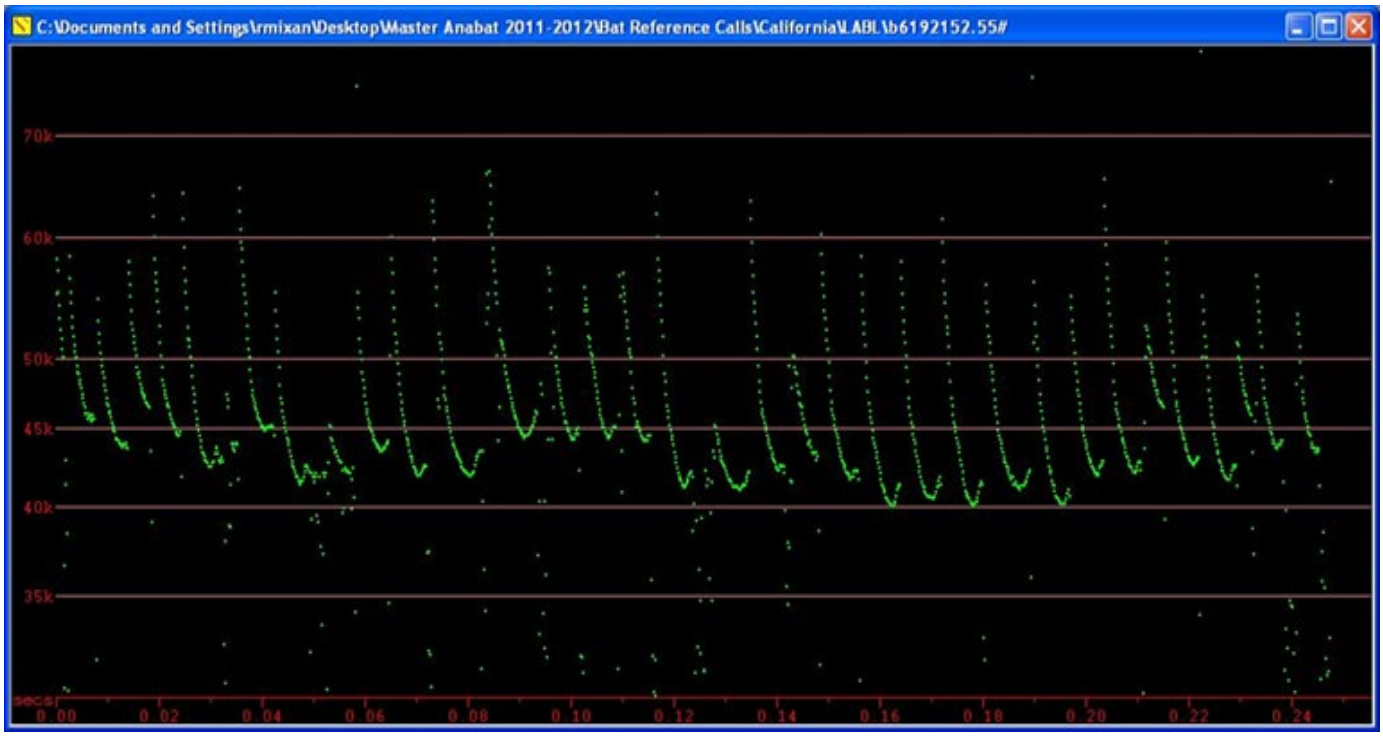
Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

System-Wide Acoustic Monitoring of LCR MSCP Bat Species

2019 Annual Report



BUREAU OF RECLAMATION

June 2020

Work conducted under LCR MSCP Work Task D9

Lower Colorado River Multi-Species Conservation Program Steering Committee Members

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U.S. Fish and Wildlife Service
National Park Service
Bureau of Land Management
Bureau of Indian Affairs
Western Area Power Administration

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Arizona Game and Fish Department
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Chemehuevi Indian Tribe

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The Nature Conservancy

Lower Colorado River Multi-Species Conservation Program

System-Wide Acoustic Monitoring of LCR MSCP Bat Species

2019 Annual Report

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June 2020

Mixan, R.J. 2020. System-Wide Acoustic Monitoring of LCR MSCP Bat Species, 2019 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada, by the Arizona Game and Fish Department, Phoenix, Arizona, under Cooperative agreement No. R19AC00003.

ACRONYMS AND ABBREVIATIONS

activity	average nightly call minutes
AKTP 1	‘Ahakhav Tribal Preserve acoustic station
BWRNWR 1	Bill Williams River National Wildlife Refuge acoustic station
CNWR-Island	Cibola National Wildlife Refuge-Island Unit acoustic station
e.g.	*exempli gratia* (for example)
HH1	Hunters Hole acoustic station
HNWR-Pintail	Havasu National Wildlife Refuge acoustic station in Pintail Slough
MLWA 1	Mittry Lake Wildlife Area acoustic station
PSRA 1	Picacho State Recreation Area acoustic station
LCR	lower Colorado River
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
occupancy	proportion of nights present per month
YEW 1	Yuma East Wetlands acoustic station

Symbols

%	percent
™	trademark

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ABSTRACT

Acoustic bat call data were analyzed from eight permanent acoustic monitoring stations (Anabat™) along the lower Colorado River from June 1 to August 31, 2010, through 2019. Five of the stations are located in riparian habitat along the Lower Colorado River that have not been restored by the Lower Colorado River Multi-Species Conservation Program (LCR MSCP) (original system-wide monitoring sites) for future comparison with activity trends at LCR MSCP conservation areas. The remaining three stations are located in restoration areas that contain mature Fremont cottonwood-Goodding's willow (*Populus fremontii-Salix gooddingii*) habitat that are not being managed by the LCR MSCP for bat species. Three new locations were added to this system-wide report in 2019: the 'Ahakhav Tribal Preserve (AKTP 1) and two LCR MSCP conservation areas, Hunters Hole (HH 1) and Yuma East Wetlands (YEW 1).The calls of the following four bat species were analyzed: western red bats (*Lasiurus blossevilli*), western yellow bats (*Lasiurus xanthinus = Dasypterus xanthinus*), California leaf-nosed bats (*Macrotus californicus*), and pale Townsend's big-eared bats (*Corynorhinus townsendii pallescens = Plecotus townsendii pallescens = C. townsendii townsendii*). Sites and species were evaluated based on activity (measured with average nightly call minutes) and daily occupancy (measured with the proportion of nights occupied per month). Activity and occupancy varied widely among sites, years, and species. Western red bats and pale Townsend's big-eared bats were recorded with the greatest activity at the Bill Williams National Wildlife Refuge (BWRNWR 1) from 2010 through 2019. Western yellow bats were recorded with the greatest activity at Yuma East Wetlands from 2010 through 2019. California leaf-nosed bats were recorded with the greatest activity at the Picacho State Recreation Area from 2010 through 2019.

INTRODUCTION

This document is a summary of acoustic bat call data collected from eight acoustic monitoring stations (Anabat™) along the lower Colorado River (LCR). The purpose of this project was to monitor the presence of bat species to inform the Lower Colorado River Multi-Species Conservation Program (LCR MSCP). The LCR MSCP is a multi-stakeholder Federal and non-Federal partnership responding to the need to balance the use of LCR water resources and the conservation of native species and their habitats in compliance with the Endangered Species Act. This program works toward the recovery of listed species through habitat and species conservation and reduces the likelihood of additional species being listed under the Endangered Species Act.

The LCR MSCP is required to create 765 acres of western red bat roosting habitat and 765 acres of western yellow bat roosting or foraging habitat by creating suitable habitat for these covered species. The creation of this habitat has accomplished other conservation strategies outlined below in the implementation of the LCR MSCP's stated objectives. Conservation strategies should include creating new habitat patches and expanding, connecting, and restoring existing patches to increase the persistence and movement of species across the landscape (Lawton et al. 2010). Further, conservation strategies should prioritize landscape-level actions in more homogeneous and intensively farmed landscapes where habitat loss and fragmentation have been more severe (Fuentes-Montemayor et al. 2017). The LCR MSCP conservation areas have been created in areas that have been intensively converted to agriculture, restoring riparian habitat to a fragmented landscape.

Acoustic bat call data are collected and analyzed to document activity trends from the eight permanent stations. Five of the stations are located in riparian habitat along the LCR that have not been restored by the LCR MSCP (original system-wide monitoring sites) for future comparison with activity trends at LCR MSCP conservation areas. The remaining three stations are located in restoration areas that contain mature Fremont cottonwood-Goodding's willow (*Populus fremontii-Salix gooddingii*) (hereafter cottonwood-willow) habitat that are not being managed by the LCR MSCP for bat species but may provide information on bat activity and occupancy within the extensive Colorado River Indian Tribes' lands in Reach 4 and in the most southern reaches, Reaches 6 and 7.

Bats have been proposed to be indicators of the integrity of natural communities and are an excellent taxa for monitoring habitats because they integrate a number of resource attributes (e.g., roosting, watering, and foraging habitats), and thus, a decrease in bat activity magnitude or diversity may indicate a decline in habitat quantity or quality (Hutson et al. 2001; Jones et al. 2009; Miller 2010; Miller et al. 2003; Rainey et al. 2006, 2009; Williams et al. 2006). Acoustic sampling is an effective and economical means to monitor bat activity. Analyses of recordings from ultrasonic bat detectors are now widely applied when assessing

bat distribution and activity over a range of temporal scales in various landscape contexts. Changes in bat species activity that suggest declining population trends or reveal limited ranges may warrant targeted investigation and shape the allocation of conservation funding support (Rainey et al. 2009). Alternatively, populations demonstrating stable or increasing population trends may require limited monitoring and funding support in the future. A key component of understanding and effectively managing bat communities is gaining a basic understanding of the inherent variation in species composition across spatial and temporal scales (Morris 1990). Understanding the variation in bat communities across time and space is fundamental for conservation efforts because managers must decide whether changes in species activities warrant management efforts.

This project targets the presence of western red bats (*Lasiurus blossevillii*), western yellow bats (*Lasiurus xanthinus*), California leaf-nosed bats (*Macrotus californicus*), and pale Townsend's big-eared bats (*Corynorhinus townsendii pallescens = Plecotus townsendii pallescens = C. townsendii townsendii*),[1] (within system-wide monitoring sites.

STUDY AREA

The study area consists of eight Anabat™ stations located along the LCR from the Havasu National Wildlife Refuge in the north to the Hunters Hole conservation area near the border with Mexico (figure 1). Five system-wide monitoring sites were generally located in areas containing a mixture of native and non-native riparian vegetation that is remnant or where older small-scale planting occurred but there was no active management or irrigation of the site. The extent of the canopy cover and overall composition varies across sites. The system-wide monitoring stations were located at Pintail Slough in the Havasu National Wildlife Refuge (HNWR-Pintail), the Bill Williams River National Wildlife Refuge (BWRNWR 1), the Cibola National Wildlife Refuge-Island Unit (CNWR-Island), the Picacho State Recreation Area (PSRA 1), and the Mittry Lake Wildlife Area (MLWA 1) (table 1; figure 1). Three new locations were added to this system-wide report in 2019: the 'Ahakhav Tribal Preserve (AKTP 1) and two LCR MSCP conservation areas, Hunters Hole (HH 1) and Yuma East Wetlands (YEW 1). These three sites differ from the original sites in that they are actively managed restoration areas that contain mature cottonwood-willow habitat. These sites had previously been monitored under Work Task F4 (post-development monitoring) but have been reassigned to Work Task D9 (system-wide monitoring). AKTP 1 is not part of a LCR MSCP conservation area, and YEW 1 and HH 1 are located outside creditable Reaches 3–5.

[1] Genetic analyses on the pale Townsend's big-eared bat indicate that the LCR is likely in the range of the Pacific Townsend's big-eared bat (*Corynorhinus townsendii townsendii*) rather than the pale Townsend's big-eared bat (Piaggio and Perkins 2005). The bats recorded along the LCR will be referred to as pale Townsend's big-eared bats in this report, as the nomenclature change has not yet been verified by the U.S. Fish and Wildlife Service.

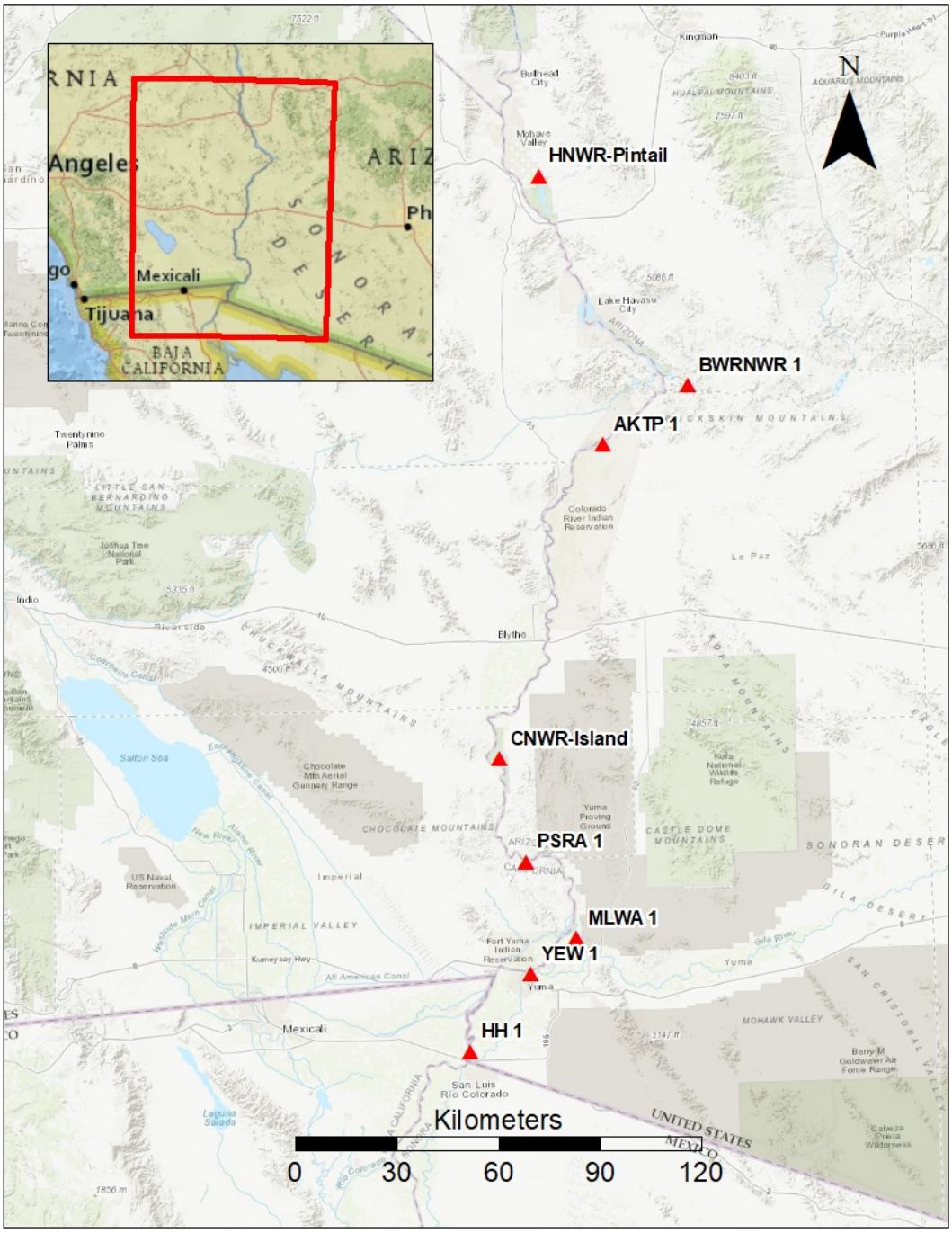

Figure 1.—Study area system-wide monitoring sites.

Table 1.—Station name, acronym, and number of nights recorded during the sampling period, and year of station deployment

Station	Station acronym	Nights recorded, 2019	Year deployed
Havasu National Wildlife Refuge-Pintail Slough	HNWR-Pintail	92	2014
Bill Williams River National Wildlife Refuge	BWRNWR 1	92	2008
‘Ahakhav Tribal Preserve	AKTP 1	92	2012
Cibola National Wildlife Refuge-Island Unit	CNWR-Island	92	2008
Picacho State Recreation Area	PSRA 1	92	2008
Mittry Lake Wildlife Area	MLWA 1	92	2008
Yuma East Wetlands	YEW 1	53	2013
Hunters Hole	HH 1	90	2013

METHODS

Data were summarized from long-term Anabat™ detectors at eight locations along the LCR (see figure 1). These stations were deployed in system-wide monitoring sites in 2008, with AKTP 1 added in 2012, HH 1 and YEW 1 added in 2013, and HNWR-Pintail added in 2014 (see table 1). These eight stations provide a temporal and spatial estimate of bat activity and daily occupancy. Since 2010, five system-wide stations have been analyzed consisting of four deployed in completely unmanaged habitat and the fifth in a restoration planting that is no longer actively managed. AKTP 1, HH 1, and YEW 1 were added to the system-wide analysis this year, and they are all located in mature restoration sites that routinely receive irrigation. This change in methodology could lead to a misrepresentation of activity and occupancy at unmanaged sites; therefore, the findings are presented by comparing the original stations as well as all eight stations.

These eight stations consist of Anabat™ II detectors with associated ZCAIM (a device that takes a frequency signal from an Anabat™ detector, detects the zero-crossings in the signal, and stores the signals on a compact flashcard) and Anabat™ SD1 and SD2 detectors. Compact flashcards at the stations accumulated data at the rate of about 12 megabytes per night during periods of high bat activity (about 1,500 calls per night), and at that rate store 4 months of data on 1-gigabyte SD cards. In order to determine summer use, each station was deployed from June 1 through August 31, 2019. The stations were monitored and data downloaded during June, July, and August, with additional trips in May and September to address any maintenance issues.

