# 2017 National Cave and Karst Management Symposium
## 16 – 20 October 2017
## Eureka Springs, Arkansas, United States of America

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## National Cave and Karst Management Symposium

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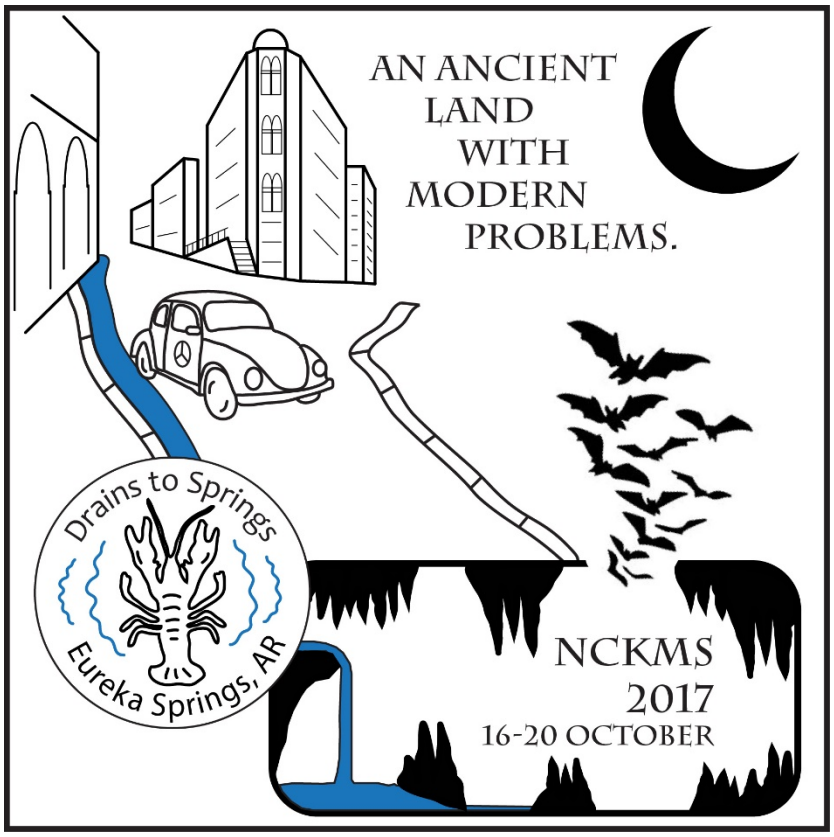


## Abstracts

# Oral Presentations

The list of oral presentations is arranged in alphabetical order by the first author of the presentation. An asterisk (*) identifies the author that is presenting the paper. Abstracts are also available on the Symposium website.

**Conservation, Management, & Techniques III (9:00 – 9:15 AM)**

**From Mayan to modern: the continued reliance and current exploitation of caves in Mexico**

Adams, Rachel Estee[*1]

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Formed entirely from limestone, the Yucatán Peninsula, Mexico is riddled with sinkholes and caves. These caves offer access to the aquifer that underlies the expanse of the peninsula. Without surface water available in the form of lakes or rivers, humans, both ancient and modern, look to the subterranean for resources. In the Yucatán, caves vary from having small pools to completely water-filled passages. The Mayans used caves for their primary water supply as well as for shelter. It is common to find evidence of this ancient civilization in the form of tools, pots, altars, and sculptures. In addition to the fascinating archeology and history, caves here are home to unique, endemic, and endangered terrestrial and aquatic organisms. Unfortunately, today, expanding urbanization has resulted in increased removal and contamination of the groundwater. Caves are rapidly being developed for large-scale tourism, effectively destroying the above and below ground environment through common commercialization efforts. While there is increased pressure to promote and sustain the quality of groundwater in the Yucatán, there is no formal agency or organization that supports the protection and conservation of caves, both dry and water-filled. Therefore, caves have been exploited and destroyed for development without regulation. Many more will be subject to the same fate. Throughout the course of my graduate studies, I have had the opportunity to visit caves across the peninsula, documenting the impact that humans have on the underground systems. In addition, my dissertation project focuses on trees that utilize the water in caves and how they influence the ecosystem both in the cave and on the surface. My research adds transformative insights to this nexus of water, ecosystem function, and human population demands by opening up the opaque underground world.

**Conservation, Management, & Techniques II (3:00 – 3:15 PM)**

**Managing endangered species on private property as assets, not liabilities or problems**

Aley, Thomas[*1]; Aley, Catherine[1]; McKenzie, Paul[2]

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This is a case history of 51 years of successful land and cave fauna management at the privately-owned Tumbling Creek Cave, Missouri. This cave has the most diverse cave fauna (with 116 species) of any cave in the United States west of the Mississippi River. The cave provides habitat for three federally endangered and one federally threatened species plus other species of conservation concern. One of the endangered species is the Tumbling Creek Cavesnail, a species endemic to this single cave. We have used 6 important strategies in managing endangered species as assets and provide examples of each. Strategy 1: Establish credibility. Either possess or acquire resource management expertise applicable to the site and the species and then implement sound management. Strategy 2: Use protection of listed species as a fundamental part of your operation. Strategy 3: Repeatedly make the point that it is a species that is endangered, not the land owner. Strategy 4: Gain recognition for the significance of the site and your conservation efforts; seek help to do more. Strategy 5: Work with (and subtly manage) agencies and key people. Strategy 6: Manage what you have, target what you want, and imagine what you and the site can accomplish. Cave and karst sites are ideal for implementing these management strategies. Many caves have endemic species; get a species list of the cave fauna. If you have a cave with endangered bats, have a bat friendly gate installed. If you have aquatic species, get the recharge area delineated and recognized by relevant entities. If there is something harmful to species of concern on your property, address it.

**Conservation, Management, & Techniques I (2:30 – 2:45 PM)**

**Developing multidisciplinary cave management plans at Great Basin National Park, Nevada**

Baker, Gretchen Marie[*1]; Roberts, Ben[1]

[1]Great Basin National Park, Baker, Nevada, United States

Federal land managers who manage cave and karst resources are tasked with developing management plans. At Great Basin National Park, upper management has directed resource management staff to develop two cave management plans: one for Lehman Caves and one for wild caves and karst. Multidisciplinary meetings have been held for over a year with maintenance, interpretation, visitor and resource protection, administration, cultural resource, and natural resource specialists. During this time, desired future conditions have been developed. For Lehman Caves, a show cave with about 30,000 visitors each year, the desire is for a cleaner

cave with less lint, upgraded infrastructure that has less impact on the cave, additional interpretive opportunities, such as wild and virtual cave tours and distance learning, and more study and monitoring of the natural and cultural resources in the cave. For the other 39 caves in the park, the Wild Caves and Karst Management Plan collates all known information about the caves and identifies data gaps, such as cultural and paleontological inventories. These plans set the stage for applying for funding to help meet the desired future conditions and fill data gaps.

**Biology II (2:15 – 2:30 PM)**

**Cave Springs Area Karst Conservation Study: a success story in karst resource management and urban development**

Beeman, Shiloh, R.G.[*1]; Aley, Thomas[1]; Slay, Michael Edward[2]

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[2] Arkansas Field Office, The Nature Conservancy, 601 North University Avenue, Little Rock, Arkansas, United States

Cave Springs Cave in northwestern Arkansas is the largest population for the Ozark Cavefish (*Troglichthys rosae*), a federally-listed threatened species that is found in the Springfield Plateau of the Ozark Highlands in Missouri, Arkansas, and Oklahoma. As northwestern Arkansas continues to grow, the recharge area for Cave Springs Cave continues to be converted from a rural agricultural setting to suburban development. This ongoing development has resulted in an increasing threat to water quality and the Ozark Cavefish at Cave Springs Cave. The Cave Springs Area Karst Conservation Study was developed in response to this ongoing situation. This study is composed of three integrated components. The first component included the development of a science-based understanding of the location and hydrologic functioning of the recharge area for Cave Springs Cave. The second component was designing karst-appropriate Best Management Practices (BMPs) based on relative land vulnerability within the recharge area that will concurrently protect Ozark Cavefish and permit continued suburban land development. The third component is developing and enacting ordinances to implement appropriate BMPs to guide further land development in the recharge area. The execution, integration, and implementation of these three components of the study will be presented.

