Western North American Naturalist 79(4), © 2019, pp. 515–522

Day roosts of *Myotis* (Mammalia: Chiroptera) in an arid riparian corridor in southwestern New Mexico

Simon P. Tye[1,2] and Keith Geluso[1,*]

[1]*Department of Biology, University of Nebraska at Kearney, Kearney, NE 68849*
[2]*Present address: Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701*

Abstract.—Riparian corridors in the western United States harbor diverse biological communities that are threatened by reductions in available freshwater, changes to natural disturbance regimes, and anthropogenic disturbances. Limited data are available about bat roosts in riparian habitats in the southwestern United States. We examined day roosts of 3 sympatric *Myotis* species, the southwestern myotis (*Myotis auriculus*), Arizona myotis (*Myotis occultus*), and Yuma myotis (*Myotis yumanensis*), along the Mimbres River in southwestern New Mexico. We tracked 3 *M. auriculus*, 3 *M. occultus*, and 1 *M. yumanensis* to 16 Fremont's cottonwoods (*Populus fremontii*), 2 velvet ash (*Fraxinus velutina*), and 1 Arizona walnut (*Juglans major*) within the floodplain. Roost trees generally had a greater diameter and greater likelihood of exhibiting fire damage than nearby trees. Moreover, several roosts were in tree species not previously known to be used by these bat species, and bats did not roost in human-made structures in this arid riparian corridor.

Resumen.—Los corredores ribereños en el oeste de Estados Unidos albergan diversas comunidades biológicas están amenazados debido a la reducción de las aguas subterráneas y superficiales. La información cononocida con respecto a los refugios de un número de murciélagos que utilizan hábitats de ribera áridos es limitada. Examinamos refugios diurnos de cuatro especies simpátricas, miotis orejudo (*Myotis auriculus*), miotis norteamoericano (*Myotis occultus*), y miotis de Yuma (*Myotis yumanensis*), a lo largo del río Mimbres en el suroeste de Nuevo México. Seguimos 3 *M. auriculus*, 3 *M. occultus*, and 1 *M. yumanensis* a 16 álamos de Fremont (*Populus fremontii*), 2 fresno de Arizona (*Fraxinus velutina*), y un nogal de Arizona (*Juglans major*). Los árboles refugio tenían mayor circunferencia, mayor diámetro y mâs cicatrizes de fuego comparados con los árboles de referencia. Además, la mayoría de los refugios estaban en especies de árboles sin observaciones previas de estas especies de murciélagos, y los murciélagos no se posaban en estructuras hechas por el hombre en este árido corredor ribereño.

Bats roost in a wide variety of natural and human-made structures, from caves and trees to bridges and buildings (Barbour and Davis 1969, Kunz and Lumsden 2003). Limited roost data are available for habitats frequently associated with numerous bat species in the western United States (Chung-MacCoubrey 1996, Rabe et al. 1998, Bernardos et al. 2004). Several bat species common to the southwestern United States, including the southwestern myotis (*Myotis auriculus*), Arizona myotis (*Myotis occultus*), and Yuma myotis (*Myotis yumanensis*), have been documented near permanent waterbodies and in woodlands (Barbour and Davis 1969, Findley et al. 1975, Chung-MacCoubrey 1996, Rabe et al. 1998), though natural roost sites remain largely undocumented in arid riparian habitats throughout the southwestern United States.

Riparian corridors in southwestern New Mexico contain high levels of avian and mammalian biodiversity (Knopf et al. 1988, Geluso 2016, Smith and Finch 2016). Many rivers in the southwestern United States are expected to experience reductions in available freshwater (MacDonald 2010, Smith and Finch 2016) and transition from perennial to intermittent or ephemeral flows over the coming decades (Jaeger et al. 2014). Moreover, models suggest high likelihoods for decadal or multidecadal droughts in the southwestern United States in the 21st century (Seager et al. 2007, Cook et al. 2015), which may contribute to additional anthropogenic development and further

*Corresponding author: gelusok1@unk.edu

SPT orcid.org/0000-0002-2131-8267

mitigation of natural disturbances near regional rivers. Natural disturbances, such as floods and wildfires, are known to promote biodiversity in arid riparian corridors (Smith and Finch 2014, Tingley et al. 2016), but their effects on bat communities in the western United States remains poorly understood (Fisher and Wilkinson 2005).

