Journal of
Bat Research & Conservation

OPEN ACCESS
www.secemu.org
DOI: 10.14709/BarbJ.12.1.2019.12

ORIGINAL ARTICLE

Acoustic surveys for local, free-flying bats in zoos: an engaging approach for bat education and conservation

Jericho C. Whiting[1,*], Bill Doering[2], David Pennock[3]

[1] Department of Biology, Brigham Young University-Idaho, 116 Benson Building, Rexburg, Idaho, USA

[2] Veolia Nuclear Solutions—Federal Services, 120 Technology Drive, Idaho Falls, Idaho, USA

[3] Idaho Falls Zoo at Tautphaus Park, 2725 Carnival Way, Idaho Falls, Idaho, USA

*Corresponding author: whitingj@byui.edu

DOI: https://doi.org/10.14709/BarbJ.12.1.2019.12

Keywords: acoustic monitoring, Anabat, conservation, education, exhibit, zoos

received: February, 11th 2019
accepted: December, 3rd 2019

ABSTRACT

Bats are a highly diverse mammal taxon, and many populations are threatened in the wild. Zoos play an important role in wildlife education for conservation, and public education and support are critical for conserving bats, especially with the recent threats of white-nose syndrome in North America and wind-energy development. Conservation exhibits at zoos for local, free-flying bats, however, are rare. Here, we used an ultrasound detector set in the Idaho Falls Zoo to document local diversity and activity of free-flying bats. We then used that information to support bat conservation education in the zoo. From June to October 2018, we recorded 15,617 bat passes. We recorded 5 resident and 2 migrant species at the zoo, 6 of which were classed as being of conservation concern. Bat activity was highest in June, at sunset, and 64% of activity occurred within 4 hours after sunset. Bats in the zoo likely roosted in buildings, trees, and other structures, as well as foraged near water and foliage; therefore, the zoo and its exhibits provided diverse, extensive habitat for local, free-flying bats that came from inside and outside of the zoo. Our data led to public education activities at the zoo; and this technique required minimal space and maintenance. Our approach of acoustical monitoring bats at zoos is a simple, portable exhibit that could lead to research and increased public education and conservation of local, free-flying bats, which will help zoos be education centers for local species.

INTRODUCTION

Bats have important roles in ecosystem function and services; including insect control, seed dissemination, and plant pollination (Kunz et al. 2011). Bats are also primary, secondary, and tertiary consumers (Patterson et al. 2003, Kunz et al. 2011). For example, bats can suppress populations of insects, with an estimated value of $22.9 billion/year to the agricultural industry in the USA (Boyles et al. 2011). Therefore, declines in bat populations could have far-reaching consequences across ecosystems and the agricultural industry (Boyles et al. 2011).

People often fear bats (Prokop & Tunnicliffe 2008); as these mammals are frequently linked with scary, negative emotions (Kahn et al. 2008). As nocturnal flying mammals, people do not experience bats as often as diurnal animals (Kingston 2016). In North America, bats belong to the most misunderstood and threatened group of vertebrates not associated primarily with aquatic habitat (Hammerson et al. 2017). Additionally, public understanding is low regarding the biology of, and ecosystem services provided by, bats (Prokop & Tunnicliffe 2008), as well as the threat of white-nose syndrome; even in areas in the USA where this disease has decimated populations (Fagan et al. 2018). Conversely, people enjoy learning about bats at zoos (Kahn et al. 2008), and zoos connect people with wildlife and stimulate pro-conservation behaviors (Skibins & Powell 2013). Reducing threats to bats depends on educating and changing human behaviors (Veríssimo 2013, Kingston 2016). Indeed, public outreach and education is critical for bat conservation (Sheffield et al. 1992, O'Shea et al. 2016).

White-nose syndrome, wind-energy development, and human disturbance of roost sites have impacted bat populations in North America (Blehert et al. 2009, Smallwood 2013, O'Shea et al. 2016). White-nose syndrome is a fungal infection causing tissue damage in bats. This disease is a recent, major threat to many bats that hibernate in caves in the USA (Blehert et al. 2009) and is estimated to have killed over five million bats of seven species (Foley et al. 2011, Bernard & McCracken 2017). Many common bat species could be at risk of declines or extinction due to this disease (Knudsen et al. 2013, Hammerson et al. 2017). Primarily a disease occurring in the eastern USA, white-nose syndrome has now spread to the western USA (Lorch et al. 2016). Wind-energy development is also expanding rapidly (Arnett et al. 2008, Hein & Schirmacher 2016), and an estimated > 600,000 bats die each year at these facilities in the USA (Smallwood 2013). Additionally, the loss and modification of hibernacula, as well as the disturbance of roosting bats by humans have long been of conservation concern for bats (Sheffield et al. 1992, O'Shea et al. 2016).

