IS A MINE A TERRIBLE THING TO WASTE? ADDITIONAL SUBTERRANEAN HABITATS FOR TROGLOBITIC FAUNA AND OTHER CAVERNICOLES IN THE OZARKS

Michael E. Slay
The Nature Conservancy
601 North University Avenue
Little Rock, Arkansas 72705, USA
mslay@tnc.org
479-973-9110

Charles J. Bitting
Buffalo National River
402 North Walnut, Suite 136
Harrison, Arkansas 72601, USA
chuck_bitting@nps.gov
501-741-5443

Abstract

Multiple studies have shown the importance of abandoned mines as surrogate habitat for bat species, but little information exists for other species that may use these habitats. Fifteen abandoned mines located on the Buffalo National River, Arkansas, near the historic mining town of Rush were inventoried from summer 2001 to summer 2005 for the presence of cavernicoles. Over 80 taxa were observed in these abandoned mines, including nine troglobites. The troglobites observed were: a terrestrial isopod (*Brackenridgia* sp.), two families of springtails (Arrhopalitidae, Entomobryiidae), two families of diplurans (Campodeidae, Japygidae), the grotto salamander (*Eurycea spelaea*), a millipede (*Causeyella* sp.), a harvestman (*Crosbyella* sp.), and an amphipod (*Stygobromus* sp.). Since these mines were driven into carbonate hillsides as discrete tunnels, a reasonable explanation for the presence of troglobites is colonization of mine passageways following the intersection of naturally occurring voids. This study suggests that abandoned mine habitats may be important to a suite of rare and interesting species, in addition to bats.

Key words: mines, cave biology, biodiversity, Buffalo National River, Arkansas, Ozarks

Introduction

While studies have shown the importance of abandoned mines as habitat for bat species (Raesly and Gates 1987, Whitaker and Rissler 1992), little information exists for other species that may use these habitats. Cavernicoles, or cave-dwelling species, are known to occur in abandoned mines (McDaniel and Gardner 1977, Dorris and Saugey 1983, Heath et al. 1986, Peck 1988, Kjaerandsen 1993, McAllister et al. 1995, Nielsen and Andreasen 1998). Relatively few cavernicoles from these studies could be considered troglobites (or cave-limited species), and a majority of species were classified as accidentals, trogloxenes, or troglophiles. Accidental species are species that wander into a cave but can't live there. Trogloxenes are species that complete part of their life cycle in caves and part outside. Troglophiles are species that may complete their entire life cycle in caves, but can also complete life cycles outside caves.

The occurrence of a troglobitic beetle in a Kentucky coal mine (Barr 1986) and the successful transplant of a rare harvestman (Opiliones) to an abandoned mine in California (Elliott 2000) suggests that mine habitats may also contain troglobites or have environmental conditions that could support troglobites. The purpose of this study was to examine abandoned mines for the presence of troglobites and characterize some of the environmental conditions associated with the mines.

Materials and Methods

From April 2001 to September 2005, we conducted biological inventories in 15 abandoned mines along the Buffalo National River, near the historic town of Rush, Arkansas (Figure 1). Mining activity in this area involved the extraction of zinc ore from carbonate rock sequences and occurred from 1900 to 1945 (Howard 1989). Fourteen of the mines were quarried into hillsides as horizontal tunnels, while one had an initial vertical drop before continuing as horizontal passage. Several mines had more than one entrance. Average mine length was 86.8 m (SE ± 24.6 m), with a range of 10 to 300 m.

In all 15 sites, visual searches and hand collections were used to record or collect organisms. During summer 2004, additional collections were made using baited pitfall traps in six mines (Toney Bend Mine #2, #3, Morning Star Mine #5, #6, #7, Long Ear Mine). Traps consisted of 30-ml, straight-sided, wide-mouth Nalgene® jars, filled with 5 ml of propylene glycol. The traps were baited with 5 ml

