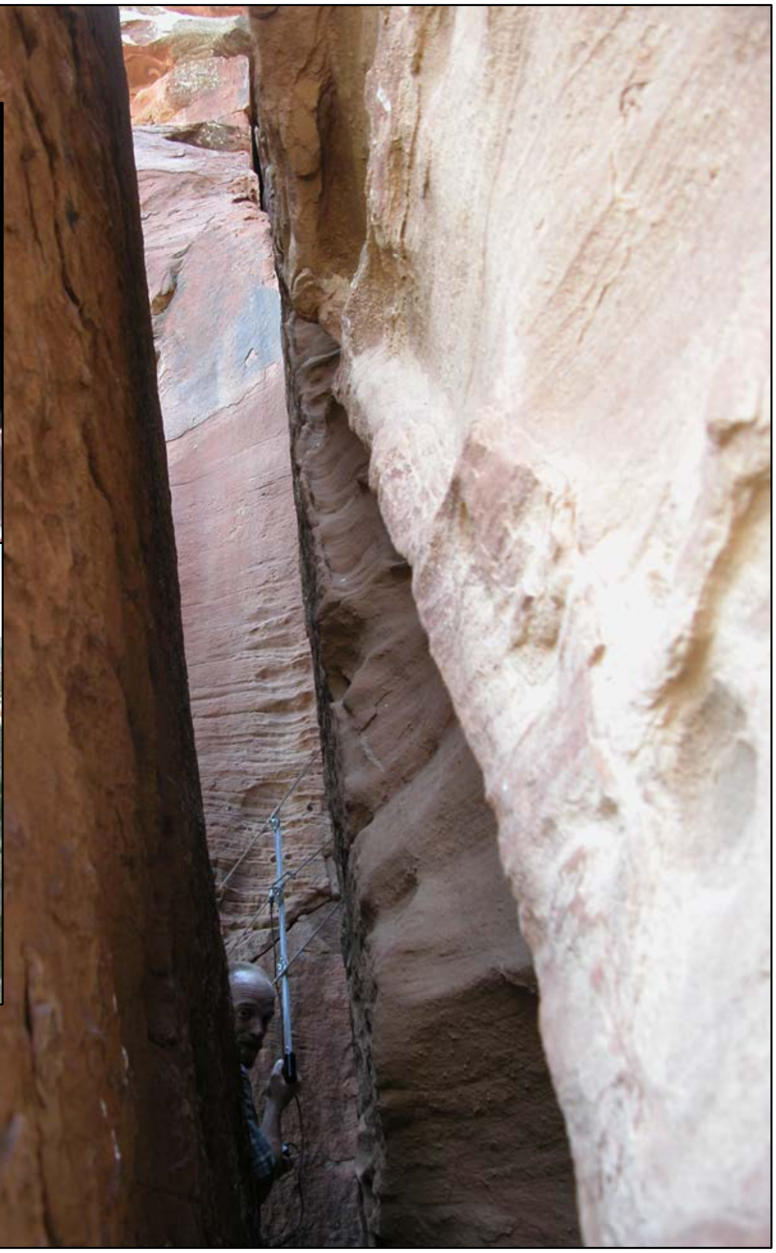
Day roosts of male pallid bats (*Antrozous pallidus*) along Purgatoire River Valley, Las Animas County, Colorado

Colorado Natural Heritage Program
Warner College of Natural Resources
Colorado State University
Fort Collins, Colorado



Colorado State University
Knowledge to Go Places

Colorado Natural Heritage Program
Warner College of Natural Resources
Colorado State University

May 2010

Day roosts of male pallid bats (*Antrozous pallidus*) Purgatoire River Valley, Las Animas County, Colorado

Robert A. Schorr
Zoologist

Cover photographs (clockwise):
1. Male pallid bat
2. Jeremy Siemers (CNHP Zoologist) in cliff crack searching for a pallid bat
3. Rob Schorr overlooking Purgatoire River valley using telemetry equipment to find pallid bats

INTRODUCTION

Bats are the second most speciose mammal order, and Colorado is home to 19 (Armstrong et al. 1994, Fitzgerald et al. 1994) of the 41 species found in North America (Wilson and Ruff 1999). Despite this diversity our knowledge of even simple natural history information, such as distribution and habitat use of bats, is constantly evolving. For example, the Allen's big-eared bat (*Idionycteris phyllotis)* was recently documented in Colorado. Likely this is not a recent expansion of range, but recognition of historic natural distribution (Hayes et al. 2009). Compared to other species of mammals our understanding of bat natural history is limited, usually restricted to those bat species that are urban-adapted or recognized vectors of human diseases (Neubaum et al. 2007, O'Shea et al. 2010).

