

Cave Biodiversity of the Southern Cumberland Plateau

Kirk S. Zigler, NSS 62696; Matthew L. Niemiller, NSS 53235; and Danté B. Fenolio

The South Cumberland Region of Tennessee, Alabama, and Georgia (Figure 1) is known for its tremendous diversity of caves, including huge pits, massive stream passages, and tight crawls. Less well known is that the region also supports tremendous cave biodiversity (Niemiller, Zigler, and Fenolio, 2013). Here we discuss many of the species that inhabit caves of the region, focusing on the southern Cumberland Plateau.

Cave Biodiversity

Four ecological classes of organisms can be found in caves: troglloxenes, subtrogllophiles, eutrogllophiles, and trogllobionts (Culver and Pipan, 2009). **Troglloxenes** are not typically found in caves and cannot persist there for long periods of time. They must either find their way back to the surface or ultimately perish. **Subtrogllophiles** are commonly found in caves but are associated with surface habitats for at least part of their life cycle. Some are seasonal inhabitants of caves and others move back and forth from cave to surface habitats for feeding, such as cave-roosting bats, cave crickets, and Allegheny Woodrats (*Neotoma magister*). **Eutrogllophiles** are commonly found underground but can be found in surface habitats. Unlike troglloxenes and subtrogllophiles, eutrogllophiles can complete their entire life cycle underground. Examples include the Cave Salamander (*Eurycea lucifuga*) and the Cave Orbweaver (*Meta ovalis*). **Trogllobionts** are obligate, permanent residents of subterranean habitats. They spend their entire life underground and are not found in surface habitats. Trogllobionts typically display morphological changes associated with subterranean living. These changes include the loss or reduction of pigment and eyes, increased appendage length and increased development of nonvisual sensory systems. Physiological and life history changes typically include decreased metabolic rates, longer lifespans and lower rates of reproduction.

This review focuses on trogllobiont diversity, as troglloxenes and trogllophiles are not strictly associated

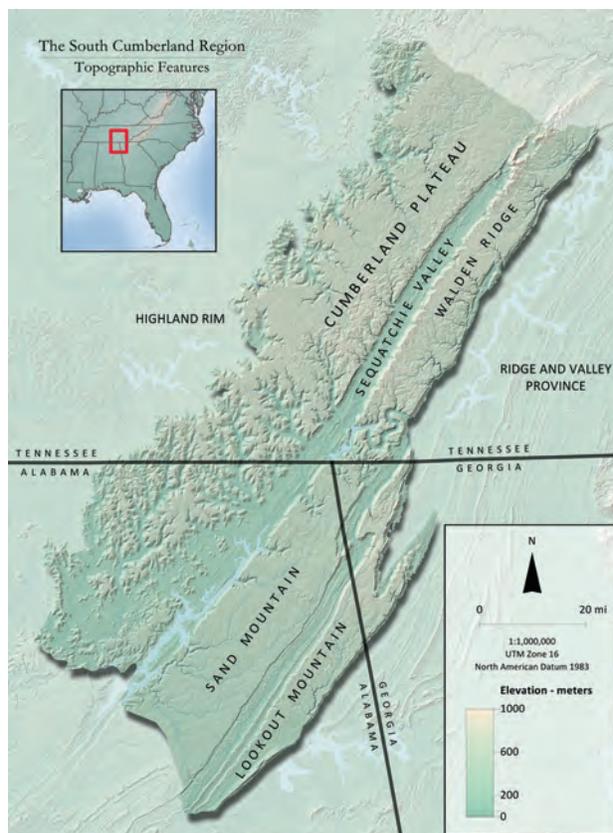


Figure 1 - The South Cumberland Region at the junction of Tennessee, Alabama, and Georgia. Figure courtesy of Nick Hollingshead.

with cave habitats and often have large ranges. This review also does not consider other organisms associated with caves, including plants, fungi, or microbes. Little is known about the subterranean biodiversity of these organisms.

