Journal of Mammalogy, 81(4):939–947, 2000

ROOSTING AFFINITIES OF TOWNSEND'S BIG-EARED BAT (*CORYNORHINUS TOWNSENDII*) IN NORTHERN UTAH

RICHARD E. SHERWIN,* DAVE STRICKLAN, AND DUKE S. ROGERS

Department of Zoology and Monte L. Bean Life Science Museum, Brigham Young University, Provo, UT 84602 (RES, DSR)
United States Department of Agriculture, Forest Service, Shrub Sciences Laboratory, Provo, UT 84602 (DS)
Present address of RES: Museum of Southwestern Biology, Division of Mammals, Department of Biology, University of New Mexico, Albuquerque, NM 87131

We surveyed abandoned mines, caves, and bridges to identify habitat preferences of day-roosting Townsend's big-eared bat (*Corynorhinus townsendii*) in northern Utah. Of 820 sites surveyed (676 mines, 39 caves, and 105 bridges), 196 (23.9%) were occupied by *C. townsendii*. Caves were the most frequently used type of roost (84.6%), 21.2% of abandoned mines were used as day roosts, and no bridges were used. Bats occupied mines and caves at lower available elevations (1,350–2,440 m), which were associated with sagebrush–grass steppe, juniper woodlands, and mountain brush vegetation. In general, roosts with single low (<1.5 m height) entrances were more likely to be occupied than those with multiple or tall entrances. Day roosts typically were subject to little disturbance by humans. Aspect and width of entrance, stability and complexity of interior, presence of multiple entrances, length of tunnel, amount of internal air flow, presence of multiple levels, and presence of internal water were not associated significantly with occupancy; however, maternity colonies tended to be located in large complex sites with multiple openings.

Key words: abandoned mines, caves, *Corynorhinus townsendii*, habitat selection, mine reclamation, roosts, Townsend's big-eared bat

Bats spend most of their lives in roosts (Kunz, 1982), and a basic understanding of roosting requirements is critical to understanding the natural history of a given species (Humphrey 1975). Additionally, protection of roosts has been identified as a priority in conserving many species of bats (Pierson 1998). Therefore, understanding factors affecting acceptance of roosts is important in the long-term management of species.

The greatest factor affecting distribution of Townsend's big-eared bat (*Corynorhinus townsendii*) may be availability of suitable roosts (Humphrey and Kunz 1976; Kunz and Martin 1982). Although some *C. townsendii* roost in abandoned buildings, bridges, and culverts (Armstrong et al. 1995; Dalquest 1947; Long 1940; Pearson et al. 1952; Ports and Bradley 1996), most populations occur in areas with expanses of exposed cavity-forming rock (i.e., limestone, sandstone, gypsum, igneous rocks) and with historic mining districts (Graham 1966; Humphrey and Kunz 1976; Kunz and Martin 1982), suggesting that *C. townsendii* ultimately may be dependent on caves and mines for survival (Barbour and Davis 1969; Twente 1960).

There has been increasing concern regarding the status of *C. townsendii* throughout its range (Szewczak et al. 1998). Much of this concern is attributed to the supposition that *C. townsendii* depends on aban-

* *Correspondent: rsherwin@unm.edu*

Downloaded from https://academic.oup.com/jmammal/article-abstract/81/4/939/2372908 by U S Dept of Agriculture user on 07 March 2019

doned mines as roosts. Twenty-three states, motivated by the danger that mines pose to the public, have initiated reclamation programs for abandoned mines (United States Department of the Interior 1997). The potential loss of habitat that may be incurred by reclamation of abandoned mines (Tuttle and Taylor 1994) makes it critical that we gain a thorough understanding of roosting and habitat requirements of *C. townsendii*.

Studies of distribution and selection of roosting habitat have focused primarily on populations in California (*C. townsendii townsendii*—Pearson et al. 1952; Pierson et al. 1991) and the 2 endangered eastern subspecies (*C. t. ingens* and *C. t. virginianus*—Burford and Lacki 1995; Clark et al. 1993, 1996; Lacki et al. 1994; Wethington et al. 1996). However, little is known about roosting habitats of populations of the subspecies *C. t. pallescens* in the Great Basin (Dobkin et al. 1995).

Our purpose was to evaluate roosting habitat of *C. townsendii* in northern Utah and to determine whether sites used by *C. townsendii* can be distinguished quantitatively from those not used based on internal and external characteristics of roosts. If distribution is dependent on availability of acceptable roosts (based solely on internal roost-site characteristics), *C. townsendii* should be distributed randomly among acceptable roosts regardless of surface-related variables. Additionally, we investigated how specific types of roosts are used and if differences exist in inter- and intraseasonal patterns of use of abandoned mines, caves, and bridges.

