) and Midwestern deciduous forest-agricultural regions (7.94 bats/MW/year; Arnett and Baerwald 2013).

Migratory, foliage- and tree cavity-roosting species of bats (e.g., hoary [*Lasiurus cinereus*], eastern red [*Lasiurus borealis*], silver-haired [*Lasionycteris noctivagans*] bats) comprise the highest proportion of documented bat fatalities at wind-energy facilities across North America (Arnett et al. 2008, Piorkowski and O'Connell 2010, Mockrin and Gravenmier 2012). Hoary, Eastern red, and silver-haired bats constitute greater than 70% of known fatalities at wind energy facilities across North American (AWWI 2014).

OBJECTIVES

RES America Developments, Inc. (RES) proposes to develop the Skookumchuck Wind Energy Project (hereafter Project) in Lewis and Thurston counties in western Washington (Fig. 1). The actual size of the Project will be determined closer to the time of construction; however, the current project design consists of 52 wind turbines with a combined generating capacity of up to 104 MW. Characteristics of the current proposed wind turbines, Vestas V110 2.0 MW turbines, include a monopole tower 80 m in height and three rotor blades each extending from a central hub with a radius of 55 m. Thus, the total maximal height of each turbine would be 135 m with a blade in the vertical position. RES contracted ABR, Inc.—Environmental Research and Services (ABR) to conduct pre-construction studies of bat use of the Project from spring through fall 2015.

The primary goal of the study was to collect acoustic information on activity levels of bats during nocturnal hours throughout the study period. Specifically, our objectives were to: (1) collect baseline information on levels of bat activity (bat passes/detector-night) for migratory bats (e.g., hoary, and silver-haired bats); non-migratory species (e.g., *Myotis* spp.); and species of concern; and (2) examine spatial (height and location) and temporal (within and among nights) variations in bat activity.

STUDY AREA

The Project is located in western Washington ~20–30 km (12.4–18.6 mi) east of Centralia and the Interstate 5 corridor (Fig. 1). The Project consists of 4 different parcels that combined total ~7,954 ha (19,654 ac) and are situated entirely on the Vail Tree Farm, private land owned and managed by the Weyerhaeuser Company (WEYCO) for timber production (Fig. 2). ABR focused survey efforts for this study on the two larger parcels of 4,088 ha and 2,049 ha. The Project ridges range in elevation from ~450–1,050 m above sea level (asl) and are separated by lower elevation stream-lined valleys, with the Skookumchuck River bisecting the project area. The region experiences moderate temperatures throughout the year with maximum temperatures ranging from 7.6–25.9° C (45.6–78.7° F) and minimum temperatures ranging from 0.8–10.8° C (33.5–51.5° F; WRCC 2016). Average annual precipitation is 116.6 cm (45.9 in) with 17.3 cm (6.8 in) snowfall at lower elevations and greater snowfall at higher elevations.

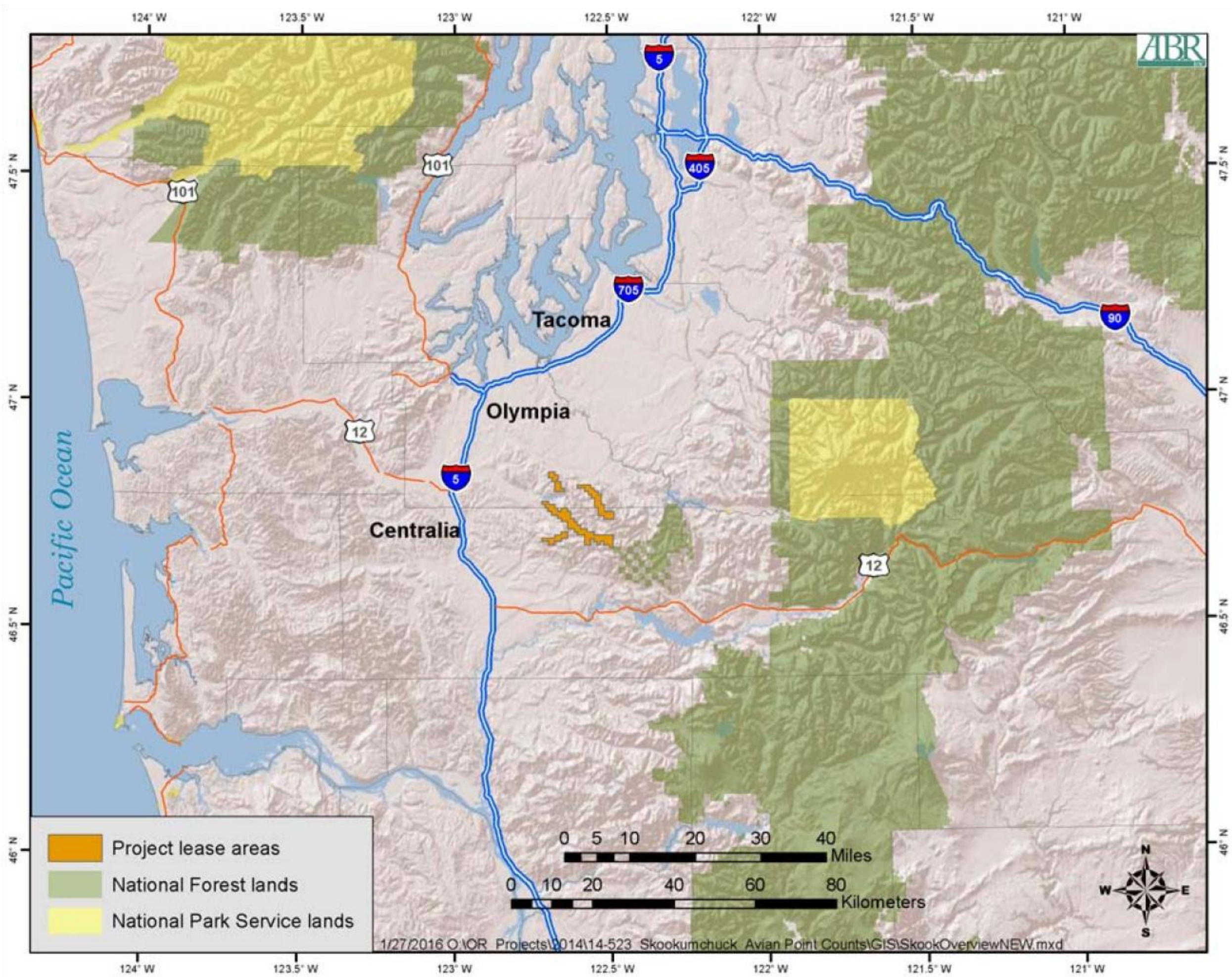

Figure 1. Vicinity map of the proposed Skookumchuck Wind Energy Project, Lewis and Thurston counties, Washington.

METHODS EQUIPMENT

Four Song Meter SM2 Bat+ acoustic detectors (Wildlife Acoustics, Inc., Massachusetts) were positioned at 2 meteorological towers and 2 ground-based stations. At 2 towers, 1 microphone was set up near ground level (~ 3 m agl) and 1 microphone was raised ~45 m up the tower (Fig. 3). At the 2 ground-based stations (G1 and G2), microphones were set up near ground level (~ 3 m agl). Detectors recorded echolocation calls onto 32 GB SDHC cards. We used SMX-UT ultrasonic omnidirectional microphones that have an approximate detection range of 30 m, (maximum of ~ 100 m; Wildlife Acoustics 2014) with the

