BAT MONITORING ON THE NEVADA TEST SITE IN SOUTH-CENTRAL NEVADA

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ABSTRACT: The Nevada Test Site (NTS) is located in south-central Nevada and encompasses approximately 3,561 square kilometers. It straddles both the Mojave and Great Basin Deserts and includes a distinct transition region between these two deserts. Because of its size and geographical location, a great deal of vegetative and physiographic diversity exists on the NTS. This diversity of habitat allows for a diverse mix of bat species to exist on the NTS. Numerous mines and tunnels occur on the NTS, which are potential roost sites for bats. Several man-made and natural water sources also occur throughout the NTS. Multiple techniques have been used to inventory and monitor the bat fauna on the NTS. These techniques have included mistnetting at water sources with and without concurrent acoustic sampling, acoustic road surveys, and acoustic sampling at mine and tunnel entrances. To date, a total of 14 species of bats has been documented on the NTS, of which seven are considered species of concern by the U.S. Fish and Wildlife Service. These include Townsend's big-eared bat (*Corynorhinus townsendii*), spotted bat (*Euderma maculatum*), small-footed myotis (*Myotis ciliolabrum*), long-eared myotis (*M. evotis*), fringed myotis (*M. thysanodes*), long-legged myotis (*M. volans*), and big free-tailed bat (*Nyctinomops macrotis*). The Townsend's big-eared bat, spotted bat, long-eared myotis, and big free-tailed bat have been found exclusively in the Great Basin Desert ecoregion, and bat species richness was highest in this region based on mistnet and acoustic surveys. The small-footed and long-legged myotis were found throughout the NTS, and the fringed myotis was found in the Mojave and Great Basin Desert ecoregions but is likely to be found in the transition ecoregion as well. The small-footed myotis, long-legged myotis, and western pipistrelle were the most frequently detected species in the Great Basin Desert ecoregion. The western pipistrelle and California myotis were the most frequently detected species in the transition ecoregion, while the western pipistrelle, California myotis, and pallid bat were the most frequently detected species in the Mojave Desert ecoregion. Acoustic sampling using the Anabat II system has greatly facilitated the monitoring of bats on the NTS, and allowed biologists to cost-effectively survey large areas for bat activity.

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INTRODUCTION

The United States Department of Energy Nevada Operations Office (DOE/NV) operates the Nevada Test Site (NTS). DOE/NV is committed to managing lands in a manner that protects the environment. Two main goals of the NTS Resource Management Plan (DOE/NV unpublished report) are to: 1) protect and conserve significant biological resources and 2) minimize cumulative impacts to biological resources. Additionally, DOE/NV is committed to characterizing trends in biological resources and determining the effects of DOE/NV activities on biological resources through a monitoring program. This monitoring program includes monitoring the bat fauna on the NTS.

Prior to the 1990s, only four bat species were known to occur on the NTS; *Antrozous pallidus* (pallid bat), *Corynorhinus townsendii* (Townsend's big-eared bat), *Myotis californicus* (California myotis), and *Pipistrellus hesperus* (western pipistrelle) (Jorgensen and Hayward 1965). During the early 1990's, bat surveys conducted in support of the Yucca Mountain Project (TRW unpublished report) and the Basic Environmental Compliance and Mitigation Program (Saethre 1994, Woodward et al. 1995) documented seven additional bat species; *Eptesicus fuscus* (big brown bat), *Euderma maculatum* (spotted bat), *Lasiurus cinereus* (hoary bat), *M. evotis* (long-eared myotis), *M. thysanodes* (fringed myotis), *M. volans* (long-legged myotis), and *Tadarida brasiliensis* (Brazilian free-tailed bat). Later, one *Lasionycteris noctivagans* (silver-haired bat) was documented when a dead individual was found near some buildings in Mercury, Nevada (M. Saethre, pers. comm. 1996). Although suspected to occur, *M. ciliolabrum* (western small-footed myotis) was not documented on the NTS until the summer of 1998 (DOE/NV unpublished report). Also, *Nyctinomops macrotis* (big free-tailed bat) was detected acoustically during bat surveys during the summer of 1999. Thus, a total of 14 bat species have been documented to occur on the NTS. Seven of these are of concern to the U.S. Fish and Wildlife Service (USFWS) because they are former Category 2 candidate species. These include *M. ciliolabrum, M. evotis, M. thysanodes, M. volans, E. maculatum, C. townsendii*, and *N. macrotis*.