During the 2019 sampling session, equipment at six stations functioned correctly and recorded acoustic data for the duration of the reporting period from June 1 through August 31. The CF card at HH 1 filled to capacity during August, resulting in 2 nights not being recorded. YEW 1, despite being brand new, had electrical issues, resulting in data gaps in June (16 nights), July (18 nights), and August (5 nights). During the check in July, YEW 1 seemed to be operating correctly. A similar data gap was observed during the August data download; the power cable was replaced, and the station operated correctly for the remainder of deployment.

Acoustic bat calls were quantified across four LCR MSCP species (western red bats, western yellow bats, California leaf-nosed bats, and pale Townsend's big-eared bats) at each station. Acoustic bat calls were recorded nightly from sunset to sunrise, and the files were processed using filters and methods developed for LCR MSCP acoustic monitoring projects (Broderick 2008). Using Analook software, a series of acoustic filters were created for the focal bat species. The analysis was based on first running files through an "All bats" filter to eliminate any files with significant background and insect noise. Then, the remaining calls were run through species-specific filters and analyzed individually to sort out species with similar call envelopes to the four focal species. Western red bat calls were then run through two species-specific filters (a low frequency and a high frequency). The low-frequency filter detected bat calls ending between 40–47.5 kilohertz, while the high-frequency filter detected bat calls ending between 52–80 kilohertz. The high-frequency filters were applied after discussions with Bureau of Reclamation biologists (S. Broderick and A. Calvert 2011, personal communication) revealed that western red bat calls at higher frequencies along the LCR had been recorded. Pale Townsend's big-eared bats are known to emit low-intensity vocalizations in an attempt to capture their Lepidopteran prey, which makes them difficult to detect with acoustic methods (O'Farrell and Gannon 1999). They produce a dual harmonic and cannot be positively identified unless the presence of this diagnostic harmonic is detected. The calls were compared and the filters tested on hand-release reference calls recorded along the LCR provided by Bureau of Reclamation biologists (S. Broderick and A. Calvert 2011, personal communication) and reference calls from across the Southwestern United States. Echolocation calls in bats predominately allow them to efficiently navigate and forage in darkness; thus, bat species occupying similar foraging habitat and niches often emit similar calls (Clement et al. 2014; Jones and Hoderied 2007; Siemers et al. 2001) and adjust their calls to suit their navigational task (Berger-Tal et al. 2008, Clement et al. 2014; Kalko and Schnitzler 1993). For these reasons, all calls that were flagged as a species of interest were visually verified, and only those calls that fit all of the call parameters for the given species and those that could confidently be identified are presented.

Call minutes were used in order to reduce bias in estimating bat activity at Anabat™ stations. A call minute is a 1-minute interval in which a particular species is recorded at least once, regardless of the number of call sequences, or the number of files for that species recorded within that minute (Broderick 2010; Brown 2006; Kalcounis et al. 1999). This call minute index reduced the bias associated with the tendency for individual bats to be detected multiple times or for multiple bats of a single species to be detected within an individual file (Miller 2001; Vizcarra et al. 2010; Williams et al. 2006). Bat minutes give a measure of activity while reducing the tendency to classify calls as the result of one bat making multiple calls or many bats making a single call. Data were also analyzed using daily occupancy and are presented as nights occupied and proportion of nights occupied at the permanent stations. The approach is based on naïve occupancy (i.e., if the species is present and within range of the stations, it will be detected); therefore, detection probabilities are not taken into account (i.e., imperfect detections). It should be noted that detection is indicative of presence, but non-detection of the species is not equivalent to absence (MacKenzie et al. 2002). Monitoring was limited to the distance in which the station could record reliable bat calls, and it is not known if a bat was present or absent just beyond the range of the station. Stations were compared based on average nightly call minutes per species and month as well as by the proportion of nights per month a species occupied the station area during the year. Both measures omit nights when a station was malfunctioning and not recording to avoid biased results. The comparisons among stations represent a qualitative measure of activity and are not to be extrapolated to evaluate population dynamics or occupancy trends. These methods provide a simple, standardized way of comparing activity across the stations and species. In this document, a detailed analysis of data collected during the 2019 sampling season is presented along with a comparison of the 2019 findings with those of the previous sampling years.

RESULTS

2019 Acoustic Detections

Western Red Bat

The greatest average nightly call minutes (activity) and proportion of nights occupied (occupancy) over the season for western red bats were recorded at YEW 1 followed by BWRNWR 1, CNWR-Island, HNWR-Pintail, MLWA 1, and PSRA 1 (equally), and AKTP 1. No western red bat activity was recorded at HH 1 (table 2). The greatest average nightly call minutes within a month were recorded at YEW 1 in July, BWRNWR 1 in August, HNWR-Pintail in August, CNWR-Island in August, MLWA 1 in June, AKTP 1 in August, and at PSRA 1 in

Table 2.—Western red bat activity and nights occupied at system-wide monitoring sites in 2019

Station	Average nightly call minutes	Nights occupied	Proportion of nights occupied
AKTP 1	0.03	3	0.03
BWRNWR 1	0.23	18	0.20
CNWR-Island	0.11	10	0.11
HH 1*	0.00	0	0.00
HNWR-Pintail	0.08	5	0.05
MLWA 1	0.04	4	0.04
PSRA 1	0.04	4	0.04
YEW 1*	0.45	15	0.28

* Represents stations that did not collect the full 92 nights of data.

June (figure 2). The greatest average nightly call minutes at system-wide sites were recorded at YEW 1 in July (0.85). The greatest proportion of nights occupied corresponded exactly with the sites and months with the greatest average nightly call minutes. The greatest proportion of nights occupied at system-wide sites were recorded at YEW 1 in August (35% of nights occupied) (figure 3).

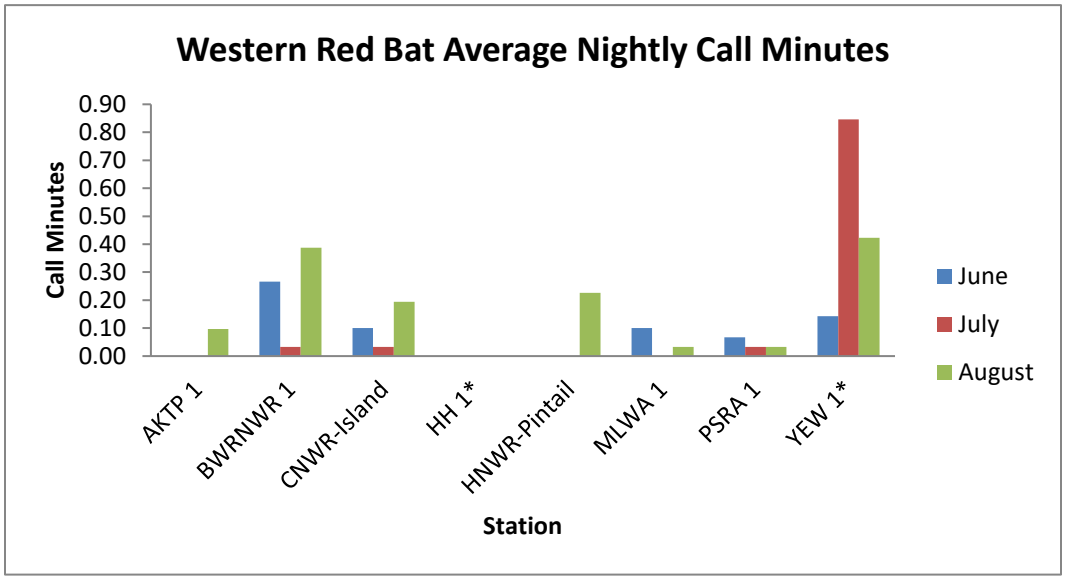

Figure 2.—Western red bat average nightly call minutes.
* Represents stations that did not collect the full 92 nights of data.

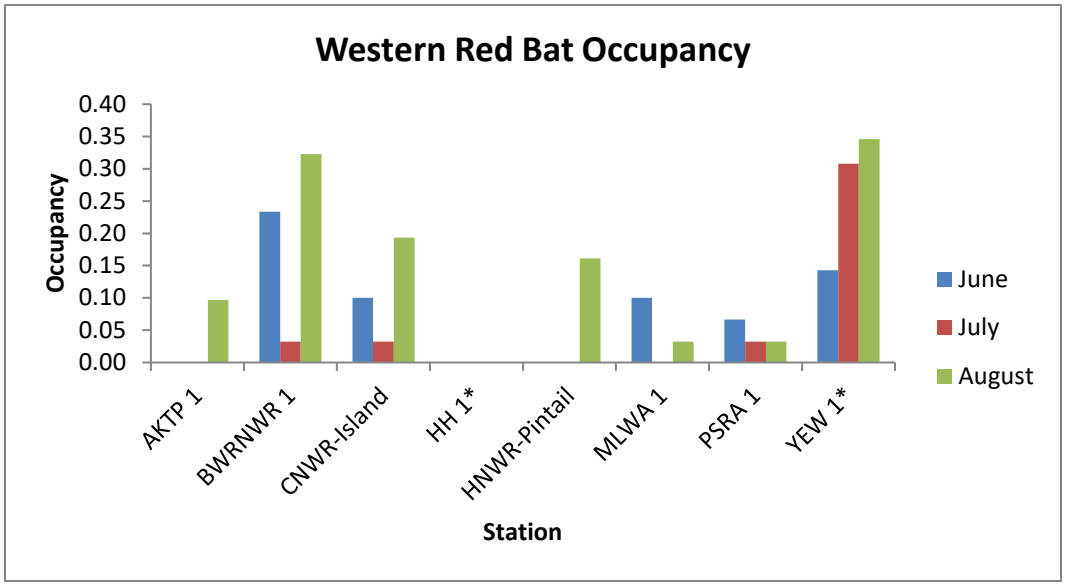

Figure 3.—Western red bat proportion of nights occupied.
* Represents stations that did not collect the full 92 nights of data.

Western Yellow Bat

The greatest average nightly call minutes (activity) for western yellow bats was recorded at YEW 1 followed by HH 1, MLWA 1, and PSRA 1 (table 3). The greatest proportion of nights occupied corresponded with nightly call minutes and was recorded at YEW 1 followed by HH 1, MLWA 1, and PSRA 1 (table 3). No western yellow bat activity was recorded at AKTP 1, BWRNWR 1, CNWR-Island, or HNWR-Pintail (table 3). The greatest average nightly call minutes was recorded at YEW 1 in June, July, and August (figure 4). The greatest proportion of nights occupied was recorded at YEW 1 in June, July, and August (figure 5). The greatest average nightly call minutes (2.62) and proportion of nights occupied (92%) were recorded at YEW 1 in July (figures 4 and 5).

Table 3.—Western yellow bat activity and nights occupied at system-wide monitoring sites in 2019

Station	Average nightly call minutes	Nights occupied	Proportion of nights occupied
AKTP 1	0	0	0
BWRNWR 1	0	0	0
CNWR-Island	0	0	0
HH 1*	0.63	22	0.24
HNWR-Pintail	0	0	0
MLWA 1	0.03	3	0.03
PSRA 1	0.01	1	0.01
YEW 1*	1.55	32	0.60

* Represents stations that did not collect the full 92 nights of data.

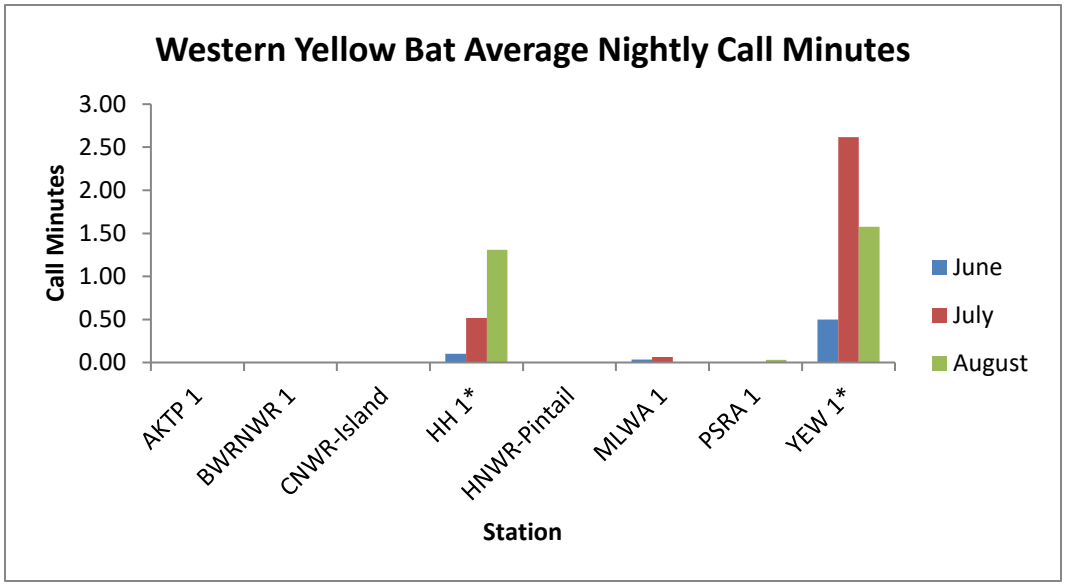

Figure 4.—Western yellow bat average nightly call minutes.
* Represents stations that did not collect the full 92 nights of data.

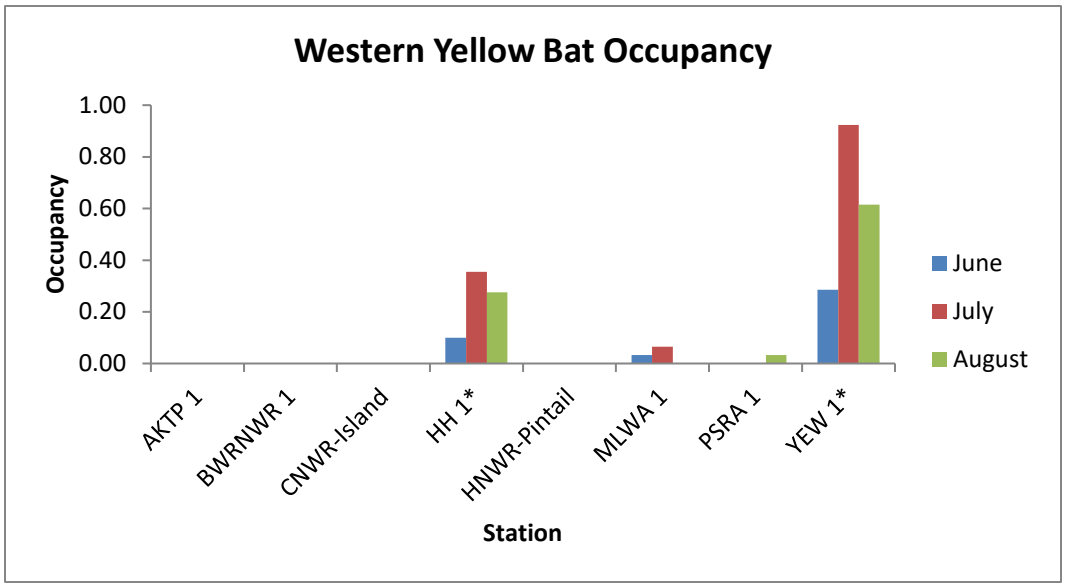

Figure 5.—Western yellow bat proportion of nights occupied.
* Represents stations that did not collect the full 92 nights of data.

California Leaf-nosed Bat

The greatest average nightly call minutes (activity) for California leaf-nosed bats was recorded at HH 1 followed by BWRNWR 1, CNWR-Island, PSRA 1 and MLWA 1 (equally), and YEW 1 (table 4). The greatest proportion of nights occupied was recorded at BWRNWR 1 and HH1 (equally) followed by CNWR-Island, MLWA 1, and PSRA 1 (all equally), and YEW 1 (table 4). No activity for California leaf-nosed bats was recorded at AKTP 1 or HNWR-Pintail. The greatest average nightly call minutes was recorded at BWRNWR 1 in June, at MLWA 1 in July, and HH1 in August (figure 6). The greatest proportion of nights occupied was recorded at BWRNWR 1 in June, at MLWA 1 in July, and at HH1 in August (figure7). The greatest average nightly call minutes (0.45) and proportion of nights occupied (24%) were at HH 1 August.

Table 4.—California leaf-nosed bat activity and nights occupied at system-wide monitoring sites in 2019

Station	Average nightly call minutes	Nights occupied	Proportion of nights occupied
AKTP 1	0	0	0
BWRNWR 1	0.15	9	0.10
CNWR-Island	0.07	5	0.05
HH 1*	0.17	9	0.10
HNWR-Pintail	0	0	0
MLWA 1	0.05	5	0.05
PSRA 1	0.05	5	0.05
YEW 1*	0.04	2	0.04

* Represents stations that did not collect the full 92 nights of data.