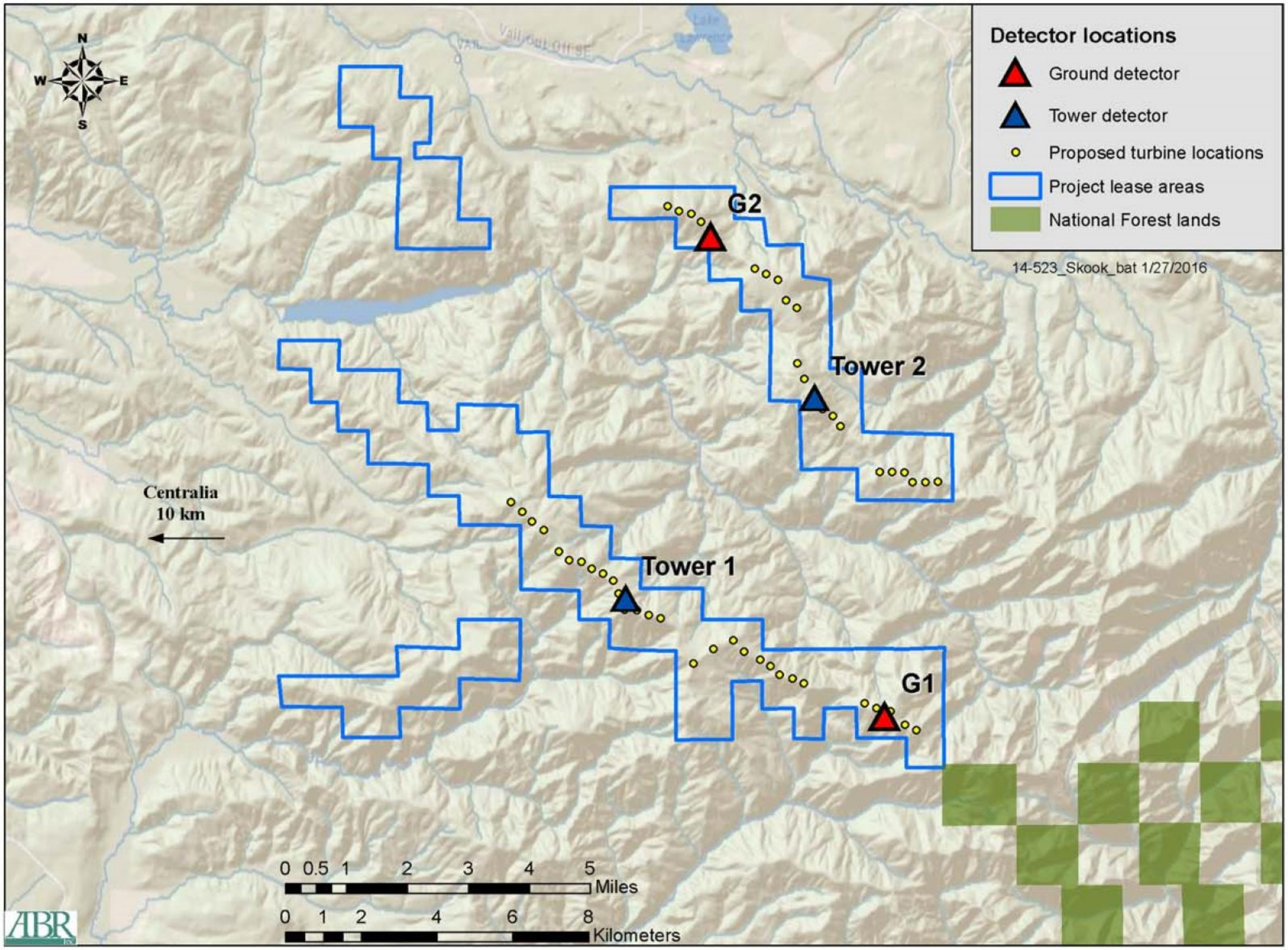

Figure 2.Map of the bat acoustic monitoring stations at the proposed Skookumchuck Wind Energy Project, Lewis and Thurston counties, Washington.

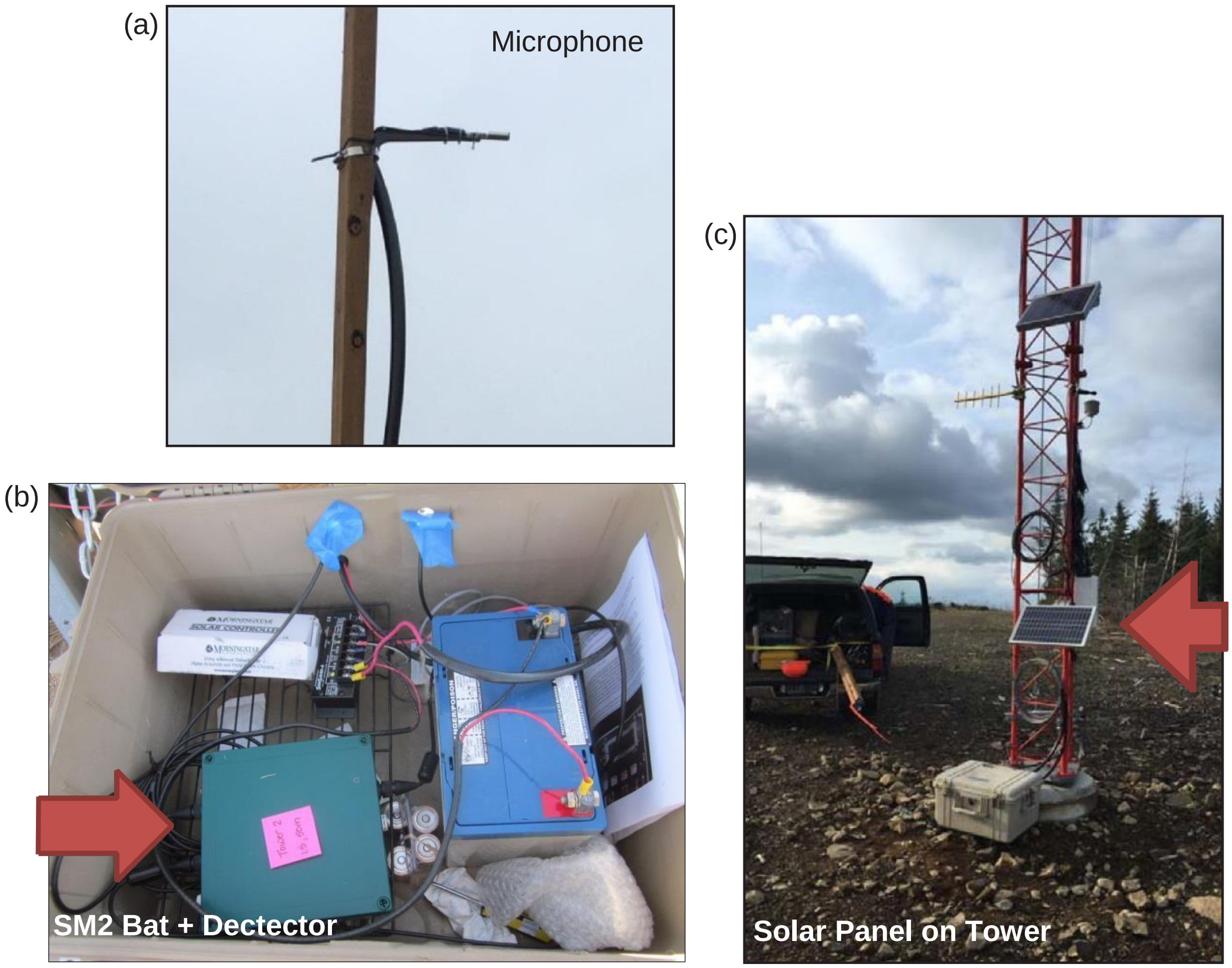

Figure 3. Photographs of bat acoustic monitoring equipment depicting a) microphones used at ground and meteorological tower locations, b) SM2 Bat + detector and solar battery housed in a waterproof Pelican case, and c) solar panel secured to tower.

actual range dependent on temperature, humidity, and frequency and intensity of echolocation call. All electronic equipment was enclosed in waterproof Pelican cases (Pelican Products, Inc., Torrance, California, USA) at the base of each tower. A photovoltaic system (Online Solar, Inc., Hunt Valley, Maryland, USA) provided continuous solar power to all detectors.

DATA COLLECTION

Methods for data collection followed guidelines described by Kunz et al. (2007b). Acoustic activity was monitored during crepuscular and nocturnal hours (~1 h before sunset to ~1 h after sunrise), with hours sampled ranging between ~8 and 14 h/night; providing data during times when bats are most active (Hayes 1997). ABR staff visited each tower every 1–2 weeks to exchange CF cards. Prior to sampling, each Song Meter was programmed using the Song Meter Configuration Utility application software to adjust for settings such as location/time, monitoring schedule, and audio settings. We used the following recording settings for each SM2 Bat+ detector: 2.5V Mic bias = OFF, Analog high pass filter = 1kHz, Gain = +36 dB, Division ratio = 16, Digital High Pass filter = 6 kHz, Digital low pass filter = OFF, Trigger dB = 18, trigger window = 2 s, and max trigger length = 8 s. The detectors with a single microphone (G1, G2, Met mast 2367) operated with a sampling frequency of 192 kHz and the 2 met masts (Met mast 2362 and Met mast 2366) with 2 microphones operated with 192 kHz sampling frequency. We recorded acoustic data files in native wave format and initially processed acoustic data with Wildlife Acoustic's Kaleidoscope (version 3.1.1) to separate information for stereo recordings, before classifying the data with SonoBat 3 (Western Washington version 3.2.1).

