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OCCURRENCE OF BATS IN HIGHLY IMPACTED ENVIRONMENTS: THE LAKE TAHOE BASIN

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In an effort to improve ecosystem function of riparian and meadow areas within the Lake Tahoe Basin (hereafter, the Basin), the US Forest Service and other state and local agencies initiated a major restoration effort. Numerous activities, such as logging, fire suppression, grazing, and human development have altered wildlife communities within the Basin over the past 150 y (Murphy and Knopp 2000) requiring the need for wildlife restoration. Many of the species that have declined use or inhabit ecologically important ecosystems such as marshes, bogs, fens, aspen groves, meadows, and riparian areas. Because marshes and meadows currently encompass a small proportion of the Basin and support a disproportionate number of species (Manley and others 2000; Schlesinger and Romsos 2000), there is interest in restoring these areas.

Planning and evaluating restoration projects can be difficult for managers because they often lack information regarding historical conditions of areas in need of restoration. Bats are a good group of species to evaluate because they typically represent a relatively large portion of mammal species found in most marsh and meadow systems, including those within the Basin. Moreover, their diverse foraging and roosting requirements, plus the relative ease of acoustic sampling, make them good candidates for monitoring (Medellín and others 2000). Bats within the Basin are particularly important to monitor in the context of restoration because 3 species are listed as federal species of special concern (Long-eared Myotis [*Myotis evotis*], Fringed Myotis [*Myotis thysanodes*], and Yuma Myotis [*Myotis yumanensis*]; Table 1) (Manley and others 2000), and an additional 2 species are listed as state species of special concern (Townsend's Big-eared Bat [*Corynorhinus townsendii*] and Spotted Bat [*Euderma maculatum*]; Table 1) (Williams 1986).

As part of a wildlife monitoring program in the Basin, we report on the occurrence of bats to (1) begin development of baseline data for use in post-restoration monitoring; (2) determine the current status of bats relative to historic records; and (3) provide guidance to agency planners for development of restoration plans aimed at enhancing wildlife habitat. Evaluation of historic records, when combined with recent surveys, allows for development of a list of species that should occur at each project site that will likely require special management efforts to ensure their occurrence and productivity (for example, desired species; Morrison 2009).

We selected study sites to correspond to restoration projects planned by the Lake Tahoe Basin Management Unit; all sites were located along the southern and western shores of Lake Tahoe. We categorized sites into 2 basic groups, sites within meadows (meadow sites) and sites located along creeks (creek sites). Not all sites were sampled each year because of funding priorities established annually by management agencies. Meadow sites sampled were Cookhouse and Big Meadow (sampled in 2004–07), Grass Lake (2004–07), High Meadow and Fountain Place (2006–07), Tallac, Taylor, and Truckee meadows (2004, 2006), and Trout and Sunset Reach (2006). Creek sites sampled in 2004 and 2006 included Burton and Ward creeks. Blackwood, McKinney, General, and Meeks creeks were sampled in 2004 and 2006–07 (Table 1).

We conducted acoustic surveys for bats using automated ultrasonic detectors (Pettersson model D240X) and cassette data recorders (Sony TCM-200) to assess bat species richness and

TABLE 1. Percent frequency of occurrence of bat species detected with ultrasonic detectors at creek (2004, 2006–2007) and meadow (2004–2007) sites, Lake Tahoe Basin, California.

		Creek sites				Meadow sites			
Common Name	Scientific Name	2004 (6)[1]	2005 (0)	2006 (6)	2007 (4)	2004 (6)	2005 (3)	2006 (10)	2007 (5)
Pallid Bat	*Antrozous pallidus*	17		17					
Townsend's Big-eared Bat[2]	*Corynorhinus townsendii*				25				20
Big Brown Bat	*Eptesicus fuscus*	100		100	75	67	100	20	40
Western Red Bat	*Lasiurus blossevillii*	17							
Spotted Bat[2]	*Euderma maculatum*						33		20
Hoary Bat	*Lasiurus cinereus*	83		28		100	100	40	
Silver-haired Bat	*Lasionycteris noctivagans*	28		100	100	17		100	100
California Myotis	*Myotis californicus*	17		28	25			20	
Small-footed Myotis	*Myotis ciliolabrum*			28				20	
Long-eared Myotis[3]	*Myotis evotis*			67	100	67	100	60	80
Little Brown Bat	*Myotis lucifugus*	100		100	100	100	100	100	100
Fringed Myotis[3]	*Myotis thysanodes*	17		50	25	67	33	60	80
Long-legged Myotis	*Myotis volans*			17	75		33		20
Yuma Myotis[3]	*Myotis yumanensis*	17		17	50	28	67		
Brazilian Free-tailed Bat	*Tadarida brasiliensis*	50		28	25	28	67	40	40