Our study characterized day roosts of 3 sympatric *Myotis* species (*M. auriculus, M. occultus,* and *M. yumanensis*) along the Mimbres River, one of the last waterways with a nearly natural flow regime in the contiguous United States. We compared day roosts with nearby structures to further understand bat roosts along this relatively unregulated river and provide data for regional habitat management decisions. The Mimbres River is actively threatened by habitat modification, excessive freshwater use, severe drought, and the proliferation of nonnative species (NMDGF 2006, Gori et al. 2014, Cook et al. 2015). Greater insight into bat roosts along naturally flowing rivers in minimally developed environments may elucidate roost selection strategies of bats that roost near regulated rivers and heavily developed areas. Furthermore, such roost data may improve regional management practices and help protect other bat species that inhabit arid riparian corridors.

METHODS

We captured bats along a 1.2-km reach of the Mimbres River about 6.4 km S and 4.4 km W of Faywood, Luna County, New Mexico (32.580664° N, 107.920828° W, WGS84, elevation 1533 m) on 20–22 May 2016 and 20 July 2017. This reach of the river was within the River Ranch Wildlife Management Area (WMA), owned and maintained by the New Mexico Department of Game and Fish. The Mimbres River is part of an endorheic or closed drainage basin and, partially due to increased freshwater use and reduced flows, often ends in lowlands north of the city of Deming, New Mexico (NMDGF 2006). There are no major diversions along the river, though occasionally river channels are mechanically adjusted and woody vegetation is removed from private land in the floodplain (NMDGF 2006). The river was mostly continuous but contained a few push-up diversions in the study area. Mean gauge heights during our study periods in 2016 and 2017 were 1.0 m and 0.4 m, respectively (~26 km upstream; United States Geological Survey, http://water.usgs.gov/waterwatch).

Former and current land use in the Mimbres Valley primarily consist of small ranches and sparsely-grazed pastures (NMDGF 2006). Three modest houses and several small sheds were the only human-made structures on the ranch. The River Ranch WMA was a former cattle ranch that used prescribed burns to manage alkali sacaton (*Sporobolus airoides*) grasslands adjacent to riparian woodlands along the Mimbres River. Fremont's cottonwoods (*Populus fremontii*), often with fire scarring and exfoliated bark, were sparsely distributed throughout these grasslands. Most deciduous trees in the floodplain formed linear patches along active and former river channels. Riparian woodlands comprised mostly Fremont's cottonwood intermixed with velvet ash (*Fraxinus velutina*), Goodding's willow (*Salix gooddingii*), western hackberry (*Celtis reticulata*), white mulberry (*Morus alba*), box elder (*Acer negundo*), and Arizona walnut (*Juglans major*). Patches of broom seep-willow (*Baccharis sarothroides*) were common near the edge of the river. Honey mesquite (*Prosopis glandulosa*) scrublands occurred at higher elevations, and a large hill with rocky outcrops, stone monoliths, and oneseed junipers (*Juniperus monosperma*) was about 0.5–0.7 km from mist-netting sites. Botanical names follow Carter (2012).

We placed mist nets (Avinet Inc., Portland, ME) at several locations over the Mimbres River at the River Ranch WMA. Nets were monitored continuously for about 4 h after sunset on 20–22 May 2016 and 20 July 2017. For each bat captured, we recorded species, sex, forearm length, weight, and capture time. We attached radio transmitters (LB-2X, Holohil Systems Ltd., Ontario, Canada) to 6 bats (2 *M. auriculus,* 3 *M. occultus,* and 1 *M. yumanensis*) in 2016 and 6 bats (2 *M. auriculus,* 2 *M. occultus,* and 2 *M. yumanensis*) in 2017. We placed radio transmitters only on adult bats. In 2016, we suspected that some females were in the early stages of pregnancy though we could not determine their status with gentle palpation. In 2017, some adult females with transmitters likely were postlactating. We captured many flying young during the night and failed to record in notes the reproductive status of the adults tagged. To attach radio transmitters, we trimmed the dorsal fur between each bat's scapulae, applied surgical glue (Perma-Type Company Inc., Plainville, CT) to each patch of trimmed fur and one side of each transmitter, adhered each transmitter to the patch of trimmed fur, and waited ~15 min for the glue to solidify. Radio transmitters were attached only to individuals that weighed >5.0 g, such that the package constituted <5% of each bat's body weight (Aldridge and Brigham 1988). We used 3-element Yagi antennas (Communications Specialists Inc., Orange, CA) and R-1000 handheld telemetry receivers (Communications Specialists Inc. Orange, CA) to track radio-tagged bats daily from 21 May 2016 to 1 June 2016 and from 21 July 2017 to 24 July 2017. If radio-tagged individuals were not located within the River Ranch WMA, we searched for them by motor vehicle for several kilometers via U.S. Route 180, which runs parallel to the river. We did not detect signals for 1 *M. auriculus* and 2 *M. occultus*. This possibly could be attributed to defective radio transmitters or possibly to individuals traveling beyond the searched area. We tracked 2 *M. yumanensis* to a location on private property and were unable to gain permission to access and identify roost structures.