The paucity of biological information is a product of the ecology of and the difficulty of surveying for bats. Bats are the only volant mammals, able to fly up to 2500 m above ground (Peurach 2003). Many bat species are nocturnal with a majority of their activity coinciding with times of reduced human activity. Also, bats roost in structures and spaces, such as caves, mines, and crevices that are difficult for humans to access. Surveying for bats usually is restricted to sampling them when they are roosting in abundance at caves, mines, or urban structures, such as bridges and buildings. Thus, effective sampling requires prior knowledge of these roosts. Alternately, netting techniques using fine netting (mist nets) established near bat resources, typically water, allow capture of those bats visiting these resources. Unfortunately, netting techniques are plagued with sampling biases because bats can evade nets or escape quickly once captured (MacCarthy et al. 2006).

Throughout North America and the World bats are gaining conservation attention. Because bats have low reproductive rates, undergo major physiological stress (from hibernation and/or migration), are susceptible to human disturbance at roost sites, are disproportionately impacted by some energy development, and are dying in massive numbers throughout eastern North America from of a new fungal disease (Blehert et al. 2009) they are receiving ever-increasing levels of conservation effort (Racey and Entwistle 2003). Almost universal among conservation plans for bats is the need to obtain better understanding of how bats use habitat (Racey and Entwistle 2003, Fenton 2003).

In Colorado, twenty percent of the mammals on the Colorado Division of Wildlife's (CDOW) Colorado State Wildlife Action Plan are bats (Colorado Division of Wildlife 2006), representing 25% of bat species found in Colorado. Designated as a candidate species for listing under the Endangered Species Act, Townsend's big-eared bat (*Corynorhinus townsendii*; COTO) is the bat species of most conservation concern in Colorado (Colorado Division of Wildlife 2006). Similarly, the Colorado Bat Working Group has determined that COTO is one of the highest bat conservation priorities within Colorado (Ellison et al. 2003, Western Bat Working Group 1998).

COTO occurs throughout western North America and has been found in coniferous forests, mixed forests, deserts, prairies, riparian zones, agricultural fields, and coastal habitats (Pierson et al. 1999). Although found in a variety of habitats, COTO's roost affinities are particularly specific, preferring caves, mines, crevices, and occasionally man-made structures (Kunz and

Martin 1982). Records of COTO in Colorado are sporadic and individuals are typically are not found in high densities (Fitzgerald et al. 1994). In addition, populations found in the western half of the state are from a different subspecies than those found on the eastern side of the Rocky Mountains (Piaggio and Perkins 2005).

Although over 150 specimens of COTO have been identified in Colorado, there has been little success documenting breeding populations. Most records are of solitary bats, with a few locations housing up to 20 bats (K. Navo, CDOW, pers. comm.). In Colorado, little is known about COTO breeding biology because only approximately 15 maternity colonies are known. The largest maternity colony of COTO in Colorado is found in the southeastern part of the state (Kirk Navo, CDOW, pers. comm.), and in 2007 an additional maternity colony was discovered in this region (Schorr pers. obs.). It is likely that more maternity colonies exist in this region, but reliance upon happenstance discovery of these colonies will limit biologists' ability to plan for COTO conservation. A proactive effort to locate new roosting and maternity colonies may provide valuable data on distribution, abundance, breeding success, and habitat affinities.

As part of the 2008 Colorado Division of Wildlife's Colorado State Wildlife Action Plan Grants, the Colorado Natural Heritage Program (CNHP) was granted funding to visit an area of southeastern Colorado where COTO had been captured previously (K. Navo, CDOW, pers. comm.) to document COTO roost use. The objective of this project was to identify COTO maternity roost use and day roost use, but the focus of the study was altered when COTO were not captured at the study site.

METHODS

Study site

Based on survey effort by the CDOW in 2007, I returned to specific water holes where COTO were captured. These water holes (troughs) were near the Purgatoire River Valley in northeast Las Animas County. Prior to beginning fieldwork I obtained permission from the local landowner to survey and travel on private lands.

Figure 1. Mist net over water trough east of Purgatoire River

Capture and transmitter attachment

Bats were captured using fine mist nets (Avinet, Inc., Dryden, NY) stretched over water troughs (Figure 1). Captured bats were carried to a processing location where critical measurements and physical features were recorded. Species, sex, time of capture, and pertinent climatic information were recorded.

Bats were restrained delicately with their anterior half in a light cotton bag and with the posterior and dorsal portion exposed. Hair between the scapulas was trimmed using curved, blunt-ended manicure scissors. Skin-Bond adhesive cement (Smith and Nephew, Inc., Largo, FL) was applied to the trimmed area and to a small (0.42-0.60 g) radiotransmitter (Model BD2N and BD2, Holohil Systems Ltd., Carp, Ontario; Figure 2) using a fine paintbrush. Glue was allowed to cure prior to placement on the bat. Hair surrounding the transmitter and hair trimmed prior to application were laid on the transmitter to help camouflage the transmitter (Figure 3). Additionally, a light dusting of talc (Johnson and Johnson Consumer Companies Inc., Skillman, NJ) was applied to ensure all tacky surfaces were covered. Bats were tracked during daylight hours to locate diurnal roosts. Once a bat's general location was identified researchers would hike as close as safely possible to describe the roost structure and characteristics.

