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Maternity Roosts of Townsend's Big-eared Bats in Lava Tube Caves of Southern Idaho

Abstract

Bats are being impacted by many threats (e.g., human disturbance of maternity roost sites and white-nose syndrome). Bat maternity roosts are a limited resource, and bats exhibit strong fidelity to these sites; therefore, identifying these features and conserving the surrounding habitat are important for bat management. Southern Idaho consists of the largest, contiguous volcanic pseudokarst area in the U.S., which provides important cave habitat for bats, but little is known about bat maternity roosts in this area. We compiled data spanning 36 years in southern Idaho to identify caves used by maternity colonies. From June 1980 to August 2016, researchers surveyed 313 caves. We documented 11 caves used by maternity colonies of Townsend's big-eared bats (*Corynorhinus townsendii*), and 10 caves that were potentially used by maternity colonies. In the 11 caves used as maternity roosts, the median number of Townsend's big-eared bats was 38, and the mean number was 49 individuals ($SD = 47.1$, range = 8 to 160 bats). Our data highlight southern Idaho as an important maternity roosting area for bats in Idaho and western North America, and provide baseline information of maternity caves prior to the arrival of white-nose syndrome, which can help managers during land-use planning in this area.

Keywords: maternity, bats, *Corynorhinus townsendii*, Snake River Plain

Introduction

Human disturbance of maternity roost sites and white-nose syndrome have impacted bat populations. The loss, modification, and disturbance of roost sites by humans have long been concerns for bat populations (McCracken 1989, Sheffield et al. 1992, Adams 2003). These concerns are especially true for Townsend's big-eared bats (*Corynorhinus townsendii*) in caves (Pierson et al. 1999, Sherwin et al. 2000, Gruver and Keinath 2006). White-nose syndrome is a major threat to

many bats that hibernate in caves (Bleher et al. 2009, Foley et al. 2011, Janicki et al. 2015), and many species of bats could be at risk of significant declines or extinction due to this disease (Frick et al. 2010, Maher et al. 2012, Ingersoll et al. 2013). Additionally, white-nose syndrome has recently been documented in the western U.S. (Lorch et al. 2016), and will likely arrive in Idaho in the next decade (Maher et al. 2012), if not sooner. Bats from the genus *Corynorhinus* can carry the fungal pathogen *Pseudogymnoascus destructans* that causes white-nose syndrome and may facilitate the spread of that fungus (Bernard et al. 2015). Because of these threats, it is essential for the conservation and management of bats and

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their habitat to document caves used as maternity roost sites (McCracken 1989, Olson et al. 2011, Lee et al. 2015).

Caves used as maternity roosts are a limited resource (McCracken 1989, Sheffield et al. 1992, Sherwin et al. 2003), and bats exhibit strong fidelity to these sites throughout the maternity season and across years (Pearson et al. 1952, Humphrey and Kunz 1976, Sherwin et al. 2003). Townsend's big-eared bats can use the same maternity roost for at least 25 years (Wainwright and Reynolds 2013, Fellers and Halstead 2015). Additionally, the destruction and modification of habitat surrounding roost sites can potentially impact the suitability of maternity sites (McCracken 1989, Sheffield et al. 1992, Fellers and Halstead 2015). Therefore, identifying maternity roost sites allows biologists to account for these resources during land-use planning, which will aid the conservation and management of maternity roosts and their surrounding habitat (Sheffield et al. 1992).

Southern Idaho consists of the largest, contiguous volcanic pseudokarst area in the United States (Veni 2002), which provides important cave habitat for bats. More than 1,500 caves exist in southern Idaho (Gillies et al. 2014, Slocum et al. 2016), and this area has one of the highest densities of bat hibernacula in western North America (Genter 1986, Gillies et al. 2014, Whiting et al. in review). A comprehensive summary of maternity sites in this area, however, has not been conducted since the mid-1990s (Pierson et al. 1999). Current, baseline data are needed to document the location and number of maternity roost caves of bats in southern Idaho. Herein, we compiled data from surveys over the past 36 years in southern Idaho to identify caves used by maternity colonies. Our goal was to provide baseline information on caves used as maternity roosts for bats, which will aid in conservation and management of these mammals and their habitat in this area.