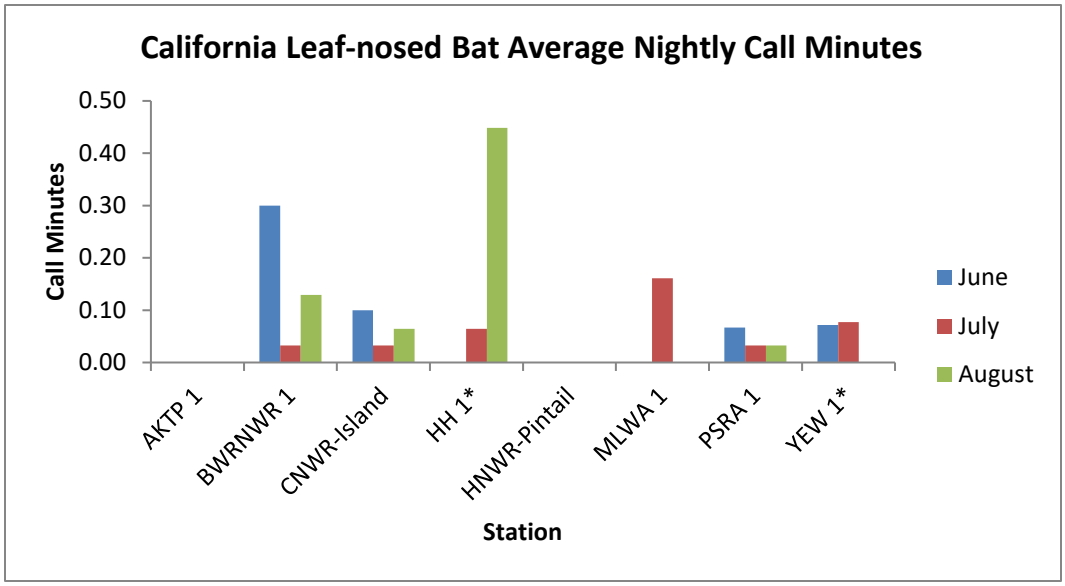

Figure 6.—California leaf-nosed bat average nightly call minutes.
* Represents stations that did not collect the full 92 nights of data.

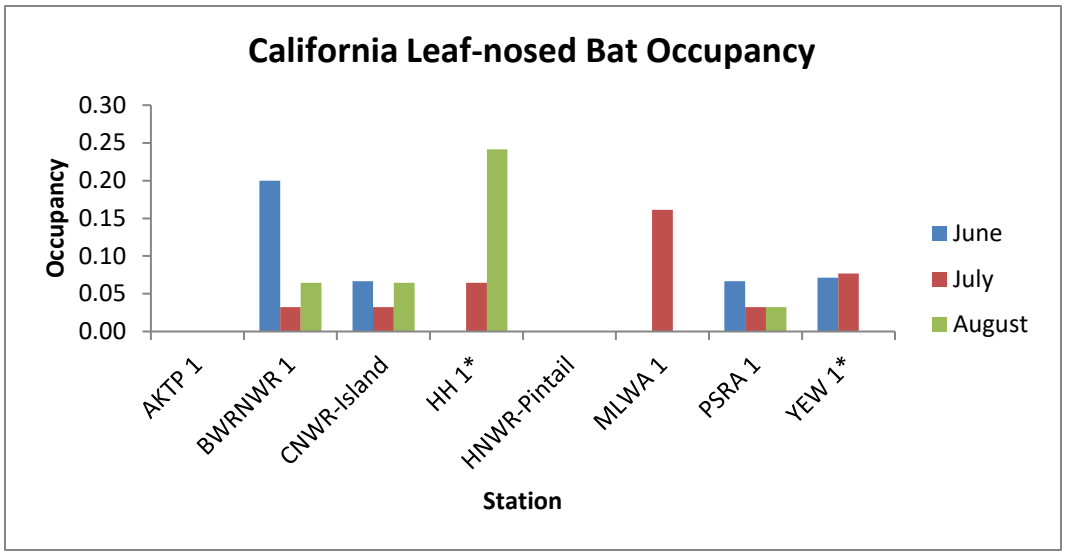

Figure 7.—California leaf-nosed bat proportion of nights occupied.
* Represents stations that did not collect the full 92 nights of data.

Pale Townsend's Big-eared Bat

Because of the conservative method of identifying Townsend's big-eared bat (*C. townsendii*) calls to species and subspecies, and the nature of their whispering calls, only one pale Townsend's big-eared bat call was recorded during 2019. This call was recorded on June 27 at BWRNWR 1.

Yearly Detections 2010–2019

Western Red Bat

Western Red Bat – BWRNWR 1

The greatest average nightly call minutes and proportion of nights occupied at BWRNWR 1 were recorded during the 2010 season followed by 2014, 2015, 2011, 2012 and 2018, 2019, 2016, 2013 and 2017 (figure 8). The 2012 and 2018 seasons had an equal amount of average nightly call minutes, but the 2018 season had a greater proportion of nights occupied (0.24 versus 0.23). The 2013 and 2017 seasons also had an equal amount of average nightly call minutes, but the 2013 season had a greater proportion of nights occupied (0.15 versus 0.13). The 2010 season had the greatest activity, with 0.98 call minutes per night and 58% of nights occupied, as compared to the 2017 season with the lowest activity of 0.17 call minutes per night and 13% of nights occupied.

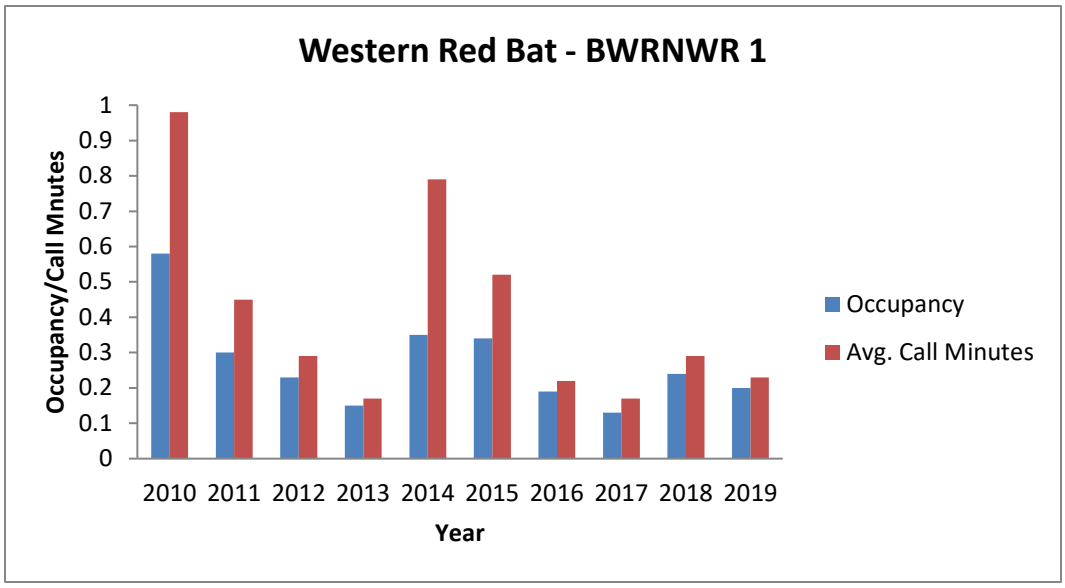

Figure 8.—Western red bat average nightly call minutes and proportion of nights occupied at BWRNWR 1.

Western Red Bat – CNWR-Island

The greatest average nightly call minutes and proportion of nights occupied at CNWR-Island were recorded during the 2010 season followed by 2011, 2016, 2018, 2014, 2017, 2019 and 2012, and 2013 (figure 9). The 2019 and 2012 seasons had an equal amount of average nightly call minutes, but the 2019 season had a greater proportion of nights occupied (0.11 versus 0.10). The 2010 season had the greatest activity, with 0.82 call minutes per night and 42% of nights occupied, as compared to the 2015 season with no activity recorded.

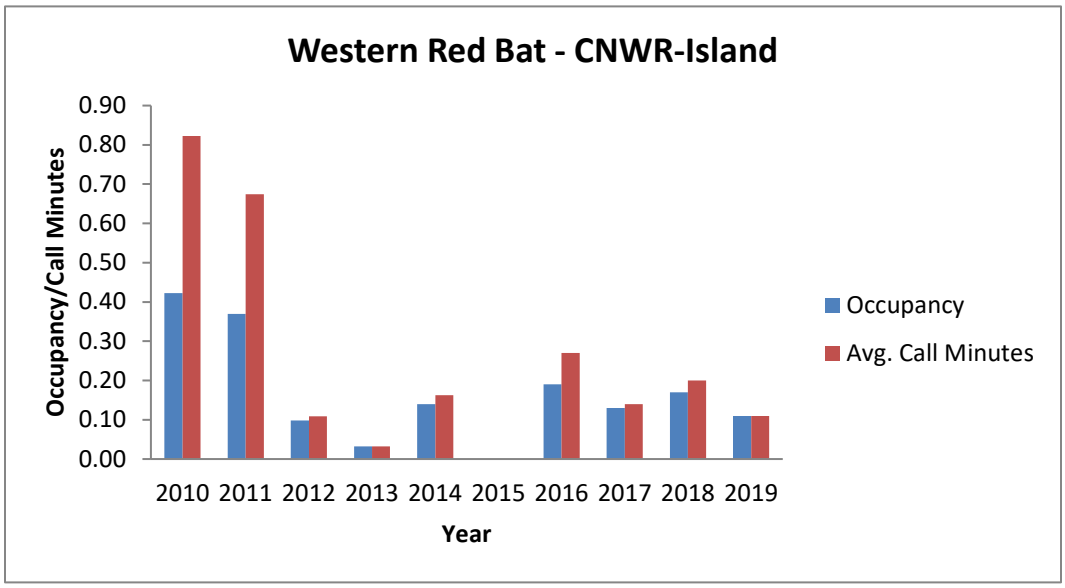

Figure 9.—Western red bat average nightly call minutes and proportion of nights occupied at CNWR-Island.

Western Red Bat – MLWA 1

The greatest average nightly call minutes at MLWA 1 was recorded during the 2014 and 2011 seasons followed by 2016, 2013, 2012, 2018, 2010, 2017, 2015, and 2019 (figure 10). The proportion of nights occupied at MLWA 1 did not correspond with average nightly call minutes in that greater average nightly call minutes and proportion of nights occupied did not necessarily parallel each other over years. A given year could have higher average nightly call minutes, but not necessarily a higher proportion of nights occupied than another year, and vice versa. Greater average nightly call minutes were recorded during the 2016 season compared to 2013, but the 2013 season had a greater proportion of nights occupied. This difference in average nightly call minutes and proportion of nights occupied may be attributed to the detector malfunction in 2016, with only the latter part of August being recorded at MLWA 1. The greatest proportion of nights occupied at MLWA 1 was recorded during the 2014 season followed by 2011, 2013, 2016, 2012, 2010/2017/2018 (equally), 2015, and 2019. Although the 2010, 2017, and 2018 seasons had an equal amount of proportion of nights occupied, 2018 had the greatest average nightly call minutes followed by 2010 and 2017. The 2014 and 2011 seasons had the greatest activity at 0.45 call minutes per night, but the 2014 season had a higher proportion of nights occupied (36% versus 27%). This difference in proportion of nights occupied may be attributed to shorter periods of more intense activity in 2011. This is compared to the 2019 season, with the least activity of 0.04 call minutes per night and 4% of nights occupied.

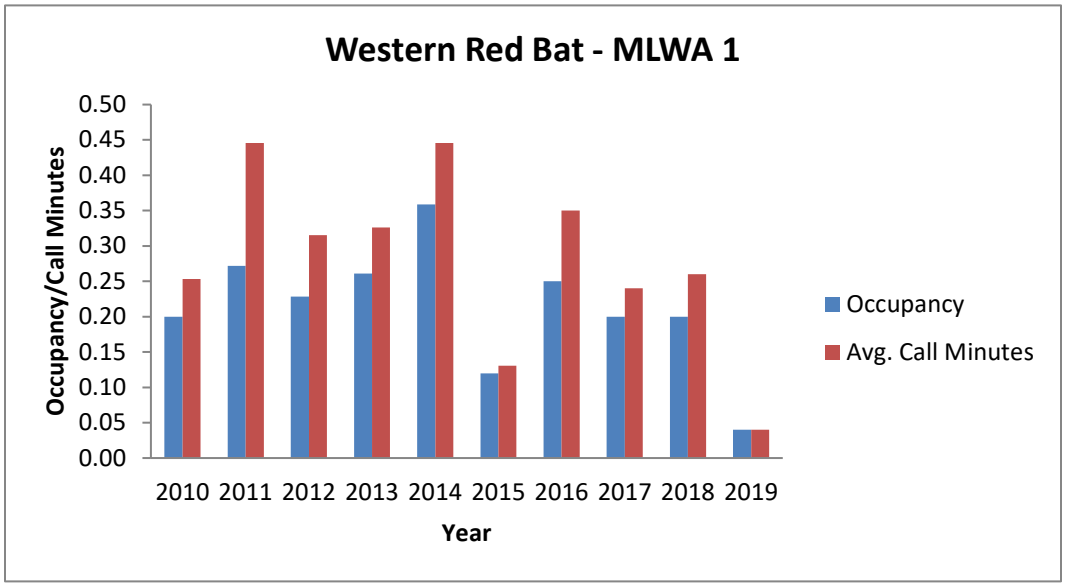

Figure 10.—Western red bat average nightly call minutes and proportion of nights occupied at MLWA 1.

Western Red Bat – PSRA 1

The greatest average nightly call minutes and proportion of nights occupied at PSRA 1 were recorded during the 2016 season followed by 2011, 2013, 2017/2018 (equally), 2012, 2019, 2014, and 2015 (figure 11). No call minutes were recorded during the 2010 season. The 2012 and 2014 seasons had the same proportion of nights occupied, but the 2012 season had greater average nightly call minutes. The 2012 season also had a greater average of nightly call minutes than 2019, but the 2019 season had a slightly greater proportion of nights occupied. The 2016 season had the greatest activity, with 0.2 call minutes per night and 16% of nights occupied.

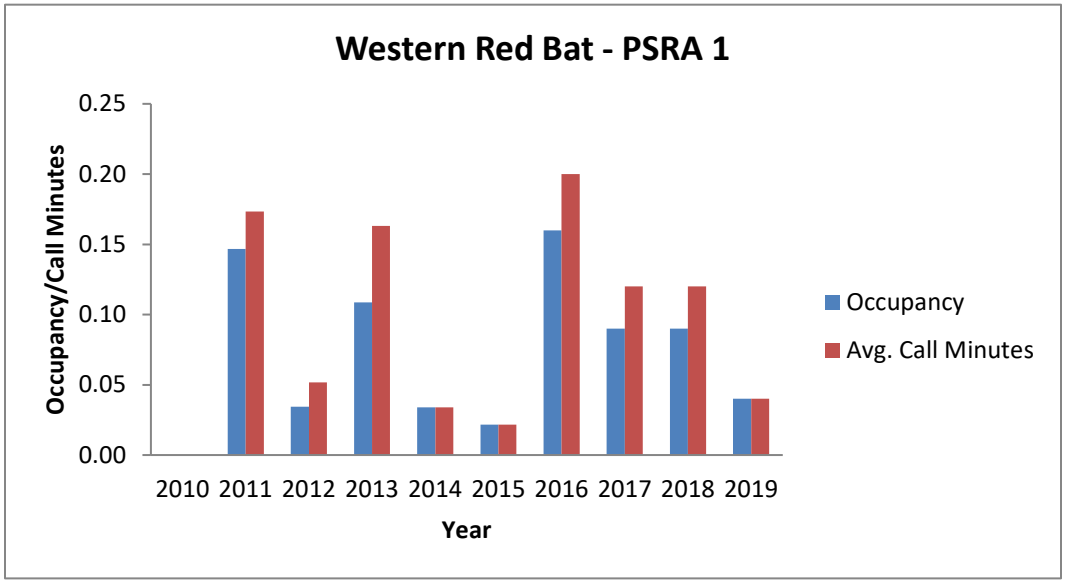

Figure 11.—Western red bat average nightly call minutes and proportion of nights occupied at PSRA 1.

Western Red Bat – HNWR-Pintail

The greatest average nightly call minutes and proportion of nights occupied at HNWR-Pintail were recorded during the 2014 season followed by 2015, 2016, 2018, 2019, and 2017 (figure 12). The 2014 season had the greatest activity, with 0.46 call minutes per night and 24% of nights occupied, as compared to the 2017 season with the least activity of 0.03 call minutes per night and 3% of nights occupied.

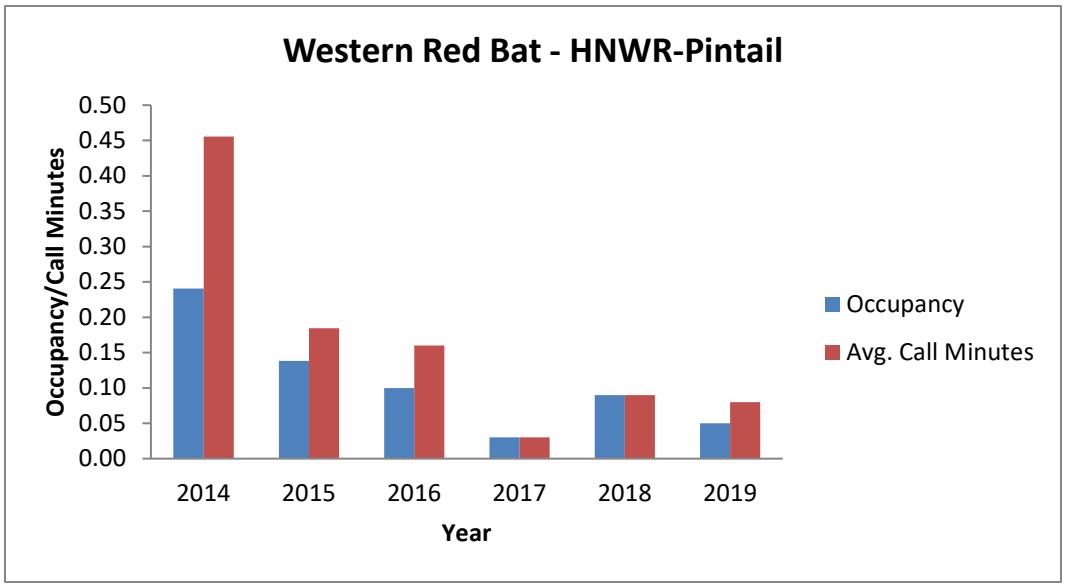

Figure 12.—Western red bat average nightly call minutes and proportion of nights occupied at HNWR-Pintail.