DATA ANALYSIS

We defined a bat pass as a wave file containing an echolocation sequence of at least 1 echolocation pulse, with each sequence separated by ≥2 seconds of silence, and maximum file length of 8 s. We attempted to record long duration, search phase bat passes from free-flying bats, to capture the most information content and provide greater species-discrimination confidence (SonoBat 2014). Search-phase passes are used by bats to detect objects at long ranges and are more consistent within a species than other types of calls. We used SonoBat (U.S. West version 3.1.4) to automatically generate species decisions (i.e, classifications) for each wave file recorded. The algorithms used by SonoBat, while derived from a robust data set acquired from a variety of environments and conditions, nevertheless encompasses a finite set of vocalizations from each species covered (SonoBat 2014), hence some uncertainty exists in the species decisions. We manually verified all bat passes for Townsend's western big-eared bat.

Of the 16 species of bats in Washington (Table 1), ten species are known to occur in the project area: 1) big brown (*Eptesicus fuscus*), 2) silver-haired (*Lasionycteris noctivagans*), 3) hoary (*Lasiurus cinereus*), 4) California (*Myotis californicus*), 5) western long-eared (*Myotis evotis*), 6) little brown (*Myotis lucifugus*), 7) fringed (*Myotis thysanodes*), 8) long-legged (*Myotis volans*), 9) Yuma (*Myotis yumanensis*), 10) Townsend's western big-eared (*Corynorhinus townsendii townsendii*), as well as migratory tree-roosting bats including hoary and silver-haired bats (Tree bats) and all bats combined (All bats).

Because our data were not normally distributed, we used non-parametric statistical tests for our analyses. We compared bat activity among stations at 3 m and 45 m using the Kruskal-Wallis test. To examine activity between altitudes at Towers 1 and 2, we used the Wilcoxon signed-rank test, including only those nights when both detectors at the towers were operational. The within-night activity rates (hours relative to sunset) observed in this study were compared with a probability distribution generated from 5,000 bootstrap simulations. For each simulation, the observed hourly activity rate was reordered randomly within each night and a new average was calculated for each hour. We define mean activity as mean passes/detector-night (number of detectors x number of nights), which is a common metric useful in comparing activity among bat acoustic studies. We report all mean bat passes as mean ± standard error (SE). We used SPSS v.18.0 for all statistical comparisons using a level of statistical significance (α) = 0.05 (SPSS 2010).

RESULTS

We conducted bat acoustic monitoring for a total of 1,284 potential detector-nights between 3 April 2015 and 2 November 2015 at 2 Met masts (Tower 1 and 2) at both ~3 m and ~ 45 m agl and also at ground-based (3 m agl) stations G1, and G2. Overall, we obtained useable data for the vast majority (97.6%, n = 1,253) of detector-nights throughout the study and were unable to collect the remaining data because of equipment malfunctions (i.e., animals chewed through acoustic cables).

GENERAL BAT ACTIVITY

We recorded 6.83 ± 0.82 mean passes/ detector-night for all bats over the course of the study (Table 2). Overall, we identified the following species listed in descending order: silver-haired, hoary, big brown, little brown, California, western long-eared, Yuma, fringed, long-legged, and Townsend's big-eared, bats (Table 2). The tree bats phonic group (silver-haired and hoary bats) accounted for most of the bat passes (5.75 ± 0.74 mean passes/detector-night).

TEMPORAL DIFFERENCES IN ACTIVITY

SEASONAL

Overall, mean activity (mean passes/stations) varied among nights and across the entire study (Fig. 4). We found much higher bat activity levels

Table 1.Federal and state status of bats in Washington.

Common Name	Scientific Name	Federal				State
		USFWS[a]	ESA[a]	BLM[a]	USFS[a]	WA[b]
Big brown bat	*Eptesicus fuscus*					PHS
California myotis	*Myotis californicus*					PHS
Canyon bat	*Parastrellus hesperus*					SM
Fringed myotis	*Myotis thysanodes*	SC		S [c]	S[c]	SM, PHS
Hoary bat	*Lasiurus cinereus*	SC				
Keen's myotis	*Myotis keenii*					SC, PHS, SGCN
Little brown myotis	*Myotis lucifugus*					PHS
Long-legged myotis	*Myotis volans*	SC				SM, PHS
Pallid bat	*Antrozous pallidus pacificus*	SC		S	S	SM, PHS
Red bat	*Lasiurus borealis*					SM
Silver-haired bat	*Lasionycteris noctivagans*	SC				
Spotted bat	*Euderma maculatum*	SC		S	S	SM
Townsend's western big-eared bat	*Corynorhinus townsendii townsendii*	SC		S	S	SC, PHS, SGCN
Western small-footed myotis	*Myotis ciliolabrum*	SC				SM, PHS
Western long-eared myotis	*Myotis evotis*	SC				SM, PHS
Yuma myotis	*Myotis yumanensis*	SC				PHS

[a] Species listed as endangered (LE) and threatened (LT) under the Endangered Species Act. SC=Species of Concern; D=delisted; C=candidate for listing; S=Sensitive; SS=Special Status, regulated by state permit procedures. Available: http://www.fws.gov/wafwo/pdf/specieslist12061 3.pdf. Accessed January 2016.

[b] State categories for WA include: State Endangered (SE), State Threatened (ST), State Candidate (SC) but not listed, State Sensitive (SS) State Monitored (SM), Species of greatest conservation need (SGCN), and Priority habitats and species (PHS). http://wdfw.wa.gov/conservation/endangered/list/Mammal/ and State of Washington bat conservation plan (Hayes and Wiles 2013) http://wdfw.wa.gov/publications/01504/wdfw01504.pdf.Accessed January 2016.

[c] Applies to Pacific Fringe-tailed bat (*Myotis thysanodes vespertinus*).

Hoary 1.52 0.35 1.85 0.37 0.00 0.00 0.00 0.00 0.85 0.13
California 0.08 0.02 0.51 0.06 0.09 0.08 0.00 0.00 0.17 0.03
Long-eared0.25 0.04 0.21 0. 04 <0.01 0.01 0.00 0.00
Little brown 0.20 0.06 1.21 0.44 0.00 0. 00 0.00 0.00 0.36 0.10.12 0.02
Fringed0.05 0.02 0.02 0.02 0.00 0.00 0.00 0.00 0.02 0.01
Long-legged0.02 0.01 <0.01 0.01 0.00 0.00 0.00 0.00 0.01 0.00
Yuma0.18 0.05 0.09 0.02 <0.01 0.01 0.00 0.00 0.07 0.01
Townsend's big-eared0.02 0.01 <0.01 0.01 0.00 0.00 0.00
Tree bats7.57 1.44 14.56 2.29 <0.01 <0. 01 0.00 0.00 0.00 0.05
0.00 0.01 0.00
All Bats

9.48 1.68 17.21 2.44 0.10 0.08 0.00 0.00 6.78 0.79

Bat passes at 45 m

Big brown 0.01 0.01 0.01 <0.01 0.01 0.01
0.
Silver-haired 0.22 0.06 0.01 <0.01 0.12 0.03
Hoary <0.01 <0.01 0.00 0.00 0.00 0.00
California 0.00 0.00 0.00 0.00 0.00 0.00
Long-eared 0.00 0.00 0.
0.00
Little brown 0.00 0.00
0.00
Fringed 0.00 0.00 0.
0.00 0.00
0.00 0.00 0.00
0.00 0.00
00
Long-legged 0.00 0.00 0.00 0.00 0.00 0.00
00
Yuma 0.00 0.00 0.00 0.00 0.00 0.00
Townsend's big-eared 0.00 0.00 0.00 0.00 0.00 0.00
Tree bats 0.22 0.06
0.01 <0.01
All Bats 0.23 0.06 0.02 0.01 0.13 0.03 0.12 0.63

00

Table 2. Mean number of bat passes identified as 1) big brown, 2) silver-haired, 3) hoary, 4) California, 5) long-eared, 6) little brown, 7) fringed, 8) long-legged, 9) Yuma, 10) Townsend's big-eared, migratory tree-roosting bats (Tree bats), and all species combined (All bats) recorded across all detectors at the proposed Skookumchuck Wind Energy Project, Washington 2015. Values represent the mean number of bat passes/detector night and standard error (SE) at a given station and altitude. All bats is the sum of all species.