Distribution

It has been known for some time that northeastern Alabama is a hot spot for cave biodiversity (Peck, 1989, 1995). Jackson County, in particular, stands out as having more trogllobionts than any other county in the United States, with Madison and Marshall Counties not

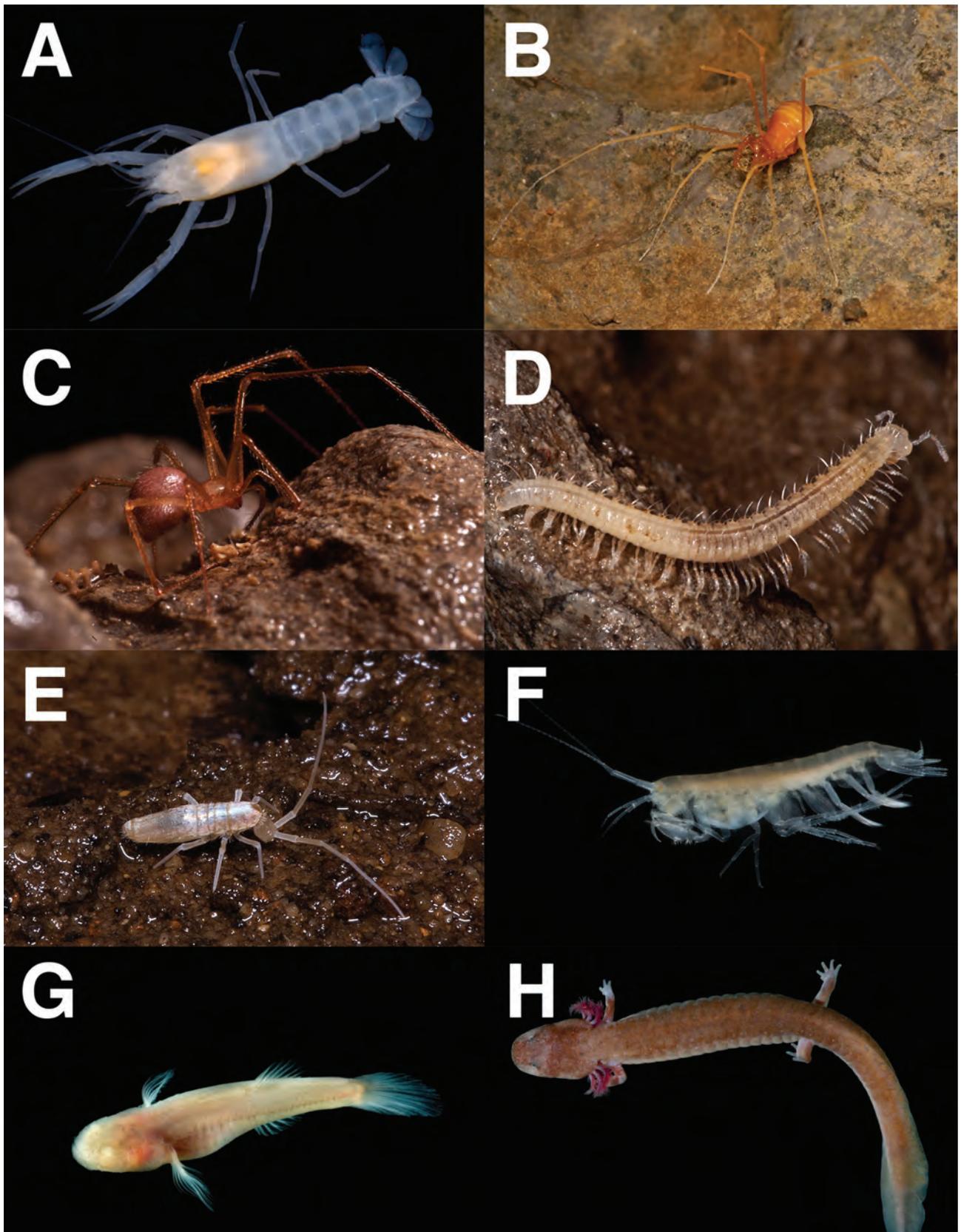


Figure 2 - Representative cave fauna of the southern Cumberland Plateau:

A) Southern Cave Crayfish (*Orconectes australis*); **B)** an undescribed cave harvestman (*Bishopella* n. sp.); **C)** Barr's Cave Spider (*Nesticus barri*); **D)** a cave millipede (*Scoterpes* sp.); **E)** a cave springtail (*Pseudosinella* sp.); **F)** a cave amphipod (*Crangonyx antennatus*); **G)** Southern Cavefish (*Typhlichthys subterraneus*); and **H)** Tennessee Cave Salamander (*Gyrinophilus palleucus*). Photos: Danté B. Fenolio

far behind (Culver, et al., 2000). The cave biodiversity of this region has been compared to that of other global hotspots of cave biodiversity including the French Pyrenees and the Dinaric karst of Slovenia (Culver, et al., 2006).

Recent work indicates that the hot spot of cave biodiversity in northeastern Alabama extends across the border into south-central Tennessee (Lewis, 2005; Niemiller and Zigler, 2013). The six-county region spanning the Tennessee-Alabama border on the southern Cumberland Plateau—Madison, Jackson, and Marshall Counties in Alabama and Franklin, Grundy, and Marion Counties in Tennessee—supports more than 150 described troglobionts (Table 1). These species represent nearly 15% of all troglobionts known from the United States, and is the greatest concentration of cave biodiversity in North America. The number of troglobionts known from this area will undoubtedly increase as more than 40 potentially new species have been mentioned in the literature but have not yet been described.

Why is the southern Cumberland Plateau such a biodiversity hot spot for troglobionts? High cave density (there are more than 4,400 caves in the six-county region) undoubtedly plays a role by providing a substantial amount of potential habitat. The region also has relatively high rainfall and surface productivity that indirectly support subterranean communities. In addition, the fragmented nature of the southern Cumberland Plateau (Figure 1) may increase the potential for cave populations to become isolated from one another, promoting the formation of new species over time. Last, three ecoregions come together in the vicinity of the southern Cumberland Plateau—the Southwestern Appalachians (including the Cumberland Plateau, Sand Mountain, and Lookout Mountain), the Ridge and Valley, and the Interior Plateau (including the Highland Rim) (Figure 1). Each of these ecoregions has significant karst and the troglobiont communities from these ecoregions have been able to intermingle in and around the southern Cumberland Plateau.

Looking at a finer scale, there are a number of particularly notable locations for cave biodiversity on the Cumberland Plateau. Hubbards Cave in Warren County, Tennessee, and Sauta Cave in Jackson County, Alabama, are two of the eight major Gray Bat (*Myotis grisescens*) hibernacula, with Hubbards Cave hosting more than 500,000 Gray Bats in recent winters. Although many

caves in the region support diverse troglobiont communities, Shelta Cave in Huntsville, Alabama, and Crystal Cave in Grundy County, Tennessee, stand out as two of just seven caves in North America known to support more than 20 troglobionts (Culver and Pipan, 2009).

Taxonomic and Ecological Diversity

Troglobiont diversity on the southern Cumberland Plateau (Figure 2) is dominated by a variety of arthropods (93%, 142 of 152 species). Particularly diverse are beetles, pseudoscorpions, millipedes, and spiders (Table 1). Beyond the arthropods, four other animal phyla are represented, with flatworms (Phylum Platyhelminthes), segmented worms (Annelida), snails (Mollusca), and vertebrates (Chordata) comprising the other 10 known troglobionts. Particularly diverse genera are *Tyrannochthonius pseudoscorpions* (27 species) and *Pseudanopthalmus* and *Ptomaphagus* beetles (12 species each). The two vertebrates are the Southern Cavefish (*Typhlichthys subterraneus*) and the Tennessee Cave Salamander (*Gyrinophilus palleucus*).

There are many more terrestrial troglobionts than aquatic troglobionts, as only 16% of the troglobionts are aquatic (25 of 152 species). The aquatic troglobionts are the two vertebrate species, a variety of crustaceans (including five crayfish), a flatworm, and several segmented worms (Table 1).