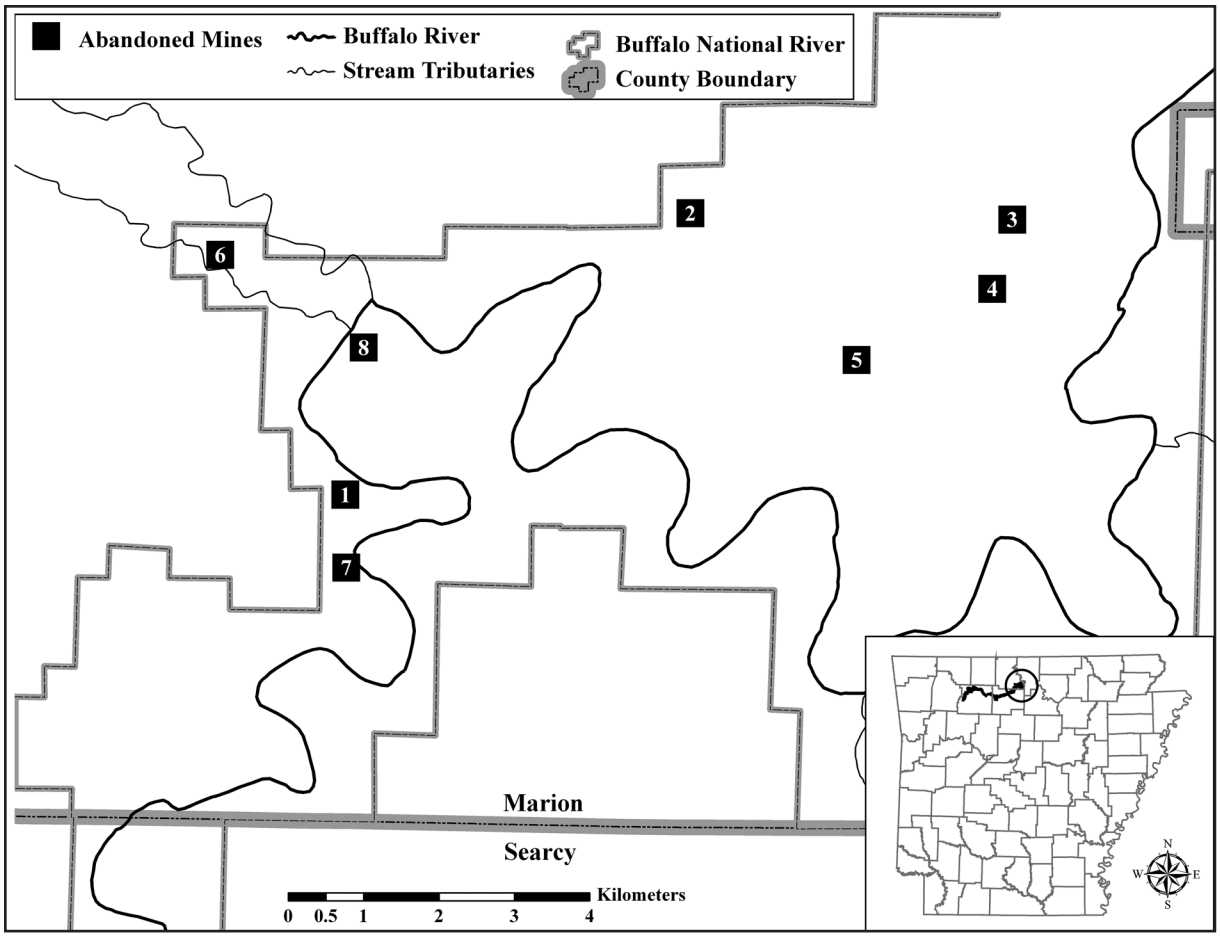

Figure 1 *Study area near Rush, Arkansas, Buffalo National River. Inset map shows counties of Arkansas, Buffalo National River (black polygon), and location of study area (black circle). Abandoned mines are shown as filled squares (▪), and the numbers correspond with specific sites: 1) Bice Mine, 2) Boat Creek Mine, 3) Bonanza Mine, 4) Fox Den Mine, 5) Long Ear Mine, Mary Agnes Mine, Prospect Cave, Sixteen Mine, 6) Morning Star Mines #5, #6, #7, #15, 7) Toney Bend Mines #2, #3, and 8) Red Cloud Mine.*

of slightly rancid limburger cheese spread smeared around the inner lip of the jars. For each trap, a hole was dug in the substrate deep enough to allow placement with the lip of the jar just at or below the floor level. Considerable care was taken to ensure that the substrate into which the trap was placed, usually clay, covered the lip of the jar, so that the top of the jar did not serve as a barrier for smaller fauna from entering the trap. A 10 cm x 10 cm x 5 cm box, constructed of 6.3-mm mesh hardware cloth, was placed over each trap to reduce the potential for trap disturbance by vertebrates such as *Peromyscus* spp., *Neotoma floridana*, and *Procyon lotor* (mice, eastern wood rat, and raccoon). Traps remained in place for approximately 72 hours.