Prior to 1998, bat monitoring on the NTS was done exclusively by capturing bats at water sources using mistnets. Since then, fixed point, mobile, and roost-site sampling, both acoustically and by capture, has been used to monitor bats on the NTS. This paper describes the approach used for monitoring bats and presents a summary of previous capture data combined with the results of fixed point, mobile, and roost-site sampling to describe the distribution and species composition of bats on the NTS.

STUDY AREA

The NTS is located in south-central Nevada approximately 105 kilometers (km) northwest of Las Vegas (Fig. 1). The NTS encompasses approximately 3,561 km2, and despite drastic changes to localized areas of the NTS due to nuclear testing activities over the past 40 years, biological resources over much of the NTS remain relatively pristine and undisturbed. DOE/NV estimates that only 7 percent of the site has been disturbed.

The southern two-thirds of the NTS is dominated by three large valleys or basins: Yucca, Frenchman, and Jackass flats (Fig. 1). Mountain ridges and hills rise above sloping alluvial fans and enclose these basins. The northern, northwestern, and west central sections of the NTS are dominated by Pahute and Rainier Mesas and Timber and Shoshone Mountains. Elevation on the NTS ranges from less than 1,000 m in Frenchman and Jackass flats to about 2,340 m on Rainier Mesa.

NTS has a climate characteristic of high deserts with little precipitation, hot summers, mild winters and large diurnal temperature ranges. Monthly average temperatures in the NTS area range from 7°C in January to 32°C in July (DOE 1996). The average annual precipitation on the NTS ranges from 15 cm at the lower elevations to 23 cm at the higher elevations. About 60% of this precipitation occurs from September through March.

The NTS is located in an area of southern Nevada that lies between the Great Basin Desert and the Mojave Desert as defined by Jaeger (1957). Within the site boundaries are found both of these desert types. Transitional areas between the two deserts are also present having been created by gradients in precipitation, elevation, temperature, and soils. Unique combinations of physical site conditions have resulted in several different vegetation communities (Ostler et al. 1998). Based on these vegetation communities, three distinct "ecoregions" occur on the NTS; the Great Basin Desert, Mojave Desert, and transition ecoregions. Additionally, several mines and tunnels and both man-made and natural water sources occur throughout the NTS. These features combined with restricted public access provide roosting and foraging resources for numerous bat species on the NTS.

METHODS

Bats were monitored on the NTS by fixed point mistnet surveys with and without concurrent acoustic sampling, mobile acoustic road surveys, and acoustic roost-site sampling at mine and tunnel entrances. Acoustic sampling was conducted using the Anabat II bat detection system (Titley Electronics, Ballina, New South Wales, Australia), which uses a zero-crossings analysis interface module and the Anabat6 software to record and store ultrasonic bat vocalizations as computer files into a laptop computer. These files can then be displayed and analyzed using the Analook software, and based on certain vocalization characteristics (e.g. minimum call frequency, slope, overall pattern), it can be determined with a high probability what species of bat emitted the vocalization (O'Farrell et al. 1999).