Materials and Methods

Study area.—We collected data at abandoned mines, caves, and bridges located on land managed by the United States Forest Service, Bureau of Land Management, Utah Department of Transportation, National Park Service, and Utah Division of Parks and Recreation and on private land in 9 counties in northern Utah. The area ranged in elevation from 1,350 to 3,600 m above mean sea level and included a complex suite of geologic provinces. Valley floors were dominated by sagebrush–grass steppe vegetation; higher elevations varied from mountain brush communities to alpine meadows and krumholtz associations.

Six hundred seventy-six abandoned mines, 39 caves, and 105 bridges were surveyed for bats and bat signs (e.g., guano, staining, insect parts, and odors). For 2 years (1996–1998), we surveyed each site at least once during 4 periods of the annual cycle: winter hibernation, summer maternity, autumn migratory, and spring migratory. Interiors of mines and caves were surveyed following protocols modified from those of Altenbach and Milford (1995) and Tuttle and Taylor (1994). Bridges were surveyed following the protocol developed by Keeley and Tuttle (1999).

Abandoned mines were located by reviewing governmental patent and claim records and topographic maps and by extensive surveys in the field. Caves were located by contacting management agencies and local caving groups and by examining records of museums for specimens collected in caves. Bridges were selected randomly from a list provided by the Utah Department of Transportation.

Mine and cave surveys.—Because of hazards posed by abandoned mines, safety was a primary concern. An air monitor (Passport, Mine Safety Appliances, Pittsburgh, Pennsylvania) that continuously measures oxygen, carbon monoxide, methane, and particulate levels was used during internal surveys. At least 2 persons entered each mine while a 3rd person remained outside and in constant radio contact. Standard safety equipment was worn at all times (Altenbach and Milford 1995).

To minimize disturbance to day-roosting bats, these bats were not handled or captured within roosts. We recorded presence, number, location, and identity of species. Internal surveys were terminated if bats were noticeably disturbed by the presence of the surveyors or if conditions did not meet safety requirements.

When internal surveys were impossible because of concerns about safety, external surveys and counts of exiting bats were conducted. Mist nets were set across entrances $\geq$0.5 h before sunset. Nets were constantly monitored, and bats were removed immediately upon capture. Total time for processing each individual was usually $<$15 min. Because external surveys did not include data regarding the interior of mines, those

Downloaded from https://academic.oup.com/jmammal/article-abstract/81/4/939/2372908 by U S Dept of Agriculture user on 07 March 2019

sites were analyzed separately from those with complete internal evaluations.

Collection of data.—Habitat variables were measured at each potential roost. Aspect and elevation of each entrance to a mine or cave were recorded. If a mine or cave had multiple openings, the number of openings was recorded, and average aspect and elevation were used in analyses. Type of vegetation was defined as the dominant vegetative community within a 3-km radius of the roost. Standard maps of vegetation, obtained from the United States Geological Survey and United States Forest Service, were used to determine types of vegetation: riparian, sagebrush–grass steppe, juniper woodland, mountain brush, aspen, and mixed conifer. Local land-use practices were categorized for a 3-km radius around each site. Distance to water was defined as distance from each potential roost to a perennial usable source of water. A body of water with a surface area ≥1 m was defined as usable.

Stability of the interior of each site was determined indirectly by assessing type of rock, degree of consolidation, and number of fractures per square meter at random points throughout the site. Interior dimensions recorded for each mine or cave included actual length, average height and width, and maximum height and width. Number of levels was recorded as the number of discrete horizontal passages. Complexity of interior was rated as simple (main passage with nonbranching side tunnels), moderate (main passage with branching side tunnels or <3 levels), or complex (main passage with multiple branching side tunnels or ≥3 levels). Air temperature was measured using a hand-held infrared thermometer (Raynger ST3, Raytek Corporation, Santa Cruz, California). Temperature was measured 20 cm below the ceiling in the twilight area and every 15 m thereafter. If the passage was <15 m in length, temperature was measured at the half-way point and at the end of the passage. Data loggers (Hobo H8, Onset Computer Corporation, Pocasset, Massachusetts) were installed in a subset of mines and caves (20 sites total) to record continuous temperature data. An estimate of disturbance by humans was made on a scale of 0 (none) to 3 (high). Air flow (intake or outflow) was measured using a standard anemometer (Davis Wind Wizard, Frostproof, Florida). Presence of standing water was noted along with average depth and temperature of water. Presence of other wildlife also was recorded. During nocturnal surveys, we recorded number and species of bats captured, time of 1st emergence, air temperature, dimensions of opening, and all surface habitat variables for all sites at which external surveys were conducted.