Because of these threats, and the low reproductive rate of bats, at least 18 of 47 species of bats are listed as being of conservation concern in the United States (O'Shea et al. 2018) and warrant attention to prevent further loss of biodiversity (Hammerson et al. 2017).

Zoos play an important role in wildlife education for conservation (Fa et al. 2014, Gusset et al. 2014). Public education and support are crucial for bat conservation (O'Shea et al. 2016, Fagan et al. 2018); however, conservation exhibits emphasizing local, free-flying bats are rare at zoos in the USA. Here, we used an ultrasound detector in a zoo to document the presence, diversity, and activity patterns of free-flying resident (i.e., bats that hibernate locally) and migrant bats (i.e., bats with seasonal continental-scale migration) (Cryan 2003) within the Idaho Falls Zoo. Specifically, we examined whether bat activity varied monthly and by time of night. We then used that information in public education opportunities at the zoo and in the community. Data from our acoustical monitoring of bats, as well as the resultant educational opportunities in the zoo about those species, has the potential to lead to greater research, awareness, and a reduction of irrational fear of bats, as well as an increase in public education about local free-flying bats, and also the threats that bats face, all of which can aid in bat education and conservation activities at zoos.

MATERIAL AND METHODS

We set one Anabat SDII detector (Titley Scientific, Columbia, MO) from 1 June to 8 October 2018 at a 12 x 23 m pond in the Idaho Falls Zoo, southeastern Idaho, USA (Fig. 1). Anabat detectors record the echolocation calls of bats (O'Farrell et al. 1999, Britzke et al. 2011, Adams et al. 2012), as many bat calls are consistent in structure and have species-specific characteristics (Fenton & Bell 1981). The Idaho Falls Zoo is accredited by the Association of Zoos and Aquariums, is open from April to October, and has approximately 150,000 visitors/year. Resident bats that have previously been recorded or captured in southeastern Idaho included the following: Townsend's big-eared bat (*Corynorhinus townsendii*), western small-footed myotis (*Myotis ciliolabrum*), little brown bat (*M. lucifugus*), big brown bat (*Eptesicus fuscus*), long-legged myotis (*M. volans*), and Yuma myotis (*M. yumanensis*); migrant species included silver-haired (*Lasionycteris noctivagans*) and hoary bats (*Lasiurus cinereus*) (Keller 1985, IDFG 2017, Whiting et al. 2018a, Whiting et al. 2018b).

Our Anabat detector was powered by external batteries and was equipped with a BatHat weatherproofing system to protect the directional microphone and reduce damage to equipment from rain (Fig. 1, Britzke et al. 2010). The detector was programmed to record from sunset to sunrise as suggested by Miller (2001) and Johnson et al. (2017). We set the division ratio at 8, and the mean sensitivity was 5.85 (range = 5.7 to 5.9). To exclude ambient noise, we oriented the microphone to maximize detection over the pond. When triggered by a bat flying near the pond, the detector created one, ≤ 15 sec. file, labeled with a unique date and time stamp. One file could have multiple bat passes of potentially more than one bat (i.e., a sequence of ≥ two echolocation calls from a bat flying by the detector) (Bernard & McCracken 2017, Heim et al. 2018).

Fig. 1 - Anabat detector, extension pole, and microphone set on a walkway over a pond in the Idaho Falls Zoo, USA, from June to October 2018.

We screened and analyzed call files in AnaLookW using filters. Filters allow researchers to scan through large datasets of bat call files to search for acoustic patterns of interest (e.g., separating bats from noise, separating bat calls by species, or species groups of interest) (O'Farrell et al. 1999, Schwab & Mabee 2014, Klüg-Baerwald et al. 2016). For our analyses, we developed custom bat filters based on a > 5,000 call library of the known species previously recorded in southern Idaho, USA, to compare the number of bat passes by month and time of day (Table 1). We hand verified all species identifications made by filters. We then plotted number of bat passes by month and by hours after sunset.