Each observed or collected taxon was given an ecological classification of accidental (AC), trogloxene (TX), troglophile (TP), or troglobite (TB). Collected invertebrates were identified to the lowest possible taxon, and invertebrates that were not identifiable to specific level were classified as morphospecies. Specimens were preserved in 70% ethanol and deposited in the Arthropod Museum at the University of Arkansas, however, these specimens remain the property of the National Park Service. The collection of invertebrates was conducted under the following permits: Arkansas Game and Fish Commission Scientific Collection Permit #020920042 and Buffalo National River, National Park Service Scientific Research and Collecting Permit #BUFF-2004-SCI-0008.

Additionally, temperature (2-cm soil depth, 2-cm air, 1-m air) and relative humidity were measured in the six sites where pitfall traps were placed. Temperature and humidity measurements were taken at the surface, entrance, twilight, and dark zones.

Results

Overall, a total of 4,620 individuals representing 82 taxa in 40 families, 26 orders, and 13 classes were observed or collected. Several taxa were not previously documented from Arkansas. A centipede, *Buethobius* prob. *oabitus* (Henicopidae), found in Long Ear Mine was the first record for this family in the state. Another state record was a terrestrial isopod, *Brackenridgia* sp., found in Morning Star Mine #6 and Toney Bend Mine #3. Additionally, two undescribed species were discovered. A new species of *Rhagidia* (Rhagidiidae: Acari) was observed in Morning Star Mine #5 and Toney Bend Mine #3, while a new genus of Japygidae (Diplura) was collected from Toney Bend Mine #2.

The most common arthropods were cave crickets, four families of flies, and tomocerid springtails (Table 1). The most common vertebrates were: Eastern pipistrelle (*Pipistrellus subflavus*), Western Slimy salamander (*Plethodon albagula*), Northern bat (*Myotis septentrionalis*), Cave salamander (*Eurycea lucifuga*), and Ozark Zigzag salamander (*Plethodon angusticlavius*). The average number of taxa per site was 19.69 (SE ± 4.67), with a maximum of 54 in Toney Bend Mine #3 and a minimum of 2 in Mary Agnes Mine (Table 2). Average number of total individuals was 291.43 (SE ± 104.87), with a range of 2-1137.

The majority (79%) of fauna were categorized as trogloxenes (N=34) and troglophiles (N=31), while accidentals made up 10% (N=8). Interestingly, troglobitic taxa (N=9) made up 11% of the fauna and occurred in two-thirds of mines (10 of 15). The nine troglobites were: an isopod (*Brackenridgia* sp.), two families of springtails (Arrhopalitidae, Entomobryiidae), two families of diplurans (Campodeidae, Japygidae), the Grotto salamander (*Eurycea spelaea*), a millipede (*Causeyella* sp.), a harvestman (*Crosbyella* sp.), and an amphipod (*Stygobromus* sp.). Average troglobitic taxa per site was 2.06 (SE ± 0.52), with a maximum of six (Toney Bend Mine #3) and a minimum of 0. For the 10 sites where troglobites occurred, average troglobitic taxa per site were three (SE ± 1.84). Total troglobitic abundance was highest in Long Ear Mine (80 individuals), with an average of 12.63 (SE ± 5.52). For the 10 sites where troglobites occurred, average troglobitic abundance was 18.36 (SE ± 24.83). The most abundant troglobite was the springtail family Arrhopalitidae (N=133). Less than 20 individuals per taxa were observed for the other troglobites.

In summer 2004, temperature decreased and relative humidity increased from surface zones to dark zones (Figure 2). The average surface temperature ranged from 21.55°C (SE ± 1.31°C) to 26.43°C (SE ± 0.95°C) across the three levels of temperature measurement, and surface relative humidity averaged 73.47% (SE ± 2.53%). Average entrance zone temperature ranged from 17.6°C (SE ± 1.14°C) to 20.91°C (SE ± 1.29°C), and entrance relative humidity averaged 88.04% (SE ± 1.27%).