Methods

Study Areas

The 313 caves we studied encompassed remote areas managed by the U.S. Bureau of Land Man-

agement (BLM) in the Sand Creek Desert, Big Desert, and Shoshone Desert; as well as areas managed by Craters of the Moon National Monument and Preserve. Those areas occupied the following counties in southern Idaho: Bingham, Blaine, Bonneville, Butte, Clark, Fremont, Gooding, Minidoka, and Power. Our study areas were located in the Upper Snake River Plain, and generally consisted of rolling hills with exposed silicic and basaltic volcanic outcrops and craters (Beck et al. 2009). Caves in those areas were formed from tubes of molten flows of basaltic lava or from lava blisters produced by pockets of trapped gas that were uncovered when the ceiling collapsed (Genter 1986, Mullican and Carraway 1990, Gillies et al. 2014). None of the caves in which surveys were conducted were solution or limestone caves (Wackenhut 1990, Doering 1996). Caves in our study areas are extremely important for hibernating Townsend's big-eared bats and western small-footed myotis (*Myotis ciliolabrum*) (Whiting et al. in review), as well as to a lesser extent for big brown bats (*Eptesicus fuscus*), little brown myotis (*M. lucifugus*), Yuma myotis (*M. yumanensis*), and long-eared myotis (*M. evotis*) (Genter 1986, Wackenhut 1990, Doering 1996). Bats generally enter caves in our study areas to hibernate in October and remain in caves until April (Keller et al. 1993, Bosworth 1994, Doering 1996).

Elevations in our study areas ranged from 684 m to 2000 m (Wackenhut 1990, Rodhouse et al. 2010, Gillies et al. 2014), and those areas were considered a cold desert consisting mainly of sagebrush (*Artemisia tridentata* ssp.) steppe vegetation (Reynolds et al. 1986, Nelle et al. 2000, Gillies et al. 2014). General weather patterns in our study areas were characterized by hot, dry summers and cold winters (Genter 1986, Reynolds et al. 1986, Wackenhut 1990). Most precipitation occurred during winter as snow and during spring as rain or snow (Reynolds et al. 1986, Wackenhut 1990, Rodhouse et al. 2010).

Craters of the Moon National Monument and Preserve is a relatively pristine and unique area that consists of extensive basalt lava fields covering $\geq 1,025$ km² (Rodhouse et al. 2010). These lava fields

have created kipukas, which are large, relatively undisturbed islands of native soil and vegetation (Tisdale et al. 1965, Bangert and Huntly 2010). Kipukas have little direct impact from humans due to the impassable nature of the surrounding lava (Tisdale et al. 1965, Bangert and Huntly 2010). Fifty-seven caves in our study areas were included in Craters of the Moon National Monument and Preserve in 1924 (Slocum et al. 2016). Five more caves were previously managed by the BLM, but were later incorporated into Craters of the Moon National Monument and Preserve in 2000 with the expansion of the monument. If caves were surveyed by BLM biologists and later incorporated into Craters of the Moon National Monument and Preserve and surveyed after 2000 by monument biologists, we considered those caves as being part of the monument. In this manuscript, names of caves have been replaced with number and letter combinations to minimize revealing locations of caves, which can lead to damage of roost sites (Sheffield et al. 1992, Wainwright and Reynolds 2013).

Survey Methods

In spring and summer, female Townsend's big-eared bats form maternity colonies in caves and mines (Twente 1955, Humphrey and Kunz 1976, Kunz and Martin 1982). During that time, males occur solitarily or in small groups (mean of two bats) in bachelor roosts (Pearson et al. 1952, Humphrey and Kunz 1976). Female Townsend's big-eared bats exhibit strong fidelity to maternity sites throughout the maternity season and across years (Pearson et al. 1952, Humphrey and Kunz 1976, Sherwin et al. 2003), even up to 25 years (Fellers and Halstead 2015). Researchers in our study areas focused surveys on maternity sites, because these areas have been identified as critical for the conservation of bats and the management of their habitat (Sheffield et al. 1992), especially Townsend's big-eared bats (Reid et al. 2010, Fellers and Halstead 2015, Lee et al. 2015). Surveys for maternity colonies are often conducted from May to September (Humphrey and Kunz 1976, Pierson and Rainey 1998, Sherwin et al. 2003). Maternity colonies of Townsend's big-eared bats often roost in conspicuous areas in densely packed

clusters, which facilitates identifying them (Reid et al. 2010, Humphrey and Kunz 1976). Additionally, this species is recognizable by their long ears (Humphrey and Kunz 1976, Genter 1986).