Analysis.—Logistic regression was used to determine which variables influenced probability of presence or absence of *C. townsendii* (binomial distribution) using the GENMOD procedure of SAS (SAS Institute Inc. 1993). The model was tested for both sexes during all seasons combined, both sexes during each season, each sex during all seasons combined, and each sex for each season. That procedure allowed for analysis of discrete and continuous data in the same model (Hardy and Field 1998). A manual stepwise function was used to remove variables that did not influence the model. A normal approximation to the binomial distribution was used to test for differences in proportions of roost types used (caves, mines, and bridges). We used *t*-tests to assess differences in sizes of colonies (maternity, bachelor, and hibernation) when comparing caves with mines.

RESULTS

Corynorhinus townsendii did not roost during the day at any of the 105 bridges surveyed, so bridges were not evaluated as potential day roosts. Of the 715 sites (676 mines, 39 caves) that were visited, 196 (27.4%) were used as day roosts by *C. townsendii* during summer and winter. Of these, 183 (25.6%) were bachelor roosts (defined as containing only adult males and nonparous females) and 13 (1.8%) were maternity roosts. Mean size of maternity colonies was 128.9 mature females per site (range, 15–550), whereas bachelor roosts typically contained a single individual (mean density of 1.5 individuals/site; range, 1–7). When multiple males occupied the same bachelor roost, individuals never roosted in contact with one another.

Internal mine and cave temperatures fluctuated as much as 10°C within a 24-h period (average daily summer deviation of ±5.05°C, range, 1–9°C; average daily winter deviation of ±5.45°C, range, 1–10°C). As a result, we decided that internal temperature was too variable and, hence, too

Downloaded from https://academic.oup.com/jmammal/article-abstract/81/4/939/2372908 by U S Dept of Agriculture user on 07 March 2019

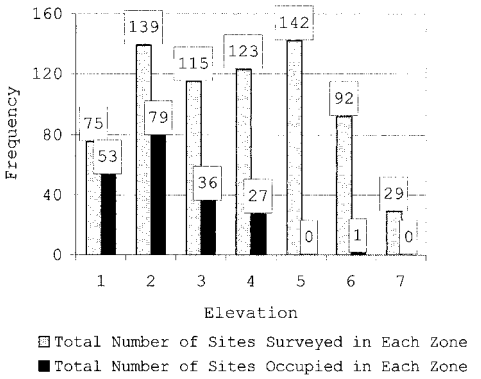

FIG. 1.—Number of sites surveyed for and used by *Corynorhinus townsendii* in different elevational zones. Number of sites surveyed is represented on the y-axis, and elevation is on the x-axis (1 = <1,700 m, 2 = 1,701–2,000 m, 3 = 2,001–2,300 m, 4 = 2,301–2,600 m, 5 = 2,601–2,900 m, 6 = 2,901–3,200 m, and 7 = 3,201–3,500 m).

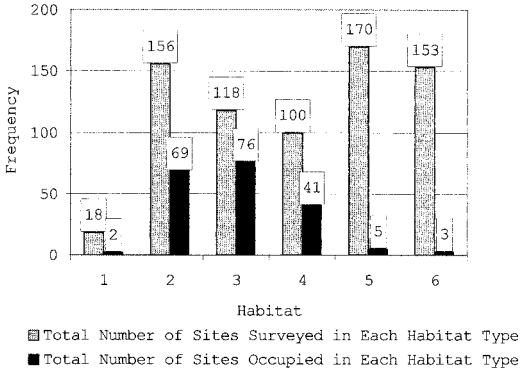

FIG. 2.—Number of sites surveyed for and used by *Corynorhinus townsendii* in different habitat types. Number of sites surveyed is represented on the y-axis, and habitat is indicated on the x-axis (1 = riparian, 2 = sagebrush–grass steppe, 3 = juniper woodland, 4 = mountain brush, 5 = aspen, and 6 = mixed conifer).

unreliable to be included in the final analysis. Distance to water also was not included in the analysis because no sites were >2 km from watering sources. Migratory use (autumn and spring) of roosts was highly variable, with animals commonly moving between different mines or caves. Our surveys probably were not conducted often enough to assess use of roosts during these periods; therefore, use of roosts by migratory bats was not included in the analyses.