During our sampling, we also held concurrent bat educational activities at the zoo. Those activities included weekly exploration stations in the zoo that discussed local bat conservation, and us giving presentations to the public regarding our bat monitoring and local bat conservation issues during a bat night at the zoo. That bat night included teaching and showing the public our bat monitoring station and discussing how bat calls are received, recorded, and analyzed. All those opportunities educated the public about bats, and potentially can change public perception about bats, which is needed for conservation of these mammals (Fa et al. 2014, O'Shea et al. 2016).

Table 1 - Parameters of bat calls used to create filters for our analyses. Depending on filter requirements, parameters included the range of values for characteristic frequency (Fc), slope of call body (Sc), minimum frequency of the call (Fmin), maximum frequency of the call (Fmax), sweep, and duration of the call. Filter parameters were based on a regional call library we produced for each species and species groups (when poor call quality did not allow filters to assign a bat pass to a species).

Filters	F_c	S_c	F_{min}	F_{max}	Sweep	Duration
Little brown bat	37-46.2	30-130	35-45	-	10-70	>3.9
Yuma myotis	50.5-55	40-95	42-56	-	-	4.5-8.4
Big brown bat	24-32	15-150	22-32	57-80	11-45	>5
Western small-footed myotis	38-45	96-250	35-45	70-120	-	2-3.6
Long-legged myotis	38-44	40-150	35-42	85-120	-	3.9-8.8
Silver-haired bat	24.5-27	0.2-12.5	-	-	1.2-45	4.2-25
Hoary bat	14-30	5-38	14-21.6	14-32	-	6.8-25
25k bats†	14-34	0-170	14-34	-	-	2-25
40k Myotis‡	38-45	28-300	35-45	-	-	0.9-9
50k bats§	50.5-60	40-500	40-55	<120	0.5-70	1.5-8.4

†This species group included poorly detected calls of big brown, silver-haired, and hoary bats.
‡This species group included poorly detected calls of western small-footed myotis, little brown myotis, and long-legged myotis.
§This species group included poorly detected calls of Yuma myotis.

RESULTS AND DISCUSSION

We recorded 15,617 bat passes over 100 nights from 1 June to 8 October. For months with > 8 days of sampling (We only sampled 8 days in October), the mean (± *SD*) number of bat passes recorded per month was 3,895 (*SD* = 4,983, range = 758 to 11,336 passes). We recorded many terminal calls (i.e., feeding and drinking buzzes) indicating that bats were foraging and drinking at the pond. During that time, we recorded seven bat species (five resident and two migrant species) at the zoo, six of which were species of conservation concern (Table 2). Bat activity was the highest in June (Fig. 2). The highest number of bat passes was recorded at sunset, and 64% of bat activity occurred within 4 hours after sunset (Fig. 3).

During our acoustic sampling we documented seven bat species, which represents 50% of the bat fauna of Idaho (Keller 1985); six of which were species of conservation concern (IDFG 2017, Neubaum et al. 2017, O'Shea et al. 2018). Big brown bats were detected in every month and are not currently a species of conservation concern. Two species, silver-haired and hoary bats, are considered migratory in Idaho (Keller 1985, IDFG 2017). Across all months, 6 bat species were only detected less than 5 times in a month. About 14 bat species occupy southern Idaho, USA (Keller 1985), and this area is important for bat conservation (Whiting et al. 2018a, Whiting et al. 2018b). Even recording low levels of bat calls for species of conservation concern can be important to understand population trends, movements, and distribution of bats. Bats in the Idaho Falls Zoo were mostly active in June and in the first few hours after sunset. We observed a drop in bat activity after July 1. We speculate that that drop in activity was because the pond at which our acoustical monitor was set was drained and cleaned on July 1. Although bat activity at the pond decreased after July 1, we still documented high levels of use at the pond during the rest of summer. Draining and cleaning artificial bodies of water in zoos is part of maintenance and management. However, in the interest of bats and in case bat educational activities are planned, zoo managers should consider a cleaning schedule which allows bats (and insects that use the water) to maximize use of waterbodies as habitat. Bats in the Idaho Falls Zoo likely roosted in buildings, trees, and other structures, as well as foraged in and near water and foliage; therefore, the zoo and its exhibits provided extensive, diverse habitat for bats. Our sampling equipment was small (i.e., one Anabat detector, extension pole, and microphone) and can be easily replicated to survey other areas at the zoo.