	G1		G2		T1		T2		Total	
Altitude/species	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Bat passes at 3 m										
Big brown	1.12	0.47	0.58	0.15	0.00	0.00	0.00	0.00	0.43	0.13
Silver-haired	6.05	1.32	12.71	2.19	<0.01	0.01	0.00	0.00	4.75	0.67

Table 2.Continued.

Altitude/species	G1 Mean	G1 SE	G2 Mean	G2 SE	T1 Mean	T1 SE	T2 Mean	T2 SE	Total Mean	Total SE
All altitudes										
Big brown					<0.01	<0.01	0.01	<0.01	0.39	0.13
Silver-haired					<0.01	<0.01	0.01	<0.01	4.90	0.70
Hoary					<0.01	<0.01	0.00	0.00	0.85	0.14
California					0.09	0.09	0.00	0.00	0.16	0.03
Long-eared					<0.01	<0.01	0.00	0.00	0.10	0.02
Little brown					0.00	0.00	0.00	0.00	0.33	0.12
Fringed					0.00	0.00	0.00	0.00	0.02	0.01
Long-legged					0.00	0.00	0.00	0.00	0.01	0.00
Yuma					<0.01	<0.01	0.00	0.00	0.07	0.01
Townsend's big-eared					0.00	0.00	0.00	0.00	0.01	0.00
Tree bats					0.11	0.03	<0.01	<0.01	5.75	0.74
All Bats					0.17	0.05	0.01	<0.01	6.83	0.82

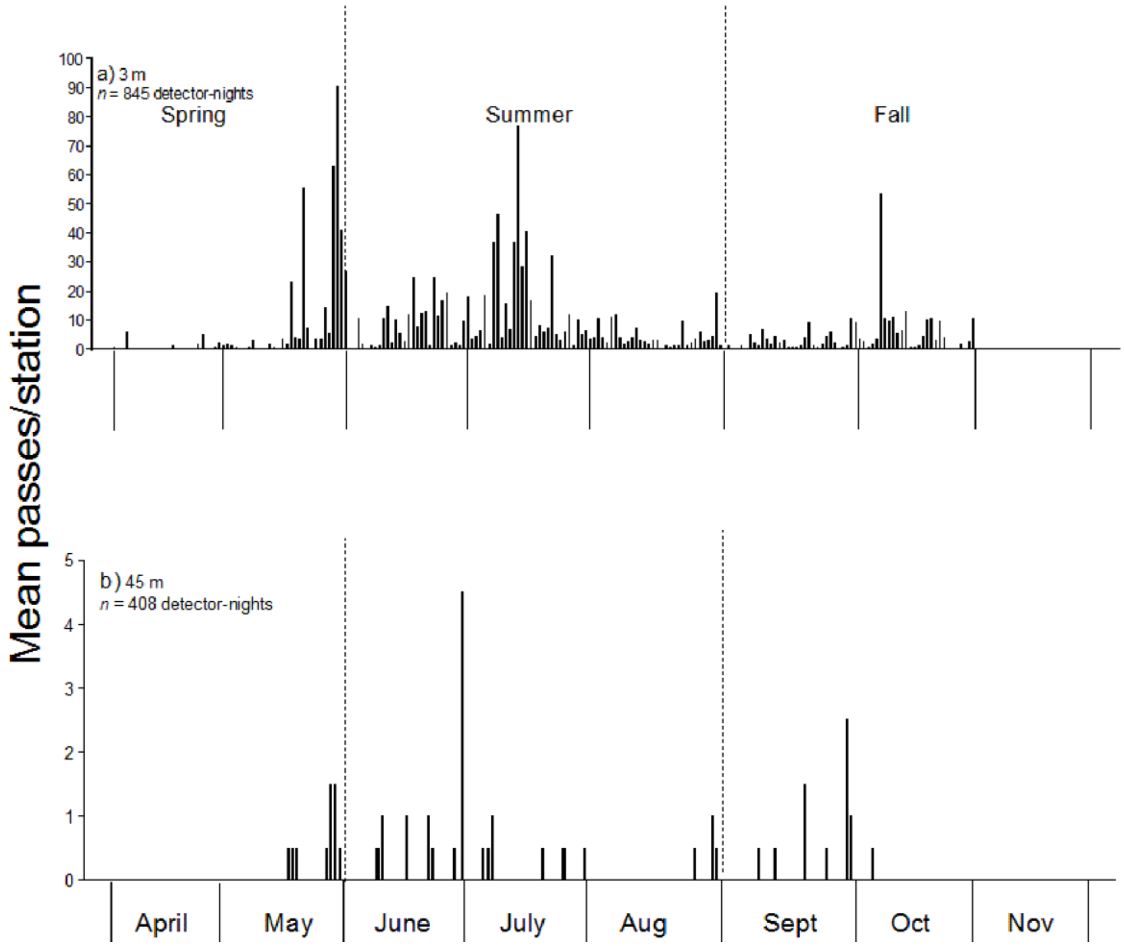

Figure 4. Mean passes/station for All bats by date at a) 3 m agl and b) 45 m agl at the proposed Skookumchuck Wind Energy Project, Washington, 2015.

at 3 m than at 45 m. At 3 m, activity was the greatest during late spring (29 May, mean = 90.3 passes/station) and mid-summer (11 July, mean = 77.0 passes/station) than fall (5 October, mean = 53.2 passes/station). We recorded little to no activity at 45 m throughout the survey period with only slight increases in activity during summer and fall (mean = ~2–4 passes/station; Fig. 4).

We observed within-night variation in overall bat activity across the entire study period (mean passes/station/hour; Fig. 5; Appendix 1). Activity varied among nocturnal hours of the night at 3 m but there was inadequate data to test this relationship at 45 m. For All bats early hours in the evening had more activity than expected whereas later hours in the evening had less activity than expected (Appendix 1), creating a pattern of high activity just after sunset, slowly decreasing until the end of sampling (Fig. 5).

SPATIAL DIFFERENCES IN ACTIVITY

BETWEEN HEIGHTS

We recorded higher activity (mean passes/detector-night) for All bats at 45 m (0.13 ± 0.03) than at 3 m (0.05 ± 0.04) and for Tree bats at 45 m (0.01 ± 0.03) than at 3 m (<0.01 ± <0.01) at Towers 1 and 2 (Appendix 2, P=<0.001), although activity levels were very low at both tower sites. Higher activity was recorded at 3 m (6.78 ± 0.79) compared to 45 m (0.13 ± 0.03) when looking at all data from the ground and tower stations (Fig. 6).

AMONG STATIONS

We found differences in bat activity (mean passes/detector-night) among stations at 3 m across the entire study for All bats, Tree bats, and all species identified (Fig. 7, Appendix 3). Across the entire study at 3 m, activity was highest for All bats at G2 (17.77 ± 2.57), followed by G1 (9.45 ± 1.76),