Prior to 1998, it was difficult to determine the difference between *M. ciliolabrum* and *M. californicus* in the field. Thus, a designation of *M. californicus/M. ciliolabrum* was assigned to these species captured before 1998. However, morphometric work by Constantine (1998) showed a 1.5 to 2.5 millimeter extension of the tail membrane on *M. ciliolabrum*, which is absent in *M. californicus*. O'Farrell (1997) found that the echolocation calls of these two species are also distinctly different. The minimum call frequency of *M. ciliolabrum* is around 40 khz while the minimum call frequency of *M. californicus* is around 50 khz. Based on these two characteristics, *M. californicus* and *M. ciliolabrum* were distinguishable after the spring of 1998.

Mistnet surveys were conducted in each of the three ecoregions during the summer and fall (May-October) of 1991-1993, 1996, and 1998-1999 at 14 water sources and one dry wash. Four water sources were located in the Great Basin Desert ecoregion, four in the transition ecoregion, and six in the Mojave Desert ecoregion. The dry wash location was also located in the Mojave Desert ecoregion. Mistnets were set up just before sunset and taken down no later than sunrise and sometimes as early as 11:00 p.m., depending on the level of bat activity. Surveys were conducted in each of the three ecoregions. The number of survey nights in each ecoregion varied with 18, 16, and five sampled in the Great Basin, Mojave, and transition ecoregions, respectively. Individual bats were identified to species, sexed, and released. In addition, morphological measurements and reproductive status were documented on many individuals.

During the summers of 1998 and 1999, acoustic surveys were conducted concurrently with mistnet surveys at six sites. Three were located in the Great Basin Desert ecoregion, two in the transition ecoregion, and one in the Mojave Desert ecoregion. Some sites were sampled multiple times during 1998 and 1999 for a total of 10 survey nights. Data was collected passively with the microphone directed at the water source during the time the mistnets were set. Acoustic data were saved directly to a laptop computer. Identification of acoustic files was verified by M.J. O'Farrell following established protocols (O'Farrell et al. 1999). Capture results were compared to acoustic sampling.

Mobile acoustic road surveys were conducted between August 1998 and July 1999. The objective of the road surveys was to sample large areas throughout the NTS for bat activity to more fully inventory the bat fauna and their distribution on the NTS. Prior to this, surveys

