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# Troglofauna of Van Buren and White County: a survey of four caves in the mideastern Cumberland plateau

Gavin Page
*University of Tennessee at Chattanooga*, qmq164@mocs.utc.edu

# **Troglofauna of Van Buren and White County: A Survey of Four Caves in the Mideastern Cumberland Plateau**

Gavin Page

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The University of Tennessee at Chattanooga
Department of Biology, Geology, and Environmental Sciences

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Dr. Stylianos Chatzimanolis
Professor of Biology
Thesis Director

Dr. Joey Shaw
Professor of Biology
Department Examiner

Dr. David Aborn
Professor of Biology
Department Examiner

# Abstract

The Cumberland Plateau in Tennessee has the highest cave-obligate biodiversity in North America. Cave-obligate species are entirely restricted to subterranean habitat and demonstrate unique troglomorphy. These species are categorized as troglobionts. However, because of their isolated occurrences, theses species are vulnerable to a variety of disturbances. This issue is furthered in the fact that only approximately 7% of the caves in this region have been surveyed. Of these caves that have been surveyed, only a small portion were professional entomological surveys, while almost no cave has ever been extensively repeat sampled. This study involved newly sampling one cave and repeat sampling three others. Caves were selected from White and Van Buren County, which respectively hold the highest cave density in the state. Species were predominantly identified to genus and then compared to the results of any or all prior surveys. All in all, 26 novel pieces of data were created regarding known species distributions and extensive numbers of troglobitic genera were found that were not listed in any prior survey.

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**ACKNOWLEDGEMENTS**

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Department of Biology, Geology, & Environmental Science, University of Tennessee at Chattanooga

## INTRODUCTION

### Scope and Purpose

An important distinction is made between those species which are cave-obligate and those which are troglophiles or trogloxenes. In 2008, Sket amalgamated standardized definitions for four categories of troglofauna. These three categories are used to classify troglofauna via their relationship to subterranean habitat. A cave-obligate species is known as a troglobite or troglobiont. Species in this classification are strictly bound to subterranean habitat. Eutroglophiles, or troglophiles, occur as surface dwelling species that are able to maintain permanent subterranean populations. Subtroglophiles are species that can be found inhabiting subterranean habitat for any length of time but are still bound to the surface for any manner of biological functions, such as feeding or mating. Lastly, are trogloxenes. These are species unable to form any manner of a subterranean population and are only found sporadically underground. Most troglofauna research, and almost all invertebrate troglofaunal research, focuses on troglobites and troglophiles. This is because these species commonly possess fascinating and unique troglomorphy and are reliant on subterranean habitat either somewhat or entirely.

Because of this reliance, cave obligate animals lead a fragile existence. Their island-like habitats lead to unique adaptations and speciation along narrow distributions. However, this causes them to be particularly vulnerable to anthropogenic threats. Unfortunately, some cave fauna and possible cave endemics are being destroyed before their species become known (Resh & Carde, 2009). In North America, cave obligate biodiversity is at its highest on the southern Cumberland Plateau located in central Tennessee. According to Niemiller & Zigler (2013a), this is likely due to high cave density, relatively high rainfall, and high surface productivity, which all support subterranean communities. Of the more than 50,000 caves reported in the United States, nearly 20% occur in Tennessee, and further, Tennessee lies just to the north of the hypothesized mid-latitude biodiversity ridge in terrestrial cave fauna in North America (Culver et al., 2006; Niemiller & Zigler, 2013b). The cave-obligate species found within these caves are largely made up of a diversity of arthropods (93%, 142 of 152 species) with other species including flatworms, vertebrates, segmented worms, and snails making up the rest (Zigler et al., 2014).