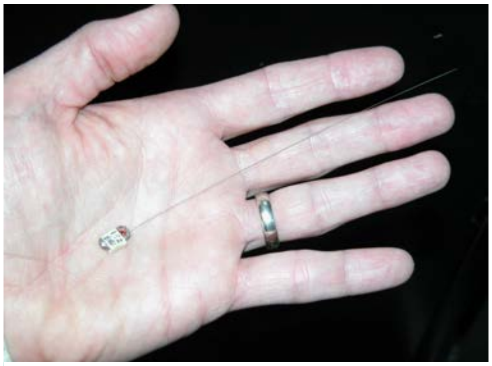


Figure 2. Holohil Systems Ltd. model BD2 radiotransmitter in hand

Figure 3. Pallid bat with transmitter.

Roost data

Data regarding roost structure, temperature, orientation, and proximity to relevant features were collected (Table 1, Figure 4). Roost temperatures were measured using an infrared noncontact thermometer (Raynger ST, Raytek Corp., Santa Cruz, CA) and ambient temperatures were measured using a hand-held thermometer (Enviro-Safe Armor Case Thermometer, TWM Solutions Inc., Trappe, PA). Distances were measured using a laser rangefinder (Yardage Pro Trophy, Bushnell Performance Optics, Lenexa, KS) and were rounded to the nearest 10 m. For features not visible from the roost, a geographic information system (ArcGIS, ESRI, Redlands, CA) was used to assess distances. Bearings

Table 1. Data collected at pallid bat roosts along the Purgatoire River Valley

Data	Units	Data values
Roost structure	NA	tree, clilff wall, rock
Aspect of roost opening	degrees	continuous
Aspect of cliff wall	degrees	continuous
Distance to nearest tree	meters	continuous
Bearing to nearest tree	degrees	continuous
Species of nearest tree	NA	juniper, pinon pine
Bearing to nearest water source	degrees	0-360
Distance to nearest water source	meters	continuous
Type of water source	NA	river, trough
Canopy cover within 2 m of roost	percent	continuous
Canopy cover within 10 m of roost	percent	continuous
Presence of guano	NA	yes/no
Presence of bats	NA	yes/no
Roost temperature	degrees Celsius	continuous
Ambient temperature	degrees Celsius	continuous
Height of emergence opening	centimeters	continuous
Width of emergence opening	centimeters	continuous
Depth of crevice	centimeters	continuous
Distance to flat ground above entrance	meters	continuous
Distance to ground below entrance	meters	continuous
Distance from roost to valley floor	meters	continuous
Distance from roost to top of mesa	meters	continuous

Figure 4. Height measurements taken at bat roosts. Horizontal red line shows location of bat roost. A. Left arrow represents height from roost to mesa top. Right arrow represents height of roost above valley floor. B. Left arrow represents height of roost above horizontal ground. Right arrow represents distance from roost to horizontal ground above roost. The roost depicted in this figure was used by two bats on separate occasions.

were assessed using a handheld compass (Silva Ranger, Johnson Outdoor Gear, Inc., Racine, WI).

RESULTS

Species captured

Mist nets were run for 7 nights at one trough and 8 nights at a second trough. During June and July of 2009, 12 pallid bats (*Antrozous pallidus*; ANPA), 13 small-footed myotis (*Myotis ciliolabrum*), 11 little brown bats (*Myotis lucifugus*), 2 big brown bats (*Eptesicus fuscus*), and 1 fringed myotis (*Myotis thysanodes*) were captured. No COTO were captured. Because of the number of pallid bats captured and because of the pallid bat's comparable body size to COTO, the project's focus shifted to address male pallid bat roost use.

Roost characteristics

Twelve male pallid bats were fitted with transmitters and 10 of those were tracked to 53 roosts (Figure 5). During most attempts to locate bats the individuals were hidden behind rock structures and inaccessible (Figures 4, 6, 7). When this occurred researchers tried to best approximate the location of the bat roost for data collection. Pallid bats were seen on 6 occasions.

Nearly all roosts were on cliff walls and facing south to southwest (mean: 178°), but with much variability (standard deviation (SD): 70°, range: 30 - 334°) and in the same general direction as the aspect of the cliff wall (165 ± 63° SD, range: 2 - 268°). Roosts were not surrounded by trees and on no occasions were trees providing canopy cover above roosts. Roost temperatures (26.0 ± 4.9°C SD) were comparable to ambient temperatures (24.3 ± 6.9°C SD). Crevices were typically narrow (7.8 ± 5.5 cm SD), but longer and more variable in length (198 ± 346 cm SD), and nearly equally distributed (55% vertical: 45% horizontal) in orientation (Figure 4). Most crevices were high on cliff walls (92 ± 46 m SD) and near the top of mesas (within 16 ± 24 m of mesa top). Typically, roosts were at heights of 86% (± 12% SD) of the height of the cliff wall. Also, roosts were typically out of reach of researchers being 26 m (± 10 m SD) above an accessible flat area and 10 m (± 12m SD) below an accessible flat area (Figure 4). Six roosts were in standing rocks near the base of cliff walls (Figure 7).