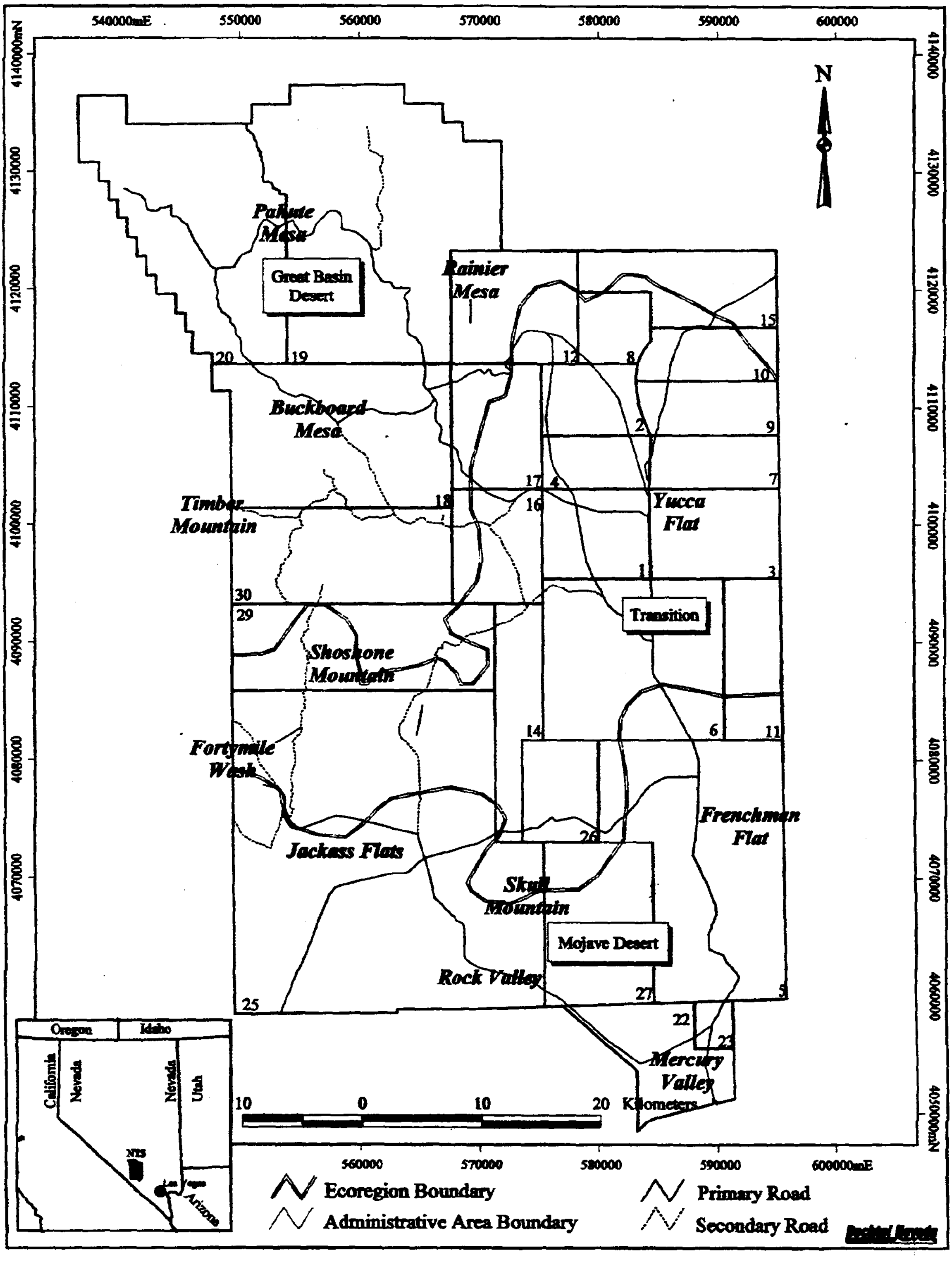

Figure l. Major roads, ecoregion boundaries, topographic features, and administrative areas of the Nevada Test Site.

were limited strictly to water sources. Four survey routes were established, and included one for the Mojave Desert ecoregion (101 km in length), one for the transition ecoregion (67 km in length), and two for the Great Basin Desert ecoregion (30 km and 75 km in length), respectively. Routes were designed to sample as many water sources as possible along the route to determine which water sources were used by bats. Furthermore, routes were sampled during the fall, spring, and summer to determine if there were seasonal differences in the bat species composition and distribution because several bat species are known to be migratory. Surveys were conducted during August and October 1998, March and April 1999, and June and July 1999. Each of the four routes were sampled during each of the three seasons except for the Mojave Desert ecoregion, which was sampled in late summer (August 18) instead of fall. Sampling entailed driving approximately 16-32 km/hour while holding the detector out the window. Upon reaching a water source, the microphone was pointed toward the water source for a period of 10-30 minutes. Data were then summarized by route and season. Species of greatest occurrence were determined by tallying the number of files of each species.

Exit surveys were conducted acoustically at two mine and three tunnel entrances between April and August 1999. One mine and all three tunnels were located in the Great Basin Desert ecoregion, and one mine was located in the transition ecoregion. Surveys began around sunset and usually lasted until 10:00 or 11:00 p.m.

RESULTS

A total of 2,027 individual bats representing 13 bat species were captured on the NTS between 1991 and 1999 (Table 1). Six of these are former Category 2 candidate species (USFWS). By far, *P. hesperus* was the most frequently captured bat species on the NTS, representing almost 50% of the total individuals captured. *M. californicus/M. ciliolabrum* was the most frequently captured species in the Great Basin Desert ecoregion, and *P. hesperus* was the most frequently captured species in the Mojave Desert and transition ecoregions. The highest species richness of bats occurred in the Great Basin Desert ecoregion.