Table 1 *The 15 most abundant fauna documented in the abandoned mines. Taxa were identified as morphospecies and ordered by total number of individuals.*

Class or Order	Family	Scientific name	Individuals
Orthoptera	Rhaphidophoridae	*Ceuthophilus gracilipes gracilipes*	964
	Phoridae	.....	632
Diptera	Heleomyzidae	.....	457
Chiroptera	Vespertilionidae	*Pipistrellus subflavus*	400
Diptera	Tipulidae	.....	273
Diptera	Mycetophilidae	.....	269
Collembola	Tomoceridae	*Tomocerus* sp.	246
Araneae	.....	.....	173
Diptera	Sphaeroceridae	.....	134
Collembola	Arrhopalitidae	.....	133
Gastropoda	.....	.....	123
Diptera	.....	.....	103
Hymenoptera	Formicidae	*Camponotus* sp.	64
Opiliones	.....	.....	64
Caudata	Plethodontidae	*Plethodon albagula*	41

Average twilight zone temperature ranged from 15.8°C (SE ± 0.62°C) to 18.71°C (SE ± 0.87°C), and twilight relative humidity averaged 90.58% (SE ± 0.77%). Average dark zone temperature ranged from 13.84°C (SE ± 1.18°C) to 15.66°C (SE ± 1.72°C), and dark relative humidity averaged 91.65% (SE ± 0.66%).

Discussion

Abandoned mines are definitely not things to waste. It is well documented that mines are important habitat for over half of the 43 bat species found in the United States (Tuttle and Taylor, 1994). In addition to being important for bats, abandoned mines provide habitat for other cavernicolous species, such as 74 taxa (excluding eight accidental taxa) observed during this study. Based on the nine troglobites observed in this study, abandoned mines are also habitat for troglobitic species.

Since mines in the current study were driven into carbonate hillsides as tunnels, there is a reasonable explanation for the presence of troglobites. Many of these mines intersect naturally occurring bedrock voids, and troglobites may have colonized mine passageways from these voids. Nearly all the troglobites in this study were also reported from surrounding caves (Graening et al. 2004, Graening et al. 2006). Lack of troglobites in previous mine studies may stem from sampling mines that were quarried in noncarbonate bedrock (Dorris and Saugey 1983, Heath et al. 1986, Saugey et al. 1985) or sampling mines in geographic locations where caves in general have few troglobites (Peck 1998).

An interesting comparison can be made between the number of troglobites documented in the more intensively sampled mines in this study and 50 biologically diverse Missouri caves (Elliott 2007). For each 50 Missouri caves, at least two troglobitic species were reported. In this study, there were eight mines with at least 2 troglobites. The average number of troglobites in the 50 Missouri caves was 5.3 (SE ± 0.3), with a range of 2-12. The average number of troglobites in the eight abandoned mines was 3.8 (SE ± 0.56), with a range of 2-6. Because of the difference in sample size, average number of troglobites was compared using a non-parametric test. No significant difference was detected for mean number of troglobites between the eight mines and 50 Missouri caves (Wilcoxon