[1] Number of study sites sampled.
[2] California species of special concern.
[3] Federal species of special concern.

frequency of occupancy of study sites. Acoustic methods are useful for quantifying occurrence and habitat use of bats (see review in Kunz and Parsons 2009). We placed detectors in suitable openings, near vegetation transition zones, or in likely flight corridors (for example, narrowing of vegetation surrounding a stream pool). The maximum range at which the calls of bats can be detected is about 30 m (Thomas and West 1989; Ahlen and Baagoe 1999). Therefore, in an effort to cover a large proportion of each site, we placed detectors in different locations on subsequent visits, with locations at least 100 m apart. Bats were recorded on 3 different nights separated by at least 1 wk from July to September 2004 and from June to August 2005–2007. To determine if an increase in the number of visits would increase the number of species detected, we recorded bats on 6 different nights at Cookhouse, Big Meadow, and Grass Lake from June to August 2007. However, the increase in sampling (visits) did not increase the overall number of species detected compared to previous years. We did not conduct acoustic surveys for bats during inclement weather.

Echolocation calls recorded by bat detectors were analyzed with acoustic analysis software (SonoBat version 2.2, DNDesign, Arcata, California). We compared sonograms of calls recorded in the field to those of established reference calls for western bats (provided by J Scewczak, Humboldt State University). Determining abundance is not possible with this survey method because detectors cannot determine the number of times a particular species (whether the same individual or different individuals) flew past. Thus for this analysis we present results as the frequency of study sites occupied by a species during each year; it is likely that we underestimated species occurrence.

Based on existing data (Orr 1949; Schlesinger and Romsos 2000), we developed a list of all bat species that occurred throughout the Basin in previous years. This list of species was then ranked by estimated overall community composition if provided in the literature. We then compared this species list with our surveys to develop a comprehensive examination of the historic and recent status of bats in the Basin, and used this analysis to develop recommendations for restoration and management.

Orr (1949) completed his surveys by the mid-1940s and summarized other records to that time. Orr's work included his own searches for bats in potential roost sites and a summary of

anecdotal records (for example, bats found dead in buildings). Of primary interest for the purpose of our study was to compare the species listed and their status relative to the more recent species summary, based largely on unpublished reports collected by Schlesinger and Romsos (2000). The list of species provided by Orr (1949) and the more recent surveys are similar, except that the recent list is much more complete owing to the rigorous sampling techniques now used for bat surveys (for example, acoustic sampling). Nevertheless, a comparison of the status assigned to mammals by Orr (1949) with recent observations provides the only means by which we can draw conclusions on changes in the mammal fauna through time. Bats are, however, relatively difficult to quantify. Orr likely encountered difficulty in sampling bats, reflected by the fact he reported only 5 bat species, 4 of which he considered common: Silver-haired Bat (*Lasionycteris noctivagans*), Big Brown Bat (*Eptesicus fuscus*), Yuma Myotis, and Little Brown Bat (*Myotis lucifugus*); he classified the Long-eared Myotis as ''rare''. Schlesinger and Romsos (2000) added the Pallid Bat (*Antrozous pallidus*), Canyon Bat (*Parastrellus hesperus*), Brazilian Free-tailed Bat (*Tadarida brasiliensis*), California Myotis (*Myotis californicus*), and Fringed Myotis to species occurring in the Basin as a result of more rigorous sampling techniques.