Intermittently from 1992 to 2002, extensive effort was made by the Idaho Cave Survey (a nonprofit organization of the National Speleological Society that had surveyed caves in southeastern Idaho since 1981)—in conjunction with the BLM, Bat Conservation International, and the North American Bat Conservation Partnership to identify, document use by bats, and map the interior of caves in the Sand Creek Desert and Big Desert (Earl and Earl 2000, 2002). All of those surveys were conducted from May through September. The mean ($\pm$ SD) number of researchers conducting surveys in the Sand Creek Desert and Big Desert was 2 ($\pm$ 0.7, range = 1 to 5 individuals). Additionally from 17 July to 1 August 2014, maternity roost searches were conducted by $\geq$ three researchers in the Shoshone Desert. During six days of searching, 32 caves were visited that were suspected to be roost sites. Moreover, from 2 June to 15 August 2016; two geologists entered 69 caves in the Shoshone Desert and documented the occurrences of maternity colonies.

Similar surveys were conducted intermittently by university researchers and biologists in Craters of the Moon National Monument and Preserve from June 1980 through August 2015 (Keller et al. 1993; Keller and Saathoff 1995, 1996; Keller 1999). Often, only a date range (e.g., 29 June to 22 August 1994) was given for those surveys. During such instances, 76% of surveys occurred from June through August. The main purpose of those surveys was to discover and document caves with potential roosting habitat for bats (Keller and Saathoff 1995, 1996; Earl and Earl 2000, 2002). In Craters of the Moon National Monument and Preserve the mean number of researchers conducting surveys fluctuated based on survey type and year, but were usually conducted by one or two people (Keller and Saathoff 1995, 1996; Keller 1999).

We searched reports, field notes, and documents from surveys to identify maternity roosts (Keller and Saathoff 1995, 1996; Keller 1999; Earl and Earl 2000, 2002). We designated a cave as a ma-

Table 1. Maternity roost sites for bats in the Sand Creek Desert (SC) and Shoshone Desert (SD) from surveys conducted from 1992 to 2016, as well as in Craters of the Moon National Monument and Preserve (CRMO) from surveys conducted from 1980 to 2015 in southern Idaho.

Cave	Area	Date surveyed	Species observed	Estimated # of bats
SC 23	SC	1996	Townsend's big-eared bat	Bats observed ^a
SC 23	SC	1999	Townsend's big-eared bat	Bats observed ^a
SC 100	SC	2000	Townsend's big-eared bat	Bats observed ^a
SC 100	SC	22 Jul 03	Townsend's big-eared bat	> 100
SC 100	SC	25 Jul 03	Townsend's big-eared bat	160 to 200
SC 100	SC	Aug 06	Townsend's big-eared bat	28 ^b
SD 1	SD	18 Jul 14	Townsend's big-eared bat	8
CM 1	CRMO	1992	Townsend's big-eared bat	Bats observed ^a
CM 3	CRMO	1998	Townsend's big-eared bat	Bats observed ^a
CM 4	CRMO	1985	Townsend's big-eared bat	Bats observed ^a
CM 4	CRMO	1999	Townsend's big-eared bat	> 24
CM 26	CRMO	Aug 08	Townsend's big-eared bat	Bats observed ^a
CM 28	CRMO	20 Jul 99	Unknown ^c	40 to 50
CM 32	CRMO	8 Jul 94	Townsend's big-eared bat	40 to 50
CM 39	CRMO	1995	Townsend's big-eared bat	35
CM 40	CRMO	1993	Townsend's big-eared bat	Bats observed ^a
CM 54	CRMO	21 Jun 90	Long-eared myotis ^d	Bats observed ^a
CM 54	CRMO	1993	Townsend's big-eared bat	60 to 80
CM 54	CRMO	1994	Townsend's big-eared bat	40

^aNumber of bats not recorded.

^bSeventeen adults and 11 juveniles captured using a harp trap at the entrance of the cave (Miller 2007).

^cLikely Townsend's big-eared bats.