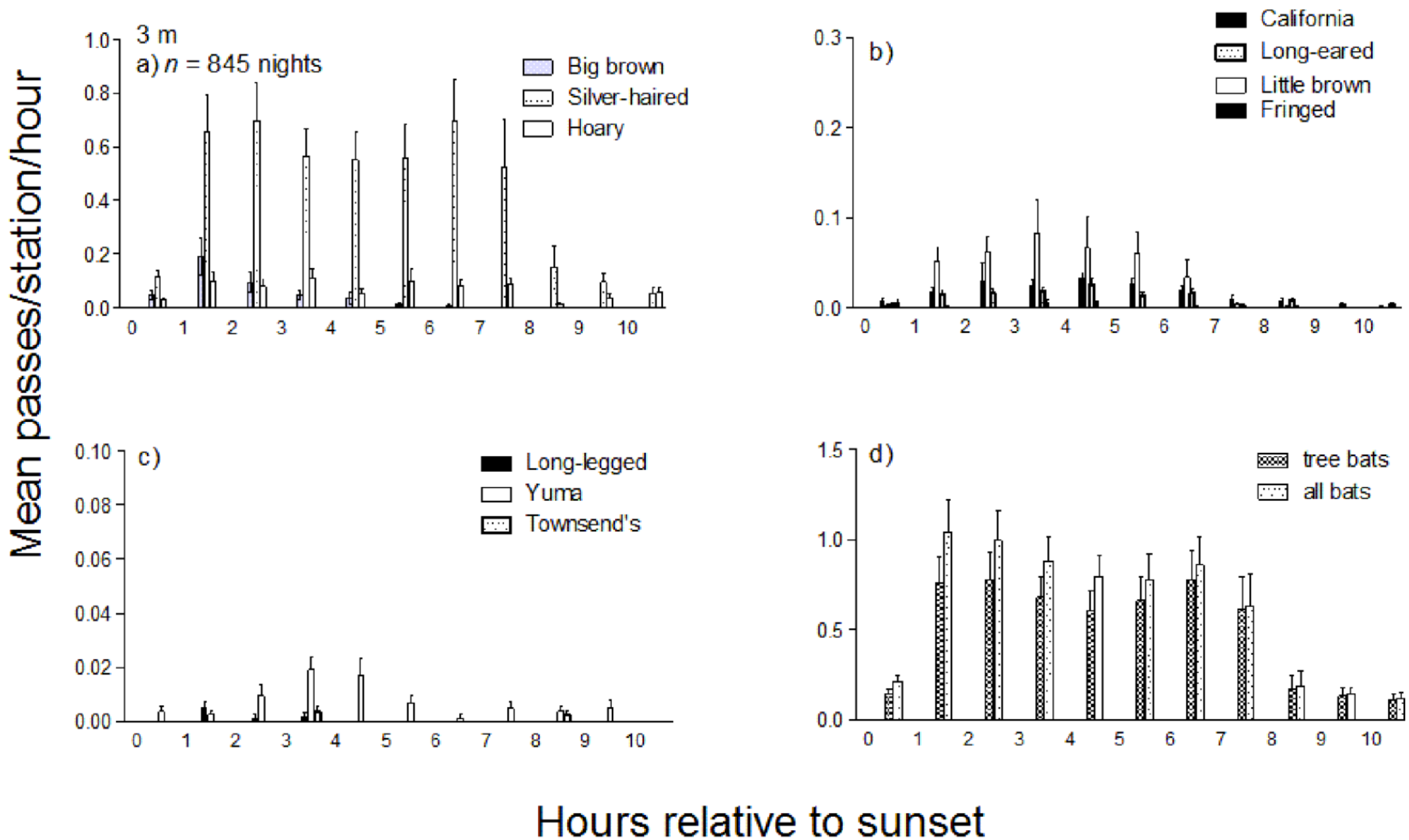

Figure 5.Mean passes/station/hour relative to sunset across the entire study at 3 m for a) big brown, silver-haired, and hoary bats; b) California, long-eared, little brown, and fringed bats; c) long-legged, Yuma, and Townsend's big-eared bats; and d) migratory tree-roosting bats Tree bats), and all species combined (All bats) at the proposed Skookumchuck Wind Energy Project, Washington, 2015.

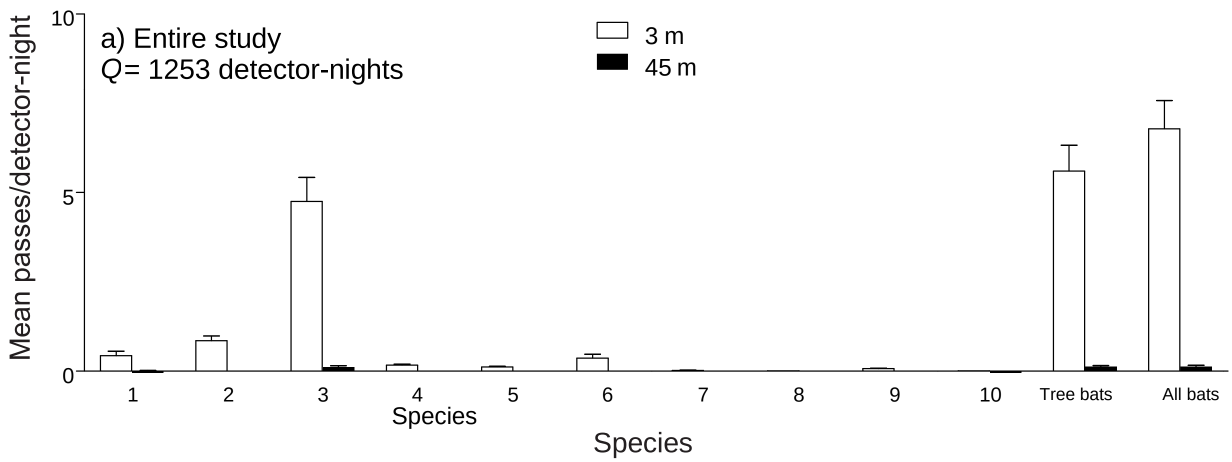

Figure 6. Mean passes/detector-night across the entire study at 3 m and 45 m across stations for 1) big brown, 2) silver-haired, 3) hoary, 4) California, 5) long-eared, 6) little brown, 7) fringed, 8) long-legged, 9) Yuma, 10) Townsend's big-eared, migratory tree-roosting bats (Tree bats), and all species combined (All bats) for the entire study at the proposed Skookumchuck Wind Energy Project, Washington, 2015.

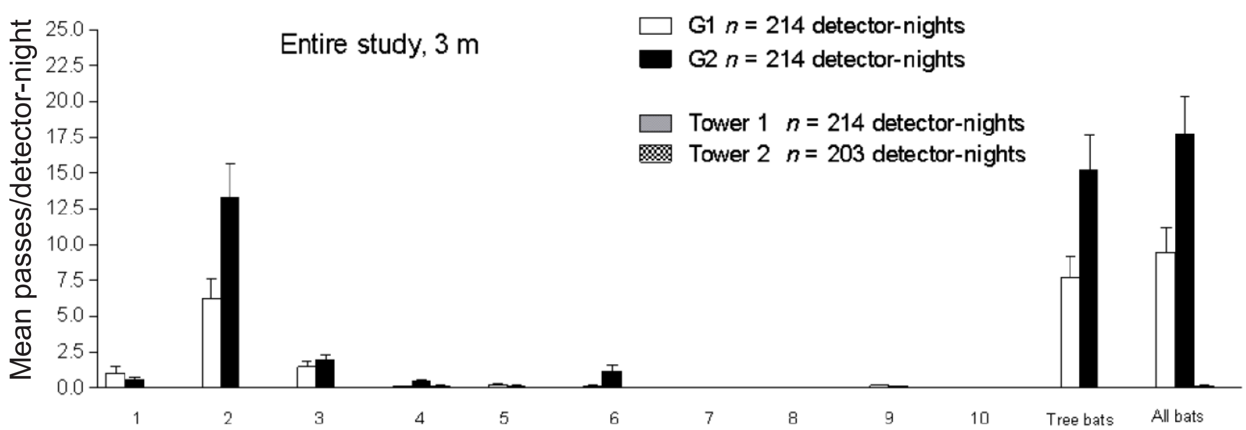

Figure 7. Mean passes/detector-night across the entire study by height (3 m only) and station for 1) big brown, 2) silver-haired, 3) hoary, 4) California, 5) long-eared, 6) little brown, 7) fringed, 8) long-legged, 9) Yuma, 10) Townsend's big-eared, migratory tree-roosting bats (Tree bats), and all species combined (All bats) for the entire study at the proposed Skookumchuck Wind Energy Project, Washington, 2015.

T1 (0.11 ± 0.09), and T2 (<0.01 ± <0.01). We did not make comparisons among met mast towers at 45 m because of minimal data.

DISCUSSION

Most of what is known regarding activity levels of bats at wind-energy facilities in North America is from the eastern half of the U.S. (Appendix 4, 5). Because a paucity of information exists concerning the spatial and temporal activity of bats in this region (Hein et al. 2013), predicting impacts of wind-power development on resident and migratory species is problematic. Furthermore, differences among studies in species assemblages and identification, landscape characteristics (e.g., habitat, elevation, and climate), sampling effort (e.g., number of detectors or towers, sampling dates, altitude of detectors, detector position) and analytical methods can make comparing bat activity difficult. To minimize variability associated with sampling design and analysis, there are recommendations for methods used in acoustic-monitoring surveys (Hayes 2000, Gannon et al. 2003, Kunz et al. 2007b). Our preconstruction study follows these recommendations and in doing so, we were able to provide baseline information on both spatial (horizontal and vertical) and temporal (nightly and seasonal) patterns of bat activity at the Project.