Western Red Bat – AKTP 1

The greatest average nightly call minutes and proportion of nights occupied at AKTP 1 were recorded during the 2016 season followed by 2019 (figure 13). No activity was recorded during the 2015, 2017, or 2018 seasons. Station malfunctions in June and July of 2015 and 2017 may partly explain the lack of detections at this site.

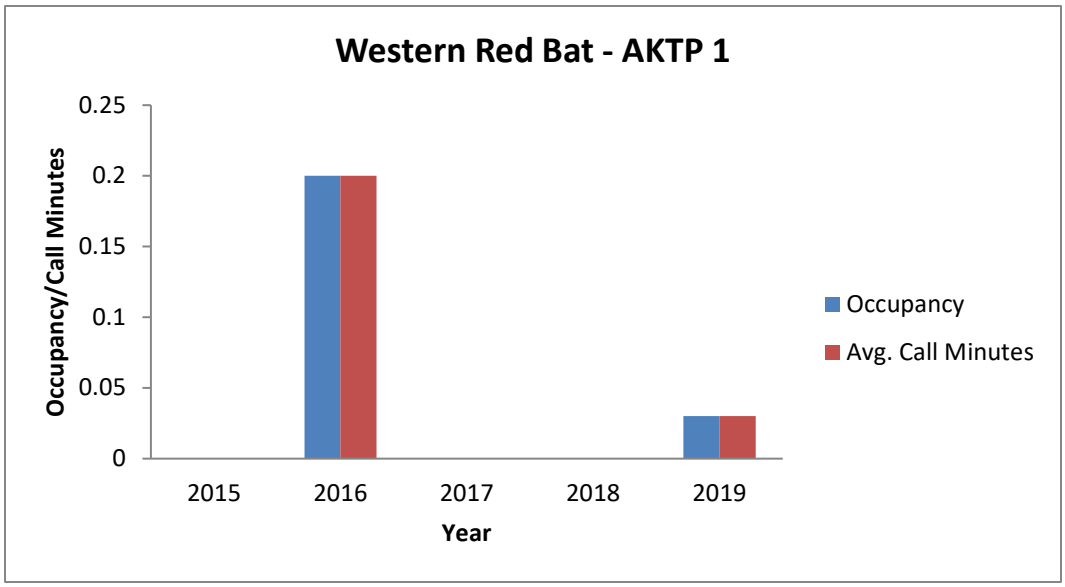

Figure 13.—Western red bat average nightly call minutes and proportion of nights occupied at AKTP 1.

Western Red Bat – YEW 1

The greatest average nightly call minutes and proportion of nights occupied at YEW 1 were recorded during the 2019 season followed by 2017, 2016, 2018, and 2015 (figure 14). The 2019 season had the greatest activity, with 0.45 call minutes per night and 28% of nights occupied, as compared to the 2015 season with the least activity of 0.09 call minutes per night and 8% of nights occupied.

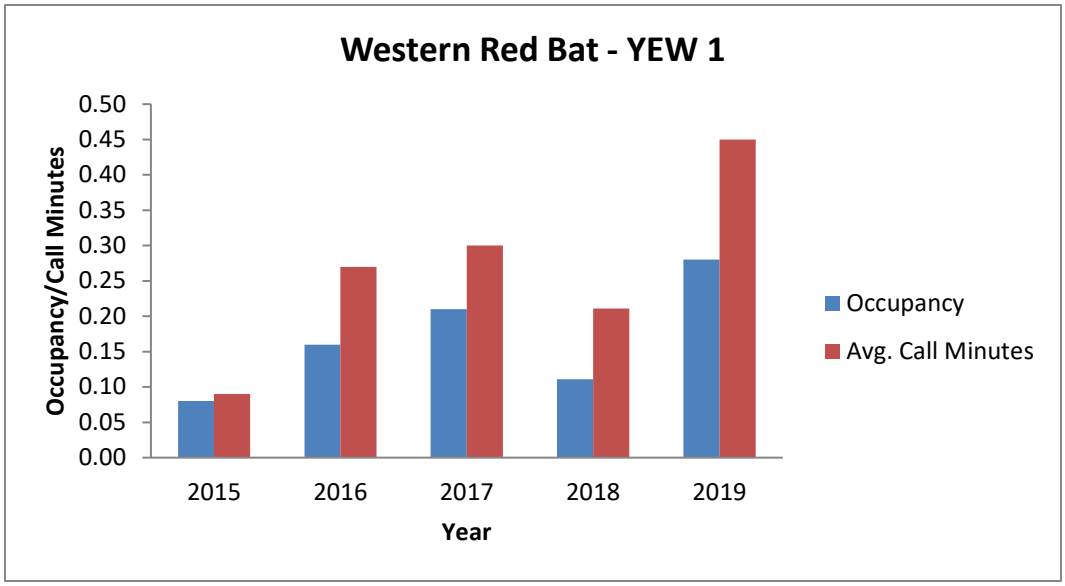

Figure 14.—Western red bat average nightly call minutes and proportion of nights occupied at YEW 1.

Western Red Bat – HH 1

The greatest average nightly call minutes and proportion of nights occupied at HH 1 were recorded during the 2018 season followed by 2017 and 2015 (figure 15). No activity was recorded during the 2016 or 2019 seasons.

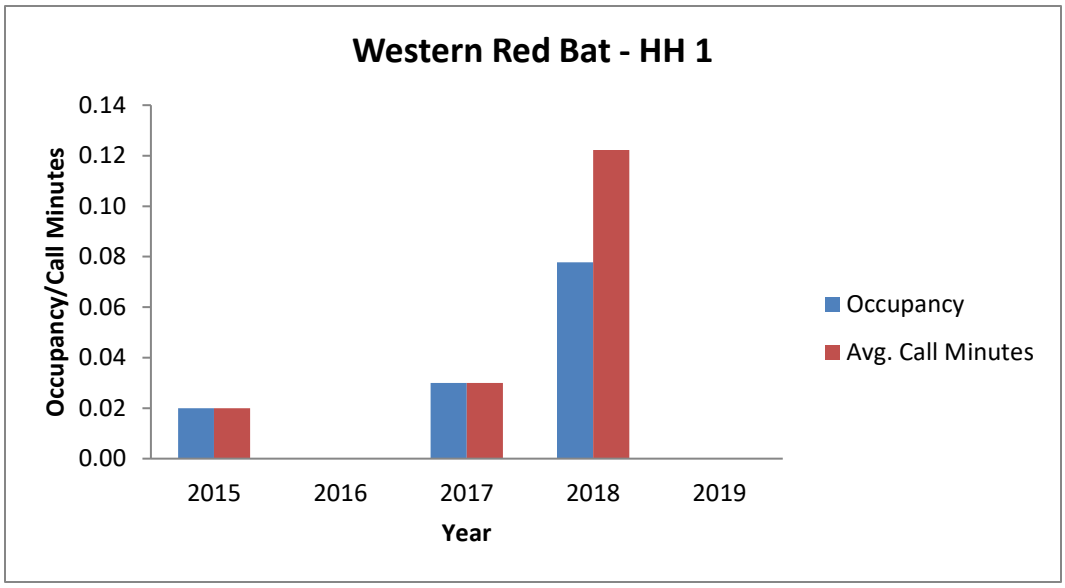

Figure 15.—Western red bat average nightly call minutes and proportion of nights occupied at HH 1.

Western Yellow Bat

Western Yellow Bat – BWRNWR 1

The greatest average nightly call minutes and proportion of nights occupied at BWRNWR 1 were recorded during the 2010 season followed by 2014, 2016, 2012/2013 (equally), 2011, and 2015/2018 (equally) (figure 16). No activity was recorded for western yellow bats during the 2017 or 2019 seasons. The 2010 season had the greatest activity of 0.13 call minutes per night and 12% of nights occupied.

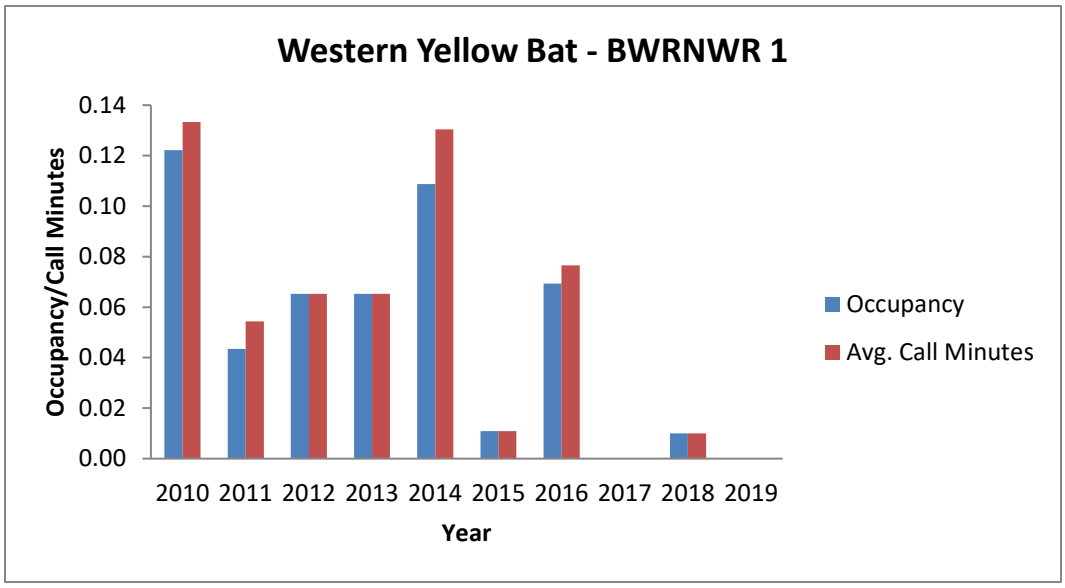

Figure 16.—Western yellow bat average nightly call minutes and proportion of nights occupied at BWRNWR 1.

Western Yellow Bat – CNWR-Island

The greatest average nightly call minutes were recorded at CNWR-Island during the 2011 season followed by 2010, 2012/2016 (equally), 2017/2018 (equally), and 2014. The proportion of nights occupied at CNWR-Island did not correspond with average nightly call minutes. The 2010 and 2012 seasons had the same proportion of nights occupied, but the 2010 season had higher average nightly call minutes. The 2012 and 2016 seasons had the same average nightly call minutes, but the 2012 season had a higher proportion of nights occupied. The 2017 and 2018 seasons had an equal amount of average nightly call minutes, but the 2017 season had a slightly higher proportion of nights occupied. The greatest proportion of nights occupied was reported during the 2011 season followed by 2010/2012 (equally), 2016, 2017, and 2014/2018 (equally) (figure 17). No activity was recorded at CNWR-Island during the 2013, 2015, or 2019 seasons. The 2011 season had the greatest activity, with 0.28 call minutes per night and 15% of nights occupied.

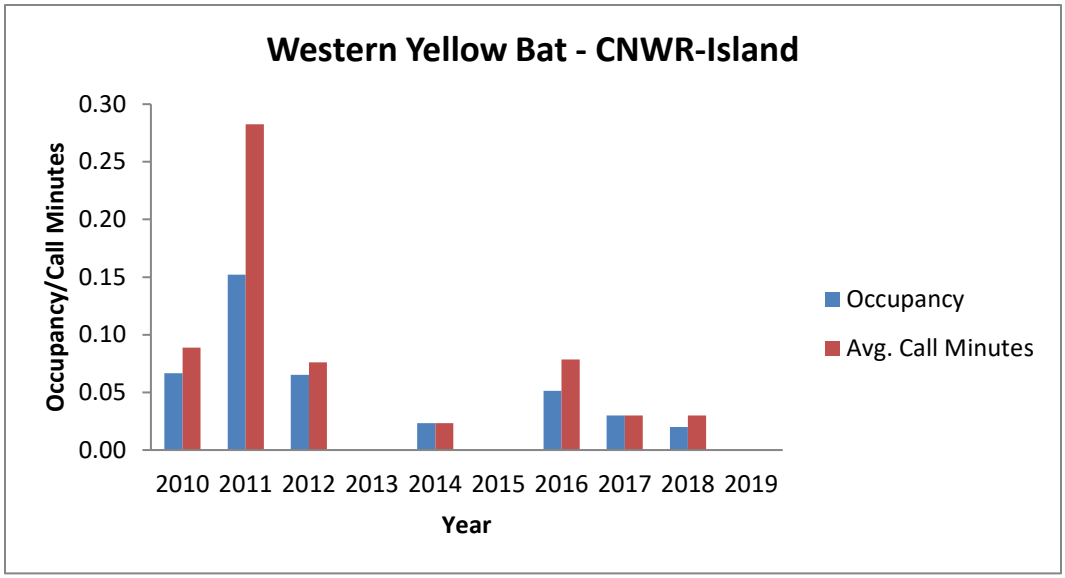

Figure 17.—Western yellow bat average nightly call minutes and proportion of nights occupied at CNWR-Island.

Western Yellow Bat – PSRA 1

The greatest average nightly call minutes and proportion of nights occupied at PSRA 1 were recorded during the 2011 and 2017 seasons (equally) followed by 2012/2014 (equally), 2013/2016 (equally), and 2019 (figure 18). No activity was recorded during the 2010, 2015, or 2018 seasons. The 2011 and 2017 seasons had the greatest activity of 0.04 call minutes per night and 4% of nights occupied.

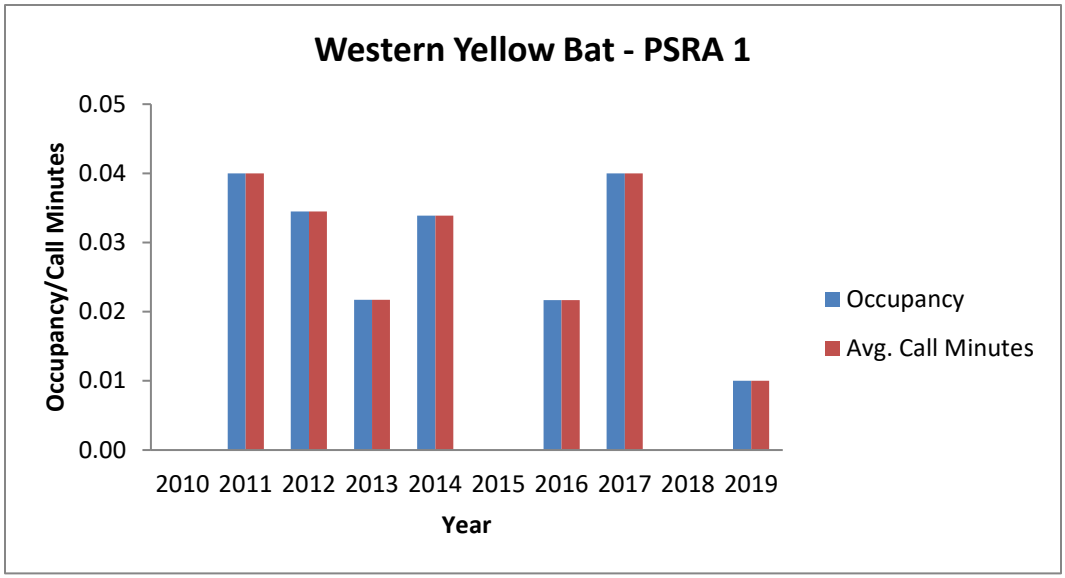

Figure 18.—Western yellow bat average nightly call minutes and proportion of nights occupied at PSRA 1.

Western Yellow Bat – MLWA 1

The greatest average nightly call minutes at MLWA 1 were recorded during the 2010 season followed by 2018, 2017, 2012/2013/2015 (equally), 2019, and 2011/2014 (equally) (figure 19). No activity was recorded during the 2016 season. The proportion of nights occupied did not correspond with the average nightly call minutes at MLWA 1. The 2012, 2013, and 2015 seasons all had the same average nightly call minutes, with the 2015 season having a lower proportion of nights occupied than 2012 and 2013. The 2012 and 2013 seasons had equal average nightly call minutes and proportion of nights occupied. The 2011 and 2014 seasons also had equal average nightly call minutes and proportion of nights occupied. The greatest proportion of nights occupied was recorded during the 2010 season followed by 2018, 2017, 2012/2013 (equally), 2015, 2019, and 2011/2014 (equally). The 2010 season had the greatest activity, with 0.16 call minutes per night and 13% of nights occupied.