We recorded characteristics for each tree containing a day roost, including species of tree, diameter at breast height (DBH), health (live, declining, or dead), and presence or absence of fire damage. We used a measuring tape to record circumference of trees to then calculate DBH. Declining trees were defined as missing >75% of their canopy and usually had several broken limbs and exfoliated bark. We also characterized all trees (>16-cm circumference) within a 17.8-m radius plot (0.1 ha) centered on the roost tree, which we termed reference trees, and compared them to roost trees (Perry and Thill 2007). The possibility exists that untagged bats may have roosted in reference trees. Due to our small sample size, we grouped all roost data for statistical analyses and listed descriptive statistics for roosts of each bat species. We performed a 2-tailed t test to compare the DBH of roost and reference trees, and a chi-square test to evaluate the significance of fire damage on roost and reference trees. To determine whether larger DBH and presence of fire damage were correlated, we used Pearson's correlation coefficient. We conducted emergence counts by watching for bats exiting trees at dusk at 3 different roosts. However, we considered the data unreliable due to the abundance of bats in the area at dusk and numerous potential roost sites in each tree. Hence, we do not report such data in this paper. The Institutional Animal Care and Use Committee at the University of Nebraska at Kearney (Protocol #020614 by K. Geluso) approved our handling, mist-netting, and telemetry techniques.

RESULTS

We tracked 3 *M. auriculus*, 3 *M. occultus*, and 1 *M. yumanensis* to 19 day roosts, including 16 Fremont's cottonwoods, 2 velvet ash, and 1 Arizona walnut (Table 1). *Myotis occultus* roosted in all 3 tree species, *M. auriculus* roosted in cottonwood and ash trees, and *M. yumanensis* was only observed roosting in cottonwoods (Table 1). Considering each day at a tree roost as a separate event (n = 54), radio-tagged bats primarily roosted in cottonwoods (78%, n = 42) and infrequently roosted in velvet ash (20%, n = 11) and Arizona walnut (2%, n = 1). While we acknowledge our small sample size for each bat species, there was minor variation in the size of roost trees between bat species: *M. auriculus* ($\bar{x}$ = 36.68 cm, SD = 14.23, n = 9), *M. occultus* ($\bar{x}$ = 40.59, SD = 17.84, n = 8,), and *M. yumanensis* ($\bar{x}$ = 25.05, SD = 0.92, n = 2). Additionally, there were differences between bat species in the distance roost trees were from the active river channel: *M. auriculus* ($\bar{x}$ = 69.17 m, SD = 52.07, n = 9), *M. occultus* ($\bar{x}$ = 107.31, SD = 82.51, n = 8,), and *M. yumanensis* ($\bar{x}$ = 11.10, SD = 8.91, n = 2).

Radio-tagged bats generally roosted either in dense groves that bordered the active river channel (n = 5) or in relatively isolated trees in the nearby sacaton grassland (n = 11). Although we were unable to determine specific localities of roosts in most trees, several roosts appeared to be in crevices near broken or senescent limbs and beneath burned or exfoliated bark. Roost trees near the Mimbres River generally had fuller canopies, more noticeable crevices, and minimal exfoliated bark, whereas isolated roost trees in the sacaton grassland typically had fewer noticeable crevices and an abundance of burned, exfoliated bark. We also observed one alternate roost or temporary refuge of an *M. auriculus* individual in a

TABLE 1. Day roosts along the Mimbres River, Luna County, New Mexico, for 7 adult bats: 3 southwestern myotis (*Myotis auriculus*), 3 Arizona myotis (*Myotis occultus*), and 1 Yuma myotis (*Myotis yumanensis*). We tracked individuals from 21 May 2016 to 1 June 2016 and from 21 July 2017 to 24 July 2017. For tree health, declining trees were defined as missing >75% of their canopy and usually had several broken limbs and exfoliated bark. References trees represent the number of trees (>16-cm circumference) within a 17.8-m radius plot (0.1 ha) centered on the roost tree (Perry and Thill 2007).