GENERAL BAT ACTIVITY

Interpretation of bat acoustic data is subject to several important caveats. The number of recorded "bat passes" is an index of relative activity, but may not correlate to individual numbers of bats (e.g., 100 bat passes may be a single bat recorded 100 different times or 100 bats each recording a single pass; Kunz et al. 2007b). Activity also may not be proportional to abundance because of variation attributed to: (1) detectability (loud vs. quiet species); (2) species call rates; (3) migratory vs. foraging call rates; and (4) attraction or avoidance of bats to the sampling area (Kunz et al. 2007b). However, interpreted properly, the index of relative activity may provide critical information of bat use at a proposed wind facility by characterizing temporal (hourly, nightly, and seasonal) and spatial (height and location) patterns (Parsons and Szewczak 2009).

We recorded a total of 5,787 bat passes across the entire study which equals 6.83 ± 0.82 mean passes/detector-night. Our results are on the low to moderate range of activity rates recorded across western North America and the Pacific Northwest (Appendix 4, 5). Our results are higher than the nearby Coyote Crest Project (1.70 passes/detector night in fall; Hein et al. 2010) but much lower than the Saddleback Mountain in southern WA (148.3 passes/detector night in fall; Appendix 5). Studies with higher rates of activity (e.g., Saddleback Mountain, WA, n = 56,595 bat passes, Johnson et al. 2009) tend to have at least some detectors located in areas of concentrated bat activity (i.e., ponds and linear forest corridors). At the Golden Hill Wind Resource Area, Sherman Co., OR, Jeffrey et al. (2008) documented a 13-fold increase in bat activity in wetland habitat compared to upland areas. Although collecting data in certain areas can inflate overall detection rates, it may provide beneficial information regarding maximum levels of relative bat activity at a particular site. In addition, activity by many species typically increases in fall. Higher activity levels are likely the result of the addition of juvenile bats (pups generally are weaned by late July), and bats preparing for winter hibernation or migration.

SPECIES COMPOSITION

Overall, 10 species of bats, encompassing a wide variety of resident and migratory bats were detected at the Project. The dominant species detected included silver-haired and hoary bats that are typically tree-roosting species; although silver-haired bats are also known to roost in caves and mines during hibernation (Beer 1956, Cowan 1933).

SENSITIVE SPECIES

Although many of the species of bats in Washington have some sort of Federal or State status (Table 1), perhaps the most sensitive is the Townsend's big-eared bat. Townsend's big-eared bats emit low decibel echolocation calls making it possible, although difficult, to detect acoustically (Gruver and Keinath 2006). Because the Project lacks large areas of suitable roosting habitat (large cliff faces, abandoned mines and buildings, and caves), it is not surprising that we only detected fiveTownsend’s big-eared bat passes. In a study conducted in Deschutes County of central Oregon, Townsend’s big-eared bats moved up to 24 kilometers from roosting habitats (hibernacula) to foraging areas where they primarily foraged over habitat consisting of open sagebrush shrubsteppe and open ponderosa pine woodlands (Dobkin et al. 1995). In California, Townsend’s bats traveled between 1.3 km (males) and 3.2 km (females) and up to 10.5 km from day roost to foraging areas (Fellers and Pierson 2002) with a maximum travel distance of 32 km (Brylski et al. 1998). Although it is unknown where this species roosts relative to the Project, it is clear they are able to travel long distances between roosting and foraging locations.

TEMPORAL ACTIVITY

Our understanding of the broad regional migratory patterns of bats are limited (Cryan 2003). Among-night variation in both bat activity and fatality at wind-energy facilities suggests that fall migration is an episodic event. Migratory patterns presumably are influenced by location (latitude and elevation), climatic conditions, life history traits, and changes in insect abundance and availability (Flemming and Eby 2005; Cryan and Veilleux 2008).

We found peaks in activity for species considered vulnerable to wind development (e.g., silver-haired and hoary bats) between late May and September during both the breeding season and migration. In Washington and Oregon, activity and fatality typically peak between mid August and September. Several studies at wind-energy facilities in eastern Oregon and Washington also have reported higher incidents of bat fatalities during August and September (Erickson et al. 2000, 2003, 2008, Johnson et al. 2003, Young et al. 2003, Gritski et al. 2008a, b, Jeffrey et al. 2008).

Farther south in California, Kerlinger et al. (2006) reported 70% of bat fatalities occurred in September. Thus, at a broader scale, migratory activity occurs at different times based on latitudinal difference among study sites. Cryan and Barclay (2009) suggested that as these regional patterns and variations exist with migration patterns and fatality of bats at wind energy sites, there may be additional factors (e.g., behavioral changes such as mating or feeding habits) that make them susceptible during autumn migration regardless of whether they are migrating long distances or not. In addition, researchers have documented that weather variables (e.g., moon illumination, wind, temperature, barometric pressure) affect activity and fatality of migratory bat species (namely hoary and silver-haired bats) at wind energy facilities (Baerwald and Barclay 2011).

Silver-haired bats (the species with the highest activity levels in this study) winter in the Pacific Northwest and in some areas of southwestern U.S. and generally migrate north in the spring (Cryan 2003). Brylski et al. (1998) reported that silver-haired bats may migrate to the southern part of California during winter months.

We observed within-night variation in overall bat activity (mean passes/station/hour). We observed modest within-night peaks in bat activity within 1–2 hours after sunset for the all bats category at 3 m. Prior to these peaks, the hour before sunset yielded lower than expected activity for the all bats category. These results support the fact that bats are less likely to be active before sunset at the Project and are consistent with numerous studies as they have reported nightly peaks shortly (1–2 hours) after sunset with a secondary peak within a few hours prior to sunset (Kunz 1973, Erkert 1982, Hayes 1997, Baerwald and Barclay 2011, Rodman et al. 2011).

Variations in nightly activity patterns are not unusual and may be species specific or attributed to changes in insect prey abundance and availability, or climate and landscape characteristics (Hayes 1997). The presence of peaks in bat activity immediately after sunset or before sunrise suggests bat roosting or foraging opportunities may be present on the project area, namely trees or rocky outcroppings.

SPATIAL ACTIVITY

Other factors, such as landscape and habitat features, also may influence migratory patterns of tree-roosting bats. Topographic features may serve as landmarks for migratory bats (Flemming and Eby 2005). Baerwald and Barclay (2009) documented higher bat activity along the foothills of the Canadian Rocky Mountains compared to flat areas located ~175 km east of the mountains. Furthermore, migratory tree-roosting bats appear more likely to travel along routes which provide suitable roosting structures (Cryan and Veilleux 2008). Hoary and silver-haired bats were observed more often within forested habitats than open prairies during fall migration (Baerwald 2008).

Studies have shown variations in bat activity at different altitudes (Kalcounis et al. 1999, Hayes and Gruver 2000). Although we had minimal bat activity at 45 m, the majority of bat passes detected were from silver-haired bats. Several studies have reported greater activity of high-frequency bats (e.g., *Myotis* spp., *Parastrellus hesperus*) at lower altitudes, and greater activity of low-frequency bats (e.g., silver-haired and hoary) at higher altitudes (Arnett et al. 2006, 2007b, Redell et al. 2006, Hein et al. 2009a). The airspace in which bats occur can sometimes be predicted by their echomorpholgy (body size, wing shape, call frequency; Aldridge and Rautenbach 1987). Larger, less maneuverable species with lower call frequencies typically fly higher and in more open habitats, whereas smaller, more maneuverable species with higher call frequencies fly lower to the ground and in more cluttered (higher vegetation, increased tree density) habitats. Because the airspace used by bats varies among species and because species impacted by wind development are detected more often at higher altitudes, it supports the rationale to monitor bat activity at multiple heights at wind-energy facilities.

It is not surprising to see spatial variation in bat activity across a project site (Mabee and Schwab 2008, Hein et al. 2009a, b, Hein et al. 2011a, Rodman et al. 2011). Variability among stations is likely attributed to differences in landscape features among sampling stations. Kunz (1982) suggested that habitat selection by bats is likely driven by the interaction between foraging and roosting requirements. Smaller species of microchiropterans (e.g., California myotis) are known to commute less than several kilometers between roosting and foraging sites (Brigham et al. 1997). However, studies indicate that some species (e.g., Townsend's big-eared bats) may fly greater distances ranging from 10–30 kilometers from roosting to foraging habitat (Dobkin et al. 1995, Kunz and Lumsden 2003, Gruver and Keinath 2006).