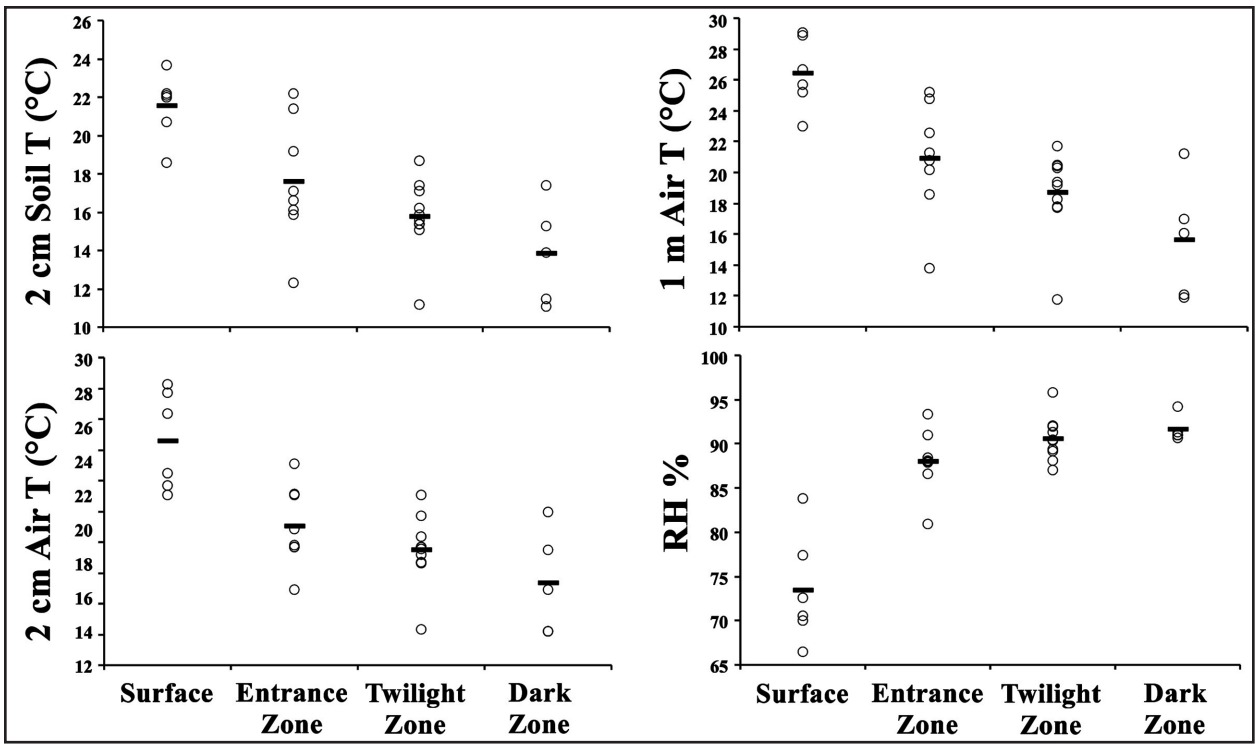

Figure 2 *Temperature (2-cm soil temperature, 2-cm air temperature, 1-m air temperature) and humidity recorded at six mines in summer 2004. Surface measurements were recorded 5 m outside the drip line of each site. Open circles (○) represent individual measurements, while black rectangles (■) represent means.*

test, Z ratio = -1.85, $p = 0.06$). There may be several reasons why no difference was detected. One reason may be the difference in sample sizes. These eight mines may not be typical, and increasing mine sample size might lower the average number of troglobites per mine. However, sampling additional mines could also increase the average number of troglobites per mine, because sampling intensity is known to influence number of species (Culver et al. 2000, Elliott 2007, Fong et al. 2007). Another explanation for the lack of significant difference may be because of sampling technique. Two techniques, visual searches and baited pitfall trapping, were used to inventory the mines, but most of the 50 Missouri caves were not sampled using baited pitfall traps. However, none of the troglobites from the eight mines were collected just from baited pitfall traps or only collected after pitfall trap placement. The lack of significant difference between the average number of troglobites is intriguing and warrants a more detailed study. We suggest that, in the Ozarks, abandoned mines in carbonate rocks may contain similar numbers of troglobites as in naturally occurring caves, and represent additional habitats for biological inventory and ecological study of cavernicoles.

Acknowledgments

Financial support for this research was provided by University of Arkansas, Buffalo National River—U.S. National Park Service, and The Nature Conservancy. Points of view are those of the authors and do not necessarily represent the position of the Department of the Interior. Special thanks go to Carol Bitting, Christy Slay, members of the Middle Ozarks Lower Earth Society (MOLES): Emily Frank and Jim Terry, and Boston Mountain Grotto: Charles Brickey, Wade Baker, Tristan and Laura Potter, for volunteering their time and energy to the project. Finally, abandoned mines are inherently less stable than natural cave passages, so they may provide a short term (geologically speaking) window into the karst habitat. The instability also leads to greater safety concerns for the researcher, who should check with the land management agency regarding policy on entering abandoned mines for the purposes of biological research.

Table 2 Faunal characteristics of the 15 abandoned mines. Mines were ordered by number (No.) of taxa, and "TB" is an abbreviation for troglobite.

Site	TB Taxa*	No. Taxa	Total Individuals	No. TB Taxa	Total TB Individuals
Toney Bend Mine #3	1, 2, 3, 4, 5, 6	54	1137	6	40
Long Ear Mine	1, 6	48	1052	2	80
Toney Bend Mine #2	3, 4, 5, 6, 8	45	1094	5	8
Morning Star Mine #5	1, 6	41	330	2	3
Morning Star Mine #6	1, 2, 5, 6	33	349	4	23
Morning Star Mine #7	1, 3, 6, 7, 9	31	169	5	35
Morning Star Mine #15	3, 4, 5, 6	10	46	4	4
Boat Creek Mine	9	10	40	1	2
Red Cloud Mine	1	7	367	1	1
Prospect Cave	--	7	8	0	0
Sixteen Mine	5, 9	6	34	2	5
Fox Den Mine	--	6	8	0	0
Bonanza Mine	7	6	13	1	1
Groundhog Mine	--	5	5	0	0
Bice Mine	--	4	4	0	0
Mary Agnes Mine	--	2	2	0	0
Mean		19.69	291.13	2.06	12.63
Standard Error		4.67	104.87	0.52	5.52
Minimum		2	2	0	0
Maximum		54	1137	6	80

***1 = Arrhopalitidae; 2 = *Brackenridgia* sp.; 3 = Campodeidae; 4 = *Causeyella* sp.; 5 = *Crosbyella* sp.; 6 = Entomobryiidae; 7 = *Eurycea spelaea*; 8 = Japyigidae; 9 = *Stygobromus* sp.**

Literature Cited

Barr, Thomas C. 1986. An eyeless subterranean beetle (*Pseudanophthalmus*) from a Kentucky coal mine (Coleoptera: Carabidae: Trechinae). *Psyche*, 93:47–50.