**Geology & Hydrology I (11:15 – 11:30 AM)**

**Casting pearls before swine 2017: how public review and analysis of an industrial hog farm's permit will protect the waters of America's first National River**

Bitting, Charles J.[*1]

[1] National Park Service, Buffalo National River, 402 N. Walnut, Suite 136, Harrison, Arkansas, United States

The citizens of Arkansas and the United States have spoken loudly and forcefully to the Arkansas Department of Environmental Quality (ADEQ) about their efforts to perpetuate a poorly designed and implemented permit for a Large Confined Animal Feeding Operation (CAFO) near the Buffalo National River. The initial permit was issued in December 2012 with the facility starting operation in June 2013. The phosphorus content of the facility's waste stream is equivalent to that of a town of 28,000 people. The waste is initially stored in earthen ponds lying upon mantled karst. It is then spread, untreated, on a series of fields, almost all of which are developed on thin soils over karst. The karst under the ponds and fields drains to the Buffalo National River. Buffalo National River is managed by the National Park Service. The Buffalo National River is intensively used by fishermen, swimmers, canoers, kayakers, and hikers from all over the U.S., and many foreign countries. The initial permit and all subsequent modifications display numerous weaknesses. The public has been quite vocal on this issue, and has raised numerous complaints, filed administrative appeals, and filed lawsuits. The latest iteration of the permit has been held up in the administrative process at ADEQ for six months, and will likely be held up for another six months. Meanwhile, the facility is being allowed to operate on a permit which expired in October 2016. This is a case study showing how citizen engagement can counteract, at least partially, lax agency regulatory efforts, misguided political lobbying, and poor environmental implementation to protect a national treasure.

**Conservation, Management, & Techniques I (1:45 – 2:00 PM)**

**Cooperative cave and karst management at Buffalo National River, Arkansas during a period of shrinking federal budgets and staffing**

Bitting, Charles J[*1]; Sapkota, Kayla[2]

[1] National Park Service, Buffalo National River, 402 N. Walnut, Suite 136, Harrison, Arkansas, United States
[2] Cave Research Foundation, 270 Casey Lane, Dover, Arkansas, United States

Funding to federal land management agencies has been shrinking over the past 20 years. Simultaneously, the population of the United States and visitation to these protected areas has increased significantly. Emerging or accelerating threats to the viability of biological systems such as White-Nose Syndrome, and physical processes such as global climate change, increase the severity of the already tenuous situation for federal land managers. A very effective and efficient partnership between the National Park Service (NPS) and the Cave Research Foundation (CRF) has been evolving at Buffalo National River over the past 15 years. For the past 4 years, NPS and CRF have worked together through a Cooperative Agreement which allows NPS to provide seed money to accelerate work at the national river by CRF in cave and karst management assistance. Nearly 150 new caves have been documented by CRF during this brief period, a large percentage of the previously documented caves have received renewed documentation in the form of biological and cartographic surveys, and a group of strong cavers has coalesced around the project. This citizen science effort has vastly improved the ability of NPS to manage the cave and karst resources. This effort has provided cavers an opportunity to

actively participate in their government by constructively improving the management of our public natural resources.

**Conservation, Management, & Techniques III (9:45 – 10:00 AM)**

**The wilderness underground of Buffalo National River**

Bitting, Charles J.[*1]

[1] National Park Service, Buffalo National River, 402 N. Walnut, Suite 136, Harrison, Arkansas, United States

The Buffalo National River contains approximately 500 documented caves. About 25% of these caves are within the Buffalo National River Wilderness. Wilderness designation and Wilderness boundaries are somewhat arbitrary and artificial in nature in that they are manmade contrivances over portions of the Earth. Caves, on the other hand, nearly always contain features and landscapes which intrinsically exhibit wilderness character. The extent of caves is difficult to define, their boundaries continue to change over time as new passages are discovered, entrances open or close naturally, and the waters feeding their hydrologic systems vary with hydrologic and atmospheric conditions. Cave wilderness designation at Buffalo National River has the potential to be used as a management tool, limiting land managers underground activities with little impact to non-wilderness surface activities where wilderness non-conforming activities can continue to be practiced, but with an eye toward conserving the wilderness character of the cave resources and values.

**Geology & Hydrology II (10:00 – 10:15 AM)**

**Morphological investigations of cavernous hydrothermal features with an emphasis on Yellowstone National Park, Wyoming**

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[1] Department of Environmental Health Science, Geography and Geotechniques Program, East Central University, 1100 E 14th Street, Ada, Oklahoma, United States
[2] Arbuckle Karst Geoscience LLC, PO Box 2352, Ada, Oklahoma, United States

Morphological investigations of hydrothermal features were performed throughout the western United States where tectonic and volcanic activity have affected groundwater circulation by geothermal convection. The fluid geochemistry and hydrogeology of most inspected features have resulted in an integrated mass-transfer system with permeability structures dominated by caverns and conduits, and self-organized to facilitate the movement of ascending thermal waters as a process known as hypogene speleogenesis. The greatest numbers of these features are found in Yellowstone National Park, where caverns have developed in mostly siliceous material from the dissolution of quartz by thermal fluids. Caverns in calcareous material are most common

outside the park and formed as thermal fluids cooled. Due to limitations of boiling thermal fluids, most of the cavernous hydrothermal features inspected were shallow and limited to the terraces of sinter deposits. However, a few cooler features were examined by visual and electronic inspection through cave diving and submersible cameras, which revealed caves extending beneath the sinter deposits into the underlying rocks. Classic hypogenic cave morphologies are obvious within these features. The development of nearly all features inspected during this study is attributable to hypogene speleogenesis, but the morphologies of cavernous openings into the thermal features may be affected by multiple processes acting synchronously with hypogene speleogenesis. Many of the caverns appear to have formed as framework caves by the accumulation of material around vents, while others have formed by erosional processes such as hydrothermal explosion or collapse within the sinter deposits to reveal cavities below. This understanding of hydrothermal features as hypogenic karst groundwater systems presents new insights into the development and function of geysers and hot springs, as well as the need for management approaches that borrow from those of more typical karst systems.

## Conservation, Management, & Techniques II (3:30 – 3:45 PM)

### A comparison of low-cost 3D scanning techniques applied to the cave environment

Covington, Matthew David[*1]; Cooper, Max Philip[1]; Jordan, Joseph Hanford[1]

[1] University of Arkansas, Department of Geosciences, 340 N. Campus Dr., 216 Gearhart Hall, Fayetteville, Arkansas, United States

The standard tool for characterizing cave passage position and morphology is the cave map, created using a line survey and hand-drawn sketch of cave walls and features. However, 3D scanning, often conducted with terrestrial laser scanners, is becoming increasingly common for applications in both cave management and cave science. The cost, size, and fragility of standard laser scanners limit the use of these devices to relatively well-funded projects within large and accessible cave passages. However, a variety of low-cost scanning techniques are also available, and these techniques are seeing rapid development by the computer science and robotics community. We argue that these low-cost techniques may have broader applicability within the cave environment, and may ultimately lead to a revolution in cave mapping. We review emerging technologies and algorithms and explicitly compare two of the most promising options: 1) Structure-from-motion photogrammetry, and 2) structured light sensors (RGB-D). Both technologies enable 3D scanning of cave passages using equipment that has costs comparable to standard cave survey equipment. These techniques are already sufficiently mature that they are being applied in studies of cave passage morphology and the processes of speleogenesis. Though substantial hurdles need to be overcome before these methods could provide a practical means of mapping caves, it is possible to envision a future where you map a cave by strapping a small device to your helmet and simply going caving.

## Geology & Hydrology II (9:00 – 9:15 AM)

### Nash Draw groundwater trace: phase one implementation

Goodbar, James[*1]; Goodbar, Andrea Kurman[2]

[1] Bureau of Land Management, 620 East Greene Street, Carlsbad, New Mexico, United States
[2] University of Arizona, 3027 E. Derrick Road, Carlsbad New Mexico, United States

Nash Draw is a karst valley approximately 29 kilometers east of Carlsbad, New Mexico, United States. This 27-km long valley trends northeast from its low point in a salt playa. The primary karst rock type there is the Permian-aged Rustler Formation resting conformably upon the Salado salt beds. The Rustler Formation contains five distinct members alternating between gypsum and dolomite. The two dolomite members are aquifers. A third brine aquifer runs at the base of the Rustler Formation on top of the Salado Formation. During the early Pleistocene, solutional processes began developing the karst valley known as Nash Draw. The apparent regional base level is the Pecos River which is separated from the lower end of Nash Draw by a narrow strip of land. The earliest human use of Nash Draw was during the late Pleistocene approximately 10,000 years ago. It is thought the area was popular because of the salt that could be harvested from naturally salty lake (Laguna Grande) at the lower end of the karst valley. Potash was discovered in the area in 1927 and mining began in 1931. Three mines began operation on the flanks of Nash Draw. The mine tailings discharge, which consists of salt (sodium chloride) and clay, has been dumped in the bottom of the karst valley. Since the mining operations began the accumulation of salt on the surface is substantial. Much of the tailings piles have covered numerous sinkholes. The management concern is whether salt from the tailings discharge ponds is entering the Pecos River. To examine this hypothesis and advance the further understanding of the groundwater flow in Nash Draw a ground water trace is being conduct. The trace will be initiated in phases. The first phase is tracing the tailings pond discharge.