We found high levels of variation in bat activity among all stations. Activity for All bats was highest at G2 (17.77 bat passes/detector night) and lower at G1 (9.45) and nearly absent at Tower 1 (0.11) and Tower 2 (<0.01). Spatial variation in bat activity across a project site is not uncommon (Mabee and Schwab 2008, Hein et al. 2009a, b). Explanations for the variation among stations may be attributed to differences in availability of roosting or foraging habitat in proximity to the detector location, or placement of detector along a commuting flyway.

BASELINE MONITORING AND FATALITIES

Our ability to identify activity patterns of bats within a season, altitude, and location may provide useful information for predicting when, where, and which bats may be most at risk of collisions with wind turbines at the Project. Because migratory bats comprise a disproportionately high percentage of fatalities (Arnett et al. 2008, Piorkowski and O'Connell 2010), it is important for studies to provide the highest resolution possible in species identification rather than consolidate bats into total bat calls or high and low frequency phonic groups (Kunz et al. 2007b). We were able to characterize bat passes to species using SonoBat which automatically generated species decisions (i.e, classifications) for each wave file recorded.

A paucity of information exists relating pre-construction activity with post-construction fatality of bats. Hein et al. (2013) compared twelve sites with paired data for pre-construction and post-construction data, and reported that a small portion of variation in fatalities was explained by bat activity (adj. R^2 = 21.8%). They concluded that it still remains uncertain whether pre- construction acoustic data is able to predict post-construction bat fatalities. Understanding this relationship is important, as current estimates suggest cumulative bat fatalities at wind energy facilities in North America from 2000–2011 range from over 650,000 to more than 1.3 million (Arnett et al. 2013).

Bat acoustic monitoring studies such as the one at the Project may be useful by providing the baseline activity levels for individual species that can be compared to the spatial and temporal distribution of fatalities documented during postconstruction monitoring. This species-specific approach may provide finer resolution data than previous studies and may therefore be better suited to post-construction fatality comparisons.

SUMMARY

The key results of our bat acoustic monitoring study were: (1) total bat passes from all detectors across the entire study was 5,787 bat passes; (2) peak mean activity (passes/station) for all bats at 3 m occurred in late May, mid-July, and early October while peak activity, although consistently low, for all bats at 45 m occurred in late June and late September; (3) mean bat activity (passes/ detector-night) for all bats was 6.83 ± 0.82 across the entire study; (4) mean activity (passes/ detector-night) for migratory tree-roosting bats was high (5.75 ± 0.74) across the entire study; (5) mean activity (passes/detector-night) across all stations was higher at 3 m (6.78 ± 0.79) than at 45 m (0.13 ± 0.03); (6) landscape variability (e.g., proximity to roosting or foraging habitat) between stations likely resulted in differences in mean activity (passes/detector-night). The highest activity for All bats was recorded at G2 (17.77 ± 2.57 bat passes/detector night).

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Appendix 1.

Comparisons between observed and expected hourly detection rates for 1) big brown, 2) silver-haired, 3) hoary, 4) California, 5) long-eared, 6) little brown, 7) fringed, 8) long-legged, 9) Yuma, 10) Townsend's big-eared, migratory tree-roosting bats (Tree bats), and all species combined (All bats) recorded across all detectors at the proposed Skookumchuck Wind Energy Project, Washington 2015. Plus (+) indicates that, on average, more bats were detected than expected, negative (-) indicates that, on average, less bats were detected than expected, and (n.s.) indicates that there was no significant difference ($P > 0.05$) between observed and expected detections.

	Hours Relative to Sunset										
Altitude	-1	1	2	3	4	5	6	7	8	9	10
3 m											
Big brown	n.s.	+	+	n.s.	n.s.	n.s.	-	-	-	-	-
Silver-haired	-	+	+	n.s.	n.s.	n.s.	+	n.s.	-	-	-
Hoary	-	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	-	n.s.	n.s.
California	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	-	-
Long-eared	-	n.s.	n.s.	n.s.	+	n.s.	n.s.	-	n.s.	-	-
Little brown	-	n.s.	n.s.	+	n.s.	n.s.	n.s.	-	-	-	-
Fringed	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Long-legged	n.s.	+	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Yuma	n.s.	n.s.	n.s.	+	+	n.s.	n.s.	n.s.	n.s.	n.s.	-
Townsend's big-eared	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Tree bats	-	+	+	n.s.	n.s.	n.s.	+	n.s.	-	-	-
All Bats	-	+	+	+	n.s.	n.s.	+	n.s.	-	-	-
45 m											
Big brown	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Silver-haired	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Hoary	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
California	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Long-eared	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Appendix 2.

Little brown	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Fringed	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Long-legged	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Yuma	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Townsend’s big-eared	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Tree bats	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
All Bats	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Appendix 3.

Mean (passes/detector-night) and standard error (SE) between heights across all seasons for passes identified as 1) big brown, 2) silver-haired, 3) hoary, 4) California, 5) long-eared, 6) little brown, 7) fringed, 8) long-legged, 9) Yuma, 10) Townsend's big-eared, migratory tree-roosting bats (Tree bats), and all species combined (All bats) recorded across all detectors at the proposed Skookumchuck Wind Energy Project, Washington 2015. Wilcoxon Signed-rank Test compares activity between heights at the 2 tower stations. Blank cells indicate insufficient data for testing.

	3.0 m		45 m		Wilcoxon Signed-rank Test	
Species	Mean	SE	Mean	SE	Z	P
Big brown	0.00	0.00	0.01	<0.01	-2.0	0.046
Silver-haired	<0.01	<0.01	0.12	0.03	-4.6	<0.001
Hoary	0.00	0.00	<0.01	<0.01	-1.0	0.317
California	0.05	0.04	0.00	0.00	-1.3	0.180
Long-eared	<0.01	<0.01	0.00	0.00	-1.0	0.317
Little brown						
Fringed						
Long-legged		<0.01				
Yuma	<0.01		0.00	0.00	-1.0	0.317
Townsend's big-eared						
Tree bats	<0.01	<0.01	0.01	0.03	-4.7	<0.001
All Bats	0.05	0.04	0.13	0.03	-4.1	<0.001

Appendix 4.

Mean (passes/detector-night) and standard error (SE) among stations by height for passes identified as 1) big brown, 2) silver-haired, 3) hoary, 4) California, 5) long-eared, 6) little brown, 7) fringed, 8) long-legged, 9) Yuma, 10) Townsend's big-eared, migratory tree-roosting bats (Tree bats), and all species combined (All bats) recorded across all detectors at the proposed Skookumchuck Wind Energy Project, Washington 2015. Kruskal-Wallis Test compares activity among stations at 3 m. We did not compare activity among stations at 45 m because of limited data.

	G1		G2		T1		T2		Kruskal-Wallis	
Altitude/species	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Z_2	P
3 m										
Big brown	1.00	0.49	0.58	0.16	0.00	0.00	0.00	0.00	69.69	<0.001
Silver-haired	6.25	1.39	13.34	2.30	<0.01	<0.01	0.00	0.00	356.84	<0.001
Hoary	1.48	0.37	1.94	0.39	0.00	0.00	0.00	0.00	125.86	<0.001
California	0.08	0.02	0.47	0.06	0.09	0.09	0.00	0.00	146.57	<0.001
Long-eared	0.22	0.05	0.18	0.04	<0.01	<0.01	0.00	0.00	61.38	<0.001
Little brown	0.16	0.05	1.14	0.46	0.00	0.00	0.00	0.00	64.32	<0.001
Fringed	0.04	0.02	0.02	0.02	0.00	0.00	0.00	0.00	14.67	0.002
Long-legged	0.02	0.01	<0.01	0.01	0.00	0.00	0.00	0.00	8.64	0.034
Yuma	0.17	0.05	0.09	0.02	<0.01	<0.01	0.00	0.00	39.37	<0.001
Townsend's big-eared	0.02	0.01	<0.01	0.01	0.00	0.00	0.00	0.00	8.64	0.034
Tree bats	7.73	1.51	15.28	2.40	<0.01	<0.01	0.00	0.00	384.72	<0.001
All Bats	9.45	1.76	17.77	2.57	0.11	0.09	0.00	0.00	432.37	<0.001

Summary of select bat acoustic studies conducted during spring migration and summer at wind-energy projects across North America. An X denotes data unavailable. No data are available for studies in other regions of the U.S.

Project[a]	Study period	Detectornights	Total passes	Detectors/station	Stations	Mean passes/ detector-night	Detector height (m)	Source

Appendix 5.