Crevices were narrow (8 ± 5 cm SD), but in a variety of lengths (200 ± 360 cm SD; range: 25 – 1500 cm) and in various orientations from vertical to horizontal. At the few locations where depth was accessible (x = 5) mean depth was 46 cm (± 32 cm SD). At 14 roosts guano was found below the roost crevice.

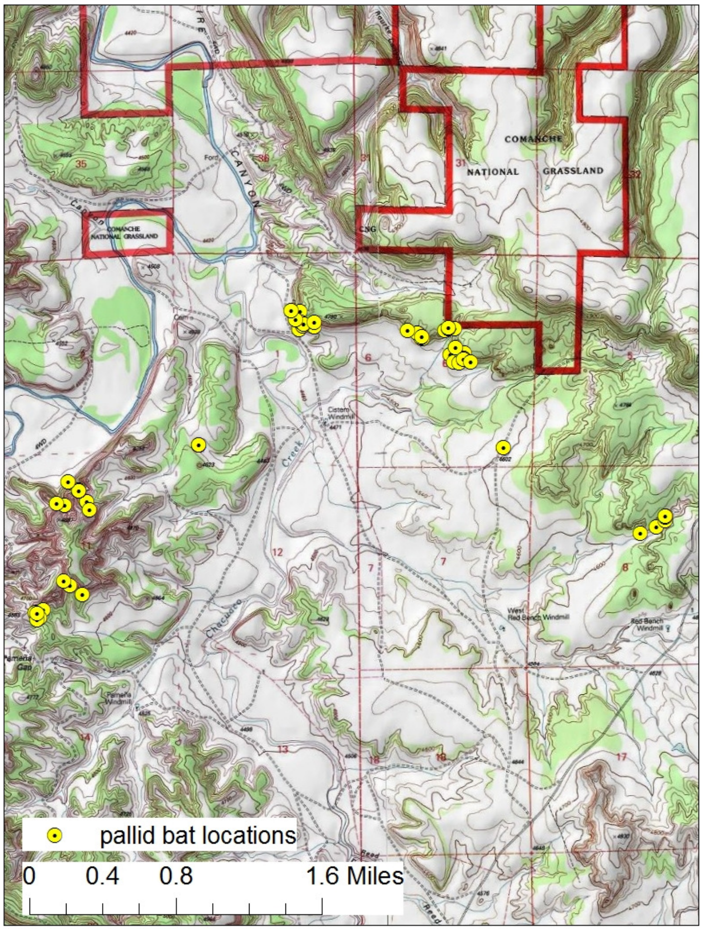


Figure 5. Pallid bat roost locations from Purgatoire River Valley

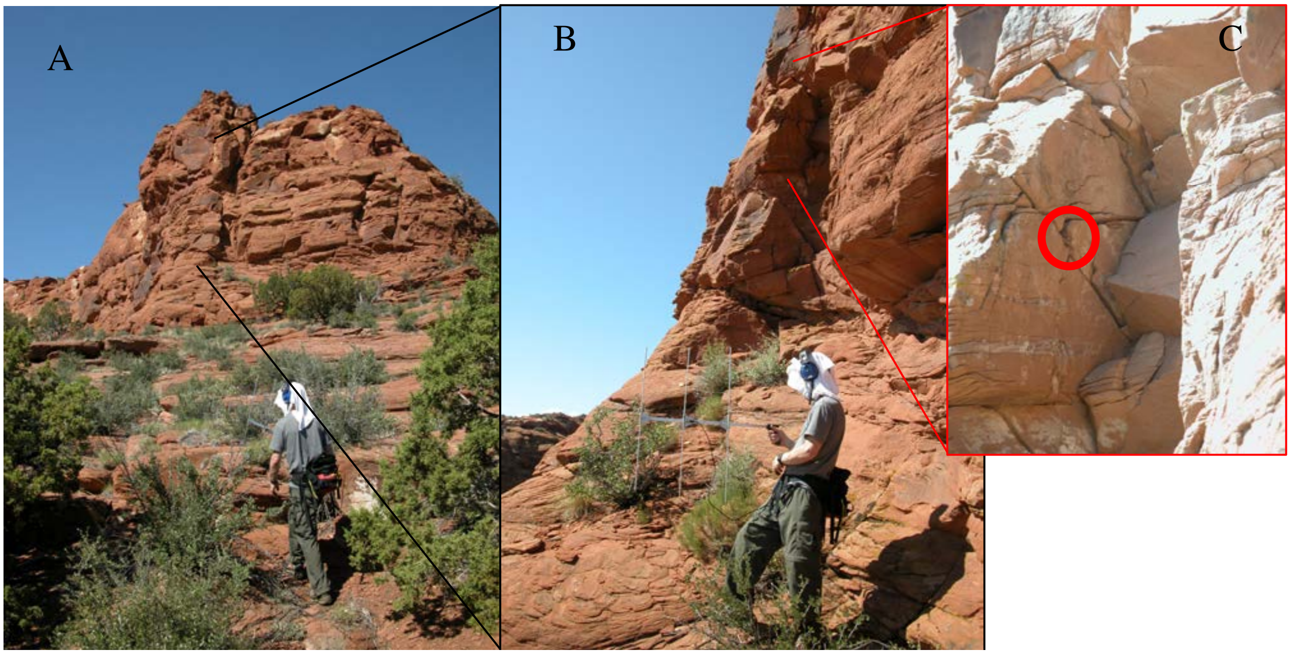


Figure 6. Location of male pallid bat roost. A. View of roost cliff structure; B. View of roost position on cliff; C. View of cliff cracks where transmitter was recovered. Red circle identifies specific crack and likely pallid bat roost.

Figure 7. Rock crevice used by a male pallid bat. A. View of rock used as a day roost by a male pallid bat. Jeremy Siemers is pointing to crack and approximate height of the roosting bat.; B. Looking into rock crack (from above) where bat was located approximately a meter below top. Red circle identifies area where bat was seen. Bat flew as researchers began temperature measurements.

Water was universally accessible to all roosts (Figure 5). Roosts were within 1.5 km (±1.2 km) of the Purgatoire River and within 820 m (±360 m) of the nearest water (capture location). Typically, a bat roosted within 1.5 km of where it was captured (1.45 ± 0.95 km), but one bat was found roosting 4.1 km from where it was captured. This bat was captured at a water trough that was not the closest trough to its roost location and was further than the Purgatoire River.

PALLID BAT ECOLOGY AND DISCUSSION

The pallid bat is a large (13-24 g) member of Vespertilionidae family that is light in color (light brown to blonde) with large (21-37 mm) ears (Hermanson and O'Shea 1983) (Figure 8). Pallid bats are found throughout arid lands of western and southwestern North America (Hermanson and O'Shea 1983). In Colorado, pallid bats are found in the western western half to the southeastern corner (Fitzgerald et al. 1994) with the densest population in Colorado likely occurring in the southwestern canyonlands (Armstrong 1972). Pallid bats roost in crevices, caves, mines, tree cavities and man-made structures (Twente 1955, Hermanson and O'Shea 1983, Lewis 1994, Baker et al. 2008) (Figure 9).