Zoos can increase their conservation outlook by integrating conservation thinking with modern problem solving (Fa et al. 2014), and a need exists for greater integration between zoos and the wider conservation community (Gusset et al. 2014). White-nose syndrome and wind-energy development are recent problems for bats in the USA, and educating the public about these issues is critical for bat conservation (O'Shea et al. 2016). Public understanding is low regarding the threat of white-nose syndrome, even in areas where this disease has decimated populations (Fagan et al. 2018). A combination of acoustical monitoring of bats at zoos and bat educational activities can help zoos inform the public about these current problems. Indeed, this approach would allow zoos to create an exhibit that would engage the public in local bat conservation of resident and migrant species. Acoustical data collected across years can be used to help with bat conservation and educating the public. Those data could also be uploaded to national websites that archive acoustical data (e.g., https://www.inaturalist.org/, https://batamp.databasin.org/), which can then be used help with wider regional analyses.

Table 2 - Number of bat passes recorded for resident and migrant bats, as well as species groups from June to October 2018 at the Idaho Falls Zoo, Idaho, USA. Bolded names are bats of conservation concern (IDFG 2017, Neubaum et al. 2017, O'Shea et al. 2018).

	June	July	August	September	October
Resident					
Little brown bat	345	2	-	-	-
Yuma myotis	60	1	-	2	-
Big brown bat	6	23	3	11	-
Western small-footed myotis	337	58	48	23	-
Long-legged myotis	179	34	15	2	-
Migrant					
Silver-haired bat	3	21	6	10	-
Hoary bat	2	3	1	-	1
Species groups					
25k myotis	4,959	1,091	957	355	3
40k myotis	6,228	527	538	159	23
50k bats	149	239	134	244	11

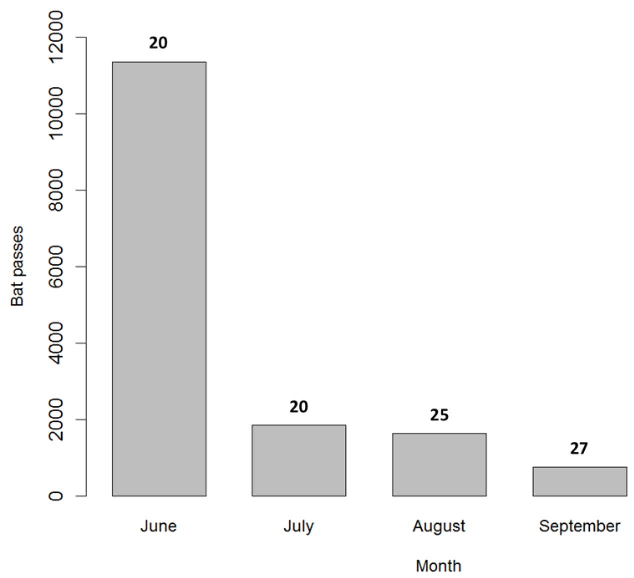

Fig. 2 - Number of bat passes (≥ two echolocation calls) by month for bats at the Idaho Falls Zoo, USA, during 2018. The number of complete nights of recording within each month is shown above the bars. We only included months with > 8 nights of sampling.

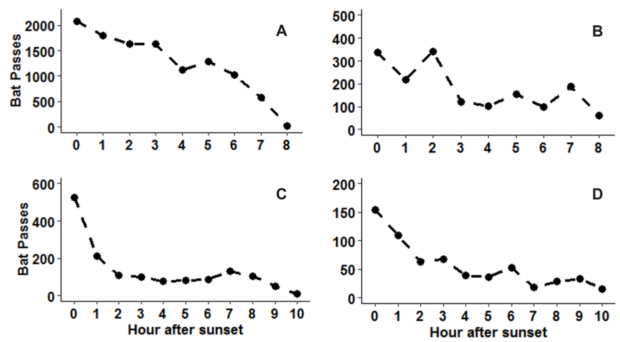

Fig. 3 - Number of bat passes by time of day (0 = sunset and each number after that represents one hour after sunset) during June (**A**), July (**B**), August (**C**), and September (**D**) at the Idaho Falls Zoo, USA, during 2018.