## Plenary Speaker, Tuesday (8:25 – 9:10 AM)

### Watershed management in a karst dominated landscape: perspectives from a Waterkeeper

Green, Jessie Jean[*1]

[1] White River Waterkeeper, P.O. Box 744, Harrison, Arkansas, United States

Waterkeepers serve as the eyes, ears, and voices of the waterbodies they protect to ensure fishable, swimmable, and drinkable water for all. White River Waterkeeper advocates on behalf of the entire 27,798 $mi^2$ White River watershed, of which over 70% falls within the karst dominated landscape of the Ozark Highland and Boston Mountain ecoregions in Arkansas and Missouri. Insufficient federal and state laws and regulations will be discussed with special regard to the Clean Water Act and protections of water quality in karst landscapes. Experiences with evaluating special studies to determine water quality impacts will be provided to discuss failed

assumptions of common study designs due to complexities related to fate and transport of pollutants.

**Biology II (1:30 – 1:45 PM)**

**Lighting and substrate effects on lampenflora microbial communities in Carlsbad Caver**n

Havlena, Zoe[*1]; Kieft, Tom[1]; Horrocks, Rod[2]; Veni, George[3]

[1] Biology Department, New Mexico Tech, 801 Leroy Pl. Socorro, New Mexico, United States
[2] Carlsbad Caverns National Park, 727 Carlsbad Caverns Highway, Carlsbad, New Mexico, United States
[3] National Cave and Karst Research Institute, 400-1 Cascades Avenue, Carlsbad, New Mexico, United States

Artificial lighting in show caves can stimulate the unnatural growth of algae and cyanobacteria, termed “lampenflora,” which has been shown to negatively impact cave resources. Carlsbad Caverns National Park recently modernized the lighting in Carlsbad Cavern replacing the sodium halide, incandescent, and fluorescent lights with an LED system that has the capacity to adjust color temperature and intensity of individual lights. To assess the influence of LED color temperature (2700°K vs. 3500°K) as well as substrate type (sediment, porous limestone, and dense limestone/calcite) and light intensity (<100 to >500 lux) on the proliferation of lampenflora, we have been monitoring growth at five sites in the Big Room of the cavern. Growth of phototrophic biofilms is being measured using reflected light spectrophotometry, and characterization of the microbial communities has been performed by DNA extraction and high-throughput amplicon sequencing of 16S and 18S rRNA genes for bacteria, archaea, and Eukarya. Resulting sequences show a diversity of microbes in the biofilms, from photosynthetic green algae, Chlorophyta; golden-brown algae, Ochrophyta; and several different types of cyanobacteria. In addition, there is a diversity of heterotrophic archaea, Eukarya, and bacteria that supports the concept of diverse and well-established biofilms at the experimental sites in the caverns. Our portable reflected light spectrophotometer has been demonstrated to effectively quantify the amount of photosynthetic biomass in a non-destructive way, and tracking over time shows changes to the biofilms within the cavern at the different light levels. This presentation represents data from nearly a full year of study, which has been funded by Carlsbad Caverns National Park in hopes of identifying optimum color temperature and intensity settings to discourage lampenflora growth.

**Biology II (1:45 – 2:00 PM)**

**Indiana Bat habitat restoration project on the Sylamore Ranger District of the Ozark-St. Francis National Forests**

Hawkins, Jessica[*1]

[1] Ozark-St. Francis National Forests, 605 West Main, Russellville, Arkansas, United States

The Sylamore Ranger District of the Ozark-St. Francis National Forests began implementing the Indiana Bat Habitat Restoration Project in 2014. Funding for the project was received through a Joint Chiefs' grant with the Natural Resources Conservation Service (NRCS). The project was aimed at treating approximately 67,151 acres of national forest system land over a period of 12 years. Activities in the project area included protection of Indiana Bat hibernacula through cave gating, interpretation and education, commercial timber harvest, prescribed burning, mechanical treatments, monitoring, etc. The overall goals of the project were to create conditions more likely to provide continual roost trees for Indiana Bats, protect Indiana Bat hibernacula from human disturbance, reduce and maintain canopy closure across primary and secondary bat conservation zones, and promote regeneration of oak, hickory, and shortleaf pine for a continual supply of available roost trees.

**Biology III (10:45 – 11:00 AM)**

**Monitoring cave aquatic biota at selected national parks in the Cumberland Piedmont Network**

Helf, Kurt Lewis[*1]; Moore, William[1]; Wells, Brenda[1]

[1] Cumberland Piedmont Network, Inventory and Monitoring Division, National Park Service, Mammoth Cave National Park, P.O. Box 8, Mammoth Cave, Kentucky, United States

Threats to stygobiont communities include chemical and thermal contamination due to land use inside and outside national park boundaries. The collection and analysis of long-term data on the abundance and distribution of stygobiont metapopulations, along with influential covariates, will enable resource managers to make informed decisions regarding cave stream protection. This monitoring protocol is focused on stygobionts inhabiting selected cave streams within three cave parks. Our monitoring objectives include: 1) estimates of status and long-term trends in abundance of common stygobionts, 2) estimates of status and long-term trends in the proportion of reaches occupied by uncommon stygobionts, 3) sampling influential habitat characteristics and water-quality/quantity parameters. Sampling events occur on two nonconsecutive dates during the dry season. Transects in wadeable cave streams can generally be surveyed from the bank. Transects in nonwadeable cave streams are surveyed by snorkelers with data recorders paddling inflatable kayaks behind. During a sampling event, two independent teams, one observer and one recorder each, collect data in a number of noncontiguous, 40- meter transects. These data include water quality/quantity, habitat characteristics, and timed independent counts

in which the observer moves slowly and quietly upstream while scanning the transect for stygobionts using a powerful headlamp or dive light. Each detected stygiobiont is called out to the data recorder along with a size estimate and any noticeable characteristics (e.g., damage). Finally, we will collect qualitative data on selected habitat characteristics such as habitat type and percent substrate composition. Data will be analysed using hierarchical models: a flexible framework in which a complex system is modeled using multiple submodels. This framework is particularly suited to inference about abundance, occupancy, species richness, and demographic characteristics because it can accommodate multiple data sets, sources of variability, scales of measurement, and varying data quality inherent in these kinds of data.

**Geology & Hydrology I (10:45 – 11:00 AM)**

**Living on crumbling karst, 1879–2017, Eureka Springs, Arkansas**

Helwig, James A.[*1]; Froelich, Jamie[1]

[1] Springs Committee, Parks and Recreation Department, Harmon Park, Eureka Springs, Arkansas, United States

Eureka Springs is sited upon a forested upland karst in the headwaters of East Leatherwood Creek in the southern Ozarks. The topography is rugged with ridges, deep ravines, and a Mississippian limestone scarp localizing numerous springs. The whole city is a recharge area divided into many patches with small springs. It is a crumbling karst characterized by shallow bedrock, patchy thick regolith, rockslides, colluvium/scree filled fans and hollows, losing streams, small caves, few sinkholes, small recharge areas, and many small or seasonal springs and seeps. Extensive cave systems and large springs are absent and deemed to be located at depths below the Devonian Chattanooga Shale aquitard and below the regional water table. The Springs Reservations, created in the late 1880s, wisely set buffer zones at the largest springs. The beauty of our town is inescapable, but the maintenance of yards, streets, and sewer and waterworks has a history of emergencies. The city has a population of 2,073, (down from 10,000 in 1890!) but this may triple during tourism events and weekends. Therefore, the financial demands on infrastructure are high, as are the noted environmental challenges. Contamination of springs remains common due to the flashy hydrology in storm events and the aging wastewater infrastructure dating back to the 1880s. Steep slopes and steep streets, and losing steep hollows limit retention of runoff by the wonderful stone walls constructed to stabilize slopes. So, the small lot sizes and steep slopes make it difficult to maintain slope stability or install sufficient retention structures to mitigate storm events. An unprecedented grassroots coalition was awarded an EPA grant in 1979 for an exfiltration study to determine the sources and magnitude of contamination of springs. Despite this knowledge and some improvements, the city still requires renewed vision and better infrastructure management than is recognized or affordable.