Figure 8. Pallid bat from western Colorado.

Pallid bats eat a variety of invertebrate and vertebrate prey items. Their diet is dominated by insects, such as cicadas, beetles, moths, grasshoppers, cockroaches, botflies, ants, crickets, katydids, walking sticks, and other invertebrates, such as scorpions, wind scorpions, and spiders (O'Shea and Vaughan 1977, Johnston and Fenton 2001, Lenhart et al. 2010). Pallid bats will occasionally eat vertebrates, such as lizards and rodents (O'Shea and Vaughan 1977, Bell 1982, Johnston and Fenton 2001, Lenhart et al. 2010), and will visit cactus and agave plants, but it is unknown whether they intentionally feed on nectar or predate flower-visiting invertebrates (Barbour and Davis 1969, Herrera et al. 1993). Foraging forays tend to be close to roosts, with few flights exceeding 3 km (O'Shea and Vaughan 1977, Bell 1982, Johnston and Fenton 2001, Baker et al. 2008).

Figure 9. Pallid bat in mine crevice. Photograph by Kirk Navo, Colorado Division of Wildlife.

Pallid bats are considered gleaners because they will regularly take prey off the ground or vegetation (Bell 1982, Hermanson and O'Shea 1983), but pallid bats will take prey, such as beetles and moths, in flight (Easterla and Whitaker 1972, O'Shea and Vaughan 1977, Bell 1982, Johnston and Fenton 2001). When feeding, the pallid bat will make repeated passes before descending on the animal or crawling to it (Bell 1982).

In the summer, male and female pallid bats may roost together or separately (Vaughan and O'Shea 1976, Hermanson and O'Shea 1983). Nursery colonies of adult females and young may number in the hundreds and bachelor roosts may be as large as 100 (Davis and Cockrum 1963, Vaughan and O'Shea 1976). During hibernation pallid bats roost singly or in small groups (Hermanson and O'Shea 1983). Diurnal summer roosts are warm (29-32°C; Vaughan and O'Shea 1976). In laboratory studies, pallid bats show highest metabolism at 25°C and reduced metabolism at 30°C and those bats that roosted in clusters had lower metabolic rates than those roosting singly (Trune and Slobodochikoff 1976). It has been suggested that the metabolism of pallid bats is optimized at warm, stable temperatures (Trune and Slobodchikoff 1976)