^dPossible misidentification, most likely Townsend's big-eared bats.

ternity roost when any number of females with pups were observed or if a large number of bats (> 20 individuals) were observed during a survey (Humphrey and Kunz 1976, Kunz and Martin 1982). We calculated a median and mean number of bats in maternity colonies when the number of bats was recorded. When an estimated range of numbers was recorded during a survey, we used the lowest value in that range for the calculation of median and mean numbers of bats. Additionally, researchers documented if piles of bat guano (up to 3 ft x 4 ft) were observed in caves (Keller et al. 1993; Earl and Earl 2000, 2002). Piles of guano are an indication of a potential maternity roost site (Humphrey and Kunz 1976). In each instance when researchers documented piles of bat guano, we considered those caves potential maternity roosts (Humphrey and Kunz 1976, Sherwin et al. 2003).

Results

Of the 313 caves surveyed in our study areas (Sand Creek Desert = 126, Big Desert = 24, Shoshone Desert = 101, Craters of the Moon National Monument and Preserve = 62), we documented 12 used by maternity colonies (Sand Creek Desert = two or 2% of caves surveyed, Shoshone Desert = 1 or 1% of caves surveyed, and Craters of the Moon National Monument and Preserve = 9 or 15% of caves surveyed; Table 1). Eleven of those caves were used by Townsend's big-eared bats (Table 1). In those 11 caves used as maternity roosts, when researchers were able to quantify number of bats (eight surveys in six caves), the median number of Townsend's big-eared bats was 38, and the mean ($\pm$ SD) was 49 individuals ($\pm$ 47.1, range = 8 to 160 bats). No other species were observed in those 12 caves used as maternity roosts, however, researchers often halted surveys after observing

Table 2. Caves potentially used by bat maternity colonies (based on the presence of guano) in the Sand Creek Desert (SC) and Big Desert (BD) from surveys conducted from 1992 to 2016, as well as in Craters of the Moon National Monument and Preserve (CRMO) from surveys conducted from 1980 to 2015 in southern Idaho.

Cave	Area	Date surveyed	Sign
SC 6	SC	05 Aug 00	Thin layer of bat guano
SC 44	SC	3 Jul 00	Large amounts of bat guano
SC 94	SC	31 Jul 99	Large amounts of bat guano
BD 22	BD	28 Sep 02	Large amounts of bat guano
BD 24	BD	28 Sep 02	Large amounts of bat guano
CM 15	CRMO	27 Sep 02	Large amounts of bat guano
CM 18	CRMO	5 Jun 13	Large amounts of bat guano
CM 35	CRMO	2014	Large amounts of bat guano
CM 45	CRMO	2014	Large amounts of bat guano
CM 47	CRMO	2014	Large amounts of bat guano

maternity colonies to limit disturbance to bats; therefore, they did not survey the entire cave in those instances. In the remaining 301 caves, 10 caves were potentially used by maternity colonies based on presence of guano (Sand Creek Desert = 3, Big Desert = 2, Craters of the Moon National Monument and Preserve = 5; Table 2).

Discussion

We documented 11 caves used by maternity colonies of Townsend's big-eared bats, and 10 caves may have been used by maternity colonies of that species. The majority (i.e., 64%) of documented and potential caves used as maternity roosts were located in Craters of the Moon National Monument and Preserve. In 1999, when the last comprehensive update occurred, three maternity roosts were documented in southern Idaho, two of which were located in Craters of the Moon National Monument and Preserve (Pierson et al. 1999). The number of recorded maternity roosts in caves for the subspecies of Townsend's big-eared bats (*C. t. townsendii*) in western North America (Piaggio and Perkins 2005) ranges from 23 in California to $\leq$ six in Arizona, Colorado, Montana, Nevada, Oregon, South Dakota, Utah, Wyoming, and British Columbia (Pierson and Rainey 1998, Pierson et al. 1999, Reid et al. 2010, Wainwright and Reynolds 2013). Moreover, in California over the last 20 to 40 years, the number of maternity colonies for this species has declined by 52% (Pierson and Rainey 1998, Fellers and

Halstead 2015). Conservation concern exists for Townsend's big-eared bats (Piaggio and Perkins 2005, Gruver and Keinath 2006). Our data indicate the importance of southern Idaho for maternity colonies of this species in western North America. More caves than we identified likely exist in our study areas that are used as maternity roosts sites by bats (Genter 1986, Wackenhut 1990, Gillies et al. 2014), further highlighting the importance of these areas for the conservation and management of Townsend's big-eared bats.