While cave obligate biodiversity is at its highest on the Southern Cumberland Plateau, cave density in the state actually peaks in the mid-Eastern Highland Rim and at the adjacent Cumberland Plateau (Fig.1) (Shofner et al., 2001). This discrepancy could be caused by the unique speleogenesis of the two areas, or perhaps, but not limited to, an absence of data surrounding the mid-Eastern Highland Rim. Absence of data is a large problem in subterranean research because there is a substantial barrier to entry for researchers wishing to perform cave surveys, which leads to cave communities being largely under researched (Culver et al., 2006). Most cave systems are contained within local knowledge and exist on private property, which makes even locating them difficult and gaining access hit-or-miss. On top of that, not many professionals are eager to explore the claustrophobic, wet, physically strenuous, and very dark conditions in search of the tiny troglobites that make the cave their home. All of this together, has led to a vast number of caves remaining unsurveyed. For emphasis, most ecoregions of Tennessee have only had approximately 7% of their caves sampled, and of these sampled caves, most were single-note observations from hobbyists and not professional sampling (Niemiller & Zigler, 2013b). Lastly, what most other research fails to mention is the lack of replication or repeated sampling, which is forgivable given the huge portion of caves not yet sampled at all. However, it is worth noting that we cannot quite understand the efficiency of once per cave sampling. Without data from repeat sampling, we cannot know how efficiently a caves biodiversity is captured in one visit. This study aims to shed some light on this issue by repeat sampling select caves.

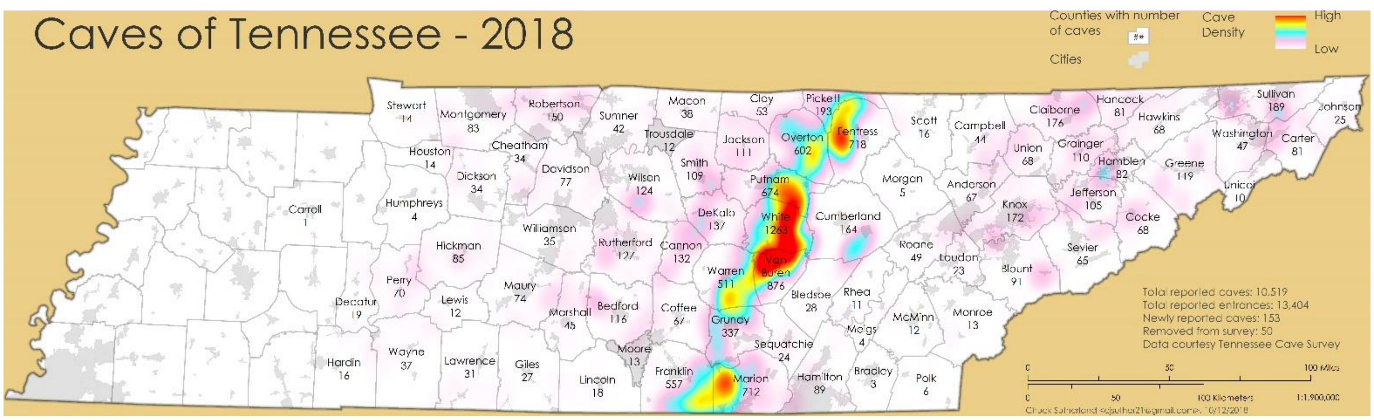


FIGURE 1. *An aggregation by TCS meeting director Chuck Sutherland which visualizes the number of caves in each TN county and clearly shows the "hotspot" of cave desity in White and Van Buren County* [14].

### Objectives

My research objective was to explore the mid-Eastern Cumberland Plateau cave hotspot in White and Van Buren County and produce data about the communities that live there in an effort to shine light on species distributions and endemisms and potentially produce novel data from a previously unsurveyed cave. Further, this research aimed to bring light to new species not yet found in any previous surveys, as well as confirm the continued existence of previously collected species by resampling caves surveyed in the past. Overall, it will contribute information to a field of research deeply lacking in data. Collection and identification will prioritize species identified as troglobitic. The reason for the emphasis on troglobites, as opposed to troglophiles, is well stated by Niemiller and Zigler in their 2013 paper:

> (1) many species occasionally enter caves and their degree of cave association is often difficult to determine, (2) cave studies and surveys report non-troglobionts to varying degrees, and (3) troglobionts are a coherent ecological grouping of species that are restricted to subterranean habitats and usually exhibit distinct morphological features aiding in their ecological classification compared to non-troglobionts.

**Previous Sampling**

Of the limited troglofaunal research on the Mid-Eastern Cumberland Plateau, Dr. Julian Lewis has famously done the most extensive work with surveys in this area and performed Tennessee cave sampling for almost a decade (Lewis, 2001, 2002, 2004, 2005a, 2005b, 2006, 2007). Most all of Dr. Lewis's work remains unpublished, or otherwise inaccessible, for the scope of this study. However, from Dr. Zigler at the University of the South, I was also able to obtain data sheets which showed all of Dr. Lewis's survey results, as well as all prior invertebrate surveys at caves in Van Buren and White county. These were data sheets compiled by Dr. Lewis and Dr. Niemiller for their significant 2013 study analyzing troglobitic species distributions and patterns of biodiversity in Tennessee.