When comparing species occurrence between the acoustic and mistnet techniques, *N. macrotis* was only detected acoustically but was not captured (Table 2). Conversely, *C. townsendii* was only detected by mistnetting and was not detected acoustically. The remaining species were detected with both methods but acoustic sampling was more effective than mistnetting.

Data from road surveys in the Great Basin Desert ecoregion indicate that *M. ciliolabrum* and *M. volans* were the species most commonly detected, and the highest number of bat species was detected during the spring survey (Table 3). The species most commonly detected in the Mojave Desert and transition ecoregions were *P. hesperus* and *M. californicus*. The highest number of bat species in both ecoregions was detected during the summer survey (Table 3).

Table 1. Bat species captured during mistnet surveys on the Nevada Test Site (1991-1999).

	Great Basin Desert		Transition		Mojave Desert	
Species	# Captured	% of Total	# Captured	% of Total	# Captured	% of Total
Myotis californicus/M. ciliolabrum	321	39.9	0	0.0	27	2.3
Pipistrellus hesperus	109	13.5	17	53.1	1004	84.4
Myotis volans	180	13.4	1	3.1	2	0.2
Eptesicus fuscus	77	9.6	0	0.0	1	0.1
Myotis ciliolabrum	58	7.2	0	0.0	0	0.0
Myotis evotis	56	7.0	0	0.0	0	0.0
Myotis thysanodes	26	3.2	0	0.0	2	0.2
Antrozous pallidus	18	2.2	4	12.5	84	7.1
Tadarida brasiliensis	13	1.6	1	3.1	44	3.7
Corynorhinus townsendii	11	1.4	0	0.0	0	0.0
Euderma maculatum	5	0.6	0	0.0	0	0.0
Lasiurus cinereus	1	0.1	0	0.0	3	0.3
Lasionycteris noctivagans	1	0.1	0	0.0	0	0.0
Myotis californicus	1	0.1	9	28.1	23	1.9
Total	805	100.0	32	100.0	1190	100.0
Grand Total	2027					

Exit surveys detected six bat species at mine and tunnel entrances in the Great Basin Desert ecoregion (Table 4). Only one species, *M. ciliolabrum*, was detected at the mine entrance surveyed in the transition ecoregion (Table 4).

DISCUSSION

Capture data from mistnetting indicated that *M. californicus/M. ciliolabrum* was the most frequently captured species in the Great Basin Desert ecoregion of the NTS. Based on the species identified in this ecoregion after 1998 (using the tail extension characteristic and minimum call frequency) and the distribution of these species as reported in the literature (Simpson 1993, Hoffmeister 1986), the vast majority of individuals caught before 1998 most likely were *M. ciliolabrum*. The acoustic data also support this conclusion.

Assuming the total number of species obtained by both acoustic and mistnet surveys equaled a complete inventory, acoustic sampling detected 93.2% and mistnetting 42.4% of the combined species present. Nonetheless, acoustic sampling did not detect all of the species present. For example, *C. townsendii* was not detected acoustically but it was captured during mistnet surveys. In contrast, *N. macrotis* was only detected acoustically and was not captured. O'Farrell and Gannon (1999) and Kuenzi and Morrison (1998) likewise found a differential species response to capture and acoustic techniques. Based on these results, it is best to use both acoustic and mistnet surveys to detect the greatest number of species present.

During road surveys, most of the bat activity on all routes in each season was detected at water sources. Very few "commuting" bats were detected along roadside corridors away from water sources with this technique. Based on these results, it would be advantageous to sample at water sources to detect most of the bat activity in a given area. Bats were also detected at or near other structures such as towers and large storage tanks and in well-lit areas, presumably to prey on abundant insects attracted to the light source.

It was not determined if bats detected at mine and tunnel entrances were actually roosting inside the mines or tunnels or just flying around the mine or tunnel entrance.