Year	Bat species	Sex	Tree species	Health	Fire damage	DBH (cm)	Distance to river (m)	Reference trees	Days at roost
2016	*M. auriculus*	M	*Populus fremontii*	Live	Yes	43.5	140.0	2	1
2016	*M. auriculus*	M	*Populus fremontii*	Declining	Yes	40.6	106.9	2	1
2016	*M. auriculus*	M	*Populus fremontii*	Live	Yes	23.3	18.2	8	7
2016	*M. auriculus*	F	*Populus fremontii*	Live	No	32.9	46.2	10	1
2017	*M. auriculus*	M	*Fraxinus velutina*	Live	No	30.1	142.4	3	2
2017	*M. auriculus*	M	*Populus fremontii*	Live	No	39.6	92.8	2	1
2017	*M. auriculus*	F	*Populus fremontii*	Dead	Yes	12.3	12.3	18	1
2017	*M. auriculus*	M	*Populus fremontii*	Live	No	46.0	41.4	0	1
2017	*M. auriculus*	F	*Populus fremontii*	Live	No	61.8	22.3	22	1
2016	*M. occultus*	M	*Fraxinus velutina*	Live	No	39.1	239.9	18	9[a]
2016	*M. occultus*	M	*Juglans major*	Declining	Yes	24.5	54.2	3	1
2016	*M. occultus*	M	*Populus fremontii*	Live	Yes	66.5	119.2	0	3
2016	*M. occultus*	M	*Populus fremontii*	Dead	Yes	41.6	95.0	4	1
2016	*M. occultus*	F	*Populus fremontii*	Live	Yes	68.0	99.6	3	1
2016	*M. occultus*	F	*Populus fremontii*	Live	No	20.5	13.0	19	1
2016	*M. occultus*	F	*Populus fremontii*	Dead	Yes	31.5	24.6	4	6
2016	*M. occultus*	M	*Populus fremontii*	Declining	Yes	33.0	213.0	3	6
2016	*M. yumanensis*	F	*Populus fremontii*	Live	No	25.7	4.8	16	4
2016	*M. yumanensis*	F	*Populus fremontii*	Live	No	24.4	17.4	19	5

[a]Two male *M. occultus* roosted in the same tree for 2 nights.

hollow branch of a small, fallen cottonwood (DBH = 39 cm) after a severe overnight thunderstorm. On nights before and after the night of the storm, this radio-tagged *M. auriculus* roosted in a cavity of a live velvet ash (DBH = 95 cm) about 0.7 km away.

Reference trees ($n = 160$) consisted of Fremont's cottonwood (69%, $n = 110$), Gooding's willow (14%, $n = 23$), velvet ash (8%, $n = 12$), western hackberry (6%, $n = 10$), Arizona walnut (2%, $n = 3$), honey mesquite (1%, $n = 1$), and oneseed juniper (1%, $n = 1$). Most reference trees were alive (94%, $n = 151$) and few were categorized as dead (4%, $n = 7$) or declining (1%, $n = 2$). Similarly, most roost trees were alive (68%; $n = 13$), though the proportion of declining (16%, $n = 3$) and dead (16%, $n = 3$) roost trees was greater than the proportion of declining and dead reference trees. Roost trees had greater DBH ($\bar{x} = 37.1$ cm, SD = 15.3) than reference trees ($\bar{x} = 17.7$ cm, SD = 10.0; $t = 5.4$, df = 18, $P < 0.001$) and a greater likelihood of exhibiting fire damage than reference trees ($\chi^2 = 11.4$, df = 1, $P < 0.005$). Presence of fire damage and greater DBH were weakly correlated ($r = 0.18$, df = 177, $P = 0.86$).

DISCUSSION

We documented 3 sympatric *Myotis* species (*M. auriculus*, *M. occultus*, and *M. yumanensis*) using natural roost structures within an arid riparian corridor in southwestern New Mexico that included several roosts in species of trees not known to be used by these bat species. Our data increase knowledge about roosting ecology of these bats in natural environments and represent important data needed to make informed management decisions to promote conservation of dynamic and threatened arid ecosystems.