Median number of Townsend's big-eared bats we documented was 38, and mean number was 49 individuals. Previous estimates for maternity colonies in Idaho were 40–50 individuals in two caves in Craters of the Moon National Monument and Preserve (Pierson et al. 1999). Maternity colony size of Townsend's big-eared bats in western North America varies from two to 500 individuals in Arizona, California, Montana, Nevada, Oregon, South Dakota, Utah, and Wyoming (Pierson et al. 1999), but usually does not exceed 100 bats (Pearson et al. 1952, Kunz and Martin 1982). In California, the median number of roosting bats was 75 individuals in 38 maternity roost sites (Pierson et al. 1999). In California over the last 20 to 40 years, however, the number of adult females at maternity roosts has declined by 55% (Fellers and Halstead 2015). Our data provide a baseline number of individuals in maternity colonies, which can be used to compare changes across years in our study areas.

Monitoring and surveying are important components of management and conservation plans for bats (Pierson et al. 1999, Wainwright and Reynolds 2013, IDFG 2017). Biologists at Point Reyes National Sea Shore in California closed entrances for humans to a maternity roost for Townsend's big-eared bats in an abandoned house that was vandalized (Fellers and Halstead 2015). Thereafter, scientists monitored the response of that bat colony for 24 years, and number of females increased at a mean annual rate of 8.7% (Fellers and Halstead 2015). Those biologists attributed that increase to the implemented closure of potential entrances to humans (Fellers and Halstead 2015), and recommend that if similar management practices are implemented at other roost sites, such actions may lead to an increase in colony size (Fellers and Halstead 2015). Some

caves in our study areas are important for human recreation and are visited extensively (Pierson et al. 1999, IDFG 2017). In our study areas, we recommend land managers monitor maternity roost sites consistently (IDFG 2017); and if disturbance is occurring, implement practices to reduce disturbance to maternity colonies. We also recommend that land managers consider maternity roost sites during land-use planning, which will aid in the conservation and management of bats and their habitat in these areas.

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Literature Cited

- Adams, R. A. 2003. Bats of the Rocky Mountain West: Natural History, Ecology, and Conservation. University Press of Colorado, Boulder.
- Bangert, R., and N. Huntly. 2010. The distribution of native and exotic plants in a naturally fragmented sagebrush-steppe landscape. *Biological Invasions* 12:1627-1640.
- Beck, J. L., J. W. Connelly, and K. P. Reese. 2009. Recovery of Greater Sage-Grouse habitat features in Wyoming big sagebrush following prescribed fire. *Restoration Ecology* 17:393-403.
- Bernard, R. F., J. T. Foster, E. V. Willcox, K. L. Parise, and G. F. McCracken. 2015. Molecular detection of the causative agent of white-nose syndrome on Rafinesque's big-eared bats (*Corynorhinus rafinesquii*) and two species of migratory bats in the southeastern USA. *Journal of Wildlife Diseases* 51:519-522.
- Bleher, D. S., A. C. Hicks, M. Behr, C. U. Meteyer, B. M. Berlowski-Zier, E. L. Buckles, J. T. H. Coleman, S. R. Darling, A. Gargas, R. Niver, J. C. Okoniewski, R. J. Rudd, and W. B. Stone. 2009. Bat white-nose syndrome: an emerging fungal pathogen? *Science* 323:227-227.
- Bosworth, W. R. 1994. Characteristics of winter activity in *Plecotus townsendii* in southeastern Idaho. M.S. Thesis, Idaho State University, Pocatello.
- Doering, R. W. 1996. Thermal implications of roost site selection in hibernating *Plecotus townsendii*. M.S. Thesis, Idaho State University, Pocatello.
- Earl, S., and A. Earl. 2000. Cave inventory and bat habitat determination and documentation in the Sand Dunes/Sand Creek Wildlife Management Area. Unpublished report on file at U.S. Bureau of Land Management, Idaho Falls, ID.
- Earl, S., and A. Earl. 2002. Cave inventory and bat habitat determination and documentation in the Big Desert Management Area, Upper Snake River District, Bureau of Land Management. Unpublished report on file at U.S. Bureau of Land Management, Idaho Falls, ID.
- Fellers, G. M., and B. J. Halstead. 2015. Twenty-five years of monitoring a Townsend's big-eared bat (*Corynorhinus townsendii*) maternity roost. *Northwestern Naturalist* 96:22-36.
- Foley, J., D. Clifford, K. Castle, P. Cryan, and R. S. Ostfeld. 2011. Investigating and managing the rapid emergence of white-nose syndrome, a novel, fatal, infectious disease of hibernating bats. *Conservation Biology* 25:223-231.
- Frick, W. F., J. F. Pollock, A. C. Hicks, K. E. Langwig, D. S. Reynolds, G. G. Turner, C. M. Butchkoski, and T. H. Kunz. 2010. An emerging disease causes regional population collapse of a common North American bat species. *Science* 329:679-682.
- Genter, D. L. 1986. Wintering bats of the upper Snake River Plain: occurrence in lava-tube caves. *Great Basin Naturalist* 46:241-244.
- Gillies, K. E., P. J. Murphy, and M. D. Matocq. 2014. Hibernacula characteristics of Townsend's big-eared bats in southeastern Idaho. *Natural Areas Journal* 34:24-30.