Lastly, the Tennessee Cave Survey (TCS) operates as the "number one authority of cave discovery, exploration, survey, and mapping of caves in Tennessee" ("Tennessee Cave Survey," n.d.). I attempted to obtain TCS sampling records as well as cave localities, but I was informed by members of their executive committee that they are not willing to distribute data or locational information even to professional researchers. This is likely due to my non-participation in the organization, as well as due to the scope of this study because some previous research has been supplied with TCS data. Nevertheless, I was able to get in contact with the director of West Tennessee who was incredibly helpful, and I am very grateful that with her help, and that of a couple other TCS cavers, I surveyed Foxhole, a previously unsampled cave in Van Buren County.

**Expected Outcomes**

In this study area, Dr. Lewis most commonly found species such as *Kleptochthonius daemonius (*pseudoscorpion)*, Scoterpes ventus* (millipede)*, Pseudanophthalmus robustus* (beetle)*, Spelobia tenebrarum* (fly)*, Caecidotea bicrenata bicrenata* (isopod)*, Sphalloplana percoeca* (planarian)*, Tolus appalachius* (harvestmen), *Chaetaspis mollis* (millipede)*, Nelsonites walteri* (beetle), and *Phanetta subterranean* (spider). Through the identification of my own collected specimens, I expect to confirm the existence of these species among the several others that Dr. Lewis collected, and I am also expecting to confirm the existence of a multitude of new uncollected species. Lastly, all specimens I collect from Foxhole will produce novel data and increase known species distributions.

## MATERIALS AND METHODS

**Ethical Statement**

When on state property, my collection of specimens was permitted by the Tennessee Department of Environment and Conservation (Scientific Study Permit No: 2020-006). When in Cagle Cave, utmost care was taken to preserve the caves historic resources. In all caves, general cave conservation guidelines were respected, all park rules were followed, and specimen collection was intended to be as minimally damaging and invasive as possible.

**Study Sites**

I worked closely with TDEC and the state park system to identify caves located on the mid-Cumberland Plateau. This is because the state parks in this area take up a large part of Van Buren and White county, especially Fall Creek Falls. Further, many caves on state property are part of public knowledge and accessible. Famously located within Fall Creek Falls State park is Rumbling Falls Cave, Camps Gulf Cave, and Lost Creek Cave, alongside an estimated one hundred others. In Rock Island State Park, is the designated National Natural Landmark Big Bone Cave. All of these caves served as potential sample sites. From here, caves had to be selected considering ease of access, permitting concerns, and viability for the presence of troglofauna. Ease of access eliminated caves such as Rumbling falls which demanded rope experience because of the opening chamber requiring a 200ft belay. Other caves could not be permitted due to preservation concerns or were closed off and not permitted in order to ease stress on bats effected by *Pseudogymnoascus destructans.*

The likelihood of encountering troglofauna was also considered when selecting caves. However, this was largely a nonconcern for most caves because I had Dr. Lewis's record of previous sampling confirming the existence of some troglobites. However, in selecting Foxhole, previous observations from TCS that the cave was wet with plenty of streamways, had lots of organic material, and was expansive enough to produce a substantial dark zone, gave plenty of evidence that the cave was worthy of sampling. These conditions were advised by Dr. Zigler, as well as substantiated by Hunt & Millar's (2001) "Cave invertebrate collecting guide." All things considered, three caves were selected on Fall Creek Falls property: Camps Gulf Cave, Lost Creek Cave, and Cagle Saltpeter Cave. With the help of TCS members, the previously unsurveyed cave Foxhole was identified and sampled.