Myotis auriculus has a relatively limited distribution, especially in the United States (Warner 1982), and is one of only a few of the *Myotis* species that do not use human-made structures (Findley et al. 1975, Warner 1982, Hoffmeister 1986, Keeley and Tuttle 1999). *Myotis auriculus* primarily inhabits ponderosa pine forests and riparian corridors, and occasionally occurs in lower-elevation coniferous and oak forests (Findley et al. 1975, Warner 1982, Cook 1986, Hoffmeister 1986). The only documented *M. auriculus* roosts are in Gambel's oak (*Quercus gambelii*) and ponderosa pine (*Pinus ponderosa*) in Arizona (Rabe et al. 1998, Bernardos et al. 2004). Bernardos et al. (2004) described 11 *M. auriculus* tree roosts, 10 in cavities and 1 beneath exfoliated bark, where authors suggested that tree height and density of oaks are top predictors for maternity roosts. Our observations represent the first documented *M. auriculus* roosts in Fremont's cottonwood, velvet ash, an arid riparian corridor, and New Mexico. *Myotis auriculus* is considered a species of medium concern by the Western Bat Working Group (Adams 2003), and future threats to arid riparian habitats likely will negatively affect populations in the southwestern United States and northern Mexico unless such habitats and nearby roost structures are protected.

Myotis occultus, formerly considered a subspecies of the little brown bat (*Myotis lucifugus;* Fenton and Barclay 1980, Piaggio et al. 2002), occurs from high-elevation pine forests to low-elevation riparian woodlands throughout the American Southwest (Hayward 1963, Barbour and Davis 1969, Hoffmeister 1986). After being designated a separate species, *M. occultus* was listed as a species of conservation need due to limited natural history information, including known roost structures (NMDGF 2006, O'Shea et al. 2018). *Myotis occultus* is known to use ponderosa pine snags (Rabe et al. 1998, O'Shea et al. 2011), Douglas-fir (*Pseudotsuga menziesii;* Rabe et al. 1998), cottonwoods (Chung-MacCoubrey 1999), Arizona white oak (*Quercus arizonica;* O'Shea et al. 2018), rock crevices (O'Shea et al. 2011), bridges (Geluso and Mink 2009), and buildings (Hayward 1963, O'Shea et al. 2011, 2018). Our study reports the first documentation of *M. occultus* roosts in velvet ash and Arizona walnut throughout the species' distribution. Moreover, our study further supports evidence that *M. occultus* roosts in native cottonwoods with fire damage in arid riparian corridors in the American Southwest (Chung-MacCoubrey 1999). Given various possible roost structures for *M. occultus,* potential variation in the timing of reproductive activities between colonies that roost in artificial (i.e., bridges and buildings) and natural structures in the same area would be informative.

Myotis yumanensis frequently inhabits low-elevation deserts, grasslands, and woodlands in the American Southwest (Findley et al.

1975, Hoffmeister 1986, O'Shea et al. 2018). Roosts for *M. yumanensis* include a wide array of human-made and natural structures (O'Shea et al. 2018), including bridges (Chung-MacCoubrey 1999, Geluso and Mink 2009), buildings (Chung-MacCoubrey 1999, Evelyn et al. 2004), mines (Barbour and Davis 1969), rock crevices (O'Shea and Vaughan 1999), cliff swallow nests (*Petrochelidon pyrrhonota;* O'Shea and Vaughan 1999), an assortment of tree species in a suburban landscape in California (Evelyn et al. 2004), and Fremont's cottonwoods in New Mexico (Chung-MacCoubrey 1999). Similar to our findings, Chung-MacCoubrey (1999) noted that *M. yumanensis* roosted in large, fire-damaged Fremont's cottonwoods in an arid riparian corridor. Previous observations and this study suggest that *M. yumanensis* uses natural structures when few human-made structures are present.

We observed *M. auriculus, M. occultus,* and *M. yumanensis* roosting in natural structures along this reach of the Mimbres River, possibly due to an abundance of potential roost structures, relatively high habitat heterogeneity, and limited anthropogenic development. Rabe et al. (1998) studied an assemblage of 8 bat species in Arizona, which included *M. auriculus* and *M. occultus,* and observed greater diversity of trees and shrubs near roost trees compared to random trees, which may support a positive association between habitat heterogeneity and natural roosts for these bat species. Previous studies suggest that cavity- and crevice-roosting bats in the southwestern United States use large-diameter, damaged trees or snags as roosts (Rabe et al. 1998, Bernardos et al. 2004). Large-diameter trees usually are more exposed to solar radiation and may contain warm microclimates that enhance growth rates and reduce energetic demands of juvenile bats (Racey 1982). Moreover, larger trees are more likely to be older and have experienced disturbance events, such as fire, droughts, and lightning strikes, that may increase roost availability with creation of cracks, crevices, and exfoliating bark.