Northeast								
Bliss, NY	4/20/05–6/13/05	54	6,032	2	1[d]	55.85[c]	15, 30	Ecology & Environment 2006
Centerville, NY	4/06/06–6/07/06	126	270	2	1	2.15	10, 25	Woodlot 2006b
Cohocton, NY	5/2/05–5/30/05	29	21	1	1	0.72	X	Woodlot 2006c
Dairy Hills, NY	5/20/05–6/01/05	10	27	1	1	2.70	1	Young et al. 2006
		107 50	4	2	2	0.04 [c]	10, 20	
Deerfield, VT	4/14/06–6/13/06	37	7	2	2	0.14 [c]	15, 35	Woodlot 2006d
			4	1	1[b]	0.11 [c]	23	
Lowell, VT	4/16/09–10/18/09	856	10,130	1–2	3	11.8	1.5–15	Stantec Consulting 2010
Howard, NY	4/15/06–6/6/06	116	50	3	1	0.43	8, 20, 50	Woodlot 2006b
Jordanville, NY	4/14/05–5/13/05	29	15	1	1	0.52	30	Woodlot 2005c
Maple Ridge, NY	4/10/05–6/22/05	74	459	3	2	1.03 [c]	7, 25, 50	Reynolds 2006
Prattsburgh, NY	4/15/05–5/30/05	57	16	2	1	0.28 [c]	15, 30	Woodlot 2005d
Roaring Brook, NY	4/18/08–6/30/08	296	838	2	2	2.83	1.5, 44	Hein et al. 2009
St. Lawrence, NY	4/13/06–5/29/06; 6/28/06–8/8/06	92	2,569	1	2[f]	19.72–55.56	~1	Kerns et al. 2007
Wethersfield, NY	4/06/06–6/07/06	126	192	2	1	1.52	10, 25	Woodlot 2006e
Midwest								
Blue Creek, OH	3/5/09–8/19/09[e]	274	264	2	1	0.96[c]	3, 45	BHE Environmental, Inc. 2009
West								
Ocotillo, CA	4/18/10–11/30/10	904[c]	200	2	2	0.2[c]	2, 50	Ocotillo Express 2011
Resolute, WY	6/2/10–9/30/10	1,089	1,111	2	5	0.00–2.75[g]	~1.5, ~44	Hein et al. 2011b
Pacific Northwest								
Skookumchuck, WA	**4/03/15–11/02/15**	**5,787**		1–2	**4**	**6.83**	**3, 45**	**Mabee et al. 2016, This study**
Coyote Crest, WA	4/15/08–6/30/08	242	20	2	2	0.08	~1.5, ~50	Hein et al. 2010

[a] Study design [e.g., sampling intensity (spatial and vertical), sampling dates, and analysis] differ among projects.
[b] Detector(s) located in areas of concentrated bat activity (i.e., tree line or pond).
[c] Calculated value, not presented in literature.
[d] Detector mounted on a silo.
[e] Interim report summarizes bat acoustics between 5 March–19 August; however, full report for 36-week period (5 March–15 November) will be available at a later date.
[f]

Appendix 6.

Detectors placed at base of met tower and near wooded edge; additionally, "roaming" detector used during summer months.

g Mean activity represented among towers at 1.5 m for high frequency, low frequency, and hoary bats = 0.18–2.75, 0.42–1.44, & 0.00–0.27 passes/night; mean activity at 44 m for high frequency, low frequency, and hoary bats = 0.00–0.13, 1.13–2.09, & 0.20–0.61.

Summary of select bat acoustic studies conducted during fall migration at wind development projects across North America and Canada. An X denotes data unavailable.

Project[a]	Study period	Detector-nights	Total passes	Detectors/station	Stations	Mean passes/detector-night	Detector Height (m)	Source
Canada								
Alberta, Canada	7/15/06–9/30/06	282	1,488[d]	3	1	5.28	1, 30, 67	Baerwald 2008
	7/15/07–9/30/07	299	1,592[d]	3	1	5.45	1, 30, 67	
Northeast								
Bliss, NY	8/15/05–10/9/05	55	3,725	2	1[b]	33.86c	15, 30	Ecology & Environment 2006
Buffalo Mtn., TN	9/1/00–9/30/03	149	X	X	X	23.70	X	Fiedler 2004
Centerville, NY	7/25/06–10/10/06	89	5	2	1	0.06	15, 35	Woodlot 2006a
Cohocton, NY	8/3/05–10/15/05	122	191	2	1	1.57	15, 23	Woodlot 2006c
Dairy Hills, NY	8/16/05–10/14/05	83	306	2	1	3.69	1, 50	Young et al. 2006
Hoosac, MA	7/27/06–11/11/06	1,296		3	4		10, 31.5, 39.2	Hein et al. 2011a
	6/1/07–10/31/07	1,836		3	4		10, 31.5, 39.2	Hein et al. 2011a
Howard, NY	8/3/05–8/19/05	25	60	2	1	2.40c	27, 48	Woodlot 2005a
	8/3/05–8/27/05	25	1,439	1	1e	57.56c	2	
Liberty Gap, WV	9/15/04 – 11/6/04	14	91	2	1	6.50c	15, 30	Woodlot 2005b
Mountaineer, WV	8/31/04–9/11/04	33	X	X	X	38.20	X	Arnett (unpublished data)
Mount Storm, WV	7/20/08–10/12/08	536	18,856	1	11[g]	39.6, 24.9g	X	Young et al. 2009
Roaring Brook, NY	7/20/07–10/15/07	528	4,257	2	3	8.06c	1.5, 44	Mabee and Schwab 2008
Roaring Brook, NY	7/01/08–10/15/08	428	2,576	2	2	6.02	1.5, 44	Hein et al. 2009a
Somerset, PA	8/1/05–11/1/05	93	9,162	3, 2	5, 7	6.57c	1.5, 22, 44	Arnett et al. 2006
St. Lawrence, NY	9/13/06–10/9/06	50	2092	1	2	9.26-32.58	~1, 10	Kerns et al. 2007
Wethersfield, NY	7/25/06–10/09/06	80	22	2	1	0.28	15, 35	Woodlot 2006a
Midwest								
Buffalo Ridge, MN	6/15/01–9/15/02	216	452	1	3	2.09c	X	Johnson et al. 2004
		77	3,718	1	1e	48.29c	~1	
Butler Ridge, WI	7/19/05–9/30/05	1,786	26,495	3, 2	3, 5	14.80c	2, 22, 48	Redell et al. 2006

Appendix 7.

Top of Iowa, IA	5/10/04–9/29/04	84	3,001	1	2	35.73c	~1	Jain 2005
West								
Dillon, CA	10/25/07–3/31/09	6,959	523; 1,798[g]	2, 3	8, 4	0.08, 0.26	2, 22, 52	Weller and Baldwin 2011
Granite Mt., CA	4/29/08–04/29/09	924[d]	961	3	1	1.04	2, 14, 30	Tetra Tech 2010
Ocotillo, CA	4/18/10–11/30/10	904[d]	200	2	2	0.2d	2, 50	Ocotillo Express 2011
Tule, CA	09/X/ 08–11/X/ 10	X	X	X	X	17.7h	1	WEST, 2011[h]; BLM 2011

Appendix 5. Continued.

Project[a]	Study period	Detectornights	Total passes	Detectors/ station	Stations	Mean passes/ detector-night	Detector Height (m)	Source
Dry Lake, AZ	7/6/06–7/8/06; 9/21/06–10/15/06	56	3, 15; 6, 76	1	2f	1.78	~1	Young et al. 2007
Foote Creek, WY	6/15/00–9/01/01 6/15/01–9/01/01	80	4, 315	1–3	1–3[e]	2.2 2.2	~1, 15	Gruver 2002; Young et al. 2003
Foote Creek, WY	6/26/00–8/13/01	80	4,315	1–3	2f	53.93c	~1, 15	Gruver 2002
Resolute, WY	8/3/09–10/18/09	762	976	5	1–3[e]	0.00–4.21h	~1.5, ~44	Hein et al. 2011b
Pacific Northwest								
Coyote Crest, WA	7/1/08–11/17/08	810	1,394	2	3	1.70	~1.5, ~50	Hein et al. 2010
Saddleback, WA	7/3/08–10/7/08	97	56,595	1	3[e]	148.34	~1	Johnson et al. 2009
Skookumchuck, WA	**4/03/15–11/02/15**	**5,787**		**1–2**	**4**	6.83	3, 45	**Mabee et al. 2016, This study**
Golden Hills, OR	7/27/07–10/28/07	294	1,552	1	4[e]	5.30c	~1	Jeffery et al. 2008