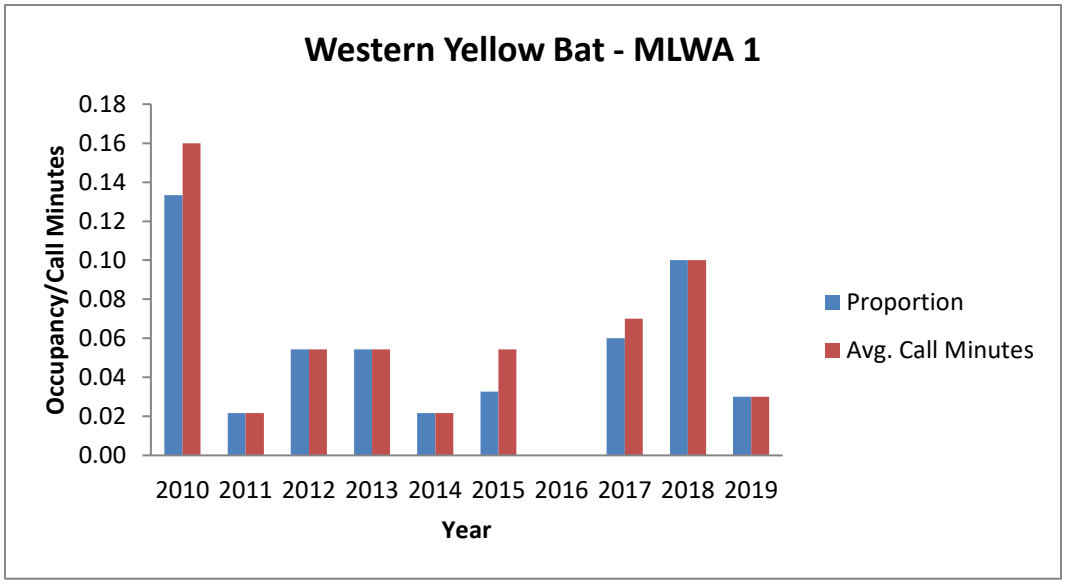

Figure 19.—Western yellow bat average nightly call minutes and proportion of nights occupied at MLWA 1.

Western Yellow Bat – HNWR-Pintail

The greatest average nightly call minutes at HNWR-Pintail were recorded during the 2015 season followed by 2016, 2018, 2014, and 2017 (figure 20). The proportion of nights occupied at HNWR-Pintail did not correspond with average nightly call minutes, with the 2018 season having higher average call minutes but a lower proportion of nights occupied than the 2014 and 2017 seasons. The greatest proportion of nights occupied at HNWR-Pintail were recorded during the 2015 season followed by 2016, 2014, 2017, and 2018. No activity was recorded during the 2019 season. The 2015 season had the greatest activity, with 0.06 call minutes per night and 5% of nights occupied.

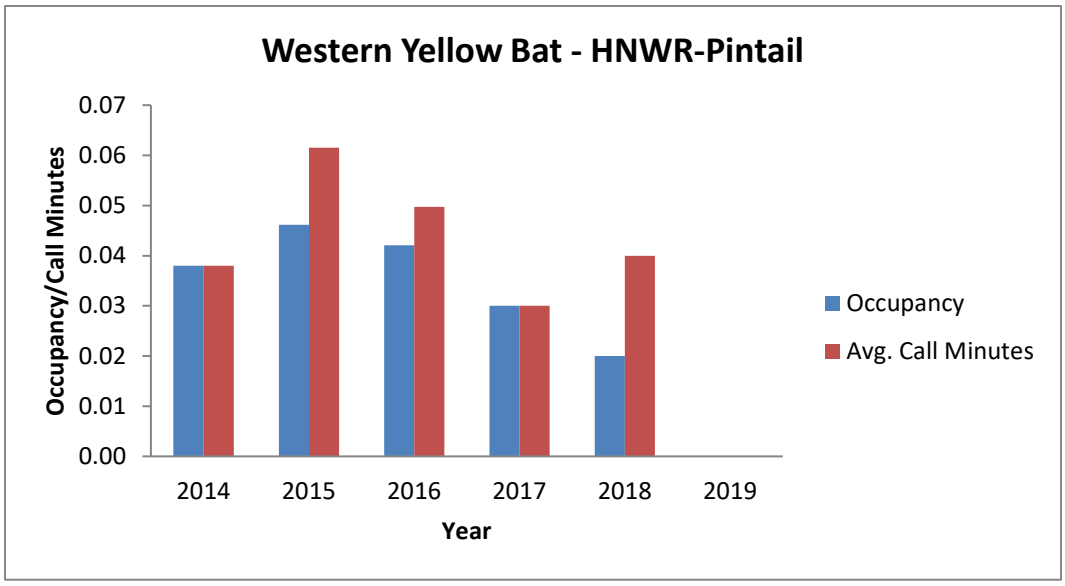

Figure 20.—Western yellow bat average nightly call minutes and proportion of nights occupied at HNWR-Pintail.

Western Yellow Bat – AKTP 1

The greatest average nightly call minutes and proportion of nights occupied at AKTP 1 were recorded during the 2016 season followed by 2015 (figure 21). No activity was recorded during the 2017, 2018, or 2019 seasons.

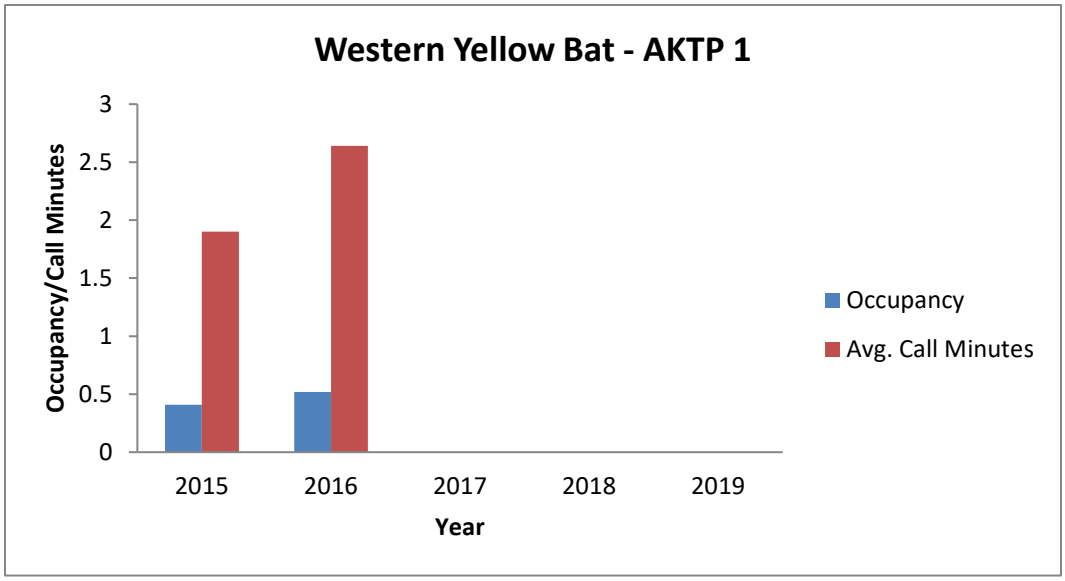

Figure 21.—Western yellow bat average nightly call minutes and proportion of nights occupied at AKTP 1.

Western Yellow Bat – YEW 1

The greatest average nightly call minutes at YEW 1 were recorded during the 2015 season followed by 2019, 2017, and 2016 (figure 22). The average nightly call minutes did not correspond with the proportion of nights occupied for the 2016 and 2017 seasons. The 2017 season had higher average nightly call minutes, but the 2016 season had a slightly higher proportion of nights occupied. The 2015 season had the greatest activity, with 2.55 call minutes per night and 70% of nights occupied, as compared to the 2018 season, with no activity recorded.

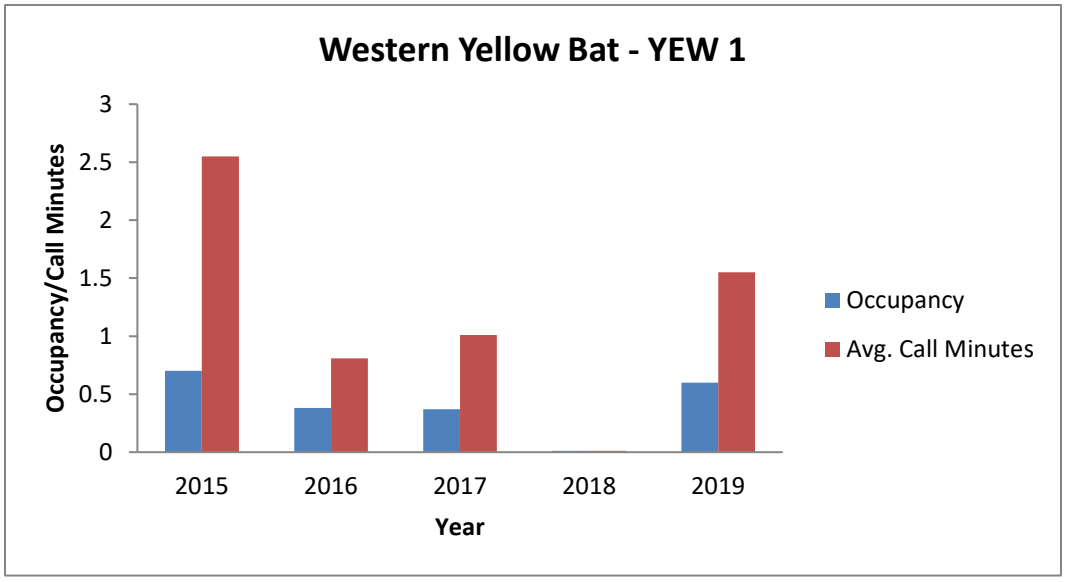

Figure 22.—Western yellow bat average nightly call minutes and proportion of nights occupied at YEW 1.

Western Yellow Bat – HH 1

The greatest average nightly call minutes at HH 1 were recorded during the 2019 season followed by 2015, 2017, 2016, and 2018 (figure 23). The proportion of nights occupied did not correspond with average nightly call minutes. The greatest proportion of nights occupied were recorded during the 2015 season followed by 2016/2017 (equally), 2019, and 2018. The 2019 season had the greatest activity, with 0.63 call minutes per night and 23% of nights occupied, as compared to the 2018 season, with the lowest activity of 0.04 call minutes per night and 4% of nights occupied.

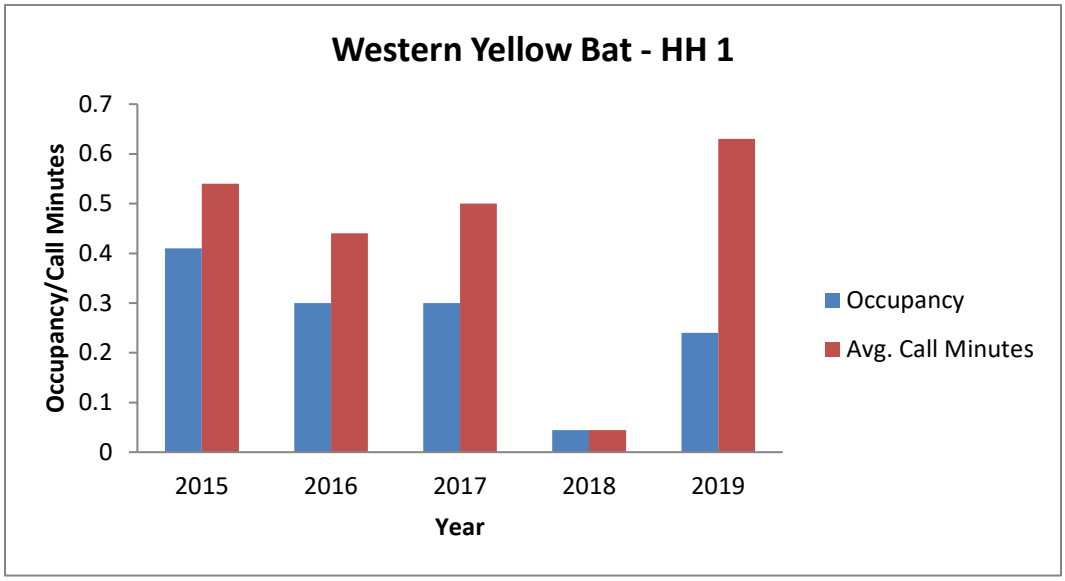

Figure 23.—Western yellow bat average nightly call minutes and proportion of nights occupied at HH 1.

California Leaf-nosed Bat

California Leaf-nosed Bat – BWRNWR 1

The greatest average nightly call minutes at BWRNWR 1 was recorded during the 2013 season followed by 2018, 2017, 2016/2019 (equally), 2015, 2012, 2014, and 2010 (figure 24). The proportion of nights occupied at BWRNWR 1 did not correspond with average nightly call minutes. The 2016 and 2019 seasons had higher average nightly call minutes but a lower proportion of nights occupied than the 2015 season. The greatest proportion of nights occupied were recorded during the 2013 season followed by 2018, 2017, 2015, 2016/2019 (equally), 2012, and 2013. The 2013 season had the greatest activity, with 0.61 call minutes per night and 38% of nights occupied, as compared to the 2011 season, with no activity recorded.

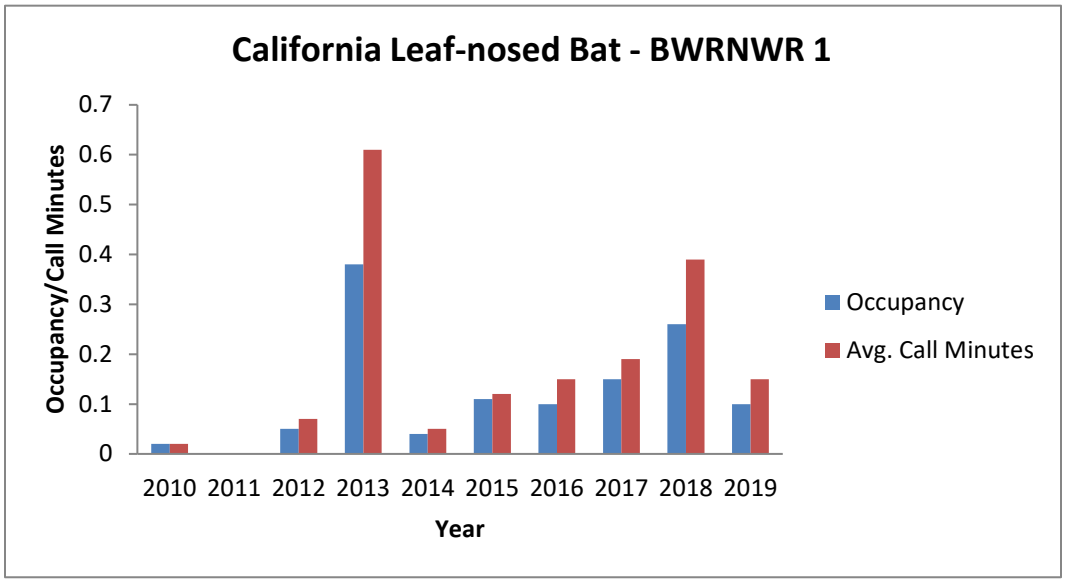

Figure 24.—California leaf-nosed bat average nightly call minutes and proportion of nights occupied at BWRNWR 1.

California Leaf-nosed Bat – CNWR-Island

The greatest average nightly call minutes at CNWR-Island were recorded during the 2010 and 2017 seasons (equally) followed by 2012, 2018, 2019, 2016, 2011, 2015, and 2013 (figure 25). No activity was recorded during the 2014 season. The proportion of nights occupied at CNWR-Island did not consistently correspond with average nightly call minutes. The 2010 and 2017 seasons had an equal amount of average nightly call minutes, but the 2017 season had a higher proportion of nights occupied. The 2010 and 2018 seasons had an equal amount of proportion of nights occupied, but the 2010 season had greater average nightly call minutes. The greatest proportion of nights occupied were recorded during the 2017 season followed by 2010 and 2018, 2012, 2019, 2016/2011 (equally), 2015, and 2013. The 2010 and 2017 seasons recorded the greatest activity, with 0.11 call minutes per night, and 2017 had the greatest proportion of nights occupied (11%).

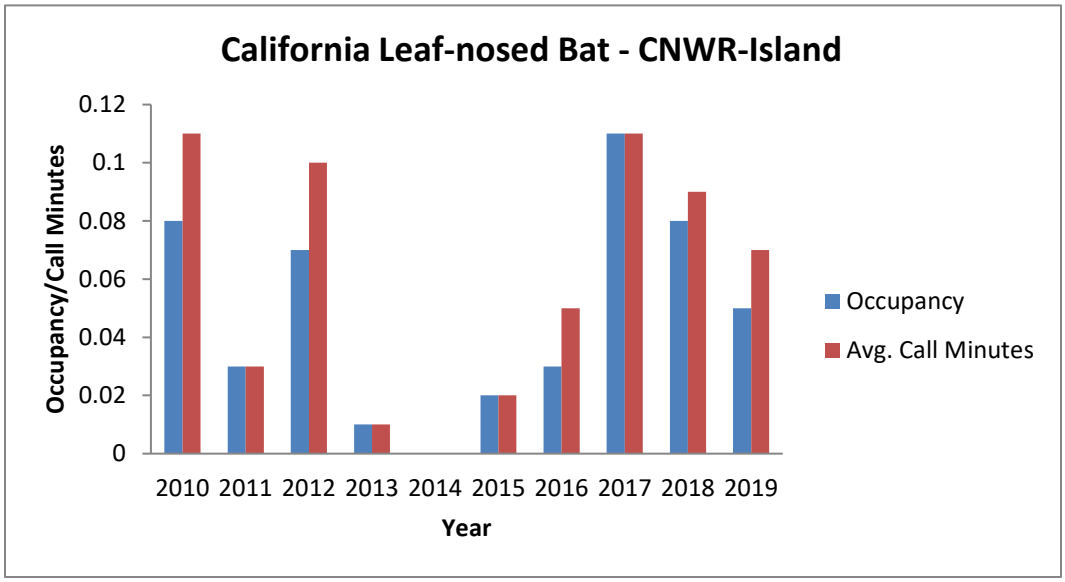

Figure 25.—California leaf-nosed bat average nightly call minutes and proportion of nights occupied at CNWR-Island.