Long- and short-term effects of hydrological disturbances, such as floods and droughts, may have benefited cavity and crevice-roosting bats inhabiting riparian woodlands along the Mimbres River by providing access to an abundance and diversity of natural roost structures. For example, major flood events rejuvenate floodplains by creating a dynamic mosaic of habitats at varying successional stages and differently aged patches of riparian woodland (Whited et al. 2007). Moreover, numerous studies have shown that the duration, intensity, and timing of hydrologic disturbances influence the growth and survival of Fremont's cottonwoods (Stromberg et al. 1997, Auchincloss et al. 2012, Andersen 2016), the most widely used natural roost structure along this segment of the Mimbres River. Conversely, branches and limbs of mature Fremont's cottonwoods often undergo precocious senescence at the canopy's periphery during warm and dry periods (Rood et al. 2000), which in turn may improve roost accessibility for cavity and crevice-roosting bats.

Natural and prescribed fires also significantly alter riparian woodlands in the southwestern United States (McPherson 1997). For example, a recent study by Bock and Bock (2014) reported that 57% of Fremont's cottonwoods, 48% of Arizona walnuts, and 32% of velvet ash trees either were killed or reduced to ground-level resprouts following a wildfire in a riparian woodland in southeastern Arizona. Fire-damaged trees often have patches of exfoliated bark or cavities that may be used as roost structures, as well as reduced canopies that benefit roost accessibility and thermal properties (Chung-MacCoubrey 1999, Kunz and Lumsden 2003). Chung-MacCoubrey (1999) and this study reported numerous day roosts in fire-damaged deciduous trees at Bosque del Apache National Wildlife Refuge and River Ranch WMA in New Mexico, respectively, which illustrate the importance of fire as a mechanism to create roost structures in arid environments. Collectively, available data suggest that hydrologic and fire disturbances facilitate the formation of discrete roost structures in arid environments. Additional research may elucidate whether certain bat species are more prone to utilize roost structures formed after different types of disturbances or extreme weather events.

Our study demonstrates the importance and widespread use of natural roost structures along one of the few remaining unregulated rivers in the contiguous United States. Brigham (1991) suggested that bats use human-made structures as roosts in developed environments possibly due to habitat modification and reductions in available natural roost structures.

Previous research in New Mexico has shown that *M. occultus* and *M. yumanensis* frequently roost in human-made structures near developed areas and heavily regulated rivers, such as the Rio Grande (Geluso and Mink 2009), though it remains unclear whether nearby natural structures also were used as roosts. Additional studies are warranted to better understand the ecology and diversity of bats near environments that experience natural or induced disturbances, as species richness, abundance, and composition in these systems may indicate ecological health (Naiman et al. 1993).

ACKNOWLEDGMENTS

We thank B.R. Andersen, E.M. Brinley Buckley, and I.R. Gomez for field assistance and R. Darr, K. Rodden, J. Winter, and V. Seamster of the New Mexico Game and Fish Department for property access and technical matters associated with research at the River Ranch WMA. We also thank 2 reviewers for comments that improved this manuscript. Funding for this project was provided by Nebraska EPSCoR and the Rural Futures Institute at the University of Nebraska, as well as a Department of Biology Undergraduate Research Award, an Undergraduate Research and Creative Activity Award, and Sponsored Programs at the University of Nebraska at Kearney.

LITERATURE CITED

ADAMS, R.A. 2003. Bats of the Rocky Mountain West: natural history, ecology, and conservation. University Press of Colorado, Boulder, CO. 328 pp.

ALDRIDGE, H.D.J.N., AND R.M. BRIGHAM. 1988. Load carrying and maneuverability in an insectivorous bat: a test of the 5% "rule" of radio-telemetry. Journal of Mammalogy 69:379–382.

ANDERSEN, D.C. 2016. Flow regime effects on mature *Populus fremontii* (Fremont cottonwood) productivity on two contrasting dryland river floodplains. Southwestern Naturalist 61:8–17.

AUCHINCLOSS, L.C., J.H. RICHARDS, C.A. YOUNG, AND M.K. TANSEY. 2012. Inundation depth, duration, and temperature influence Fremont cottonwood (*Populus fremontii*) seedling growth and survival. Western North American Naturalist 72:323–333.