Internal surveys.—Complete internal surveys were conducted at 372 abandoned mines (55%) and 39 caves (100%). One hundred twelve sites (79 mines and 33 caves) were used as day roosts by *C. townsendii*. Of these, 100 were bachelor roosts and 12 were maternity roosts. Presence of *C. townsendii* in those caves and mines was influenced strongly by external factors. Day roosts were concentrated at lower elevations ($\chi = 35.99$, $P < 0.001$; Fig. 1) and were associated with sagebrush grassland ($\chi = 5.23$, $P < 0.05$), juniper woodland ($\chi = 6.17$, $P < 0.05$), and mountain brush ($\chi = 7.44$, $P < 0.05$; Fig. 2). Mines and caves with single openings were more likely to be occupied ($\chi = 7.53$, $P < 0.05$) than sites with multiple openings, and sites with little or no human disturbance ($\chi = 24.24$, $P < 0.0001$) were more likely to be occupied than disturbed sites. Bats were more likely to use sites with small to midsize openings (<1.5 m height; $\chi = 16.92$, $P < 0.0001$). Aspect, stability of interior, dimensions of interior, length of passage, number of levels, complexity of interior, air flow, presence of internal water, width of entrance, local land-use practices, and distance to nearest known roost were not significant factors affecting selection of a site as a roost (all $P \geq 0.17$).

Although internal features (i.e., length, number of levels) did not significantly affect overall selection of roosts, similarities were noted among maternity roosts. Nine of 12 maternity roosts (75%, not including maternity roosts identified from external surveys) had multiple levels ($\bar{X} = 2.3$ levels) and multiple openings ($\bar{X} = 2.1$ openings) and tended to have large internal dimensions and high levels of human disturbance ($\bar{X}$ rating = 3). It is likely that the small number of maternity roosts compared with bachelor roosts may be confounding possible differences between bachelor and maternity sites. However, when males were

Downloaded from https://academic.oup.com/jmammal/article-abstract/81/4/939/2372908 by U S Dept of Agriculture user on 07 March 2019

TABLE 1.—Use of different roost types by Townsend's big-eared bat (*Corynorhinus townsendii*).

Roost type	No. sites surveyed	No. sites used	No. sites			Mean (range) size of colony		
			Bachelor	Maternity	Hibernation	Maternity	Bachelor	Hibernation
All sites	820	196	183	13	85	128.9 (15–550)	1.5 (1–7)	7.1 (1–58)
Mines[a]	676	163	158	5	56	54.6 (15–150)	1.3 (1–5)	6.9 (1–18)
Mine exit surveys	304	84	83	1				
Caves	39	33	25	8	29	175.75 (25–550)	1.7 (1–7)	7.2 (1–58)
Bridges	105	0						

[a] Internal and external surveys combined.

analyzed separately, neither the variables nor levels of significance changed.

External surveys.—Complete interior surveys were not possible at 304 (45%) abandoned mines because of deteriorating interior conditions, poor air quality (usually low oxygen), partial or total collapse of tunnel, or overall complexity (i.e., problems associated with reaching upper and lower levels of mine complexes). At those 304 mines, only external surveys were conducted, and those surveys were limited to the maternity period in summer. Eighty-four of these mines (27.6%) were identified as summer day roosts for *C. townsendii*, including 83 bachelor roosts and 1 maternity roost. Presence of *C. townsendii* was associated with lower elevation ($\chi = 43.31$, $P < 0.001$; Fig. 1) located in sagebrush grassland ($\chi = 5.23$, $P < 0.05$), juniper woodland ($\chi = 6.31$, $P < 0.001$), or mountain brush ($\chi = 7.83$, $P < 0.05$). No other surface variables were associated with occupancy of a site (all $P > 0.05$).

Abandoned mines.—One hundred sixty-three of 676 mines surveyed (24%) were used as day roosts. Of these, 5 were maternity roosts (0.7%), with a mean colony size of 54.6 mature females/site (range, 15–150) and 158 were bachelor roosts (23.4%), with an average of 1.3 adult males or nonparous females/site (range, 1–5). Bats in those maternity colonies used multiple mines, moving an average of 2.2 times during the maternity period. Typically, maternity colonies moved immediately prior to parturition and again in midsummer (after young were volant but not yet weaned). No mines used as maternity roosts were used for hibernation. Bachelor sites were used sporadically (38% chance of occupancy on subsequent visits) throughout summer, with males often moving among different mines. Fifty-six (74.7%) bachelor roosts identified during internal surveys were also used for hibernation. Hibernating colonies in abandoned mines averaged 6.9 individuals/site (range, 1–18).