**Specimen Collection**

Specimens were collected mostly by hand with the exception of Lost Creek Cave. Due to the ability for repeat access to the cave, the systems large nature, favorable subterranean conditions, and high number of visually observed specimens, Lost Creek was an ideal location for pitfall trapping. Pitfall traps were placed variously throughout the cave. These traps consisted of a small 250ml Tri-corner beaker buried and molded into the cave floor so that it was level with the soil. The pitfall traps would then be filled with 70% ethanol and covered with a finely gauged poultry netting to prevent larger vertebrates from falling into the trap. Smeared on top of the poultry netting was canned tuna. It has been shown that smelly meat or cheese can be very effective for attracting all manner of invertebrates, but especially scavenger-predators; it is essential to bait pitfall traps in cave environments because invertebrate density is so low (Hunt & Millar, 2001). Traps were placed within the cave and removed approximately 48 hours after placement. This is an ideal period to remain active because of the observed high invertebrate density in the cave. Due to the indiscriminatory nature of baited pitfall traps, they should be used with good judgment and not left in the cave too long so that they might over collect (Hunt & Millar, 2001). The traps were placed strategically throughout the cave, particularly near locations with organic matter such as wood rat droppings, guano, and plant material. They were also spread far enough apart as to not over collect in one particular location. They were also placed in areas with adequate moisture, low air current, and in prediction of known species behavioral patterns.

In all other caves, and while placing and removing traps from Lost Creek, species were collected under visual observation. According to Hunt & Millar (2001), "the selective nature of hand collecting makes it the most preferable method of sampling cave fauna" (p.11). With a keen eye and lots of crawling around on hands and knees and peering into small crevices in the wall, specimens were observed. Species would be gently picked up by wetting a small paintbrush into a vial of ethanol and picking them off whatever surface they were found. They would then be stored in various vials through the cave expedition. If easily captured by hand via a brush, small net, or pipet, then aquatic isopods, amphipods, and copepods were also collected. Again, careful searching occurred in places most likely to contain troglofauna and that were advantageous towards known species behavioral patterns. For example, locations with moisture and organic matter like wood rat droppings, guano, and plant material were always carefully searched.

**Specimen Sorting and Preparation**

Coming out of the cave, specimens of all types were jumbled together. From Lost Creek Cave, specimens were largely contained in a web of Rhaphidophoridae, which were greatly attracted to the baited traps. Specimens were also in dirty water and or mixed in with pieces of dirt and tuna. After each cave visit, preliminary work began by taking specimens out of their vial or containers, cleaning them of dirt, tuna, or other debris, and then placing them into clean vials with identification labels.

From there, specimens were sorted out into their own vials via there orders and distinct differences. Preliminary hypotheses were also placed for many of the species observations. These were based on Dr. Lewis's prior findings in those caves or the prior knowledge that only one species in a particular genus exists in a particular geographic area. In addition to locality label, specimens were also provided a unique code which linked them to a data sheet where specimen identification will be recorded (Fig. 2).

| Cagle Cave (C) | | | | | |
|---|---|---|---|---|---|
| | | | | | Notes |
| | Common | Family | Genus | | |
| | | | | | |
| Arachnida: | | | | | |
| C1 | Dwarf Spider | Linyphiidae? | Phanetta? | | |
| C2 | Psuedoscorpion | Chthoniidae? | | | |
| C3 | Harvestman | Laniatores? | | | |
| | | | | | |
| Crustacea: | | | | | |
| C4 | Isopod | | | | |
| C5s (3) | Amphipods | | | | |
| | | | | | |
| Diptera: | | | | | |
| C6s (3) | Dung Flys | Sphaeroceridae | Spelobia? | | |
| C7 | Unknown Fly | | | | |
| C8 | Unknown Fly | | | | |
| C9 | Unknown Fly | | | | |
| C10 | Unknown Fly | | | | |
| C11 | Unknown Fly | | | | All white |

FIGURE 2. Example data sheet for Cagle Cave specimens

**Species Identification**

Species were identified by various means to the genus level and occasionally to the species level when all possible. Recognizing the scope of this study, available equipment, and my professional skill level, a genus targeting identification was sufficient. Almost all cave invertebrates are incredibly tiny and commonly under a centimeter in total body length. Many species are only a few millimeters in size. Identifying these species to the genus level regularly requires observing and distinguishing minute morphological structures present on specimens. Identifying to the species level typically requires professional expertise in that particular insect order, high powered microscopes not limited to scanning electron microscopes, and dissections of the specimens internal structures. A couple of my specimens were less than a millimeter in total length, and therefore, were not able to be identified beyond basic taxon. A few species presented easily speciating features while others existed in monophyletic taxon's, which made their identification to the species level possible. Troglophiles and trogloxenes were identified to the family level with a few exceptions being identified further. Identification was carried out utilizing various resources. A couple specimens were identified by sending pictures to various experts. Beetles were identified using the keys from AMERICAN BEETLES (2001). Most other specimens were identified using freely accessible published dichotomous keys, either as a guide to a whole insect order, or found in the original literature wherein the species was first described. The identification of straightforward specimens, as well as the starting point to most other identifications, began with Niemiller and Zigler's (2013a) "Cave life of TAG: a guide to commonly encountered species in Tennessee, Alabama, and Georgia."