BARBOUR, R.W., AND W.H. DAVIS. 1969. Bats of America. University Press of Kentucky, Lexington, KY. 286 pp.

BERNARDOS, D.A., C.L. CHAMBERS, AND M.J. RABE. 2004. Selection of Gambel oak roosts by southwestern myotis in ponderosa pine–dominated forests, northern Arizona. Journal of Wildlife Management 68:595–601.

BOCK, C.E., AND J.H. BOCK. 2014. Effects of wildfire on riparian trees in southeastern Arizona. Southwestern Naturalist 59:570–576.

BRIGHAM, R.M. 1991. Flexibility in foraging and roosting behavior by the big brown bat (*Eptesicus fuscus*). Canadian Journal of Zoology 69:117–121.

CARTER, J.L. 2012. Trees and shrubs of New Mexico. Revised and expanded. Mimbres Publishing, Silver City, NM. 524 pp.

CHUNG-MACCOUBREY, A.L. 1996. Bat species composition and roost use of pinyon-juniper woodlands of New Mexico. Pages 118–123 *in* R.M.R. Barclay and R.M. Brigham, editors, Proceedings of the Bats and Forests Symposium, October 19–21, 1995. B.C. Ministry of Forests, Research Branch, Victoria, Canada.

CHUNG-MACCOUBREY, A. 1999. Maternity roosts of bats at the Bosque del Apache National Wildlife Refuge: a preliminary report. Pages 187–190 *in* D.M. Finch, J.C. Whitney, J.F. Kelley, and S.R. Loftin, technical coordinators, Rio Grande ecosystems: linking land, water, and people toward a sustainable future for the Middle Rio Grande Basin. USDA Forest Service, Proceedings RMRS-P-7.

COOK, B.I., T.R. AULT, AND J.E. SMERDON. 2015. Unprecedented 21st century drought risk in the American Southwest and Central Plains. Science Advances 1(1): e1400082.

COOK, J.A. 1986. The mammals of the Animas Mountains and adjacent areas, Hidalgo County, New Mexico. Occasional Papers of the Museum of Southwestern Biology 4:1–45.

EVELYN, M.J., D.A. STILES, AND R.A. YOUNG. 2004. Conservation of bats in suburban landscapes: roost selection by *Myotis yumanensis* in a residential area in California. Biological Conservation 115: 463–473.

FENTON, M.B., AND R.M.R. BARCLAY. 1980. Myotis lucifugus. Mammalian Species 142:1–8.

FINDLEY, J.S., A.H. HARRIS, D.E. WILSON, AND C. JONES. 1975. Mammals of New Mexico. University of New Mexico Press, Albuquerque, NM. 360 pp.

FISHER, J.T., AND L. WILKINSON. 2005. The response of mammals to forest fire and timber harvest in the North American boreal forest. Mammal Review 35:51–81.

GELUSO, K. 2016. Mammals of the active floodplains and surrounding areas along the Gila and Mimbres rivers, New Mexico. Final report submitted to the New Mexico Department of Game and Fish, Santa Fe, NM. 166 pp.

GELUSO, K., AND J.N. MINK. 2009. Use of bridges by bats (Mammalia: Chiroptera) in the Rio Grande Valley, New Mexico. Southwestern Naturalist 54:421–429.

GORI, D., M.S. COOPER, E.S. SOLES, M. STONE, R. MORRISON, T.F. TURNER, D.L. PROPST, G. GARFIN, M. SWITANEK, H. CHANG, ET AL. 2014. Gila River flow needs assessment. The Nature Conservancy, Santa Fe, NM. 515 pp.

HAYWARD, B.J. 1963. A maternity colony of *Myotis occultus*. Journal of Mammalogy 44:279.

HOFFMEISTER, D.F. 1986. Mammals of Arizona. University of Arizona Press and Arizona Game and Fish Department, Tucson, AZ. 602 pp.

JAEGER, K.L., J.D. OLDEN, AND N.A. PELLAND. 2014. Climate change poised to threaten hydrologic connectivity and endemic fishes in dryland streams. Proceedings of the National Academy of Sciences of the United States of America 111:13894–13899.

KEELEY, B.W., AND M.D. TUTTLE. 1999. Bats in American bridges. Resource Publication 4. Bat Conservation International, Inc., Austin, TX. 41 pp.

KNOPF, F.L., R.R. JOHNSON, T. RICH, F.B. SAMSON, AND R.C. SZARO. 1988. Conservation of riparian ecosystems in the United States. Wilson Bulletin 100:272–284.