Table 2. Comparison of species occurence based on mistnet and acoustic surveys on the Nevada Test Site, 1998-1999.

	Number of Samples Where Species Were Detected		
Species	Mistnet only	Acoustic only	Both methods combined
Antrozous pallidus	0	5	2
Corynorhinus townsendii	1	0	0
Eptesicus fuscus	0	5	3
Lasiurus cinereus	1	2	0
Lasionycteris noctivagans	0	2	1
Myotis californicus	0	3	2
Myotis ciliolabrum	0	4	4
Myotis evotis	0	1	2
Myotis thysanodes	1	3	0
Myotis volans	1	0	2
Nyctinomops macrotis	0	1	0
Pipistrellus hesperus	0	5	3
Tadarida brasiliensis	0	3	2
Total	4	34	21

Table 3. Bats detected during acoustic road surveys on the Nevada Test Site, 1998-1999.

	Great Basin Desert						Transition			Mojave Desert		
Species	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Summer	Spring	Summer
Myotis volans	X	x	x						x	x		
Eptesicus fuscus	x	x							x	x	x	x
Myotis ciliolabrum	x	X	X	X	X	X			x			x
Tadarida brasiliensis	x	x		x		x		x	x		x	x
Lasionycteris noctivagans	x	x			x							
Myotis californicus		x					X	x	x	x	X	x
Pipistrellus hesperus		x	x					X	X	X	x	X
Antrozous pallidus									x			x
Lasiurus cinereus								x				

X=Species most commonly detected; x=Species detected at least once

At one tunnel, two individuals were observed crawling out of a hole in the door of the tunnel with night vision goggles, suggesting these bats were using this tunnel as a day roost. Only a few of the numerous mines and tunnels found on the NTS have been surveyed for bats. Future monitoring will focus on conducting more exit surveys of mines and tunnels to better document bat use of these important resources. Radiotelemetry studies should also be conducted to determine specific roost site locations in order to manage and protect these critical resources.

Based on results from both mistnet and acoustic sampling techniques, the Great Basin Desert ecoregion supports the highest bat species richness, and although former Category 2 candidate species (USFWS) are found throughout the NTS, the largest number of these species are found in the Great Basin Desert ecoregion. Four of these species (*C. townsendii, E. maculatum, M. evotis, and Nyctinomops macrotis*) have been found exclusively in this ecoregion. Additionally, the species most commonly detected in the Great Basin Desert ecoregion were *M. ciliolabrum, M. volans, and P. hesperus*. The species most commonly detected in both the Mojave Desert and transition ecoregions were *P. hesperus* and *M. californicus*. These findings are consistent with results from other researchers studying bats in southern Nevada and nearby California (Ramsey 1995, Szewczak et al. 1998, O'Farrell and Bradley 1970) with the exception of *C. townsendii*, which was found in Mojave mixed desert scrub and blackbrush vegetation types in these studies.

The Anabat II system has proven to be an invaluable, cost-effective tool for acoustically detecting bats on the NTS. Furthermore, the approach for monitoring bats on the NTS using both mistnet and acoustic sampling techniques in each of the three distinct ecoregions has led to a better understanding of the distribution and species composition of bats throughout the NTS. Bat monitoring will continue to be an integral part of ecological monitoring on the NTS to protect and conserve these important biological resources and their habitat.

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Table 4. Bats detected acoustically during exit surveys at select mines and tunnels on the Nevada Test Site, 1999.

	Great Basin Desert				Transition
Species	A Tunnel	B Tunnel	N Tunnel	Old Climax Mine	Mine Mountain
Myotis ciliolabrum	X			x	X
Myotis californicus	x		x		
Myotis evotis	x			x	
Pipistrellus hesperus	x	X	x		
Myotis thysanodes		X		X	
Myotis volans		X	X		

X=Species most commonly detected; x=Species detected at least once

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