## Geology & Hydrology I (11:00 – 11:15 AM)

### Blanchard Springs Caverns and a billion points of light

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[1] Ozark-St. Francis National Forests, PO Box 427, Jasper, Arkansas, United States
[2] Ozark-St. Francis National Forests, 605 West Main, Russellville, Arkansas, United States

The Center for Advanced Spatial Technologies (CAST) and the Ozark-St. Francis National Forests entered into a cooperative agreement to do a complete 3D point cloud survey scan of all the visitor facilities and cave tour. Because the infrastructure of the Blanchard Visitor Information Center and Caverns was developed in the late 60's and early 70's, there is a need to look at infrastructure updates that look at safety, energy conservation, protection of geologic features, protection of threatened and endangered species, and the preservation of heritage sites. New technology available today allows for detailed mapping of the visitor center and the caverns so that appropriate updates can be planned. This mapping also helps resource professionals with research and modeling that will help with the preservation of this very unique site that is the home of threatened, endangered, and sensitive species.

## Conservation, Management, & Techniques I (2:15 – 2:30 PM)

### Ecology-based cave and karst forest management recommendations and best management practices for working forests

Holliday, Cory[*1]; Hale, Stuart D.[2]; Groves, Christopher[3]

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[2] Clinch Valley Program, The Nature Conservancy, 146 East Main Street, Abingdon, Virginia, United States
[3] Department of Geography and Geology, Western Kentucky University, Bowling Green, Kentucky, United States

Currently, applied cave and karst best management practices (BMPs) for forestry in North America are extremely variable and inconsistent; this is even true within individual agencies. Erosion and soil loss has been identified as one of the principle threats associated with forestry, and is the mitigating circumstance behind most forestry BMPs. Karst features and landscapes add unique and additional threats and circumstances to erosion from forestry, yet there is no broad acceptance of karst landscape specific BMPs in North America. Many existing karst forestry BMPs suggest dramatic management prescriptions without offering evidence of their derivation or functional expectations. The Nature Conservancy (TNC) has developed a suite of scientifically derived and evidence-based cave and karst specific forest management considerations and BMPs. These draw from multiple fields of study with an emphasis on ecology, erosion, and habitat refugia. The newly created cave and karst forestry BMPs are carefully designed using the best available data to define appropriate resource protections, while

striving to minimize the loss of manageable acreage. These management recommendations are designed to incorporate easily into modern forest management planning and employ familiar language and BMPs from leading conservation forest guidance such as that from the Forest Stewardship Council (FSC) and the Sustainable Forestry Initiative (SFI). The new BMPs include karst management zones (KMZs) that are analogous and complimentary to existing streamside management zones (SMZs), which are broadly accepted with existing forestry BMPs. TNC's goals for developing these evidence-based BMPs are to offer up-to-date, realistic cave and karst specific forestry BMPs that are easily employable on any karst terrain, easily adaptable to existing forest management plans, and more beneficial to forests, caves, and their ecological communities. We hope their evidence-based nature will encourage wide-ranging acceptance in all types of working forests and incorporation into other conservation forestry initiatives.

**Biology III (11:15 – 11:30 AM)**

**BatCaver – Citizen science to identify critical bat habitat in western Canada**

Horne, Greg[*1]; Davis, Martin[2]; Critchley, Dave[3]; Rae, Jason[4]; Lausen, Cori[5]

[1] BatCaver Program, Wildlife Conservation Society Canada, Box 2202, Jasper, Alberta, Canada
[2] BatCaver Program, Wildlife Conservation Society Canada, Box 164, Tahsis, British Columbia, Canada
[3] BatCaver Program, Department of Biological Sciences, School of Applied Sciences and Technology, Northern Alberta Institute of Technology, 11762 106 Street NW, Edmonton, Alberta, Canada
[4] BatCaver Program, Wildlife Conservation Society Canada, 2021 Perrier Road Unit 5, Nelson, British Columbia, Canada
[5] Wildlife Conservation Society Canada, Box 606, Kaslo, British Columbia, Canada

BatCaver (batcaver.org) is a Wildlife Conservation Society Canada citizen science research project in western Canada addressing the threat of White Nose Syndrome (WNS) to bats through locating of winter bat habitat. The draft Environment Canada Recovery Strategy for Little Brown Myotis, Northern Myotis, and Tri-colored Bat identifies these species as Endangered, and their hibernacula as critical habitat. Because WNS affects bats while they hibernate, the goal of BatCaver is to locate these features to inform management and enable future mitigation. BatCaver is a network of cavers helping to locating mine and cave hibernacula. Cavers deploy bat detectors (Roost Loggers, Titley Scientific), and temperature and relative humidity data loggers (iButtons, Maxim Integrated or Hobos, Onset) in locations that have potential for bat hibernation, ideally placing them near sites that bats might hibernate (e.g., deep stable climate chambers). Bat evidence, such as guano and skulls, is collected. Bat detectors might be deployed at mouths of underground features that are not safe to enter. Equipment is deployed while caves/mines are summer accessible and loggers continue recording throughout the hibernation period. Once sites are accessible again, equipment is retrieved, and acoustic and microclimate data are analyzed to determine if the site was used by bats, and whether microclimates are within optimal growth range of the fungus that causes

WNS. If bat activity is recorded, follow-up at sites that are accessible in winter (not snow buried or avalanche threatened), may allow bats to be observed during the hibernation period. This is to verify species, in some cases test for presence/baseline WNS (i.e., swab of wings or substrates, collection of carcasses for genetic testing), and count numbers of bats to determine significance of site. To date, more than 70 bat hibernacula have been identified in western Canada, some housing as many as four species of bats.

**Conservation, Management, & Techniques II (3:45 – 4:00 PM)**

**The design concept behind the new LED lighting system at Carlsbad Cavern, New Mexico**

Horrocks, Rodney D.[*1]

[1] Carlsbad Caverns National Park, 3225 National Parks Highway, Carlsbad, New Mexico, United States

The new LED lighting system at Carlsbad Cavern was designed to highlight individual features, a different concept from the previous 1975 Ray Grenald design. His design used warm and cool lights to accentuate depth with much of the cave dimly lit in order to stimulate the imagination of the visitors. This gave visitors' eyes time to relax and generate anticipation for a handful of more brightly lit features. With the new design, the cave was divided into 145 named scenes, with a scene defined as a feature that was easily separated from adjacent scenes. Light was used to accentuate and dramatize an already spectacular cave in an artistic rendition, a process known as "painting with light." By using texture, color, shadow, and contrast, features were highlighted for which the cave is famous: huge chambers, large formations, profuse decorations, and complex mazes. A sense of mystery was intentionally evoked by creating black holes in numerous side passages and pits. Many highlighted features (30%) were not lit in the previous lighting system. In order to maintain one foot candle of ambient light on the trail, some features in the vicinity of the trail were lit. However, in order to protect delicate cave resources, other features within reach of the trail were intentionally not lit. Additionally, the "crazy" lights in the cave were all eliminated: those lights that had to be accessed by rope, long ladders, or exposed traverses. It is now possible to adjust the intensity of each LED light from 0-100% and the color temperature from 1800-4000 K from the comfort and safety of the trail through a radio controller and ruggedized laptop. The color temperature used most often in the new system, especially in wet areas, is between 2600-2700 K, which has been found to discourage, but not eliminate, algae growth.

**Conservation, Management, & Techniques I (2:00 – 2:15 PM)**

**Developing camouflaging techniques for the new cave lighting system at Carlsbad Cavern**

Horrocks, Rodney D.[*1]

[1] Carlsbad Caverns National Park, 3225 National Parks Highway, Carlsbad, New Mexico, United States

In 2016, a new LED cave lighting system was installed in Carlsbad Cavern. Prior to any work being done, a camouflaging plan was developed to disguise the cables and fixtures in this new system. The black cables contrasted against the lightly-colored cave surfaces and artificial straight lines attracted visitors' attention to those cables. Although colored mortar was successfully used to hide the cables in the previous lighting system, that technique caused unacceptable impact to cave resources and was not even considered as an alternative for the new system. The new camouflaging techniques use local sediment, loose rock, or previously broken formations in order to not introduce foreign materials to the cave ecosystem. Techniques developed include: painting cables located further from the trail with a local sediment slurry, burying cables where possible, using blast rubble along rock walls, using broken formations or loose rocks to cover cables, and in some cases rerouting cables to more effectively use shadows and cracks. Because there is no single camouflaging technique that worked in every situation, multiple techniques were used on most cable runs. In addition to disguising the cables, the camouflaging project also placed fixtures in dimly lit areas to reduce visual impact. Specially fabricated shrouds were placed in the snoot of each fixture to reduce visibility glare, with the goal of visitors' eyes being naturally drawn to the highlighted features and not distracted by being able to see into the lights. If visitors wonder where the light comes from, upon searching they will be able to find the unobtrusive fixtures in ambient low-light conditions. The success of the on-going camouflaging work is directly attributable to Lois Manno and her volunteer work groups from the Sandia Grotto of the National Speleological Society.