Caves.—Caves were more likely to be occupied than were mines ($Z = 8.22$, $P < 0.0001$). Thirty-three of 39 caves (84.6%) were used as day roosts. Caves were more likely to be occupied by maternity colonies than were mines ($Z = 5.44$, $P < 0.001$); 20.5% of caves were used as maternity roosts (Table 1). Maternity colonies in caves were larger ($\bar{X} = 175.8$; range, 25–550 mature females) than maternity colonies in mines ($t = 1.76$, $d.f. = 9$, $P = 0.05$). Maternity colonies in caves did not move among different caves during the maternity period; rather, each colony remained in a given cave for the duration of the maternity period, with colonies disbanding in late August–early September. The 25 bachelor roosts (64% of all caves) contained an average of 1.7 individuals (range, 1–7), with no differences observed in number of adult males or nonparous females in caves as compared with mines ($t = 0.85$, $d.f. = 24$, $P = 0.27$). Bachelor colonies in caves were more temporally stable than those in mines, with each actual cave roost having an 89% chance of occupancy on subsequent visits.

Downloaded from https://academic.oup.com/jmammal/article-abstract/81/4/939/2372908 by U S Dept of Agriculture user on 07 March 2019

Twenty-nine (88%) of the occupied caves were used during summer and hibernation. Hibernacula were occupied by an average of 7.2 individuals (range, 1–58), with no difference in colony size between caves and mines ($t = 0.99$, $d.f. = 28$, $P = 0.33$).

Discussion

We surveyed abandoned mines, caves, and bridges in all elevational and vegetational zones within the study area, and our results indicate that *C. townsendii* in northern Utah is not a habitat generalist with respect to selection of roosts. Rather, this species selected roosts within specific and predictable characteristics. These results supported those of Ports and Bradley (1996: 50), who described *C. t. pallescens* as being associated with ''foothills covered with pinyon pine and Utah juniper.'' Sites with small to midsize openings located at low to middle elevations in areas dominated by sagebrush grassland, juniper woodlands, and mountain brush communities were most likely to be occupied by *C. townsendii,* suggesting that external variables are of primary importance in determining selection of roosting sites by *C. townsendii.*

Association of *C. townsendii* with pinyon juniper may be related directly to foraging habits. Studies conducted in Oregon (Whitaker et al. 1981), New Mexico, and Arizona (Ross 1967) indicate that *C. townsendii* feeds primarily on Lepidoptera and Coleoptera, along with other insects, including neuropterans, dipterans, and hymenopterans. These bats likely forage along edges of habitats, and they may be gleaners, picking prey from surfaces of plants (Brown et al. 1994; Caire et al. 1984). Haymond (1998) found that *C. townsendii* in Idaho most commonly foraged in the interface between juniper woodlands and sagebrush–grass steppe. The interface of juniper woodlands and sagebrush–grass steppe in our study area presents a distinct edge that provides suitable foraging for this species. This edge effect may explain, in part, the observed association between roosting locations and specific vegetative types. However, it is possible that the correlation of roosts with elevational zones and vegetative types may be influenced by some other environmental (biotic or abiotic) factor, such as mean ambient temperature (Tuttle and Taylor 1994), local precipitation, or number of snow-free days.

Association of roosts with juniper woodlands is notable in that recent fire suppression and grazing activities have resulted in an increase in the distribution and abundance of juniper woodlands (Belsky 1996; Davenport et al. 1998; Yorks et al. 1994). This increase coupled with the recent creation of ''artificial'' roosts (i.e., mines) may have resulted in expansion of suitable habitat for *C. townsendii* (assuming that traditional cave roosts were not destroyed in the creation of these mines—J. S. Altenbach, pers. comm.).

Because of the small number of maternity roosts, it was not possible to make a statistical assessment of differences between bachelor and maternity roosts. However, qualitatively, internal variables at maternity roosts appeared to differ from those at bachelor roosts. Maternity roosts were more likely to have larger entrances and multiple openings. Maternity colonies in caves were larger and more spatially stable than those found in mines. We propose several hypotheses to explain these differences. Caves represent an older, more dependable roosting resource (mean age of abandoned mines within the study area was 81 years); therefore, it is possible that abandoned mines have not been present long enough to be inhabited by large populations of *C. townsendii.* Abandoned mines may be colonized by pioneering individuals or groups that have not had sufficient time to build large colonies relative to groups in caves.