- Gruver, J. C., and D. A. Keinath. 2006. Townsend's big-eared bat (*Corynorhinus townsendii*): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region, Golden, CO.
- 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.
- Idaho Department of Fish and Game. 2017. Idaho State Wildlife Action Plan, 2015. Idaho Department of Fish and Game, Boise, Idaho.
- Ingersoll, T. E., B. J. Sewall, and S. K. Amelon. 2013. Improved analysis of long-term monitoring data demonstrates marked regional declines of bat populations in the eastern United States. *PLoS One* 8: e65907.
- Janicki, A. F., W. F. Frick, A. M. Kilpatrick, K. L. Parise, J. T. Foster, and G. F. McCracken. 2015. Efficacy of visual surveys for white-nose syndrome at bat hibernacula. *PLoS One* 10: e0133390.
- Keller, B. L. 1999. Thermal characteristics of lava caves in the North Caves Area and bat species present at Pond Cave, Craters of the Moon National Monument, Butte County, ID. Unpublished report on file at Craters of the Moon National Monument and Preserve, Arco, ID.
- Keller, B. L., W. R. Bosworth, and R. W. Doering. 1993. Final technical report: bat habitat research. Unpublished report on file at Wastren Advantage, Idaho Falls, ID.
- Keller, B. L., and R. T. Saathoff. 1995. A survey of day roosting by *Plecotus townsendii* in lava-tube caves at Craters of the Moon National Monument, Butte County, Idaho. Unpublished report on file at Craters of the Moon National Monument and Preserve, Arco, ID.
- Keller, B. L., and R. T. Saathoff. 1996. A netting survey of water and cave areas used by bats at Craters of the Moon National Monument, Butte County, Idaho. Unpublished report on file at Craters of the Moon National Monument and Preserve, Arco, ID.
- Kunz, T. H., and R. A. Martin. 1982. *Plecotus townsendii*. *Mammalian Species* 175:1-6.
- Lee, D. N., R. C. Stark, W. L. Puckette, M. J. Hamilton, D. M. Leslie, and R. A. Van Den Bussche. 2015. Population connectivity of endangered Ozark big-eared bats (*Corynorhinus townsendii ingens*). *Journal of Mammalogy* 96:522-530.
- Lorch, J. M., J. M. Palmer, D. L. Lindner, A. E. Ballmann, K. G. George, K. Griffin, S. Knowles, J. R. Huckabee, K. H. Haman, C. D. Anderson, P. A. Becker, J. B. Buchanan, J. T. Foster, and D. S. Blehert. 2016. First detection of bat white-nose syndrome in Western North America. *mSphere* 1:e00148-16.
- Maher, S. P., A. M. Kramer, J. T. Pulliam, M. A. Zokan, S. E. Bowden, H. D. Barton, K. Magori, and J. M. Drake. 2012. Spread of white-nose syndrome on a network regulated by geography and climate. *Nature Communications* 3:1306.
- McCracken, G. F. 1989. Cave conservation: special problems of bats. *National Speleological Society Bulletin* 51:47-51.
- Miller, K. E. G. 2007. Connectivity, relatedness, and winter roost ecology of Townsend's big-eared bat (*Corynorhinus townsendii*). M.S. Thesis, Idaho State University, Pocatello.
- Mullican, T. R., and L. N. Carraway. 1990. Shrew remains from Moonshiner and Middle Butte Caves, Idaho. *Journal of Mammalogy* 71:351-356.
- Nelle, P. J., K. P. Reese, and J. W. Connelly. 2000. Long-term effects of fire on sage grouse habitat. *Journal of Range Management* 53:586-591.
- Olson, C. R., D. P. Hobson, and M. J. Pybus. 2011. Changes in population size of bats at a hibernaculum in Alberta, Canada, in relation to cave disturbance and access restrictions. *Northwestern Naturalist* 92:224-230.
- 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.
- Piaggio, A. J., and S. L. Perkins. 2005. Molecular phylogeny of North American long-eared bats (Vespertilionidae: *Corynorhinus*); inter- and intraspecific relationships inferred from mitochondrial and nuclear DNA sequences. *Molecular Phylogenetics and Evolution* 37:762-775.
- Pierson, E. D., and W. E. Rainey. 1998. Distribution, status, and management of Townsend's big-eared bat (*Corynorhinus townsendii*) in California. California Department of Fish and Game, Sacramento, CA.
- Pierson, E. D., M. C. Wackenhut, J. S. Altenbach, P. Bradley, P. Call, D. L. Genter, C. E. Harris, B. L. Keller, B. Lengus, L. Lewis, B. Luce, K. W. Navo, J. M. Perkins, S. Smith, and L. Welch. 1999. Species conservation assessment and strategy for Townsend's big-eared bat (*Corynorhinus townsendii townsendii* and *Corynorhinus townsendii pallescens*). Idaho Conservation Effort, Idaho Department of Fish and Game, Boise, ID.
- Reid, A., T. Hill, R. Clarke, J. G. William, and J. Krebs. 2010. Roosting ecology of female Townsend's big-eared bats (*Corynorhinus townsendii*) in southeastern British Columbia: implications for conservation management. *Northwestern Naturalist* 91:215-218.
- Reynolds, T. D., J. W. Connelly, D. K. Halford, and W. J. Arthur. 1986. Vertebrate fauna of the Idaho National Environmental Research Park. *Great Basin Naturalist* 46:513-527.