KUNZ, T.H., AND L.F. LUMSDEN. 2003. Ecology of cavity and foliage roosting bats. Pages 3–89 *in* T.H. Kunz and M.B. Fenton, editors, Bat ecology. University of Chicago Press, Chicago, IL.

MACDONALD, G.M. 2010. Water, climate change, and sustainability in the Southwest. Proceedings of the National Academy of Sciences of the United States of America 107(50):21256–21262.

MCPHERSON, G.R. 1997. Ecology and management of North American savannas. University of Arizona Press, Tucson, AZ. 208 pp.

NAIMAN, R.J., H. DÉCAMPS, AND M. POLLOCK. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecological Applications 3:209–212.

[NMDGF] NEW MEXICO DEPARTMENT OF GAME AND FISH. 2006. Comprehensive wildlife conservation strategy for New Mexico. New Mexico Department of Game and Fish, Santa Fe, NM.

O'SHEA, T.J., P.M. CRYAN, AND M.A. BOGAN. 2018. United States bat species of concern: a synthesis. Proceedings of the California Academy of Sciences, Series 4, 65:1–279. Supplement I.

O'SHEA, T.J., P.M. CRYAN, E.A. SNIDER, E.W. VALDEZ, L.E. ELLISON, AND D.J. NEUBAUM. 2011. Bats of Mesa Verde National Park, Colorado: composition, reproduction, and roosting habits. Monographs of the Western North American Naturalist 5:1–19.

O'SHEA, T.J., AND T.A. VAUGHAN. 1999. Population changes in bats from central Arizona: 1972 and 1997. Southwestern Naturalist 44:495–500.

PERRY, R.W., AND R.E. THILL. 2007. Roost characteristics of hoary bats in Arkansas. American Midland Naturalist 158:132–138.

PIAGGIO, A.J., E.W. VALDEZ, M.A. BOGAN, AND G.S. SPICER. 2002. Systematics of *Myotis occultus* (Chiroptera: Vespertilionidae) inferred from sequences of two mitochondrial genes. Journal of Mammalogy 83:386–395.

RABE, M.J., T.E. MORRELL, H. GREEN, J.C. DEVOS JR., AND C.R. MILLER. 1998. Characteristics of ponderosa pine snag roosts used by reproductive bats in northern Arizona. Journal of Wildlife Management 62: 612–621.

RACEY, P.A. 1982. Ecology of bat reproduction. Pages 57–104 *in* T.H. Kunz, editor, Ecology of bats, Plenum Press, New York, NY.

ROOD, S.B., S. PATIÑO, K. COOMBS, AND M.T. TYREE. 2000. Branch sacrifice: cavitation-associated drought adaptation of riparian cottonwoods. Trees 14:248–257.

SEAGER, R., M. TING, I. HELD, Y. KUSHNIR, J. LU, G. VECCHI, H.-P. HUANG, N. HARNIK, A. LEETMAA, N.C. LAU, ET AL. 2007. Model projections of an imminent transition to a more arid climate in southwestern North America. Science 316:1181–1184.

SMITH, D.M., AND D.M. FINCH. 2014. Use of native and nonnative nest plants by riparian-nesting birds along two streams in New Mexico. River Research and Applications 30:1134–1145.

SMITH, D.M., AND D.M. FINCH. 2016. Riparian trees and aridland streams of the southwestern United States: an assessment of the past, present, and future. Journal of Arid Environments 135:120–131.

STROMBERG, J.C., J. FRY, AND D.T. PATTERN. 1997. Marsh development after large floods in an alluvial aridland river. Wetlands 17:292–300.

TINGLEY, M.W., V. RUIZ-GUTIÉRREZ, R.L. WILKERSON, C.A. HOWELL, AND R.B. SIEGEL. 2016. Pyrodiversity promotes avian diversity over the decade following forest fire. Proceedings of the Royal Society B 283: 20161703.

WARNER, R.M. 1982. Myotis auriculus. Mammalian Species 191:1–3.

WHITED, D.C., M.S. LORANG, M.J. HARNER, F.R. HAUER, J.S. KIMBALL, AND J.A. STANFORD. 2007. Climate, hydrologic disturbance, and succession: drivers of floodplain pattern. Ecology 88:940–953.

Received 7 March 2019
Revised 15 June 2019
Accepted 16 July 2019
Published online 9 December 2019