Many of the studies of pallid bat roosting ecology are based on females or breeding colonies (Vaughan and O'Shea 1976, O'Shea and Vaughan 1977, Lewis 1996). Few studies have addressed the roosting characteristics of male pallid bats (Baker et al. 2008). This study was able to identify and describe diurnal roosts of male pallid bats from the eastern part of their range. The roosts and the cliffs chosen by male pallid bats faced southwest to southeast, but rarely had a northerly orientation. Big brown bats in forests of Saskatchewan selected cavity roosts with southerly orientations that may reduce the evaporative effects of east-west winds (Kalcounis and Bringham 1998). Male pallid bats may derive a thermal advantage from southern-facing roosts, similar to woodpeckers (Inouye 1976, Inouye et al. 1981). Forest-dwelling long-legged bats (*Myotis volans*) and silver-haired bats (*Lasionycteris noctivagans*) tend to select roosts in trees that are above the surrounding canopy and allow more solar radiation exposure (Betts 1996, Ormsbee and McComb 1998).

Along the Purgatoire River Valley I found male pallid bats roosting at temperatures similar to those reported in previous studies. However, rarely was I able to confirm that the infrared noncontact thermometer was recording temperatures where bats were located. Because bats infrequently were seen I could not confirm that the temperatures being recorded reflected the microsite temperatures where bats were roosting. The best opportunities to confirm roosting temperatures occurred when bats were observed roosting in rocks (N = 6). Temperatures at these locations (27 ± 3°C) were comparable to those observed at cliff crevices (26 ± 5°C), but these temperatures were higher than those of the ambient temperatures (21 ± 6°C; T-test p-value: 0.08). For reproductive females, warmer roost temperatures mean lower metabolism (Trune and Slobodchikoff 1976) and higher reproductive activity (Lewis 1993). Clusters of pallid bats are able maintain warm temperatures and drive metabolism lower than singly roosting pallid bats (Trune and Slobodchikoff 1976). Compared to summer-roosting females, summer-roosting males do not roost in colonies or clusters and do not realize the energetic savings experienced by larger groups of roosting bats.

Body temperature management influences how other bat species select roost sites. The thermoneutral zone for little brown bats is between 32.5-37.5°C, and the internal temperature of occupied little brown bat roosts was 35°C (Burnett and August 1981). Singly-roosting male little brown bats show reduced metabolism at 25-30°C (Kurta and Kunz 1988). Bat roost selection can be driven by the phenology of the species and temperature. Male big brown bats use torpor to a greater degree during the day than reproductive females do, and thus should select cooler roosting climates than females (Hamilton and Barclay 1994). Female Bechstein bats (*Myotis bechsteinii*) select cooler roosts prior to reproduction, then select warmer roosts during pregnancy and lactation (Kerth et al. 2001). Pregnant western long-eared bats (Myotis evotis) choose horizontal crevices that warm quickly during the day (Churuszcz and Barclay 2002).

Female pallid bats switch between thin slab roost during cool seasons and deeper rock crevices in warmer seasons (Lewis 1996). During cooler seasons slab roosts allow easier access to solar radiation and warmer microclimates, whereas deeper rock crevices provide respite from extreme temperatures during the warmer seasons. Also, females will move deeper into a roost or closer to the egress to satisfy microclimate needs (Vaughan and O'Shea 1976). I expected males to roost in vertical crevices because of the broad thermal gradient these structures provide (O'Shea and Vaughan 1977). Orientation of roosts near the Purgatoire River Valley was not consistent (23:19, vertical:horizontal). It is possible that males move among day roosts to satisfy the desired thermal climate (Lewis 1996).

No bats were found roosting together, but on one occasion a male pallid bat used a diurnal roost that was previously used by another pallid bat. It is possible that ideal thermoregulatory microclimates are shared and communicated among local pallid bat males. Rarely was a bat found in the same crevice it used previously, however, a bat returned to the same general cliff wall. Lewis (1996) found low roost-site fidelity in female pallid bats, switching roost approximately every 1.5 days. For females this behavior may have been driven by ectoparasite load (Lewis 1996). Many of the male pallid bats I followed had bat flies (Family Nycteribiidae) crawling through their pelage. Bat flies are common parasites on pallid bats (Whitaker and Easterla 1975, Lewis 1996), and their life cycle is spent at roosts and on individuals (Lewis

1996). On one male pallid bat in this study, 5 bat flies were seen. Despite the frequency of roost switching several roosts were used repeatedly based on the amount of guano accumulated below the roost.