**Conservation, Management, & Techniques I (1:30 – 1:45 PM)**

**BrandenBark™, a management tool for bark roosting bats**

Janos, Gregg[*1]; Baer, Zachary[1]; Gumbert, Mark[1]; Adams, Joshua[1]; Roby, Piper[1]; Sewell, Price[1]; Borthwick, Richard[1]; Baer, Lois Kate[1]; Brandenburg, Michael[2]

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Multiple imperiled bat species utilize cave and karst features during the winter months as hibernacula; however, during the summer months these bats leave their hibernacula and utilize tree bark roosts. As a result, summer habitat enhancement can prove to be an important tool in

assisting populations of bark roosting bat species, especially those with low population numbers and/or those impacted by White-nose Syndrome. BrandenBark™ is an artificial roost structure developed to mimic the natural summer habitat of bark roosting bats. BrandenBark™ structures have documented use by six bat species, including the federally endangered Indiana Bat. Within a study site at Fort Knox, Kentucky, BrandenBark™ structures were used to supplement degrading habitat used by Indiana Bats. Subsequent monitoring efforts at Fort Knox have documented bats regularly utilizing BrandenBark™ structures with 77.2% of roost visits confirming bat presence and 72.7% of the structures having confirmed use within three months of installation. BrandenBark™ average emergence counts compare favorably with the United States Fish and Wildlife Service's average adult maternity colony size estimates in natural roosts. The second highest Indiana bat maternity emergence count has been recorded from BrandenBark™ (n=451), compared to the highest known natural roost exit count of 475. Overall, Indiana Bat use of 13 BrandenBark™ structures has resulted in a total of 248 bat days. Temperature stability tests show the temperature difference between ambient air and real bark was not different than the temperature difference between ambient air and BrandenBark™ ($F_{1,5}$ = 0.0489, P = 0.8338). BrandenBark™ has been deployed as a mitigation/habitat enhancement tool by federal and state agencies as well as private organizations to provide immediate, long-lasting roosting habitat for imperiled bark roosting bats that rely on karst features in winter. To date, 181 BrandenBark™ structures have been installed in eight states and one Canadian province.

**Conservation, Management, & Techniques III (10:30 – 10:45 AM)**

**Online permitting of cave preserve visitors to enhance visitor experience, manage risk and inform conservation efforts**

Knott, Ray[*1]

[1] Southeastern Cave Conservancy, 4311 7th Avenue, Chattanooga, Tennessee, United States

The Southeastern Cave Conservancy, Inc. manages 31 cave preserves in six southeast states. All but two of these preserves are open for recreational caving. Prior to the implementation of the online permit system, it was difficult to 1) quantify the number of preserve visitors to each preserve, 2) fully utilize liability releases as part of an overall risk management strategy, and 3) understand the impacts of visitation on sensitive sites. Visitation numbers were anecdotally reported via volunteer preserve management teams and liability releases, if completed, were stored in electronic and hard-copy formats in various locations. Additionally, the organization did not have contact information for preserve visitors beyond the permit holder. With input from stewardship volunteers, staff began designing an online permit system which would formalize permitting on all preserves managed by the Southeastern Cave Conservancy, Inc. Using a database application designer and open source tools, the online permit system was completed and tested on two preserves over a three-month period in the Fall of 2016. The online permit system went live system-wide on 1 January 2017. Since implementation, the online permit system has issued 1,813 permits for 7,361 preserve visitors. The organization now has visitation data to compare to observed changes on preserves and in caves. These data will help guide stewardship decisions based on visitation levels at individual sites. The system allows for each preserve or

site to have custom visitation parameters and approval procedures. Individual preserve management plans can be adjusted to ensure visitation does not cause undue harm to sensitive sites while maintaining a mission-driven objective to provide for recreational caving in a responsible manner. In addition to obtaining stewardship goals, the online permit system has allowed the organization to collect liability releases from all preserve visitors and to increase its audience for mission-based communications and donor solicitations.

**Geology & Hydrology II (9:15 – 9:30 AM)**

**Karst aquifers protection: a scientific and legislative conundrum**

Kosič Ficco, Katarina[*1,2]; Thaler, Evan[3]; Brahana, John Van[4,5]; Ficco, Michael James[6,7]

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[7] Cave Conservancy of Virginias, 13131 Overhill Lake Ln., Glen Allen, Virginia, United States

The need for enhanced protection of karst aquifers is increasing on a yearly basis, because these valuable water resources face deterioration and over-exploitation worldwide. From the scientific perspective, enhancing karst aquifer protection through legislative mechanisms seems to be an unequivocal part of the solution, and this is often inhibited by financial restrictions. However, the challenges can extend beyond financial barriers. The example of vulnerability mapping of an area within the Big Creek basin in Newton County, Arkansas will help present the obstacles that policy makers could face while trying to develop a framework for protection and management of karst aquifers.

**Geology & Hydrology II (10:15 – 10:30 AM)**

**Atrazine transport through a soil-epikarst system**

Lerch, Robert N.[*1]; Groves, Chris G.[2], Miller, Benjamin V.[2,3]; Polk, Jason S.[2]

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[2] Hoffman Environmental Research Institute, Western Kentucky University, Bowling Green, Kentucky, United States
[3] U.S. Geological Survey, Lower Mississippi-Gulf Water Science Center, Nashville, Tennessee, United States

Row crop and livestock production contaminate soils and groundwater of the karst aquifer systems within south-central Kentucky's Pennyroyal Plateau. We investigated the transport of atrazine from field application to the epikarstic drainage system beneath a field with active row-crop farming. Because of the thick residuum soils (~3 m) that overlie the St Louis Limestone at the site, the working hypothesis of the study was that the soils would exert control on the degradation and transport of atrazine to the epikarst drains. The Crumps Cave study site is a shallow autogenic drainage system with a recharge area of ~1 ha that contains two epikarst drains (WF-1 and WF-2) which were monitored for atrazine, deethylatrazine (DEA), and deisopropylatrazine (DIA) concentrations from Jan 2011 to May 2012. Atrazine concentrations in both drains did not increase above winter background levels for nearly two months following application when levels spiked and reach peak concentrations (38.5 µg $L^{-1}$ at WF-1 and 0.83 µg $L^{-1}$ at WF-2) during an early May 2011 event. Atrazine, DEA, and DIA were detected in 100% of the samples, and metabolites accounted for 54-94% of the monthly total loads, except in May 2011. Median dealkylated metabolite to atrazine ratios (DMAR) were ~5:1 at both sites, and seasonal DMAR patterns corresponded with changes in soil temperature. These data support the hypothesis that a combination of sorption and degradation in the soil column above the epikarst controlled the transport of atrazine and its metabolites, resulting in delayed atrazine transport following application and continual transport of the weakly sorbed metabolites to the epikarst aquifer. Management practices that improve soil quality, leading to increased retention and degradation of herbicides, and the use of strongly sorbed, non-persistent herbicides would improve groundwater quality in this region.

**Biology II (2:30 – 2:45 PM)**

## The Lee County cave isopod (*Lirceus usdagalun*) debacle: an endangered species discovered not to be a species

Lewis, Julian Jerome[*1]; Lewis, Salisa Loreen[1]; Orndorff, William David[2]

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[2] Virginia Department of Recreation and Conservation, 8 Radford Street, Suite 102A, Christiansburg, Virginia, United States

The 1949 revision of the isopod genus *Lirceus* resulted in an assemblage of 13 unidentifiable species with descriptions based on nebulous, non-genitalic morphological characteristics. Frequently collected from springs and caves for environmental projects throughout eastern North America, their value as ecological indicators was negated since none could be identified. Two rare, site-endemic stygobiont species were well-described from southwestern Virginia in the 1970s: *Lirceus usdagalun* and *L. culveri*. The Lee County cave isopod (*L. usdagalun*) was listed

as a federally endangered species in 1992 following extirpation of one of two known populations. In 2015 the senior author commenced revision of the genus *Lirceus* sponsored by a Smithsonian fellowship. Working at the Smithsonian in 2016 examining the type collections of the *Lirceus* species, evaluation revealed the key genitalic characters of *L. usdagalun* (and *L. culveri*) were identical with the syntopic, spring-dwelling *L. hargeri.* To address this identity crisis concerning an endangered species, another stint at the Smithsonian was conducted later in 2016 to examine and identify thousands of *Lirceus* specimens, followed by field evaluation of Appalachian *Lirceus*. Molecular genetic analysis underway has mirrored morphological findings. *Lirceus hargeri* is now considered a polymorphic species distributed from southern Virginia to Georgia with six subspecies. These are the result of an ancestral species dispersing through the upper Tennessee River Valley, with isolation in Virginia's inter-mountain karst belts resulting in varying troglomorphic populations. Six proposed subspecies: (1) *hargeri* –epigean, Virginia and Tennessee; (2) *usdagalun* –Lee County, Virginia*;* (3) *culveri*—Scott County, Virginia; (4) new subspecies 4 – stygobiont, Tazewell County, Virginia; (5) new subspecies 5–previously undetected stygobiont, Washington County, Virginia; and (6) new subspecies 6 –epigean, Tennessee, Georgia. The Lee County cave isopod can retain endangered status as a subspecies.