- Rodhouse, T. J., E. A. Beever, L. K. Garrett, K. M. Irvine, M. R. Jeffress, M. Munts, and C. Ray. 2010. Distribution of American pikas in a low-elevation lava landscape: conservation implications from the range periphery. *Journal of Mammalogy* 91:1287-1299.
- Sheffield, S. R., J. H. Shaw, G. A. Heidt, and L. R. McClenaghan. 1992. Guidelines for the protection of bat roosts. *Journal of Mammalogy* 73:707-710.
- Sherwin, R. E., D. Stricklan, and D. S. Rogers. 2000. Roosting affinities of Townsend's big-eared bat (*Corynorhinus townsendii*) in northern Utah. *Journal of Mammalogy* 81:939-947.
- Sherwin, R. E., W. L. Gannon, and J. S. Altenbach. 2003. Managing complex systems simply: understanding inherent variation in the use of roosts by Townsend's big-eared bat. *Wildlife Society Bulletin* 31:62-72.
- Slocum, K., T. Stefanic, and T. J. Rodhouse. 2016. Bat hibernacula surveys in Craters of the Moon National Monument and Preserve: 2016 status report. National Park Service. Unpublished report on file at Craters of the Moon National Monument and Preserve, Arco, ID.
- Tisdale, E. W., M. Hironaka, and M. A. Fosberg. 1965. An area of pristine vegetation in Craters of the Moon National Monument, Idaho. *Ecology* 46:349-352.
- Twente, J. W. 1955. Aspects of a population study of cavern-dwelling bats. *Journal of Mammalogy* 36:379-390.
- Veni, G. 2002. Revising the karst map of the United States. *Journal of Cave and Karst Studies* 64:45-50.
- Wackenhut, M. C. 1990. Bat species overwintering in lava-tube caves in Lincoln, Gooding, Blaine, Bingham, and Butte counties, Idaho with special reference to annual return of banded *Plecotus townsendii*. M.S. Thesis, Idaho State University, Pocatello.
- Wainwright, J. M., and N. D. Reynolds. 2013. Cave hibernaculum surveys of a Townsend's big-eared bat (*Corynorhinus townsendii*) colony at Mount St. Helens, Washington. *Northwestern Naturalist* 94:240-244.
- Whiting, J. C., B. Doering, G. Wright, D. K. Englestead, J. A. Frye, and T. Stefanic. In review. Bat hibernacula in southern Idaho: implications for monitoring and management. *Western North American Naturalist*.

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