Observed differences in use of roost types may be explained by the fact that abandoned mines were available in higher localized densities than were caves. If abandoned mines present roosting opportunities similar to those of caves, this higher density

Downloaded from https://academic.oup.com/jmammal/article-abstract/81/4/939/2372908 by U S Dept of Agriculture user on 07 March 2019

of potential roosts could result in a more even distribution of smaller maternity colonies. A 3rd alternative is that abandoned mines represent suboptimal habitat for *C. townsendii* and, therefore, serve as population sinks in which ''fringe'' populations are located. Maternity colonies in abandoned mines tended to be less stable spatially than those in caves. Mine-based maternity colonies relocated throughout maternity periods between several different mines, whereas cave-based maternity colonies remained within the same cave from parturition until the colony disbanded in autumn. This behavior is particularly interesting because caves generally had much higher levels of human disturbance than did mines. Whether this movement is adaptive (the animals are maximizing opportunities offered by a higher density of roost sites) or is maladaptive (no single mine is adequate to sustain the colony throughout the maternity period, so several sites must be used) is not known. Roost switching by maternity colonies has also been noted for *C. t. virginianus* in Kentucky (Lacki et al. 1994). Those colonies switched roosting sites among natural caves, with the causal factor undetermined.

It also is possible that this apparent discrepancy between caves and mines is an artifact of the study design and constraints on data collection. Because of dangers posed by abandoned mines, particularly vertical workings, complete internal surveys were made at only 372 (55%) of 676 mines visited, and it is likely that some mines that were surveyed external actually were used by *C. townsendii* during various parts of the year (J. S. Altenbach, pers. comm.). Although efforts were made to conduct external surveys at sites not entered or with partial internal surveys, some actual roosts probably were misidentified as being unused during external surveys. It also is not possible to identify hibernacula by conducting external surveys. Anthropogenic events that create hardrock mines (e.g., blasting, tunneling, stoping, ore removal) over a short period of time coupled with the geologic features in which major ore deposits are located (e.g., fault zones, ''rotten rock'') result in a high proportion of hazardous sites. As a result, abandoned mines that were surveyed completely tended to represent those that were dug into consolidated material and were less complex in nature. Caves, in contrast, are generally formed over long periods of time through various weathering events that tend to result in a more stable and less hazardous internal environment. As a result, all caves visited were surveyed completely, regardless of size and complexity. The fact that *C. townsendii* selects sites with little human disturbance (with the notable exception of cave-based maternity colonies) indicates that these unsafe mines likely are occupied by this species, because the more unsafe and unsurveyable a site is, the less likely it is to be impacted by humans.

The fact that maternity roosts were located with seeming disregard to levels of disturbance by humans (compared with bachelor and hibernation roosts) indicates that reproductive females may be constrained by specific roosting requirements that override costs of disturbance (e.g., temperature). Disturbance at several maternity roosts within the study area has been severe and often resulted in direct mortality of mature females and their young. Nevertheless, females continued to use these specific sites, ignoring seemingly usable roosts nearby.

Similar studies conducted throughout the western United States indicate a trend toward use of abandoned mines by *C. townsendii*. In California, over 40% of known roosts are located in abandoned mines and buildings (E. D. Pierson, pers. comm.). Kuenzi et al. (1999) reported that *C. townsendii* was the most common species of bat hibernating in abandoned mines in western central Nevada. Likewise, M. Perkins (in litt.) reported that many traditional roosts in caves in Oregon were abandoned or greatly reduced in size, whereas use of abandoned mines appeared to be increasing. Abandoned

Downloaded from https://academic.oup.com/jmammal/article-abstract/81/4/939/2372908 by U S Dept of Agriculture user on 07 March 2019

mines in Utah were used regularly by *C. townsendii* during all seasons. Differences in activity between populations in caves and those in relatively new roosting opportunities (abandoned mines) are intriguing. Nevertheless, the fact that approximately one-quarter of all abandoned mines surveyed are used as day roosts by this species indicates that these mines represent an important resource that may be critical to the long-term viability of local populations.

At the landscape level, predictions can be made regarding likelihood of presence of *C. townsendii*. However, the perception that individual sites within a habitat of choice can be identified as roosts based on easily selected and measured variables is false. The dynamic nature of this system makes it difficult, if not impossible, to quickly and easily assess the value of potential roosts.

Nomadic tendencies of mine-based summer *C. townsendii* colonies implies that single-season preclosure surveys may not be adequate to identify critical sites. For example, the mobile nature of maternity colonies in abandoned mines suggests that not only must a single site be protected (as would be appropriate for a cave) but alternative maternity roosts also must be identified and protected to ensure continued viability of that particular colony. It also is critical that adequate external surveys be conducted at sites where concerns for human safety preclude complete internal surveys.

Because of temperature fluctuations in many sites, microclimate readings made at a single point in time should not be used as an absolute indicator of internal climate. Rather, continuous readings should be taken throughout a site and for extended periods of time (Betts 1997). Point readings may be misleading and, in the worst case, could lead to the mistaken closure of abandoned mines that actually are suitable for use as roosts.