California Leaf-nosed Bat – PSRA 1

The greatest average nightly call minutes were recorded at PSRA 1 during the 2013 and 2014 seasons (equally) followed by 2012, 2015, 2016, 2011/2017 (equally), and 2018/2019 (equally) (figure 26). The proportion of nights occupied at PSRA 1 did not consistently correspond with average nightly call minutes. The 2013 and 2014 seasons had the same average nightly call minutes, but the 2013 season had a higher proportion of nights occupied. Similarly, the 2018 and 2019 seasons had the same average nightly call minutes, but the 2019 season had a higher proportion of nights occupied. The 2012 and 2015 seasons had the same proportion of nights occupied, but the 2012 season had higher average nightly call minutes. The 2011 and 2016 seasons also had the same proportion of nights occupied, with the 2016 season having higher average nightly call minutes. The 2011 and 2017 seasons had an equal amount of average nightly call minutes, but the 2011 season had a slightly higher proportion of nights occupied. The greatest proportion of nights occupied was recorded during the 2013 season followed by 2014, 2012/2015 (equally), 2011/2016 (equally), 2017, 2019, and 2018. The 2013 season had the greatest activity, with 0.39 call minutes per night and 28% of nights occupied, as compared to the 2010 season, with no activity recorded.

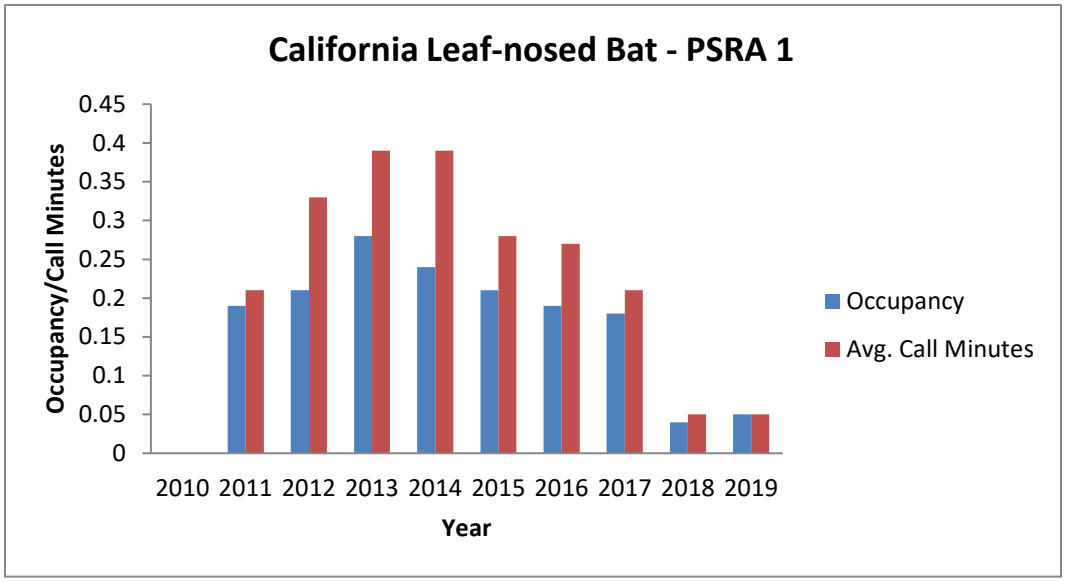

Figure 26.—California leaf-nosed bat average nightly call minutes and proportion of nights occupied at PSRA 1.

California Leaf-nosed Bat – MLWA 1

The greatest average nightly call minutes at MLWA 1 were recorded during the 2016 season followed by 2010, 2013, 2017, 2019, 2018, 2011, and 2012 (figure 27). No activity was recorded during the 2014 or 2015 seasons. The proportion of nights occupied at MLWA 1 did not correspond with average nightly call minutes in all cases. The 2013 and 2017 seasons had an equal proportion of nights occupied, but the 2013 season had a greater number of average nightly call minutes. The greatest proportion of nights occupied were recorded during the 2016 season followed by 2010, 2013/2017 (equally), 2019, 2018, 2011, and 2012. The 2016 season had the greatest activity, with 0.30 call minutes per night and 20% of nights occupied.

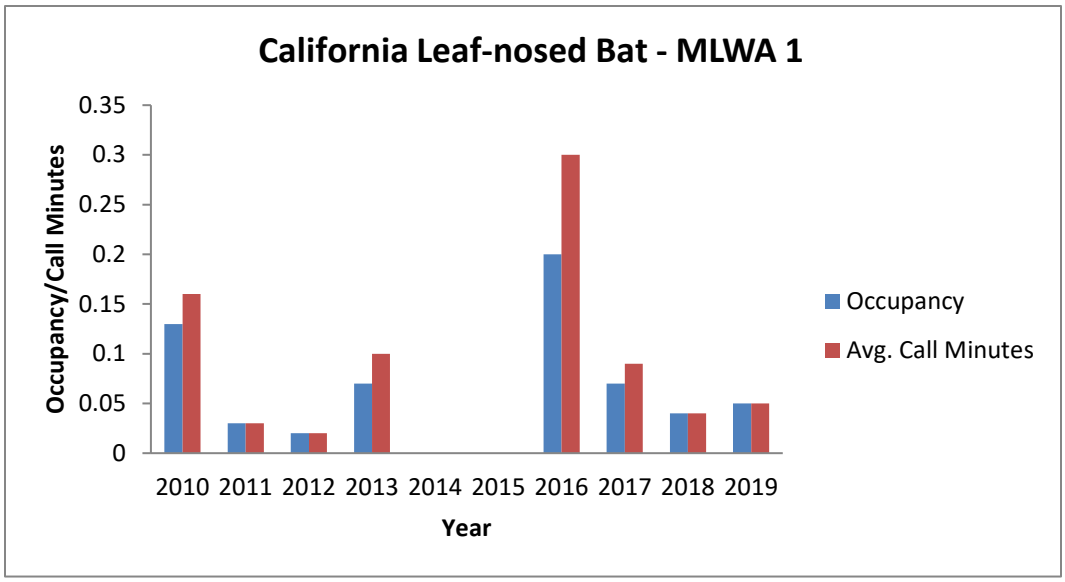

Figure 27.—California leaf-nosed bat average nightly call minutes and proportion of nights occupied at MLWA 1.

California Leaf-nosed Bat – HNWR-Pintail

The greatest average nightly call minutes and proportion of nights occupied at HNWR-Pintail were recorded during the 2017 season (figure 28). No activity was recorded during the 2014, 2015, 2016, 2018, or 2019 seasons.

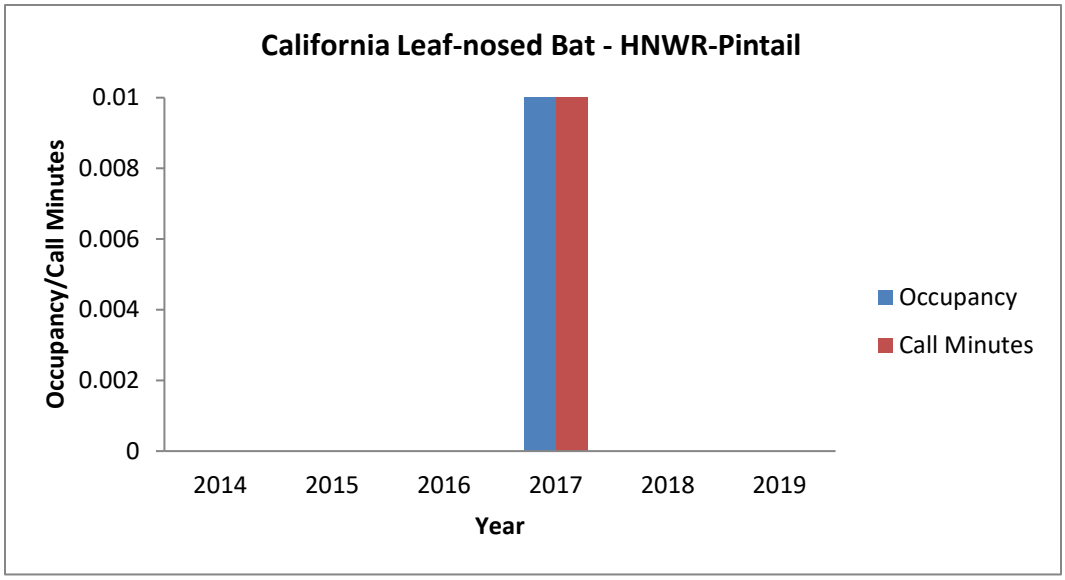

Figure 28.—California leaf-nosed bat average nightly call minutes and proportion of nights occupied at HNWR-Pintail.

California Leaf-nosed Bat – AKTP 1

The greatest average nightly call minutes and proportion of nights occupied at AKTP 1 were recorded during the 2018 season followed by 2017 and 2016 (figure 29). No activity was recorded during the 2015 or 2019 seasons.

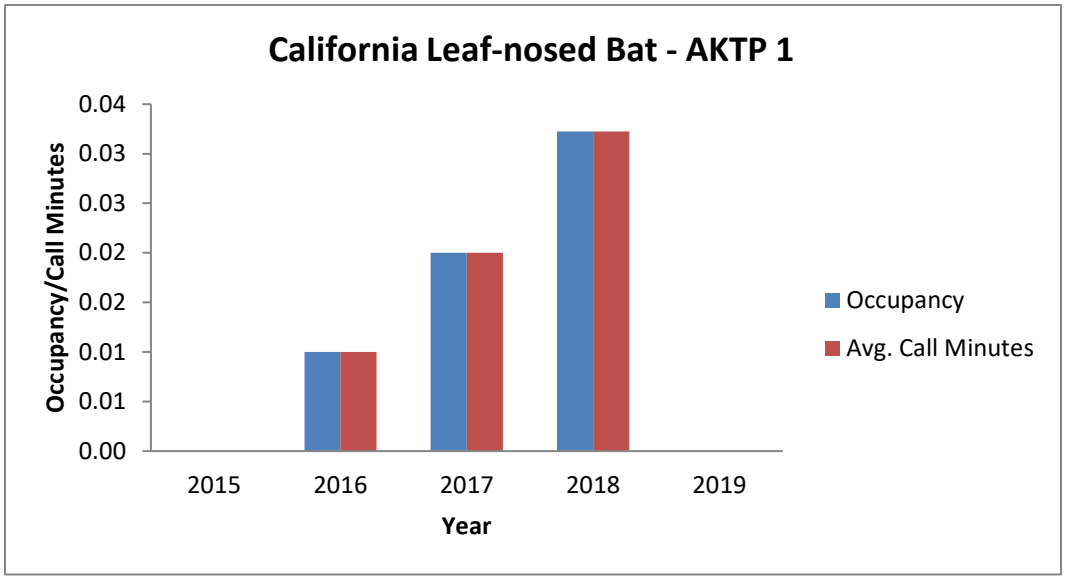

Figure 29.—California leaf-nosed bat average nightly call minutes and proportion of nights occupied at AKTP 1.

California Leaf-nosed Bat – YEW 1

The greatest average nightly call minutes and proportion of nights occupied at YEW 1 were recorded during the 2015 season followed by 2017 and 2019 (equally) (figure 30). No activity was recorded during the 2016 or 2018 seasons.

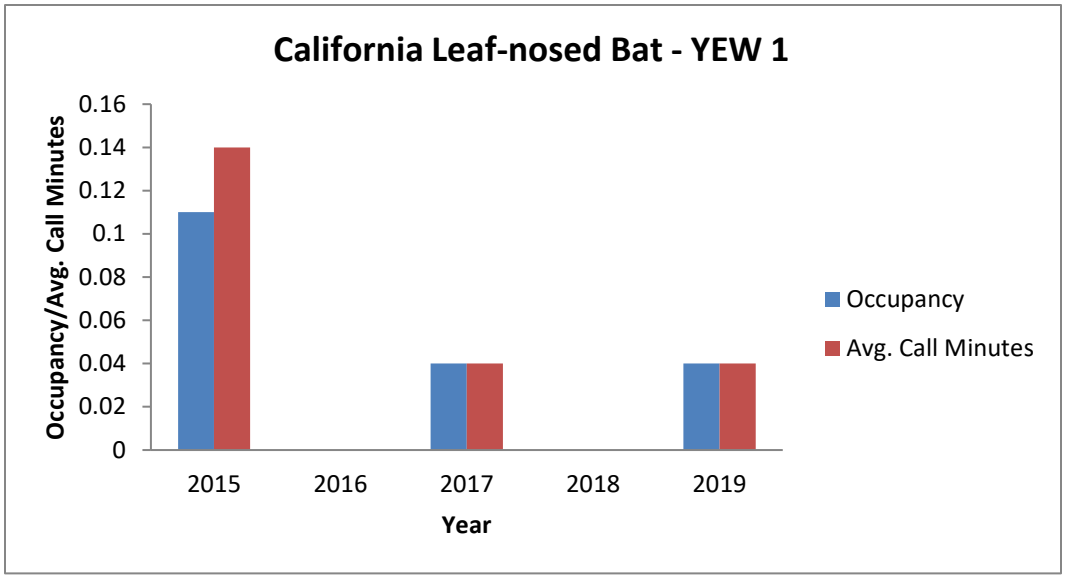

Figure 30.—California leaf-nosed bat average nightly call minutes and proportion of nights occupied at YEW 1.

California Leaf-nosed Bat – HH 1

The greatest average nightly call minutes at HH 1 was recorded during the 2019 season followed by 2017, 2018, and 2016 (figure 31). The average nightly call minutes and the proportion of nights occupied did not correspond exactly, with the 2018 season having a greater proportion of nights occupied but less average nightly call minutes than the 2017 season. No activity was recorded during the 2016 or 2018 seasons. The 2019 season had the greatest activity, with 0.17 call minutes per night and 10% of nights occupied, as compared to the 2015 season, with no activity recorded.

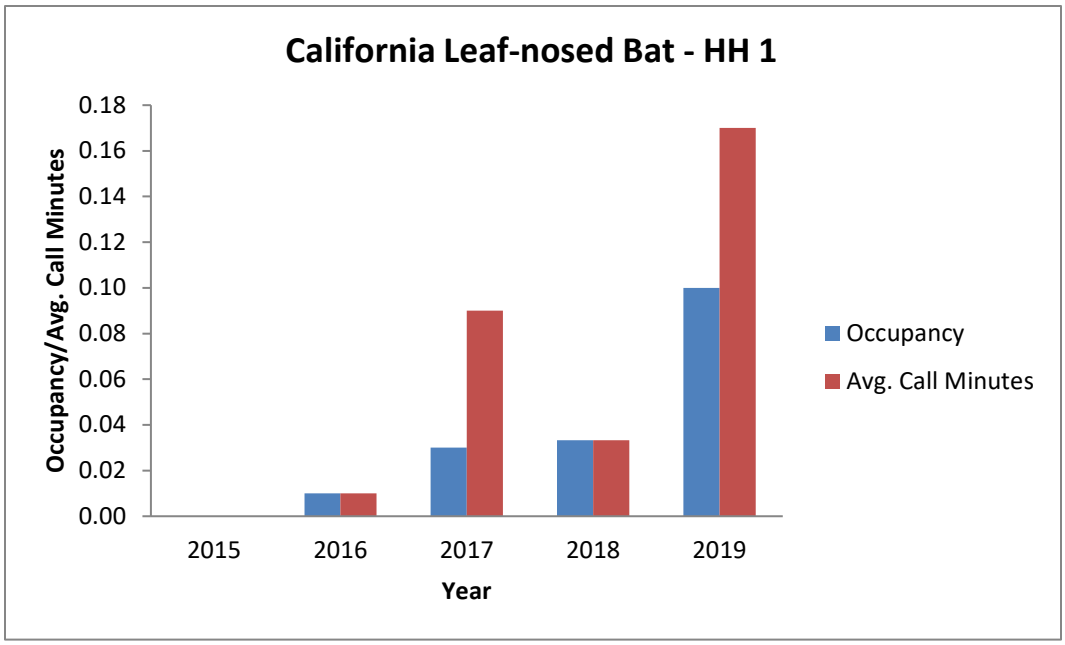

Figure 31.—California leaf-nosed bat average nightly call minutes and proportion of nights occupied at HH 1.

Yearly Activity and Occupancy Over All Sites

Western Red Bat

At the five original system-wide sites monitored since 2010, western red bat average nightly call minutes and proportion of nights occupied peaked in 2010 and 2011 (figure 32). The 2014 season saw a relatively high amount of activity and occupancy, but overall lower levels of activity and occupancy have been recorded after the 2010 and 2011 seasons, with the lowest levels of activity and occupancy recorded in 2017 and 2019.

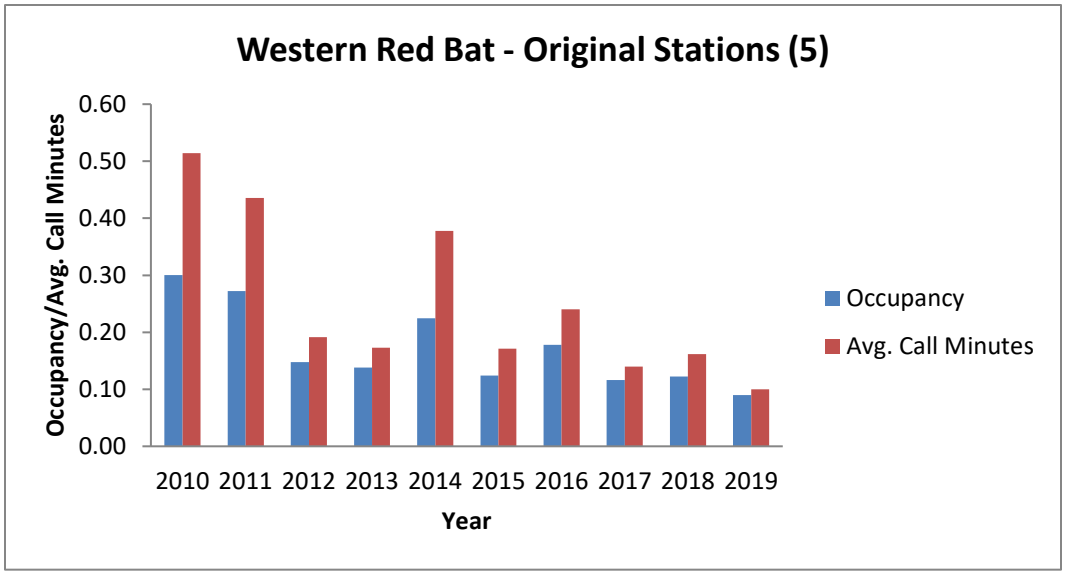

Figure 32.—Western red bat average nightly call minutes and proportion of nights occupied at all original system-wide stations.