We identified 13 bat species at the creek sites, 7 of which were observed during all years of study (Table 1). The Little Brown Bat was the most frequently recorded species, followed by the Big Brown Bat and Silver-haired Bat. Although observed yearly, the California Myotis, Fringed Myotis, Yuma Myotis, and Brazilian Free-tailed Bat were recorded at less than 50% of the creek sites. The occurrence of the Hoary Bat (*Lasiurus cinereus*) decreased, whereas that of the Silver-haired Bat increased, across the study years. The Long-legged Myotis (*Myotis volans*) increased in occurrence during the last 2 y of study. The Townsend's Big-eared Bat, Western Red Bat (*Lasiurus blossevillii*), and Small-footed Myotis (*Mytois ciliolabrum*) were only recorded during 1 y and on few of the study sites.

We identified 13 bat species on the meadow sites, 5 of which were observed during all years of study (Table 1). The Little Brown Bat was the most frequently recorded species, followed by the Long-eared Myotis, Big Brown Bat, and Fringed Myotis. The occurrence of the Hoary Bat decreased, whereas that of the Silver-haired Bat increased across the study years. The Spotted Bat and Long-legged Myotis were recorded on 1 site during each of 2 y of study. The Townsend's Big-eared Bat, California Myotis, and Small-footed Myotis were only recorded during 1 y and on few of the study sites. The difficulty in detecting some species, such as the Townsend's Big-eared Bat, likely resulted in an underestimate of occurrence.

Overall species richness and the most frequently recorded species were similar between creek and meadow sites, with Little Brown Bat, Big Brown Bat, Silver-haired Bat, Fringed Myotis, and Brazilian Free-tailed Bat the most regularly recorded species across sites and years. We cannot explain the change in occurrence of Hoary Bats and Silver-haired Bats across years given that our sampling methods and time of sampling were consistent. These changes in apparent occurrence could also be an artifact of our relatively short-term sampling within a year. More intensive sampling would have been needed to thoroughly investigate detection probabilities of bats (for example, see MacKenzie and others 2006)

Compared to historic records in the Basin, we detected all of the species reported by Orr (1949), and all but 1 (Canyon Bat) of those reported by Schlesinger and Romsos (2000). The Canyon Bat was, however, seldom encountered in previous studies and can be considered rare or of uncertain status. In contrast, we recorded 4 species not reported by Orr (1949) or Schlesinger and Romsos (2000): Townsend's Big-eared Bat, Western Red Bat, Spotted Bat, and Small-footed Myotis.

Our recent surveys and compilation of previous bat surveys in the Basin indicate that at least 5 species should occur on most creek and meadow sites, with or without restoration: Silver-haired Bat, Big Brown Bat, Yuma Myotis, Little Brown Bat, and Long-eared Myotis. The California Myotis was recorded commonly in previous studies (Schlesinger and Romsos 2000), although this species was rare on our meadow sites. In contrast, whereas we frequently recorded the Brazilian Free-tailed Bat, this species was seldom recorded in past work (Schlesinger and Romsos 2000). Thus, the status

of both the California Myotis and Brazilian Free-tailed Bat can be classified as ''moderately common''.

The Western Red Bat was only recorded in 2004 at 1 creek site. The Western Red Bat roosts in the leaves of deciduous trees, such as cottonwood (*Populus* spp.) (Shump and Shump 1982). The site where the Western Red Bat was recorded, General Creek, contains a few remnant cottonwoods. The paucity of deciduous tree species such as cottonwood (relative to historic conditions) identifies a potentially valuable restoration action.

The 2 state species of special concern, the Townsend's Big-eared Bat and Spotted Bat, were only recorded during our surveys. Even with our increased survey effort at Cookhouse and Grass Lake in 2007 (6 visits to each site), we only detected each species on a single night. We recommend that additional surveys be conducted in the locations where we recorded these species to improve our understanding of their status (rare, seasonal, resident, or vagrant) in the Basin.

The 3 species listed as federal species of special concern, the Fringed Myotis, Yuma Myotis, and Long-eared Myotis, were recorded in previous studies although their abundance was uncertain. Except for the Long-eared Myotis, federal species of concern were rarely recorded in our surveys. Because of the disparity in survey results within the Basin, we recommend specific attention be given to these 3 species in planning restoration activities.

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