Differences between use of caves and use of mines presents a potential dilemma for land managers. Caves may represent a more critical resource than abandoned mines for *C. townsendii*; however, in most cases, it is easier to protect abandoned mines than to protect caves. Abandoned mines generally are viewed as an attractive nuisance, and their closure for safety reasons overrides any recreational value offered by these sites. Caves, in contrast, are protected by the Federal Cave Resource Protection Act of 1988 and generally are viewed as a recreational resource by management agencies and the public. It is important, however, to ensure that the relative ease of protecting abandoned mines (relative to caves) does not result in lack of suitable protection of caves used as roosts.

Acknowledgments

We are grateful to the Uinta National Forest for financial and logistical support, particularly D. Arling, B. Easton, T. Tidwell, C. Nunn-Hadfield, C. Thompson, and D. Nelson. We acknowledge financial and logistical support given by B. Blackwell and other personnel of the Utah Division of Wildlife Resources. We thank L. Romin of the Utah Department of Transportation for permitting us to survey bridges and S. Haymond, E. D. Pierson, M. J. O'Farrell, W. L. Gannon, and M. C. Belk for reviewing early drafts of this paper. We also acknowledge the many volunteers, whose hours of assistance are deeply appreciated. This project was supported in part by a grant to R. E. Sherwin from the Bat Conservation International Student Scholarship Program and from the Challenge Cost-Share Program of the United States Forest Service.

Literature Cited

Altenbach, J. S., and H. E. Milford. 1995. Evaluation and management of bats in abandoned mines in New Mexico. Pp. 326–330 in Proceedings of the 1993 National Cave Management Symposium, Carlsbad, New Mexico (D. Pate, ed.). American Cave Conservation Association, Horse Cave, Kentucky.

Armstrong, D. M., R. A. Adams, K. W. Navo, J. Freeman, and S. J. Bissel. 1995. Bats of Colorado. Colorado Division of Wildlife, Denver.

Barbour, R. W., and W. H. Davis. 1969. Bats of America. The University Press of Kentucky, Lexington.

Belsky, A. J. 1996. Western juniper expansion: is it a threat to arid northwestern ecosystems. Journal of Range Management 49:53–59.

Betts, B. J. 1997. Microclimate in Hell's Canyon

Downloaded from https://academic.oup.com/jmammal/article-abstract/81/4/939/2372908 by U S Dept of Agriculture user on 07 March 2019

mines used by maternity colonies of *Myotis yumanensis.* Journal of Mammalogy 78:1240–1250.

BROWN, P. E., R. D. BERRY, AND C. BROWN. 1994. Foraging behavior of Townsend's big-eared bats (*Plecotus townsendii*) on Santa Cruz Island. Pp. 367–369 in Fourth California Islands Symposium (W. L. Halvorson and G. J. Maender, eds.). Santa Barbara Museum of Natural History, Santa Barbara, California.

BURFORD, L. S., AND M. J. LACKI. 1995. Habitat use by *Corynorhinus townsendii virginianus* in the Daniel Boone National Forest. The American Midland Naturalist 134:340–345.

CAIRE, W., J. F. SMITH, S. MCGUIRE, AND M. A. ROYCE. 1984. Early foraging behavior of insectivorous bats in western Oklahoma. Journal of Mammalogy 65: 319–324.

CLARK, B. K., B. S. CLARK, D. M. LESLIE, JR., AND M. S. GREGORY. 1996. Characteristics of caves used by the endangered Ozark big-eared bat. Wildlife Society Bulletin 24:8–14.

CLARK, B. S., D. M. LESLIE, JR., AND T. S. CARTER. 1993. Foraging activity of adult female Ozark big-eared bats (*Plecotus townsendii ingens*) in summer. Journal of Mammalogy 74:422–427.

DALQUEST, W. W. 1947. Notes on the natural history of the bat *Corynorhinus rafinesquii* in California. Journal of Mammalogy 28:17–30.

DAVENPORT, D. W., D. D. BRESHEARS, AND B. P. WILCOX. 1998. Sustainability of pinon–juniper ecosystems—a unifying perspective of soil erosion thresholds. Journal of Range Management 51:231–240.

DOBKIN, D. S., R. D. GETTINGER, AND M. G. GERDES. 1995. Springtime movements, roost use, and foraging activity of Townsend's big-eared bat (*Plecotus townsendii*) in central Oregon. The Great Basin Naturalist 55:315–321.

GRAHAM, R. E. 1966. Observations on the roosting habits of the big-eared bat, *Plecotus townsendii* in California limestone caves. Cave Notes 8:17–22.

HARDY, I. C. W., AND S. A. FIELD. 1998. Logistic analysis of animal contests. Animal Behaviour 56:787–792.