**Biology III (11:00 – 11:15 AM)**

**Partial cave closures for study of microbiome in Grand Canyon Caverns, a sulfuric hypogene dry cave in north central Arizona, revealed a biotechnologically relevant community and had no deleterious economic impact**

Lusk, Bradley[*1]; Keeler, Raymond[2]

[1] #ScienceTheEarth, Mesa, Arizona, United States
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Microbial and elemental analyses were conducted at Grand Canyon Caverns, a privately-owned, commercial, sulfuric hypogene dry cave in north-central Arizona. Sampling was conducted on multi-colored rock formations with the consistency of fine powder within the cave spanning the distance of 1–3 $m^2$. The owner agreed to limit access to newly discovered sites within the cave in order to preserve the microbial community. Microbial community analysis was conducted by collecting 14 samples from various multi-colored formations. DNA was extracted from samples followed by amplicon sequencing of the V4 region of the 16S rDNA with the 515f/806r barcode primers in triplicate. Amplifications were pooled and sequenced on an Illumina MiSeq. OTUs were filtered using QIIME and taxonomy was assigned against the Greengenes database. Digested dry rock samples were analyzed using inductively coupled plasma mass spectrometry (ICP-MS). Ticket sales were tracked before and during times of limited access to areas of the cave to assess the economic impacts. Analysis of the cave microbiome revealed ~900 distinct genera of bacteria and archaea. Presence of genera varied across 14 sampling locations and included *Arcobacter* (1.0 ± 0.7%), *Amycolatopsis* (1.6 ± 2.3%), *Bacteroides* (2.6 ± 1.8%), *Phormidium* (1.1 ± 1.1%), *Pseudonocardia* (15.7 ± 17.3%), *Streptococcus* (0.7 ± 0.6%), *Streptomyces* (2.4 ± 3.1%), and unclassified (1.3 ± 1.1%). ICP-MS indicated that elemental composition varied and contained primarily iron (6.2 ± 3.5 g/l) and calcium (1.1 ± 1.1 g/l).

Ticket sales did not decrease due to limited access to areas of the cave. This study demonstrates that cave conservation and scientific discovery have limited negative economic impacts on cave recreation and reveals the opportunity to discover microorganisms that may be beneficial for the development of novel industrial biotechnologies and medicines.

**Biology I (10:00 – 10:15 AM)**

**Current status updates of 17 rare cave beetles of the genus *Pseudanophthalmus* in Virginia**

Malabad, Thomas Edward[*1]; Ficco, Katarina Kosič[1]; Orndorff, William David[1]

[1] Virginia Department of Conservation and Recreation, Division of Natural Heritage, 8 Radford Street, Suite 102A, Christiansburg, Virginia, United States

In the karst regions of western Virginia, beetles of the genus *Pseudanophthalmus* are all cave-limited troglobionts. Virginia is home to 31 described *Pseudanophthalmus* species and sixteen or more undescribed species. Under a cooperative agreement with the U.S. Fish and Wildlife Service, Virginia DCR staff are performing a status assessment of 17 of Virginia's rarest cave beetles that were listed in the Center for Biodiversity's 2011 multispecies listing petition. Before this study, eight species were known from only a single cave each, and no species from more than four caves. Eighty-eight sampling events were performed, including 48 to caves where the target species was previously known. At least one visit was made to 28 of 32 caves where a target species was known, including at least one for each species. For 15 of these 17 species, *Pseudanophthalmus* sp. have been verified in at least one of the previously known sites. Of these, nine have been verified to species, with six pending taxonomic confirmation. In addition, up to 15 new localities for eight of the species were identified. Of these, five have been confirmed to species level, with the remainder pending taxonomic confirmation. *Pseudanophthalmus* sp. were collected from 59 different caves over the course of this project. Once determinations are complete, a clearer picture of the distribution and rarity of these species will emerge. Although bait stations were set, beetles were found at most sites by hand collections in suitable habitat, typically near flowing or standing water. Hydrologic conditions influenced sampling success. Beetles were more abundant in the Valley and Ridge Province, especially to the south, and less abundant in the Shenandoah Valley. Only three of the 17 species are not clearly secure and merit further investigation to see if listing under the ESA is warranted.

**Biology I (9:15 – 9:30 AM)**

**Making cave crickets famous: managing karst landscapes and conservation messages**

McCann, Cait[*1]

[1] Wildland Conservation Division, City of Austin, 3621 South Ranch Road 620, Austin, Texas, United States

In Austin, Texas, residents voted to fund the purchase of over 40,000 acres of land for the protection of endangered species habitat and recharge to the Edwards Aquifer starting in 1996. In addition to two species of neotropical birds, six endangered karst invertebrates benefit from this protection as well as twenty-five percent of the aquifer's recharge zone and seven percent of the contributing zone. Twenty years later, this karst landscape now finds itself at odds with one of the fastest developing areas in the United States, attracting many new residents who didn't participate in the sometimes heated discussions that led to this significant conservation of sensitive lands. The City's Wildland Conservation Division staff work not only to manage the land, but also the public messaging about why cave conservation matters for endangered species, water resources, and people. In addition to training educational cave trip leaders and hike guides each year, Wildland Conservation staff, along with local partner organizations, seek to build tangible connections to the karst landscape through off-site strategies including YouTube documentaries about land management, animations of macro invertebrates through augmented reality games and apps, and local art exhibits that connect people with plants, crickets, and ultimately the underground conduits of karst ecosystems.

## Geology & Hydrology I (11:45 – 12:00 PM)

### Examining the hydrogeology of the unique fenster-type karst in the western Great Smoky Mountains, Tennessee

Miller, Benjamin V.[*1]; Bradley, Michael[1]; Kulp, Matt[2]

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[2] National Park Service, Great Smoky Mountains National Park, Gatlinburg, Tennessee, United States

In the western Great Smoky Mountains, the Ordovician Knox Group, a sequence of dolomite and limestone, is exposed in several carbonate fensters in the overlying Pre-Cambrian sandstones and phylllite. The fensters facilitate allogenic recharge, where streamflow from the surrounding insoluble strata sinks at the contact with the underlying Knox Group and results in karst development. Though the karst is limited in area and the overall number of caves is low, the resources are significant; Bull Cave is the deepest cave in Tennessee at 281 meters deep, two caves are major bat hibernacula, and Cades Cove, one of the most-visited sites in the National Park Service, is a large-scale karst feature. Recent work by the U.S. Geological Survey, beginning in 2017, seeks to improve understanding of the hydrologic behavior of the karst areas through hydrologic and geochemical monitoring, seepage runs, and dye tracing. Instrumentation was placed in the main stream in the lower portion of Bull Cave, a sump in White Oak Blowhole, and a karst wetland in Cades Cove. Additionally, a stream gage was installed along Abrams Creek, the main stream flowing through Cades Cove. Dye injections were conducted in Bull Cave, White Oak Blowhole, Rainbow Cave, and Kelly Ridge Cave, following equipment installation in the caves. Traces were performed to determine the flow paths of the cave streams and aid in delineating recharge areas for the springs located below the caves. From this work, at least four different spring basins are now known in Tuckaleechee Cove, the resurgence point for

the caves in the study. The karst of the Smokies presents challenges due to the difficult nature of the caves, accessibility of the terrain, and complexities of the geologic setting. The study is being conducted in cooperation with Tennessee Wildlife Resources Agency, Great Smoky Mountain National Park, and the Tallassee Fund.