Endemism

Limited by the challenge of migrating between caves, many troglobionts have extremely small ranges. Of the ca. 450 terrestrial troglobionts in the eastern United States, 45% are endemic to a single cave (Christman, et al., 2005). Within the six-county region discussed here, nearly a third (49 of 152 species) of troglobionts are known from a single cave (Table 1). The frequency of endemism varies across taxonomic groups. About 70% of pseudoscorpions are single-cave endemics, whereas less than 10% of millipedes are. The list of single-cave endemics is dominated by pseudoscorpions (29 species) and beetles (12 species), with a handful of other taxonomic groups represented (Table 1). Further study may identify new populations of some currently “endemic” species, removing them from the list of single-cave endemics. These changes will be balanced by the discovery and description of new species that are restricted to single caves.

Taxonomic Group	Species	Endemics
Arthropods		
Arachnids		
Pseudoscorpions	39	28
Spiders	8	1
Harvestmen	4	1
Mites	1	
Crustaceans		
Crayfish	5	1
Isopods	5	1
Amphipods	5	
Copepods	3	
Ostracods	2	
Shrimp	1	
Non-insect hexapods		
Springtails	10	1
Diplurans	3	
Insects		
Beetles	42	12
Flies	1	
Myriapods		
Millipedes	13	1
Flatworms	1	
Segmented worms	3	3
Snails	4	
Vertebrates		
Fishes	1	
Salamanders	1	
Total species:	152	49

Table 1 - The taxonomic diversity of troglobionts from the southern Cumberland Plateau (Jackson, Madison, and Marshall Counties in Alabama and Franklin, Marion, and Grundy Counties in Tennessee). The number of species from each taxonomic group and the number of single-cave endemic species are indicated.

In contrast to the numerous endemic species, a handful of troglobionts have ranges that span most or all of the Cumberland Plateau and beyond. These include the Southeastern Cave Pseudoscorpion (*Hesperochernes mirabilis*), the Subterranean Sheet-Web Spider (*Phanetta subterranea*), the Cave Dung Fly (*Spelobia tenebrarum*), and the Southern Cavefish. How these species achieved and maintain such large ranges are open questions. Some of these species may actually represent complexes of morphologically cryptic species. For example, recent molecular studies suggest that the Southern Cavefish is actually composed of several genetically distinct lineages, including four lineages found along the southern Cumberland Plateau (Niemiller, Near, and Fitzpatrick, 2012; Niemiller, et al., 2013).

Threats to Cave Biodiversity

As troglobiont populations are rarely quantified and troglobionts may be present at low densities, detecting changes in their populations over time is challenging. However, it is clear that populations of cave animals are vulnerable to a variety of threats, including groundwater pollution and the modification of habitats around cave entrances.

As an example of radical modification of habitat around a cave entrance, the construction of Nickajack Dam and the subsequent formation of Nickajack Reservoir in the 1960s flooded Nickajack Cave in Marion County, Tennessee. This may have led to the extinction of *Pseudanophthalmus nickajackensis*, a cave beetle known only from that site. Cave populations are also vulnerable to less radical habitat changes. An example of this is the extirpation of the Alabama Cave Shrimp (*Palaemonias alabamiae*) from Shelta Cave. This federally endangered species was first collected from Shelta Cave in 1958 but has not been observed there since 1973. The loss of this population may have resulted from the abandonment of the cave by a Gray Bat maternity colony (and subsequent loss of nutrient input to the cave) in the 1970s, and/or increased runoff of pollutants into the cave (Cooper and Cooper, 2011). Fortunately, other populations of the Alabama Cave Shrimp are known, but the loss of this population from this well-studied and carefully managed cave highlights the vulnerability of troglobiont populations.

A handful of cave-dwelling species from the region are federally protected. Gray Bats and Indiana Bats (*Myotis sodalis*) are listed as endangered by the US Fish and Wildlife Service. Two troglobionts, the Alabama Cave Shrimp and the Alabama Cavefish (*Speoplatyrhinus poulsoni*, known only from Key Cave in Lauderdale County), are also listed as endangered. Seven troglobionts from Tennessee, including six cave beetles (all from the genus *Pseudanophthalmus*) and the Berry Cave Salamander (*Gyrinophilus gulolineatus*), are Candidate Species for the Endangered Species List, awaiting a final determination on their conservation status. However, these species are not found in the southern Cumberland Plateau.