HAYMOND, S. 1998. Summer habitat use by three vespertilionid bats in sagebrush-steppe in southeastern Idaho. M.S. thesis, Brigham Young University, Provo, Utah.

HUMPHREY, S. R. 1975. Nursery roosts and community diversity of Nearctic bats. Journal of Mammalogy 56:321–346.

HUMPHREY, S. R., AND T. H. KUNZ. 1976. Ecology of a Pleistocene relict, the western big-eared bat (*Plecotus townsendii*), in the southern Great Plains. Journal of Mammalogy 57:470–494.

KEELEY, B. W., AND M. D. TUTTLE. 1999. Bats in American bridges. Bat Conservation International, Austin, Texas.

KUENZI, A. J., G. T. DOWNARD, AND M. L. MORRISON. 1999. Bat distribution and hibernacula use in western central Nevada. The Great Basin Naturalist 59: 213–220.

KUNZ, T. H. 1982. Roosting ecology of bats. Pp. 1–55 in Ecology of bats (T. H. Kunz, ed.). Plenum, New York.

KUNZ, T. H., AND R. A. MARTIN. 1982. *Plecotus townsendii.* Mammalian Species 175:1–6.

LACKI, M. J., M. D. ADAM, AND L. G. SHOEMAKER. 1994. Observations on seasonal cycle, population patterns and roost selection in summer colonies of *Plecotus townsendii virginianus* in Kentucky. The American Midland Naturalist 131:34–42.

LONG, W. S. 1940. Notes on the life histories of some Utah mammals. Journal of Mammalogy 21:170–180.

PEARSON, O. P., M. R. KOFORD, AND A. K. PEARSON. 1952. Reproduction of the lump-nosed bat (*Corynorhinus rafinesquei*) in California. Journal of Mammalogy 33:273–320.

PIERSON, E. D. 1998. Tall trees, deep holes, and scarred landscapes: conservation biology of North American bats. Pp. 309–325 in Bat biology and conservation (T. H. Kunz and P. A. Racey, eds.). Smithsonian Institution Press, Washington, D.C.

PIERSON, E. D., W. E. RAINEY, AND D. M. KOONTZ. 1991. Bats and mines: experimental mitigation for Townsend's big-eared bat at the McLaughlin Mine in California. Pp. 31–42 in Proceedings V: issues and technology in the management of impacted wildlife. Thorne Ecological Institute, Aspen, Colorado.

PORTS, M. A., AND P. V. BRADLEY. 1996. Zoogeography and habitat affinities of bats from eastern Nevada. The Great Basin Naturalist 56:48–53.

ROSS, A. 1967. Ecological aspects of the food habits of insectivorous bats. Proceedings of the Western Foundation of Vertebrate Zoology 1:205–264.

SAS INSTITUTE INC. 1993. SAS technical report P-243 SAS/STAT software: the GENMOD procedure. Release 6.09. SAS Institute Inc., Cary, North Carolina.

SZEWCZAK, J. M., S. M. SZEWCZAK, M. L. MORRISON, AND L. S. HALL. 1998. Bats of the White and Inyo mountains of California–Nevada. The Great Basin Naturalist 58:66–75.

TUTTLE, M. D., AND D. A. R. TAYLOR. 1994. Bats and mines. Bat Conservation International, Austin, Texas.

TWENTE, J. W. 1960. Environmental problems involving the hibernation of bats in Utah. Proceedings of the Utah Academy of Science 37:67–71.

UNITED STATES DEPARTMENT OF THE INTERIOR. 1997. 20th Anniversary Surface Mining Control and Reclamation Act. Parts 1 and 2. Office of Surface Mining, Washington, D.C.

WETHINGTON, T. A., D. M. LESLIE, JR., M. S. GREGORY, AND M. K. WETHINGTON. 1996. Prehibernation habitat use and foraging activity by endangered Ozark big-eared bats (*Plecotus townsendii ingens*). The American Midland Naturalist 135:218–230.

WHITAKER, J. O., JR., C. MASER, AND S. P. CROSS. 1981. Food habits of eastern Oregon bats, based on stomach and scat analyses. Northwest Science 55:281–292.

YORKS, T. P., N. E. WEST, AND K. M. CAPELS. 1994. Changes in pinyon–juniper woodlands in western Utah's Pine Valley between 1933–1989. Journal of Range Management 47:359–364.

Submitted 25 November 1998. Accepted 1 February 2000.

Associate Editor was Allen Kurta.

Downloaded from https://academic.oup.com/jmammal/article-abstract/81/4/939/2372908 by U S Dept of Agriculture user on 07 March 2019