At the eight system-wide sites, consistent monitoring has occurred since 2015, allowing for a comparison between years from 2015 through 2019. The greatest average nightly call minutes and proportion of nights occupied were recorded in 2016 followed by 2018, 2017, and 2015/2019 (equally) (figure 33).

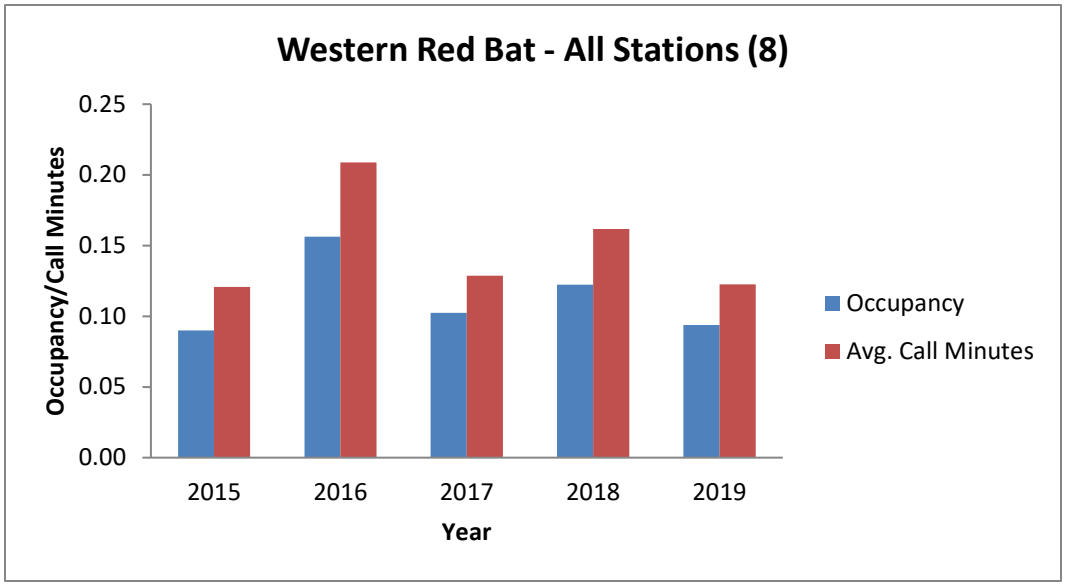

Figure 33.—Western red bat average nightly call minutes and proportion of nights occupied at system-wide stations, using new methodology.

The greatest average nightly call minutes and proportion of nights occupied aggregated across all sample years were recorded at BWRNWR 1 followed by MLWA 1, YEW 1, CNWR-Island, HNWR-Pintail, PSRA 1, AKTP 1 and HH 1 (figure 34). CNWR-Island and YEW 1 had an equal amount of occupancy, but YEW 1 had a slightly higher number of average nightly call minutes.

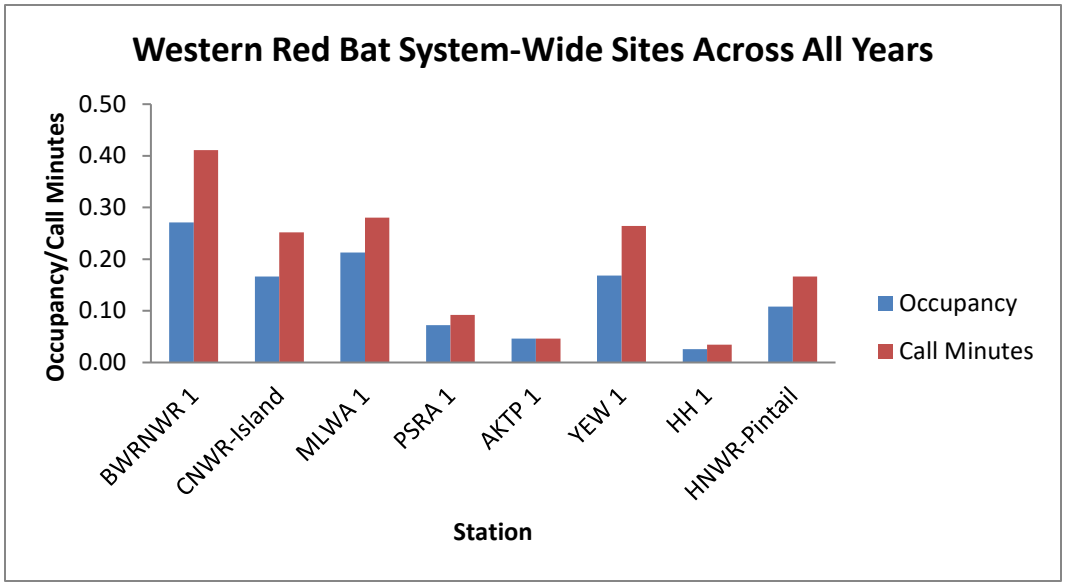

Figure 34.—Western red bat average nightly call minutes and proportion of nights occupied at system-wide stations across all years.

Western Yellow Bat

At the five original system-wide sites monitored since 2010, western yellow bat average nightly call minutes and proportion of nights occupied peaked in 2010 and 2011 (figure 35). Lower levels of activity and occupancy have been recorded after the 2010 and 2011 seasons, with the lowest levels of activity and occupancy recorded in 2015 and 2019.

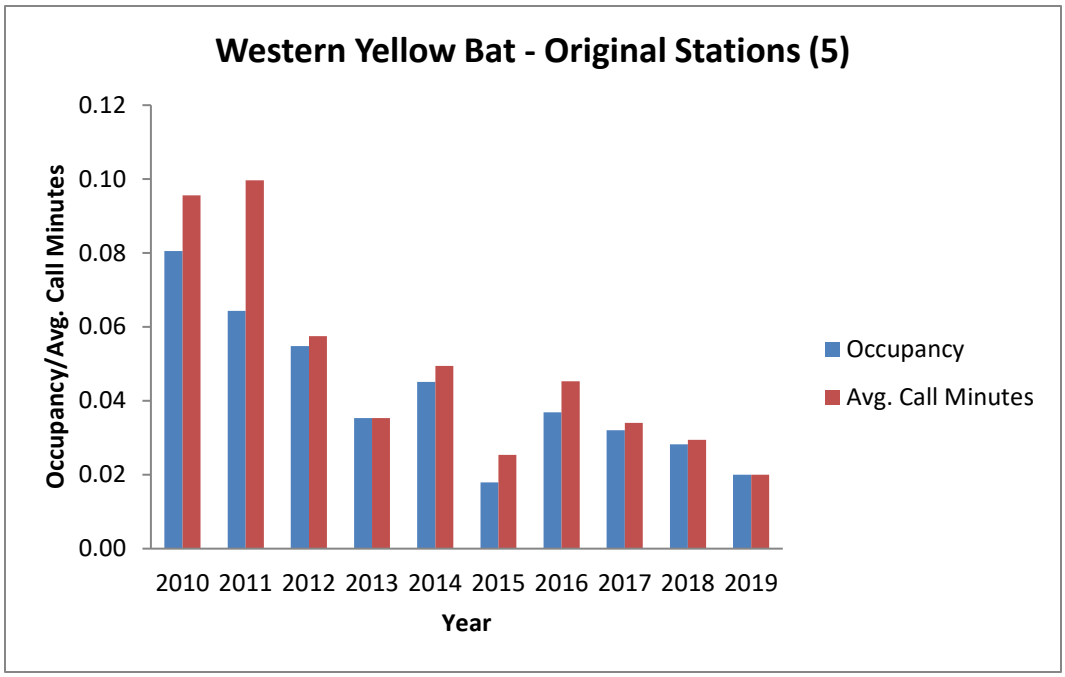

Figure 35.—Western yellow bat average nightly call minutes and proportion of nights occupied at all original system-wide stations.

At the eight system-wide sites, consistent monitoring has occurred since 2015, allowing for a comparison between years from 2015 through 2019. The greatest average nightly call minutes and proportion of nights occupied were recorded in 2015 followed by 2016, 2019, 2017, and 2018 (figure 36).

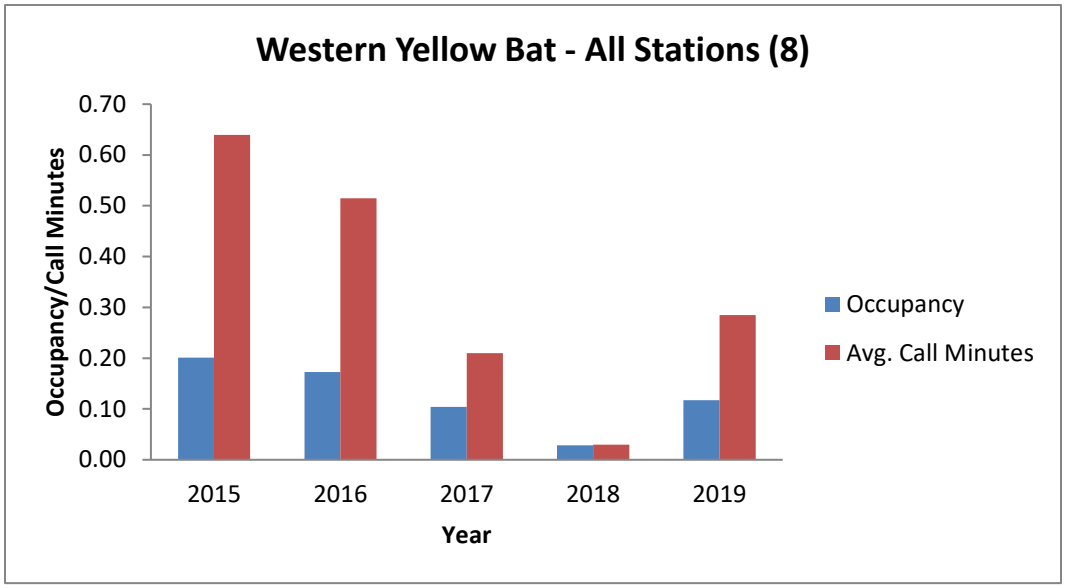

Figure 36.—Western yellow bat average nightly call minutes and proportion of nights occupied at all system-wide stations, using new methodology.

The greatest average nightly call minutes and proportion of nights occupied aggregated across all sample years were recorded at YEW 1. HH 1 had the next greatest proportion of nights occupied followed by AKTP 1, but AKTP 1 had far greater average nightly call minutes than HH 1. BWRNWR 1 and MLWA 1 had an equal proportion of nights occupied, but BWRNWR 1 had greater average nightly call minutes. MLWA 1 and CNWR-Island had an equal amount of average nightly call minutes, but MLWA 1 had a slightly higher proportion of nights occupied. HNWR-Pintail and PSRA 1 had the least amount of average nightly call minutes and proportion of nights occupied (figure 37).

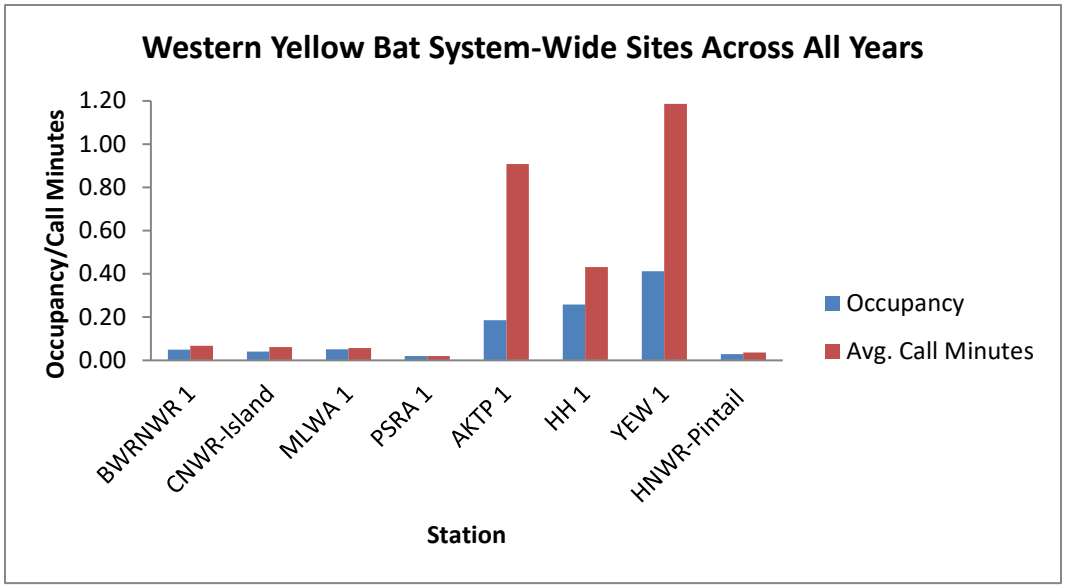

Figure 37.—Western yellow bat average nightly call minutes and proportion of nights occupied at all system-wide stations, using new methodology.

California Leaf-nosed Bat

At the five original system-wide sites monitored since 2010, California leaf-nosed bat average nightly call minutes and proportion of nights occupied were highest in 2013 followed by 2016 (figure 38). The 2012 season had a higher number of average nightly call minutes than 2017, but 2017 had a higher proportion of nights occupied. The lowest levels of activity and occupancy were recorded in 2010, 2011, 2019, 2014, and 2015.

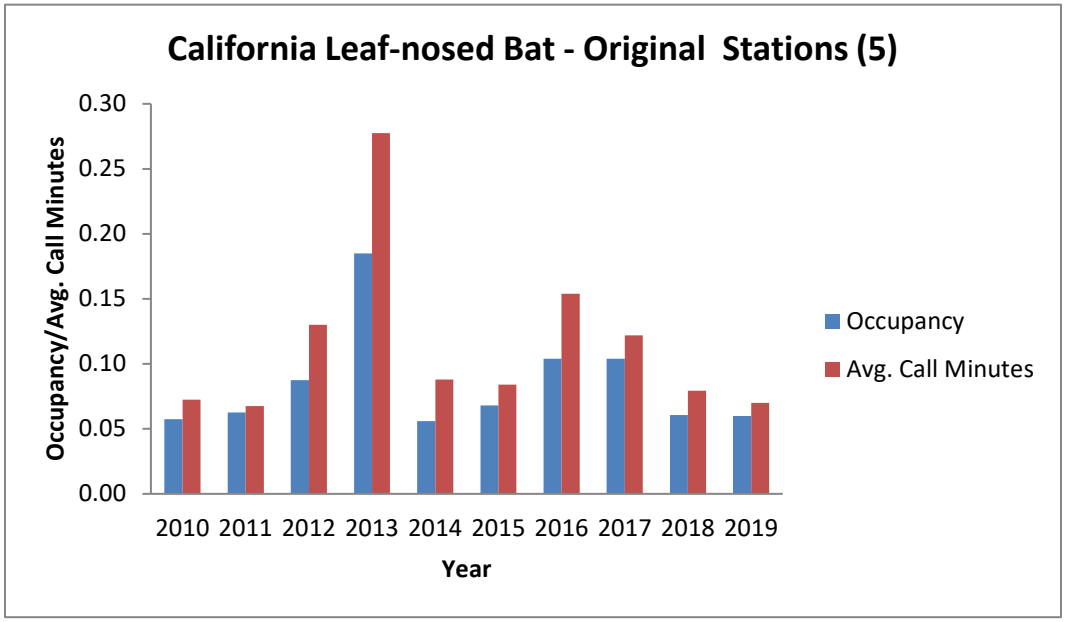

Figure 38.—California leaf-nosed bat average nightly call minutes and proportion of nights occupied at all original system-wide stations.

At the eight system-wide sites, consistent monitoring has occurred since 2015, allowing for a comparison between years from 2015 through 2019. The greatest average nightly call minutes were recorded in 2016 followed by 2017, 2018, 2015, and 2019 (figure 39). Average nightly call minutes did not correspond with proportion of nights occupied. The greatest proportion of nights occupied were recorded in 2017 followed by 2016, 2018, 2015, and 2019 (figure 39).