An emerging threat to cave biodiversity in the region is white-nose syndrome (WNS). Now known from Tennessee, Alabama, and Georgia, it remains to be seen how great an impact WNS will have on cave-roosting bats

in the region. Beyond being a tremendous threat to bats, other cave species are threatened by WNS as bats are a critical link between nutrient-poor caves and surface resources. Any decrease in the number of bats in caves will affect cave ecosystems. The consequences of WNS for cave ecosystems will only become clear over time.

Summary

The southern Cumberland Plateau in Tennessee and Alabama has more troglobiont diversity than any comparable area in North America and is a cave biodiversity hot spot of global importance. This diversity is dominated by terrestrial arthropods, in particular beetles and pseudoscorpions. Endemism is high, particularly for pseudoscorpions. A handful of species are federally protected as Endangered Species, but threats to most species are not well documented. An emerging threat to cave communities in the region is WNS. As new species are discovered and described, our understanding of these diverse communities will improve.

About the Authors

Kirk Zigler is an Associate Professor of Biology at the University of the South in Sewanee, Tennessee. Matthew Niemiller is a postdoctoral researcher at the University of Kentucky. Danté Fenolio is a biologist and head of the Department of Conservation and Research at the San Antonio Zoo.

For more information

Christman M.C., Culver D.C., Madden M.K., White D. (2005). Patterns of endemism of the eastern North American cave fauna. *Journal of Biogeography* 32:1441-1452.

Cooper J.E., Cooper M.R. (2011). Observations on the biology of the endangered stygobiotic shrimp *Palaemonias alabamiae*, with notes on *P. ganteri* (*Decapoda: Atyidae*). *Subterranean Biology* 8:9-20.

Culver D.C., Pipan T. (2009). *The Biology of Caves and Other Subterranean Habitats*. Oxford: Oxford University Press. 256 p.

Culver D.C., Master L.L., Christman M.C., Hobbs H.H. III (2000). Obligate cave fauna of the 48 contiguous United States. *Conservation Biology* 14: 386–401.

Culver D.C., Deharveng L., Bedos A., Lewis J.J., Madden M., Reddell J.R., Sket B., Trontelj P., White D. (2006). The midlatitude biodiversity ridge in terrestrial cave fauna. *Ecography* 29: 120–128.

Lewis J.J. (2005). Bioinventory of caves of the Cumberland escarpment area of Tennessee. Technical report. Nashville: Tennessee Chapter of the Nature Conservancy. 158 p.

Niemiller M.L., Graening G.O., Fenolio D.B., Godwin J.C., Cooley J.R., Pearson W.R., Near T.J., Fitzpatrick B.M. (2013). Doomed before they are described? The need for conservation assessments of cryptic species complexes using an amblyopsid cavefish (*Amblyopsidae: Typhlichthys*) as a case study. *Biodiversity and Conservation* 22: 1799–1820.

Niemiller M.L., Near T.J., Fitzpatrick B.M. (2012). Delimiting species using multilocus data: diagnosing cryptic diversity in the southern cavefish *Typhlichthys subterraneus* (Teleostei: Amblyopsidae). *Evolution* 66: 846–866.

Niemiller M.L., Zigler K.S. (2013). Patterns of cave biodiversity and endemism in the Appalachians and Interior Plateau of Tennessee, USA. *PLOS One* 8(5):e64177.

Niemiller M.L., Zigler K.S., Fenolio D.B. (2013). *Cave Life of TAG: A Guide to Commonly Encountered Species in Tennessee, Alabama and Georgia*. Biology Section of the National Speleological Society, Huntsville, Alabama. 45 p.

Peck S.B. (1989). The cave fauna of Alabama. Part I. The terrestrial invertebrates (excluding insects). *Bulletin of the National Speleological Society* 51:11-33.

Peck S.B. (1995). The cave fauna of Alabama. Part II. The insects. *Bulletin of the National Speleological Society* 57:1-19.