Culver, David C., Lawrence L. Master, Mary C. Christman, Horton H. Hobbs, III. 2000. Obligate cave fauna of the 48 contiguous United States. *Conservation Biology*, 14:386–401.

Dorris, Peggy R., and David A. Saugey. 1983. Spiders collected from abandoned mine tunnels in the Ouachita National Forest. *Proceedings of*

the Arkansas Academy of Science, 37:81–82.

Elliott, William R. 2000. Conservation of the North American cave and karst biota. Chap. 34, pp. 671-695 *in* Wilkens, H., D.C. Culver, and W.F. Humphreys (eds.), *Subterranean Ecosystems*. Ecosystems of the World, 30. Elsevier, Amsterdam. xiv + 791 pp.

Elliott, William R. 2007. Zoogeography and biodiversity of Missouri caves and karst. *Journal of Cave and Karst Studies*, 69:135–162.

Fong, Daniel W., David C. Culver, Horton H. Hobbs III and Tanja Pipan. 2007. *The Invertebrate Cave Fauna of West Virginia, Second Edition*. West Virginia Spelological Survey, Bulletin 16, Barrackville, West Virginia. 163 pp.

Graening, Gary. O., Michael E. Slay, and Karen Tinkle. 2004. Subterranean fauna of Arkansas, Part 1: Subterranean biodiversity of the Sylamore Ranger District, Ozark National Forest, Arkansas. *Journal of the Arkansas Academy of Sciences*, 57:44–58.

Graening, Gary, O., Michael E. Slay, and Charles J. Bitting. 2006. Cave fauna of the Buffalo National River. *Journal of Cave and Karst Studies*, 68:153–163.

Heath, Darrell R., David A. Saugey, and Gary A. Heidt. 1986. Abandoned mine fauna of the Ouachita Mountains, Arkansas: vertebrate taxa. *Proceedings of the Arkansas Academy of Science*, 40:33–36.

Howard, J. Michael. 1989. Rush Creek Mining District, Marion County, Arkansas: a synoptic view. *Rocks and Minerals*, July/August, 1989:284–292.

Kjaerandsen, J. 1993. Diptera in mines and other cave systems in southern Norway. *Entomologica Fennica*, 4:151–160.

McAllister, Chris T., Stanley E. Trauth, and Linda D. Gage. 1995. Vertebrate fauna of abandoned mines at Gold Mine Springs, Independence County, Arkansas. *Proceedings of the Arkansas Academy of Science*, 49:184–187.

McDaniel, V. Rick, and James E. Gardner. 1977. Cave fauna of Arkansas: vertebrate taxa. *Proceedings of the Arkansas Academy of Science*, 31:68–71.

Nielsen, B. Overgaard, and Andreasen, M. Holst. 1998. The parietal association of Diptera in two man-made subterranean shelters: A limestone mine and a bomb-shelter. *Entomologiske Meddelesler*, 66:55–64.

Peck, Stewart B. 1988. A review of the cave fauna of Canada and the composition and ecology of the invertebrate fauna of caves and mines in Ontario. *Canadian Journal of Zoology*, 66:1197–1213.

Raesly, Richard L., and J. Edward Gates. 1987. Winter habitat selection by north temperate cave bats. *American Midland Naturalist*, 118:15–31.

Saugey, David A., Gary A. Heidt and Darrell R. Heath. 1985. Summer use of abandoned mines by the Caddo Mountain salamander, *Plethodon caddoensis* (Plethodontidae) in Arkansas. *Southwestern Naturalist*, 30:318–319.

Tuttle, Merlin D., and Daniel A. Taylor. 1994. *Bats and Mines*. Resource Publication No. 3. Bat Conservation International, Inc. Austin, Texas. 40 pp.

Whitaker, John O., and Leslie J. Rissler. 1992. Winter activity of bats at a mine entrance in Vermillion County, Indiana. *American Midland Naturalist*, 127:52–59.