Although this study did not address the target species (COTO) it did provide valuable information on the use of rock and cliff crevices by pallid bats. For many cavernicolous bat species, conservation strategies prioritize those features that are easier for humans to access (caves and mines); however, many bat species may utilized crevices to a greater degree than previously known (Churuszcz and Barclay 2002, Lausen and Barclay 2003). Basing conservation strategies solely on abundance at maternity colonies is misleading because it neglects other phenological needs for the species and can neglect solitary roosting individuals (Neubaum et al. 2006). Obtaining a better understanding on why these features are chosen will inform conservation planning efforts and bat habitat management. The spread of White Nose Syndrome may be accentuated by social behavior of communal roosting and cold temperatures of hibernacula (Blehert et al. 2009). Species that select solitary, warm roosts may be less susceptible to infection, or may provide opportunities for understanding the dynamics of such diseases.

What still needs to be addressed is the prevalence of COTO maternity colonies in the Purgatoire River Valley. Given this species' critical conservation status, and the likelihood of White Nose Syndrome reaching Colorado (recently documented in western Oklahoma), it is important to know where to conserve breeding habitat and what locations to prioritize. Maternity colonies of bats in southeastern Colorado, including those of COTO, are likely to be the first to encounter White Nose Syndrome. Future surveys in the valley may document reproductive females, but it will be important to be able to follow these individuals back to the roost and document reproduction. It may be more fruitful to conduct an exhaustive search of mines and caves in this region, then follow dispersing COTO males and females to new roosts.

ACKNOWLEDGMENTS

I would like to thank Jeremy Siemers, Jessica Healy, and Cassandra Gearhardt of CNHP for their assistance in the field. Thank you to Joy and Steve Wooten who graciously allowed access to their property and history lessons about the lands along the Purgatoire River. I thank the Audubon Society of Greater Denver for a small grant for additional equipment needs.

LITERATURE CITED

Armstrong, D. M., R. A. Adams, and J. Freeman. 1994. Distribution and ecology of bats of Colorado. University of Colorado Museum Natural History Inventory of Colorado 15:1-83.

Baker, M. D., M. J. Lacki, G. A. Falxa, P. L. Droppelman, R. A. Slack and S. A. Slankard. 2008. Habitat use of pallid bats in coniferous forests of northern California. Northwest Science 82:269-275.

Barbour, R. W., and W. H. Davis. 1969. Bats of America. University of Kentucky Press, Lexington. 285 pp.

Bell, G. P. 1982. Behavioral and ecological aspects of gleaning by a desert insectivorous bat *Antrozous pallidus* (Chiroptera: Vespertilionidae). Behavioral Ecology and Sociobiology 10:217-223.

Betts, B. J. 1996. Roosting behavior of silver-haired bats (*Lasionycteris noctivagans*) and big brown bats (*Eptesicus fuscus*) in northeast Oregon. Pp. 55-61 in Bats and forest symposium (R. M. R. Barclay and R. M. Brigham, eds.). British Columbia Ministry of Forests, Victoria.

Blehert, 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. Bat white-nose syndrome: an emerging fungal pathogen? Science 323:227.

Burnett, C. D., and P. V. August. 1981. Time and energy budgets for day roosting in a maternity colony of *Myotis lucifigus*. Journal of Mammalogy 62:758-766.

Churuszcz, B. J., and R. M. R. Barclay. 2002. Thermoregulatory ecology of a solitary bat, *Myotis evotis*, roosting in rock crevices. Functional Ecology 16:18-26.

Davis, R., and E. L. Cockrum. 1963. “Malfunction” of homing ability in bats. Journal of Mammalogy 44:131-132.

Colorado Division of Wildlife. 2006. Colorado Wildlife Action Plan. Colorado Division of Wildlife. Denver, Colorado. 78 pp.

Easterla, D. A., and J. O. Whitaker, Jr. 1972. Food habits of some bats from Big Bend National Park, Texas. Journal of Mammalogy 53:887-890.

Ellison, L. E., M. B. Wunder, C. A. Jones, C. Mosch, K. Navo, K. Peckham, J. E. Burghardt, J. Annear, R. West, J. Siemers, R. A. Adams, and E. Brekke. 2003. Colorado Bat Conservation Plan. Colorado Committee of the Western Bat Working Group (Colorado Bat Working Group). 107 pp.

Fenton, M. B. 2003. Science and the conservation of bats: where to next? Wildlife Society Bulletin 31:6-15.

Fitzgerald, J. P., C. A. Meaney, and D. M. Armstrong. 1994. Mammals of Colorado. University of Colorado Press, Niwot. 467 pp.

Hamilton, I. M., and R. M. R. Barclay. 1994. Patterns of daily torpor and day-roost selection by male and female big brown bats (*Eptescius fuscus*). Canadian Journal of Zoology 72:744-749.

Hayes, M. A., K. W. Navo, L. R. Bonewell, C. J. Mosch, and R. A. Adams. 2009. Allen's big-eared bat (*Idionycteris phyllotis*) documented in Colorado based on recordings of its distinctive echolocation call. Southwestern Naturalist 54:499-501.

Hermanson, J. W., and T. J. O'Shea. 1983. *Antrozous pallidus*. Mammalian Species 213:1-8.