# RESULTS

**OBSERVED KNOWN TROGLOBIONTS**

| ***IDENTIFICATION*** | | ***CAVE LOCALE*** | | | |
|---|---|---|---|---|---|
| **TAXON** | **Species** | **Cagle Cave** | **Camps Gulf Cave** | **Foxhole Cave** | **Lost Creek Cave** |
| **ACARI** | n/a | X | | | |
| **ARANEAE** | *Kleptochthonius daemonius* | X | | | |
| | *Tolus appalachia* | X | X | | |
| | *Phanetta subterranea* | | | | X |
| **COLEOPTERA** | Carabidae *Nelsonites* | X | X | X | X |
| | Carabidae *Pseudanophthalmus* | | | X | X |
| **COLLEMBOLA** | Entomobryidae *Pseudosinella** | X | X | | X |
| **COPEPODA** | n/a | | | | X |
| **DIPLURA** | Campodeidae *Litocampa* | X | | X | X |
| **DIPLOPODA** | Trichopetalidae *Scoterpes* | X | | X | X |
| | Abacionidae *Tetracion* | X | | X | X |
| | Cleidogonidae *Pseudotremia* | | | X | |
| **AMPHIPODA** | Crangonyctitidae *Stygobromus** | X | | X | X |
| **ISOPODA** | Asellidae *Caecidotea* | X | | | X |
| **DIPTERA** | *Spelobia tenebrarum* | X | X | X | X |

*Table 1. Total observation of collected species in this survey as identified to fullest capability. "X" indicates the presence of a particular species in that cave locale. * Identification holds a higher degree of uncertainty.*

## Data Observation and Limitation

Species identifications were divided with all known troglobionts being singled out. Theses species are displayed above in Table 1, while an appendix of all other collected troglophiles and trogloxenes is located at the very end of this report. A total of ten unique taxa were collected between the four caves comprising of 14 known troglobitic genera. Between these specimens, *Spelobia tenebrarum* and Carabidae *Nelsonites* were collected from all four caves. Cagle Cave and Lost Creek Cave both yielded the most unique occurrences with 11 different genera being collected from each cave respectively. Camps Gulf Cave produced the lowest number of genera. However, this is largely misrepresentative of the biodiversity of the cave. In surveying the cave, my cave partner and I had much difficulty in navigating through a maze like and cramped area of breakdown. Beyond this were several large wet rooms that likely contain many uncollected trogliobionts. This is substantiated by J.J. Lewis's prior collection of the cave.

In addition to these 14 known troglobitic genera, a total of 16 seemingly unique families were collected and categorized as troglophiles and trogloxenes. These were by and large disproportionately collected at Cagle Cave and Lost Creek Cave. Sciaridae and Rhaphidophoridae were collected at all four caves. Of particular note is an unknown fly from Cagle Cave that was tiny, completely white, and had soft delicate wings with no visible venation. Uniquely, a species of flea was also found at Cagle. Fleas can sometimes be brought into caves by wood rats, bats, or other vertebrates. Many troglophiles and trogloxenes were found far into the dark zone of Lost Creek Cave. Two unique rove beetles as well as diving beetles and various flies were found deep within the cave.

**Comparison With Prior Surveys**

The only prior survey of Cagle Cave was carried out by J.J. Lewis in 2005. At that time, he reported observing *Phanetta subterranea*, *Kleptochthonius daemonius, Pseudanophthalmus robustus,* and *Spelobia tenebrarum.* In my survey, all of theses genera were reconfirmed, with the exception of *Phanetta subterranea*. I did collect a spider some ways into the entrance zone, which I thought was likely to be *Phanetta subterranea* but was not recognized as such by Dr. Marc Milne at the University of Indianapolis. He suggested the spider belonged to Amaurobiidae *Amaurobius.* Of special note is the reconfirmation of *Kleptochthonius daemonius,* which has so far only been observed in about a dozen caves in Van Buren and White county (Lewis, 2005). Apart from theses species, I also collected an unknown species of mite, *Tolus appalachia*, *Nelsonites, Pseudosinella, Litocampa, Scoterpes, Tetracion, Stygobromus,* and *Caecidotea.* This accounts for nine previously unknown genera being described from this location.