In subsequent years we will be collaborating with the U.S. Fish and Wildlife Service on this project; such collaboration can help zoos form powerful conservation partnerships. Indeed, proposals regarding our project have been funded and will pay for an exhibit in the zoo that will further connect the public to local bat conservation.

Over 700 million people visit zoos worldwide each year, and these institutions help in conserving biodiversity (Conde et al. 2011). Some authors have indicated that zoos should open more space and exhibits for conserving animals (Fa et al. 2014, Gusset et al. 2014), but this is difficult because of the size of required habitat (Keulartz 2015), as well as the expense. Recently, another author has indicated that zoos should strive to emphasize conservation of local, regional species and smaller species, because of limited space (Keulartz 2015). Our exhibit requires no extra space, food, care, and minimal maintenance. Furthermore, acoustical monitoring of bats can be a simple, low-cost exhibit (Fig. 1), which could be incorporated easily at any size zoo or a more elaborate set-up (e.g., multiple detectors set around a zoo and a cave-like structure that people enter to learn about local bats). Such exhibits will help zoos stand out as conservation centers for local animals (Keulartz 2015).

ACKNOWLEDGEMENTS

We thank the US Department of Energy, Idaho Operations Office at the Idaho National Laboratory Site for funding bat monitoring (contract number DE-NE0008477).

REFERENCES

ADAMS, A. M., JANTZEN, M. K., HAMILTON, R. M. & FENTON, M. B. (2012). Do you hear what I hear? Implications of detector selection for acoustic monitoring of bats. *Methods Ecol Evol,* 3(6): 992-998. https://doi.org/10.1111/j.2041-210X.2012.00244.x

ARNETT, E. B., BROWN, W. K., ERICKSON, W. P., FIEDLER, J. K., HAMILTON, B. L., HENRY, T. H., JAIN, A., JOHNSON, G. D., KERNS, J., KOFORD, R. R., et al. (2008). Patterns of bat fatalities at wind energy facilities in North America. *Journal of Wildlife Management,* 72(1): 61-78. https://doi.org/10.2193/2007-221

BERNARD, R. F. & MCCRACKEN, G. F. (2017). Winter behavior of bats and the progression of white-nose syndrome in the southeastern United States. *Ecol Evol,* 7(5): 1487-1496. https://doi.org/10.1002/ece3.2772

BLEHERT, D. S., HICKS, A. C., BEHR, M., METEYER, C. U., BERLOWSKI-ZIER, B. M., BUCKLES, E. L., COLEMAN, J. T. H., DARLING, S. R., GARGAS, A., NIVER, R., et al. (2009). Bat white-nose syndrome: an emerging fungal pathogen? *Science,* 323(5911): 227. https://doi.org/10.1126/science.1163874

BOYLES, J. G., CRYAN, P. M., MCCRACKEN, G. F. & KUNZ, T. H. (2011). Economic importance of bats in agriculture. *Science,* 332(6025): 41-42. https://doi.org/10.1126/science.1201366

BRITZKE, E. R., SLACK, B. A., ARMSTRONG, M. P. & LOEB, S. C. (2010). Effects of orientation and weatherproofing on the detection of bat echolocation calls. *Journal of Fish and Wildlife Management,* 1(2): 136-141. https://doi.org/10.3996/072010-jfwm-025

BRITZKE, E. R., DUCHAMP, J. E., MURRAY, K. L., SWIHART, R. K. & ROBBINS, L. W. (2011). Acoustic identification of bats in the Eastern United States: a comparison of parametric and nonparametric methods. *Journal of Wildlife Management,* 75(3): 660-667. https://doi.org/10.1002/jwmg.68

CONDE, D. A., FLESNESS, N., COLCHERO, F., JONES, O. R. & SCHEUERLEIN, A. (2011). An emerging role of zoos to conserve biodiversity. *Science,* 331(6023): 1390-1391. https://doi.org/10.1126/science.1200674

CRYAN, P. M. (2003). Seasonal distribution of migratory tree bats (*Lasiurus* and *Lasionycteris*) in North America. *Journal of Mammalogy*, 84(2): 579-593. https://doi.org/10.1644/1545-1542(2003)084%3C0579:SDOMTB%3E2.0.CO;2