**Biology II (2:00 – 2:15 PM)**

**New techniques for determining occurrence and demographics of cave crayfish**

Mouser, Joshua B.[*1]; Van Den Bussche, Ronald A.[2]; Niemiller, Matthew L.[3]; Wood, Chris[2]; Ashley, David[4]; Brewer, Shannon K.[5]

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[4] Missouri Western State University, Rogersville, Missouri, United States
[5] U.S. Geological Survey, Oklahoma Cooperative Fish and Wildlife Research Unit, Oklahoma State University, 007 Agricultural Hall, Stillwater, Oklahoma, United States

Many species of cave crayfishes are of conservation concern due to narrow distributions and threats to groundwater quality. To protect stygobiotic organisms, we need to adopt innovative techniques for studying their populations. For example, environmental DNA (eDNA) is a new technique that can be used to detect presence of organisms via DNA shed in the environment. In addition to knowing where stygobionts occur, we need to better understand their life history. Recent work has demonstrated that lobsters and crayfishes can be aged via their gastric mill instead of relying on indirect techniques, such as length-frequency histograms. Our objectives were to assess the use of eDNA for detection of cave crayfishes and determine if using hard structures for aging cave crayfishes could be used for demographic analysis. For eDNA analysis, we collected 2-L water samples from groundwater throughout the Ozark Highlands ecoregion. DNA was extracted using a modified phenol-chloroform method. DNA was amplified using quantitative polymerase chain reaction (qPCR) with a primer/probe combination to increase specificity. We collected 50 *Faxonius neglectus* and two *Cambarus setosus* to test the use of hard structures for aging crayfish. Preliminary results show amplification of *C. setosus* DNA. Age estimates of *F. neglectus* via gastric mills match estimates from length-frequency histograms until year 5. Gastric mills of cave crayfishes display rings that appear similar to rings found in surface species. Future work will focus on amplifying DNA from groundwater samples where other species of cave crayfishes and cavefishes occur. Also, we will raise crayfish in the lab and confirm that the rings visualized on hard structures correspond to yearly rings. Results of our study demonstrate that two new techniques may advance the way we study stygobiotic populations.

**Biology I (10:15 – 10:30 AM)**

**Rediscovery and conservation status of short-range endemic *Pseudanophthalmus* cave beetles (Carabidae: Trechini) in Tennessee, Alabama, and Georgia**

Niemiller, Matthew L.[*1]; Zigler, Kirk S.[2]; Ober, Karen A.[3]; Carter, Evin T.[4]; Engel, Annette S.[5]; Moni, Gerald[6]; Philips, T. Keith[7]; Stephen, Charles D.R.[8]

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[3] Department of Biology, College of the Holy Cross, Worcester, Massachusetts, United States
[4] Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, Tennessee, United States
[5] Department of Earth and Planetary Sciences, University of Tennessee, Knoxville, Tennessee, United States
[6] Tennessee Cave Survey, Nashville, Tennessee, United States
[7] Department of Biology, Western Kentucky University, Bowling Green, Kentucky, United States
[8] Department of Biological Sciences, Auburn University, Auburn, Alabama, United States

The North American endemic cave beetle genus *Pseudanophthalmus* is exceptionally diverse, with >150 described taxa in karst regions of the eastern United States. Eighty-seven percent of taxa, however, are at risk of extinction due to small, restricted distributions, low abundance, and several potential anthropogenic threats to their habitats. Several species in TAG (Tennessee, Alabama, and Georgia) are exceedingly rare with some taxa considered candidates for listing under the U.S. Endangered Species Act. Each of these species are extreme short-range endemics, and some of which have not been observed in several decades. Between July 2013 and August 2017, we search >200 caves through the Appalachians and Interior Low Plateau karst regions of TAG to determine if populations were still extant, to search for new populations, and to estimate relative abundance. We confirmed the continued existence of several species, including *P. fowlerae*, *P. insularis*, *P. paulus*, and *P. tiresias*, which had not been observed in 52, 60, 50, and 42 years, respectively. Although U.S. Fish and Wildlife Service ruled that six species do not warrant federal listing, all species continue to have restricted ranges and remain at an elevated risk of extinction.

**Biology III (11:30 – 11:45 AM)**

**Using environmental DNA to detect and monitor rare and endangered groundwater fauna: a case study**

Niemiller, Matthew L.[*1]; Porter, Megan L.[2]; Keany, Jenna[3]; Gilbert, Heather[3]; Fong, Daniel W.[4]; Culver, David C.[3]; Hobson, Christopher S.[5]; Kendall, K. Denise[1]; Davis, Mark A.[6]; Taylor, Steven J.[6]

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[4] Department of Biology, American University, Washington, DC, United States
[5] Virginia Natural Heritage Program, Virginia Department of Conservation and Recreation, Richmond, Virginia, United States
[6] Illinois Natural History Survey, Prairie Research Institute, University of Illinois at Urbana-Champaign, Champaign, Illinois, United States

Effective conservation and management of biodiversity is limited by a lack of critical knowledge on species' distributions and abundances. This problem is particularly exacerbated for species living in habitats that are exceptionally difficult to access or survey, such as groundwater habitats. Environmental DNA (eDNA) represents a rapid, noninvasive, and potentially cost-effective new tool for detection and monitoring of biodiversity that occur in such habitats. We investigated the utility of eDNA in detecting the federally endangered Hay's Spring Amphipod *Stygobromus hayi* and a co-occurring common congener *S. tenuis potomacus* from unique groundwater associated habitats in the Washington, DC metro area. We developed taxon-specific primers and probes for each species to amplify *Stygobromus* DNA using qPCR. In silico and in vitro validation demonstrated specificity of each designed assay. Assays were then used to screen water samples collected from ten seepage springs. *Stygobromus hayi* was detected at four seepage springs, including one potential new locality, while *S. t. potomacus* was detected at four springs, two of which were new localities. This study is the first to our knowledge to successfully employ an eDNA approach to detect rare or threatened invertebrates from subterranean ecosystems. Our study highlights challenges of employing an eDNA approach for the detection and monitoring of invertebrates in groundwater habitats that are difficult to study, including accounting for PCR inhibition and the potential for cryptic genetic diversity.

## Conservation, Management, & Techniques II (4:15 – 4:30 PM)

### Karst considerations in the siting of interstate utility corridors: examples from two major natural gas transmission pipelines proposed to cross western Virginia

Orndorff, William David[*1]; Malabad, Thomas Edward[1]; Kosič Ficco, Katarina[1]

[1] Virginia Natural Heritage Program, Department of Conservation and Recreation, 8 Radford Street, Suite 102A, Christiansburg, Virgina, United States

In 2014, companies proposed the 42" diameter Atlantic Coast (ACP) and Mountain Valley (MVP) pipelines to move natural gas at pressures up to 1440 psi from Marcellus gas wells to the East Coast, crossing karst regions of the Virginias. Karst was of geotechnical and environmental concern to both projects during the National Environmental Policy Act (NEPA) process and development of the Environmental Impact Statement (EIS) by the Federal Energy Regulatory Commission (FERC). Project consultants with extensive cave/karst expertise performed karst surveys and developed mitigation plans. Desktop review incorporated data and technical

guidance from state cave surveys, the Virginia Department of Conservation and Recreation (DCR) Natural Heritage Program and Cave Board, and other state agencies. Significant Caves (Virginia Cave Protection Act) became focal points, with corridors revised reducing impacts by ACP to Burnsville Cove and Cochrans Cave, and by MVP to six Significant Caves. Field surveys verified locations and identified undocumented karst features, resulting in further route adjustments. High sensitivity features were identified for mitigation, mainly isolation from drainage during construction. Less attention was paid to downslope sinkpoints receiving allogenic runoff from the project. Dye tracing Virginia DCR performed with the New River Land Trust, funded by Cave Conservancy of the Virginias, demonstrated connections between such runoff and the Significant Slussers Chapel – Mill Creek Cave system, resulting in reroutes reducing stream crossings in the allogenic zone. Initially, neither project performed dye tracing to determine fate of contaminants discharged to karst in areas without prior traces. Virginia DCR recommended these areas be traced. The final EIS issued to each project in summer 2017 by FERC granting conditional approval did not require dye traces, but Virginia Department of Environmental Quality requested it for state permitting and studies are currently underway. Similar, future utility projects on karst would benefit by greater consideration of the karst systems downstream of the construction zone.