In 2005, J.J. Lewis also sampled Camps Gulf Cave. Among crayfish and cave fish he observed nine different invertebrate genera. Of those genera, I reconfirmed *Nelsonites* and *Spelobia tenebrarum.* Although I was likely not able to get to the correct location to reconfirm the existence of most of the species that J.J. Lewis observed, of the data I did produce, the existence of *Tolus appalachia* and *Pseudosinella* in Camps Gulf Cave was previously unknown.

Next, is Lost Creek Cave, which apart from also being sampled by J.J. Lewis in 2005, has been visited a few times in the past for collection purposes. In these surveys, *Kleptochthonius daemonius, Scoterpes ventus, Pseudanophthalmus robustus, Spelobia tenebrarum* and *Caecidotea bicrenata bicrenata* have been observed. I reconfirmed all of these genera except *Kleptochthonius daemonius.* Apart from these, I also collected *Phanetta subterranea*, *Nelsonites, Pseudosinella,* an unknown copepod, *Litocampa, Tetracion,* and *Stygobromus.* This accounts for seven previously unknown genera being described from this location.

Lastly, I observed eight genera at Foxhole cave. These genera all produce novel data because the cave had never before been sampled.

# DISCUSSION

### Evaluating Research Objective

All in all, among the four caves, I produced 26 novel species distributions. This can help us begin to understand the true ranges of these species and genera and understand when and where they need to be protected. I reconfirmed the existence of many species and identified many more that were not yet known from a particular cave. My expected outcomes also held particularly true, as well as my goal of demonstrating evidence for the effective resampling of caves. The resampling of caves is also supported by a previous survey at Carter State Natural Area, which is the only one of its kind from this region (Wakefield & Zigler, 2012).

### Interpretation

Studies such as this one demonstrate that while we recognize that we have a poor grasp on Tennessee cave biodiversity and distribution, we also likely have a poor grasp on the biodiversity of caves we have only surveyed once. A researcher could take a glance at Cagle Cave and see that it only has four different troglibionts and conclude that it is therefore not a very biodiverse cave. In fact, in permitting through TDEC, my surveying was briefly opposed due to the supposed adverse conditions to support invertebrates present in the cave. However, in my survey I have likely confirmed the existence of at least eleven different genera of troglibionts, let alone species. It is unknown at this point how many other caves will continue to carry this misinformation. Cagle Cave is remarkable in this aspect because it is a very small cave when compared to its close-by neighbors of Lost Creek Cave and Camps Gulf Cave. It also has a history of human disturbance and large-scale modification because of the caves historical use for saltpeter mining. However, to protect remnants of this mining operation as delicate historical resources, the cave entrance was locked. This likely had the effect of allowing a flourishing of the caves troglobitic fauna.

However, in contrast, Lost Creek Cave produced the same number of genera, yet has a high level of human disturbance and foot traffic. In the cave, trash occasionally even flushes to the lower levels, while you can find old campfires and graffiti in the opening stretches. Granted, Lost Creek Cave is much larger than Cagle Cave, which is what might allow it to support similar biodiversity under greater disturbance. The cave also had large amounts of trogloxenes and troglophiles even deep into the dark zone. This could be caused by any number of surface opening sinks or cracks dropping into the cave, the stream that flows throw the cave and to the surface acting as an easy transportation lane, or the caves unique air currents that draw animals inside through its large hallway. Further, especially in the case of trogloxenes, these species are maladapted to the subterranean conditions and likely often turn into food for the caves native population. This coupled with the caves observed flushing of organic matter and subsequent wet conditions, as well as its large overall size, could create optimal conditions for biodiversity.

Foxhole Cave seemed to have all the qualifications for a cave that could match the biodiversity of the other two, but in my survey, while certainly not lacking, it had three less observed genera. However, this could simply serve to illustrate the point of resampling further. Foxhole Cave had never before been sampled, while the other two caves had; we know the effectiveness of second sampling so I would strongly predict that a second visit to the cave would produce at least one or two genera not observed in my survey.