Inouye, D. W. 1976. Non-random orientation of entrance holes to woodpecker nests in aspen trees. Condor 78:101-102.

Inouye, R. S., N. J. Huntly, and D. W. Inouye. 1981. Non-random orientation of Gila woodpecker nest entrances in saguaro cactus. Condor 83:88-89.

Johnston, D. S., and M. B. Fenton. 2001. Individual and population-level variability in diets of pallid bats (*Antrozous pallidus*). Journal of Mammalogy 82:362-373.

Kalcounis, M. C., and R. M. Bringham. 1998. Secondary use of aspen cavities by tree-roosting big brown bats. Journal of Wildlife Management 62:603-611.

Kerth, G., K. Weissmann, and B. König. 2001. Day roost selection in female Bechstein bats (*Myotis bechstenii*): a field experiment to determine the influence of roost temperature. Oecologia 126:1-9.

Kunz, T. H., and R. A. Martin. 1982. *Plecotus townsendii*. Mammalian Species 175:1-6.

Kurta, A., and T. H. Kunz. 1988. Roosting metabolic rate and body temperature of male little brown bats (*Myotis lucifugus*) in summer. Journal of Mammalogy 69:645-651.

Lausen, C. L., and R. M. R. Barclay. 2003. Thermoregulation and roost selection by reproductive female big brown bats (*Eptesicus fuscus*) roosting in rock crevices. Journal of Zoology London 260:235-244.

Lenhart, P. A., V. Mata-Silva, and J. D. Johnson. 2010. Foods of the pallid bat, *Antrozous pallidus* (Chiroptera: Vespertilionidae), in the Chihuahuan Desert of western Texas. Southwestern Naturalist 55:110-142.

Lewis, S. E. 1993. Effect of climatic variation on reproduction by pallid bats (*Antrozous pallidus*). Canadian Journal of Zoology 71:1429-1433.

Lewis, S. E. 1994. Night roosting ecology of pallid bats (*Antrozous pallidus*) in Oregon. American Midland Naturalist 132:219-226.

Lewis, S. E. 1996. Low roost fidelity in pallid bats: associated factors and effects on group stability. Behavioral ecology and sociobiology 39:335-344.

MacCarthy, K. A., T. C. Carter, B. J. Steffen, and G. A. Feldhamer. Efficacy of the mist-netting protocol for Indiana bats: a video analysis. Northeastern Naturalist 13:25-28.

Neubaum, D. J., K. R. Wilson, and T. J. O'Shea. 2007. Urban maternity-roost selection by big brown bats in Colorado. Journal of Wildlife Management 71: 728-736.

Ormsbee, P. C., and W. C. McComb. 1998. Selection of day roosts by female long-legged myotis in the central Oregon Cascade Range. Journal of Wildlife Management 62:586-603.

O'Shea, T. J., and T. A. Vaughan. 1977. Nocturnal and seasonal activities of the pallid bat, *Antrozous pallidus*. Journal of Mammalogy 58:269-284.

O'Shea, T.J., L.E. Ellison, D.J. Neubaum, M.A. Neubaum, C.A. Reynolds, and R.A. Bowen. 2010. Recruitment in a Colorado population of big brown bats: breeding probabilities, litter size, and first-year survival. Journal of Mammalogy 91: 418-428

Peurach, S. C. 2003. High-altitude collision between an airplane and a hoary bat (*Lasiurus cinereus*). Bat Research News 44:2-3.

Piaggio, A. J., and S. L. Perkins. 2005. Molecular phylogeny of North American long-eared bats (Vespertilionidae: Corynorhinus); inter- and intraspecific relationships inferred from the mitochondrial and nuclear DNA sequences. Molecular Phylogenetics and Evolution 37:762-775.

Racey, P. A. and A. C. Entwistle. 2003. Conservation ecology of bats. Pp. 680-743 *in* Bat Ecology (T. H. Kunz and M. B. Fenton, eds.). University of Chicago Press, Chicago, Illinois. 779 pp.

Trune, D. R., and C. N. Slobodchikoff. 1976. Social effects of roosting on the metabolism of the pallid bat (*Antrozous pallidus*). Journal of Mammalogy 57:656-663.

Twente, J. W., Jr. 1955. Some aspects of habitat selection and other behavior of cavern-dwelling bats. Ecology 36:706-732.

Vaughan, T. A., and T. J. O'Shea. 1976. Roosting ecology of the pallid bat, *Antrozous pallidus*. Journal of Mammalogy 57:19-42.

Western Bat Working Group. 1998. Western bat species: regional priority matrix. Western Bat Working Group Workshop, 9-13 February 1998, Reno, Nevada.

Whitaker, J. O., Jr., and D. A. Easterla. 1975. Ectoparasites of bats from Big Bend National Park, Texas. Southwestern Naturalist 20:241-254.

Wilson, D. E., and S. Ruff. The Smithsonian Book of North American Mammals. Smithsonian Institute, Washington, D.C. 750 pp.