FA, J. E., GUSSET, M., FLESNESS, N. & CONDE, D. A. (2014). Zoos have yet to unveil their full conservation potential. *Anim Conserv,* 17(2): 97-100. https://doi.org/10.1111/acv.12115

FAGAN, K. E., WILLCOX, E. V. & WILLCOX, A. S. (2018.) Public attitudes toward the presence and management of bats roosting in buildings in Great Smoky Mountains National Park, Southeastern United States. *Biology Conservation,* 220: 132-139. https://doi.org/10.1016/j.biocon.2018.02.004

FENTON, M. B. & BELL, G. P. (1981). Recognition of species of insectivorous bats by their echolocation calls. *Journal of Mammalogy,* 62(2): 233-243. https://doi.org/10.2307/1380701

FOLEY, J., CLIFFORD, D., CASTLE, K., CRYAN, P. & OSTFELD, R. S. (2011). Investigating and managing the rapid emergence of white-nose syndrome, a novel, fatal, infectious disease of hibernating bats. *Conservation Biology,* 25(2): 223-231. https://doi.org/10.1111/j.1523-1739.2010.01638.x

GUSSET, M., FA, J. E. & SUTHERLAND, W. J. (2014). A horizon scan for species conservation by zoos and aquariums. *Zoo Biology,* 33(5): 375-380. https://doi.org/10.1002/zoo.21153

HAMMERSON, G. A., KLING, M., HARKNESS, M., ORMES, M. & YOUNG, B. E. (2017). Strong geographic and temporal patterns in conservation status of North American bats. *Biology Conservation,* 212(A): 144-152. https://doi.org/10.1016/j.biocon.2017.05.025

HEIM, O., LENSKI, J., SCHULZE, J., JUNG, K., KRAMER-SCHADT, S., ECCARD, J. A. & VOIGT, C. C. (2018). The relevance of vegetation structures and small water bodies for bats foraging above farmland. *Basic and Applied Ecology,* 27: 9-19. https://doi.org/10.1016/j.baae.2017.12.001

HEIN, C. D. & SCHIRMACHER, M. R. (2016). Impact of wind energy on bats: a summary of our current knowledge. *Human-Wildlofe Interactions,* 10(1): 19-27. https://doi.org/10.26077/x7ew-6349

IDFG. (2017). Idaho State Wildlife Action Plan, 2015. *US fish and wildlife service, wildlife and sport fish restoration program.*

JOHNSON, J. S., TREANOR, J. J., LACKI, M. J., BAKER, M. D., FALXA, G. A., DODD, L. E., WAAG, A. G. & LEE, E. H. (2017). Migratory and winter activity of bats in Yellowstone National Park. *Journapl of Mammalogy,* 98(1): 211-221. https://doi.org/10.1093/jmammal/gyw175

KAHN, P. H., SAUNDERS, C. D., SEVERSON, R. L., MYERS, O. E. & GILL, B. T. (2008). Moral and fearful affiliations with the animal world: children's conceptions of bats. *Anthrozoos,* 21(4): 375-386. https://doi.org/10.2752/175303708x371591

KELLER, B. L. (1985). A simplified key for Idaho bats. *Tebiwa: the Journal of the Idaho Museum of Natural History,* 22: 57-63.

KEULARTZ, J. (2015). Captivity for conservation? Zoos at a crossroads. *Journal of Agricultural and Environmental Ethics,* 28(2): 335-351. https://doi.org/10.1007/s10806-015-9537-z

KINGSTON, T. (2016). Cute, creepy, or crispy—how values, attitudes, and norms shape human behavior toward bats. In: Bats in the Anthropocene: conservation of bats in a changing world. ed.: Springer, Cham. eBook. p.571-595. https://doi.org/10.1007/978-3-319-25220-9_18

KLÜG-BAERWALD, B. J., GOWER, L. E., LAUSEN, C. L. & BRIGHAM, R. M. (2016). Environmental correlates and energetics of winter flight by bats in southern Alberta, Canada. *Canadian Journal of Zoology,* 94(12): 829-836. https://doi.org/10.1139/cjz-2016-0055

KNUDSEN, G. R., DIXON, R. D. & AMELON, S. K. (2013). Potential spread of white-nose syndrome of bats to the Northwest: epidemiological considerations. *Northwest Sciencie,* 87(4): 292-306. https://doi.org/10.3955/046.087.0401