**Identifications of Note**

I have already mentioned that the observation of *Kleptonius daemonius* in Cagle Cave was a rather exciting find. Finding the unbefore collected *Tolus appalachia* in both Cagle Cave and Camps Gulf Cave is rather significant, because as Dr. Zigler notes, they are quite rare with a small number of observations, due in part to their elusive nature.

The presence of *Nelsonites* in every single cave is also somewhat significant because they have a narrow distribution and have only been found in the counties near my study area. Their coexistence among their close relative *Pseudanophthalmus* also poses some interesting questions. All four of my sampled caves now have observations of both *Nelsonites* and *Pseudanophthalmus.* Both of these beetles are predatory ground beetles, with *Nelsonites* just being larger by a few millimeters and possessing slightly altered morphology. Molecular studies have also recently diagnosed *Nelsonites* as a derived clade from within *Pseudanophthalmus* (Philips et al., 2013). Understanding the evolutionary influences behind the morphology and adaptations of *Nelsonites* that allow them to persist alongside *Pseudanophthalmus* while occupying a similar niche could be an interesting source of insight. Lastly, I recommend further investigation into my collected *Nelsonite* specimens because they appear to share several identifying characteristics to *Darlingtonea*.

I also made mention that my Collembola and Amphipoda identifications hold a higher degree of uncertainty. Therefore, I recommend further investigation into their identity. Further, I was not able to identify my collected mite from Cagle Cave, nor my copepod from Lost Creek Cave, so I recommend an investigation into their identity as well.

My collection of Campodeidae *Litocampa* individuals also hold significance because Dr. Zigler notes that specimens from this genus in my study area have not yet had their species described and likely contains some number of undescribed species (Niemiller & Zigler, 2013a). Lastly, in Foxhole Cave, I observed all three of Tennessee's troglobiont millipedes together in one cave, which is remarkable. Of particular note is the observation of Cleidogonidae *Pseudotremia,* which was exclusively found at Foxhole. Both Trichopetalidae *Scoterpes* and Abacionidae *Tetracion* have been found in the other caves of my survey, but Cleidogonidae *Pseudotremia* is quite rare and has not been found in caves of my study area previously (Niemiller & Zigler, 2013a).

**Concluding Statement**

It is my ultimate goal that this research can add a piece to the puzzle when it comes to understanding Tennessee cave biodiversity. Also, that it may stress a larger degree of skepticism when it comes to interpreting previous single-sample data. Tennessee sits at an incredibly unique place in the world by possessing caves of incredible biodiversity of which we have barely started to scratch the surface. As we continue to understand these ecosystems, I hope we can come to understand that they deserve our protection and care because their uniqueness cannot be found anywhere else in the world and can never be replaced if lost. This is a field of study approachable from hundreds of different positions of inquiry and open for thousands of questions.

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## APPENDIX: COLLECTED TROGLOPHILES AND TROGLOXENES

| ***IDENTIFICATION*** | ***CAVE LOCALE*** |
|---|---|
| Amaurobiidae *Amaurobius* (Spider) | C |
| Mycetophilidae *sensu stricto* (Fungus Gnat) | C, F |
| Psychodidae (Drain Fly) | C |
| Sciaridae (Black Fungus Gnat) | C, G, F, L |
| Chironomidae (Nonbiting Midge) | C |
| Unknown Diptera (Fly) | C |
| Unknown Siphonaptera (Flea) | C |
| Rhaphidophoridae (Cave Cricket) | C, G, F, L |
| Tomoceridae (Springtail) | L |
| *Brathinus nitidus* (Rove Beetle) | L |
| Staphylinidae *Oxypoda* (Rove Beetle) | L |
| Dytiscidae (Diving Beetle) | L |
| Carabidae *Trechus* (Ground Beetle) | L |
| Tipulidae (Crane Fly) | L |
| Heleomyzidae (Fly) | L |
| Unknown Diplopoda (Millipede) | L |

*Appendix: All other collected specimens that are not confirmed troglobionts. Identified to family where possible. C= Cagle Cave, F= Foxhole Cave, G= Camps Gulf Cave, L= Lost Creek Cave*