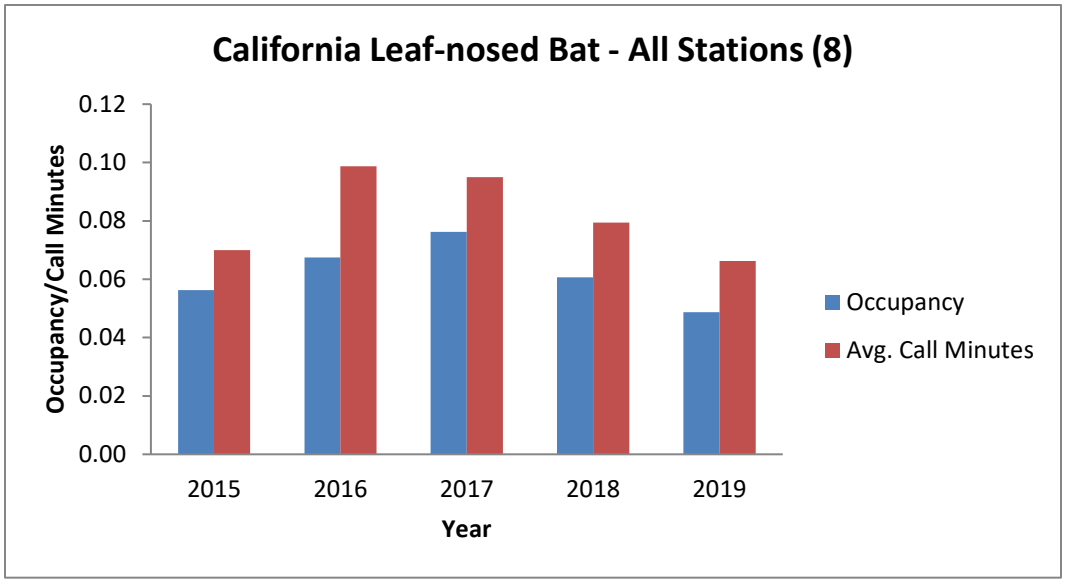

Figure 39.—California leaf-nosed bat average nightly call minutes and proportion of nights occupied at all system-wide stations, using new methodology.

The greatest average nightly call minutes and proportion of nights occupied aggregated across all sample years were recorded at PSRA 1 followed by BWRNWR 1, MLWA 1 and CNWR-Island. YEW 1 had a higher proportion of nights occupied than HH 1, but HH 1 had higher average nightly call minutes. AKTP 1 and HNWR-Pintail had the least amount of average nightly call minutes and proportion of nights occupied (figure 40).

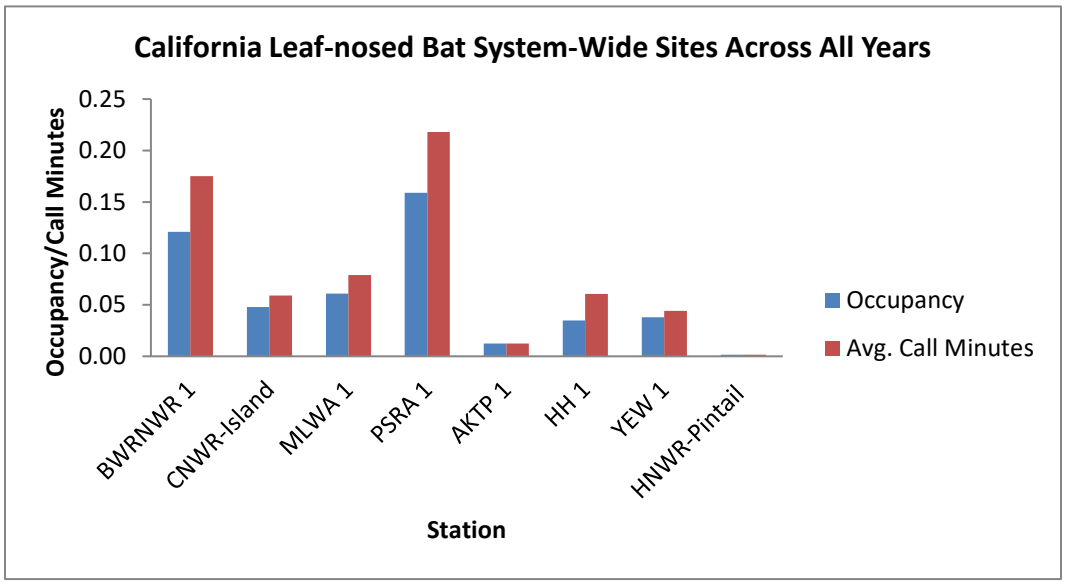

Figure 40.—California leaf-nosed bat average nightly call minutes and proportion of nights occupied at all system-wide stations, using new methodology.

DISCUSSION

Western Red Bat

This year, three stations were added: AKTP 1, HH 1, and YEW 1. The original five system-wide stations consisted of four deployed in completely unmanaged habitat and the fifth in a restoration planting that is no longer actively managed. AKTP 1, HH 1, and YEW 1 are all located in mature restoration sites that routinely receive irrigation. This change in methodology could lead to a misrepresentation of activity and occupancy at unmanaged sites; therefore, the findings are presented by comparing the original stations as well as all eight stations.

The greatest average nightly call minutes and proportion of nights occupied for western red bats in 2019 was recorded at YEW 1. The second greatest activity for western red bats in 2019 was recorded at BWRNWR 1 followed by CNWR-Island, HNWR-Pintail, PSRA 1, and MLWA 1 (equally), and AKTP 1. No activity was recorded at HH 1 in 2019 (see table 2).

Activity fluctuates from year to year and between sites. In general, activity and occupancy has appeared to decrease at the original five stations from 2010, with 2019 having the least recorded, aggregated average nightly call minutes and proportion of nights occupied across these stations. Activity and occupancy at all eight stations from 2015 through 2019 fluctuated much less, with 2016 seeing the greatest activity and occupancy and 2015/2019 (equally) the least. The only site where the greatest activity and occupancy were recorded in 2019 compared to all other years was at YEW 1 (see figure 14). The high activity and occupancy may be partly explained by the station malfunctioning and potentially recording only during times corresponding with higher activity and occupancy (53 of 92 possible nights recorded). The lowest activity and occupancy recorded at YEW 1 occurred during the 2015 season (see figure 14). MLWA 1 and HH 1 recorded the lowest activity and occupancy since deployment in 2019 (see figures 10 and 15). MLWA 1 recorded the greatest activity and occupancy during the 2011 and 2014 seasons, with an equal amount of activity, and 2014 having a greater proportion of nights occupied (see figure 10). BWRNWR 1 recorded the fourth lowest activity and occupancy since deployment in 2019, with the greatest recorded in 2010 and the least in 2013 and 2017 (equal activity with greater occupancy in 2013) (see figure 8). CNWR-Island had the fourth lowest activity and occupancy, with the greatest recorded in 2010 and the least in 2015 (see figure 9). PSRA 1 was lower, on average, for 2019 and recorded the fifth highest occupancy but the fourth lowest activity. The greatest activity and occupancy recorded at PSRA 1 took place in 2016 and the least in 2010 (see figure 11). AKTP 1 had the second highest activity and occupancy in 2019, with the greatest recorded in 2016 and the least in 2015, 2017, and 2018 equally (see figure 13). HNWR-Pintail had the second lowest activity and occupancy recorded in 2019, with the greatest recorded in 2014 and the least in 2017 (see figure 12).

A fire occurred at CNWR-Island on August 29, 2011, burning the surrounding cottonwood-willow habitat that may have served as roosting and foraging habitat for western red bats. While the habitat seems to be recovering, activity and occupancy have yet to recover to pre-fire levels. Similarly, a fire started at HNWR-Pintail on August 8, 2015. The area surrounding the station burned but left it operational, and a patch of cottonwoods near the station were also left unburned. The surrounding habitat may be starting to recover, but activity and occupancy levels have remained low compared to the pre-fire levels of 2014.

The greatest overall average nightly call minutes for western red bats between 2010 and 2019 was recorded at BWRNWR 1 followed by MLWA 1, YEW 1, CNWR-Island, HNWR-Pintail, PSRA 1, AKTP 1 and HH 1. Aggregated average nightly call minutes and proportion of nights occupied fluctuate from year to year for western red bats, but there does seem to be a downward trend at the original five sites since the start of monitoring in 2010. This downward trend may be associated with natural variations in the life cycle of western red bats or a change in patches of suitable foraging and roosting habitat they use along the LCR (see figures 32, 33, and 34).

Western Yellow Bat

The greatest average nightly call minutes and proportion of nights occupied for western yellow bats in 2019 was recorded at YEW 1 followed by HH 1, MLWA 1, and PSRA 1. No activity was recorded at AKTP 1, BWRNWR 1, CNWR-Island, or HNWR-Pintail in 2019 (see table 3).

Across all system-wide monitoring sites, activity for western yellow bats varied between 2010 and 2019. Overall, low levels of activity and occupancy were detected at the original five system-wide sites in June, July, and August. This species has been recorded using system-wide monitoring sites largely during migration periods (May and September) (Mixan and Diamond 2016). Western yellow bats almost exclusively utilize non-native palms (*Washingtonia robusta* and *Washingtonia filifera*) as roosts. These palms are dispersed sparsely around system-wide monitoring sites. This sparse dispersal of roosting habitat is likely associated with the lack of western yellow bat activity recorded during the June, July, and August sampling period.

The addition of the new sites (AKTP 1, HH 1 and YEW 1) has increased activity and occupancy at system-wide sites. These sites are located in mature restoration areas surrounded by agricultural fields and some residential development. These surroundings provide more roosting opportunities in non-native palms than the original sites, leading to greater activity and occupancy. Like western red bats, there seems to be a downward trend at original system-wide locations since 2010 and 2011, with the least amount of occupancy recorded in 2019 (equal to 2015) and the least amount of average nightly call minutes (see figure 35). Comparing

all eight stations since 2015, a downward trend appears, but it is not as pronounced as at the original sites, with 2019 having greater activity and occupancy than 2017 and 2018, but substantially less than 2015 and 2016 (see figure 36). A cause for this drop in activity since 2016 can partially be explained by the lack of calls at AKTP 1 from 2017 through 2019. This station recorded a large degree of acoustic activity and occupancy in 2015 and 2016 but none from 2017 through 2019. The station malfunctioned in 2017 and recorded a large volume of low frequency calls in 2018 (see figure 21). It was thought that the microphone could be malfunctioning or that clutter from overgrown vegetation or insects could be causing the detector to record poor quality calls. The detector and microphone were replaced for the 2019 season, and vegetation was trimmed from around the microphone, but similar problems persisted with a large volume of low-frequency calls recorded. The microphone sensitivity was dialed back in an attempt to preserve space on CF cards and to eliminate any potential data gaps. It is possible a water pump or other piece of machinery is causing interference with this detector; moving the station to alleviate this problem should be explored prior to the next recording season.

The greatest activity and occupancy aggregated across years has been recorded at YEW 1 followed by HH 1 and AKTP 1. HH 1 had greater occupancy than AKTP 1, but AKTP 1 had greater average nightly call minutes (see figure 37). AKTP 1 had the second highest average nightly call minutes and third highest occupancy despite recording no calls from 2017 through 2019 (see figure 21). Western yellow bats have been captured and recorded at AKTP 1 in previous studies (Diamond et al. 2012), and their acoustic absence is believed to be the result of a malfunctioning detector and/or mechanical noise interference and not a true absence. The least amount of activity and occupancy was recorded at PSRA 1 from 2010 through 2019 (see figure 37).

The stations with the greatest activity and occupancy (AKTP 1, HH 1, and YEW 1) are located in mature conservation areas that are in closer proximity to a larger number of available roosting sites and most likely provide a greater opportunity to forage.

California Leaf-nosed Bat

Activity for California leaf-nosed bats in 2019 was greatest at HH 1 followed by BWRNWR 1, CNWR-Island, MLWA 1 and PSRA 1, and YEW 1. CNWR-Island, MLWA 1, and PSRA 1 had the same occupancy, but CNWR-Island had greater average nightly call minutes. No activity was recorded at AKTP 1 or HNWR-Pintail (see table 4).

The greatest activity and occupancy recorded at BWRNWR 1 from 2010 through 2019 occurred during the 2013 season, with the least in 2011 (see figure 24). The greatest activity recorded at CNWR-Island was recorded in the 2010 and 2017

seasons, with an equal amount of activity, but the 2017 season had a greater proportion of nights occupied. The least amount of activity and occupancy at CNWR-Island was recorded during the 2014 season (see figure 25). At PSRA 1, the greatest activity and occupancy occurred during the 2013 and 2014 seasons with an equal amount of activity, but the 2013 season had a greater proportion of nights occupied. The least amount of activity and occupancy was recorded during the 2010 season (see figure 26). The greatest amount of activity and occupancy recorded at MLWA 1 occurred during 2016, with the least recorded in 2014 and 2015 (see figure 27). Only one California leaf-nosed bat call has been recorded at HNWR-Pintail from 2014 through 2019. This call was recorded in June during the 2017 season (see figure 28). The highest activity and occupancy recorded at HH 1 from 2015 through 2019 was recorded in 2019, with the least in 2015 (see figure 31). The greatest activity and occupancy at AKTP 1 occurred during 2018, with the least in 2015 and 2019 equally (see figure 29). The above-mentioned malfunctions and probable noise interference at AKTP 1 are almost certainly the reason no activity was recorded in 2019, as this species has been captured at AKTP 1 in the past. At YEW 1, the greatest activity and occupancy was recorded during 2015, with the least in 2016 and 2018 (see figure 30).

Across all the original system-wide sites aggregated across years from 2010 through 2019, California leaf-nosed bat activity and occupancy was relatively stable, with the exception of 2013, which had substantially greater activity and occupancy than any other season. The lowest activity and occupancy was recorded equally in 2010, 2011, and 2019 (see figure 38). Similarly, activity and occupancy were relatively stable at all eight stations from 2015 through 2019, with the lowest activity recorded equally in 2015 and 2019, and the lowest occupancy recorded in 2019. Recorded activity and occupancy was within 0.03 of the highest and lowest years from 2015 through 2019 (see figure 39).

California leaf-nosed bat activity and occupancy varied between sites from 2010 through 2019. The greatest activity and occupancy were recorded at PSRA 1 followed by BWRNWR 1, MLWA 1, CNWR-Island, HH 1, YEW 1, AKTP 1, and HNWR-Pintail. CNWR-Island and HH 1 had an equal amount of average nightly call minutes, but CNWR-Island had a higher proportion of nights occupied (see figure 40).

Pale Townsend's Big-eared Bat

Because of the conservative method of identifying pale Townsend's big-eared bat calls to species and subspecies, and the nature of their whispering calls, only one call was recorded at any site (BWRNWR 1) in 2019. One pale Townsend's big-eared bat call was recorded during 2016 monitoring at BWRNWR 1. Other calls were recorded between 2010 and 2016 during June, July, and August: two calls and two days of occupancy at BWRNWR 1 in 2013 and 1 call and 1 day of occupancy at CNWR-Island in 2013.

Summer Residency

Summer residency for western red bats and western yellow bats at system-wide monitoring sites along the LCR varies from year to year, and these species are likely present in low density as compared to the conservation areas (Mixan and Diamond 2016). Historically, little documentation for these species had been reported along the LCR. Western yellow bats were first recorded along the LCR in Yuma, Arizona (Constantine 1966), with single yearly records occurring in the 1980s (Constantine 1998) and 1990s (Brown 1996). Western yellow bats were also captured at the Bill Williams River National Wildlife Refuge in the 1990s (Brown 1996). They have now been captured in at least seven LCR MSCP conservation areas and use these areas frequently to forage (Diamond et al. 2012). The level of activity detected for western yellow bats at system-wide monitoring sites may be consistent with activity along the LCR, pre-implementation of the conservation areas. Western red bat documentation along the LCR was similarly lacking. Western red bats had been captured in tributaries of the LCR (including at the Bill Williams Wildlife Refuge) and recorded acoustically in 2001 and 2002 at the Havasu and Imperial National Wildlife Refuges (Brown 2006), but the first western red bat captured along the main stem of the LCR occurred in 2009 at the ‘Ahahkav Tribal Preserve (Calvert and Neiswenter 2012). As with western yellow bats, the activity detected for western red bats at system-wide monitoring sites may be consistent with activity along the LCR before implementation of the conservation areas. However, there is a downward trend in activity and occupancy for western red bats and western yellow bats at the original system-wide sites from 2010 through 2019, with the 2010 and 2011 seasons having the highest aggregated activity and occupancy for both species. It is possible as conservation area sites mature, they may provide preferable foraging habitat for western yellow bats and preferable foraging and roosting habitat for western red bats.

California leaf-nosed bats were first recorded along the LCR by Grinnell (1918) and are year-round residents with several large maternity, bachelor, and winter roosts. California leaf-nosed bat distribution and activity is limited by the distance they forage from their cavern roosts, which has been recorded at 10.9 miles (Maturango Museum and Brown-Berry Biological Consulting 2018). Activity at the four deployed stations in completely unmanaged habitat and the fifth in a restoration planting that is no longer actively managed is likely comparable to activity along the LCR before restoration of the conservation areas, though foraging affinities may have changed for this species as conservation areas matured. California leaf-nosed bats are foraging generalists, and it is plausible that conservation areas may be supporting a more abundant or preferred prey source than system-wide monitoring sites, thus attracting more activity if these areas fall within the foraging range of their roosts. Unlike western red bats and western yellow bats, there is not a downward trend in aggregated activity at original system-wide sites and with the new methodology (all eight sites) for California leaf-nosed bats, with 2013 and 2016 seeing the greatest activity at

original system-wide sites, and 2016 and 2017 under the new methodology at all eight sites. California leaf-nosed bat acoustic calls are characterized by a low amplitude, and similar to *Myotis* spp., which makes them difficult to record and document. Comparing historical capture records and acoustic data is out of the scope of work for this report but would provide a clearer picture of activity and occupancy at these sites.

Pale Townsend's big-eared bats were first recorded by Grinnell (1914) and, like California leaf-nosed bats, are year-round residents along the LCR, though with fewer known roosts. As already mentioned, this species is difficult to detect with acoustic monitoring, leading to difficulty in assessing activity. They are also limited by the distance they can forage from their cavern roosts, which has been recorded at 9.5 miles (Maturango Museum and Brown-Berry Biological Consulting 2018) in the study area.

The activity from 2010 through 2019 for covered and evaluation species at system-wide monitoring sites on a macroscale fluctuates among years and sites, with a downward trend in activity emerging for western red bats and western yellow bats from the highs in activity recorded in the 2010 and 2011 seasons.

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