KUNZ, T. H., BRAUN DE TORREZ, E., BAUER, D., LOBOVA, T. & FLEMING, T. H. (2011). Ecosystem services provided by bats. *Ann NY Acad Sci,* 1223(1):1-38. https://doi.org/10.1111/j.1749-6632.2011.06004.x

LORCH, J. M., PALMER, J. M., LINDNER, D. L., BALLMANN, A. E., GEORGE, K. G., GRIFFIN, K., KNOWLES, S., HUCKABEE, J. R., HAMAN, K. H., ANDERSON, C. D., et al. (2016). First detection of bat white-nose syndrome in Western North America. *mSphere,* 1(4): e00148-16. https://doi.org/10.1128/mSphere.00148-16

MILLER, B. W. (2001). A method for determining relative activity of free flying bats using a new activity index for acoustic monitoring. *Acta Chiropterologica,* 3(1): 93-105.

NEUBAUM, D. J., NAVO, K. W. & SIEMERS, J. L. (2017). Guidelines for defining biologically important bat roosts: a case study from Colorado. *Journal of Fish and Wildlife Management,* 8(1): 272-282. https://doi.org/10.3996/102015-jfwm-107

O'FARRELL, M. J., MILLER, B. W. & GANNON, W. L. (1999). Qualitative identification of free-flying bats using the Anabat detector. *Journal of Mammalogy,* 80(1): 11-23. https://doi.org/10.2307/1383203

O'SHEA, T. J., CRYAN, P. M., HAYMAN, D. T., PLOWRIGHT, R. K. & STREICKER, D. G. (2016). Multiple mortality events in bats: a global review. *Mammal Review,* 46(3): 175-190. https://doi.org/10.1111/mam.12064

O'SHEA, T. J., CRYAN, P. M. & BOGAN, M. A. (2018). United States bat species of concern: a synthesis. *Proceedings of the California Academy of Sciences,* 65: 1-279.

PATTERSON, B. D., WILLIG, M. R. & STEVENS, R. D. (2003). Trophic strategies, niche partitioning, and patterns of ecological organization. In: Bat ecology. ed.: University of Chicago Press. Chicago, EEUU. p.536-579.

PROKOP, P. & TUNNICLIFFE, S. D. (2008). "Disgusting" animals: primary school children's attitudes and myths of bats and spiders. *Eurasia Journal of Mathematics, Science & Technology Education,* 4(2): 87-97. https://doi.org/10.12973/ejmste/75309

SCHWAB, N. A. & MABEE, T. J. (2014). Winter acoustic activity of bats in Montana. *Northwestern Naturalist,* 95(1): 13-27. https://doi.org/10.1898/NWN13-03.1

SHEFFIELD, S. R., SHAW, J. H., HEIDT, G. A. & MCQENAGHAN, L. R. (1992). Guidelines for the protection of bat roosts. *Journal of Mammalogy,* 73(3): 707-710.

SKIBINS, J. C. & POWELL, R. B. (2013). Conservation caring: measuring the influence of zoo visitors' connection to wildlife on pro-conservation behaviors. *Zoo Biology* 32(5): 528-540. https://doi.org/10.1002/zoo.21086

SMALLWOOD, K. S. (2013). Comparing bird and bat fatality-rate estimates among North American wind-energy projects. *Wildlife Society Bulletin,* 37(1): 19-33. https://doi.org/10.1002/wsb.260

VERÍSSIMO, D. (2013). Influencing human behaviour: an underutilised tool for biodiversity management. *Conservation Evidence,* 10: 29-31.

WHITING, J. C., DOERING, B., WRIGHT, G., ENGLESTEAD, D. K., FRYE, J. A. & STEFANIC, T. (2018a). Bat hibernacula in caves of Southern Idaho: implications for monitoring and management. *Western North American Naturalist,* 78(2) :165-173. https://doi.org/10.3398/064.078.0207

WHITING, J. C., DOERING, B., WRIGHT, G., ENGLESTEAD, D. K., FRYE, J. A., STEFANIC, T. & SEWALL, B. J. (2018b). Long-term bat abundance in sagebrush steppe. *Sci Rep,* 8(1): 12288. https://doi.org/10.1038/s41598-018-30402-z