**Biology III (11:45 – 12:00 PM)**

**Geospatial assessment of landscape threats effecting Oklahoma karst species**

Slay, Michael Edward[*1]

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The Ozarks contain an underground wilderness of caves, springs and aquifers that over the millennia have formed in the carbonate bedrock of the region. The porous and fractured nature of karst terrain makes it susceptible to pollution caused by incompatible land use, and these same landscape alterations may reduce the availability of high quality foraging and roost habitats for cave-dwelling bats. More generally, human visitation and vandalism likely threaten all karst species. To understand these impacts, a Geographic Information System (GIS)-based index model was developed that assessed site-specific threats associated with 28 Oklahoma karst species (4 bat species, 8 terrestrial cave species, and 16 aquatic cave species) using threat indicators derived from 25 geospatially available datasets. Threats were assessed for 94 karst habitats (caves, springs, or seeps). In addition, a groundwater vulnerability model was developed for northeastern Oklahoma using a modification of the Environmental Protection Agency's DRASTIC model. Nearly all sites are experiencing some level of threat. Karst sites experiencing a high level of modelled threat are distributed across northeastern Oklahoma, but many highly threatened sites are concentrated near or north of the U.S. Highway 412 corridor. In addition to identifying highly threatened individual sites, the model characterizes threat at species and community levels. In Oklahoma, the threat model is being used to evaluate conservation priorities at all three of these levels, and it is being used to reassess and update a 2003 Ozark Ecoregional Conservation Assessment Plan developed by The Nature Conservancy.

## Geology & Hydrology II (9:45 – 10:00 AM)

### Karst hydrology and geomorphology of the Upper-Mississippian Pennington Formation in Savage Gulf State Natural Area, Tennessee

Steinmann, Hali[*1]

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Mississippian aged carbonates underlie the fluviokarst landscape of central Tennessee, where river incision has long been linked with the development of solutional caves on the Cumberland Plateau escarpment. Relatively little attention has been given to discontinuous karstification in the uppermost Mississippian unit, the Pennington Formation, wherein pockets of carbonate rock occur irregularly in a matrix of insoluble shale and sandstone. This research takes a geomorphological approach towards understanding speleogenesis and controls on drainage in the Pennington Formation, using Savage Gulf State Natural Area in Tennessee as a case study. Pennington caves, swallets, and karst springs in the upper reaches of Big Creek and its tributary, Firescald Creek, were surveyed and fluorescent dye tracer tests were conducted to establish connectivity between active parts of the hydrologic system. Discharge and saturation index of sinking and resurging waters were determined where possible. Data were digitized for spatial analysis in a GIS, which helps to visualize and contextualize the dynamic nature of drainage through the Pennington Formation. Karst processes in the Pennington Formation have implications not only for Cumberland Plateau geomorphology, but also for local ecology and biodiversity, water quality, and land management.

## Conservation, Management, & Techniques III (9:30 – 9:45 AM)

### The excavation of caves for education

Thompson, Drew Rollin[*1]

[1] Balcones Canyonlands Preserve, Austin Water/Wildlands Conservation Division, Reicher Ranch, 2621 South FM 620 Road, Austin, Texas, United States

In 2013 Dr. Nico Hauwert of the City of Austin's Watershed Protection Department created a team of seven cave specialists to oversee and coordinate the restoration and studies of the city's caves and karst lands. Among many other duties, the cave team excavated and restored caves and other karst features to create underground classrooms for the Watershed Protection Department's Education Outreach Program. Historically, the majority of caves and sinkholes in Austin and surrounding areas were filled in by landowners and developers to dispose of trash and debris, reduce public trespassing, and to protect livestock. By removing the trash and fill from the caves and features, it gave us the opportunity to improve recharge and educate the public about the

ecosystem and the function of the aquifer and what we can do to protect it. Now the caves are being utilized by many educators to expose more than 3,000 patrons a year to this sensitive and complex natural resource. With the reopening of these caves, we now face the challenges of preservation and management.

**Conservation, Management, & Techniques II (4:00 – 4:15 PM)**

**Plugging the management holes in karst environments**

Turk, Teresa A.[*1]

[1] Teresa Turk Enterprises, 1408 W Cleveland St., Fayetteville, Arkansas, United States

In 2012, a large swine Confined Animal Feeding Operation (CAFO) was approved for a Regulation 6, NPDES permit by the Arkansas Department of Environmental Quality (ADEQ) located six miles upstream of the Buffalo National River (BNR) at Carver. The facility called C&H generates almost 3 million gallons of untreated swine waste annually that is spread on many fields adjacent to Big Creek, the fifth largest tributary of the BNR. Currently ADEQ did not renew the Regulation 6 permit but is now considering granting a Regulation 5 state permit. During the public comment period, ADEQ received over 20,000 comments by citizens heavily in favor of not granting the permit. The presentation will roll back time to 2012 prior to C&H's regulation 6 permit approval and proved recommendations to ADEQ for a revised permit approval process. Many of the recommendations are current requirements and procedures used by other states and will be focused on rural areas with karst geology.

**Biology I (9:45 – 10:00 AM)**

**Anthropogenic threats to the River Cave and Ha Ha Tonka Spring karst systems at Ha Ha Tonka State Park, Camden County, Missouri**

Vaughn, Allison[*1]

[1] Missouri Department of Natural Resources, 1659 East Elm Street, Jefferson City, Missouri, United States

In 2007, the Missouri Department of Conservation ranked River Cave as the 5$^{th}$ most biodiverse cave in Missouri. Known for its significant colony of federally endangered Gray Bats, Indiana Bats, four salamander species, cavefish and a suite of aquatic invertebrates, River Cave remains protected as part of the 70-acre Karst Natural Area. With increasing occurrences of flash flood events since the 1990s, the losing stream that traverses the cave and flows to Ha Ha Tonka Spring through a natural sump has become choked with increasing amounts of road gravel and fines. The stream, Dry Hollow, exists parallel to a gravel road that has witnessed increased urbanization at the park's border. On the 1.6 mi. of gravel road frontage, culvert systems and ditching projects have occurred, resulting in massive gravel loading in the stream. As Dry

Hollow enters the cave's back sinkhole, the cave, and ultimately Ha Ha Tonka Spring—Missouri's 12th largest and part of the natural area—significant amounts of road gravel continue to accrue following heavy rain events. This karst system, nominated for National Natural Landmark status in 1979 and 2011, is increasingly threatened, with cave and spring biota populations notably declining. The massive gravel accretion from Dry Hollow Road as a direct result of continuous road improvement and ditching projects has resulted in rapid declines in amphipod and salamander populations, in the complete blockage of ancillary cave passages, and, today, islands of gravel filling in the spring branch. In September 2017, the park applied for funding for a multi-tiered project to mitigate this issue including paving the road, creating a catch basin for the remaining gravel, removing gravel from the sinkhole to prevent entry into the cave, and dredging the spring. It was recommended that the park seeks external partnerships to fund this important project.

## Geology & Hydrology II (9:30 – 9:45 AM)

### Preliminary analysis of water chemistry for select Northwest Arkansas caves

Wentz, Nathan J.[*1]; Slay, Michael Edward[2]

[1] Arkansas Department of Environmental Quality, North Little Rock, Arkansas, United States
[2] Arkansas Field Office, The Nature Conservancy, 601 North University Avenue, Little Rock, Arkansas, United States

In March 2017, the Northwest Arkansas Council predicted that within three years Northwest Arkansas will be be one of the nation's 100 largest metropolitan statistical areas. Per day population growth as increased annually over the last five years. Growth from 2015 to 2016 increased by 1.7 person/day from 30.3 to 31.7 people/day, respectively. Effects from consistent urban growth on surface water and groundwater in Northwest Arkansas have been documented for the last three decades. Objectives of this study are to develop baseline water chemistry conditions for minimally developed cave systems as well as utilize historical data to evaluate changes through time in highly developed systems. Study sites were selected by ranking occurrence of Species of Greatest Conservation Need (SGCN) and accessibility. One year of monthly monitoring is complete for five sites in Benton County (Bear Hollow Cave, Blowing Springs Cave, Civil War Cave, Cave Springs Cave, Logan Cave), two sites in Madison County (Withrow Springs, War Eagle Creek Cave), and one site in Washington County (Elm Springs). At each site, nutrients and ions (chlorides, sulfates, total dissolved solids, and specific conductance) were analyzed monthly, while metals (total and suspended) were analyzed every other month. Average total phosphorus concentrations ranged from 0.03 mg/L at four of the eight sites to 0.11mg/L at Civil War Cave. Civil War Cave also has the highest average ion concentrations. Water temperature was higher at more urban sites (Cave Springs Cave and Civil War Cave), and water temperature at Cave Springs Cave is roughly 1 degree warmer than temperatures reported 15 years ago. Land use differences within recharge areas may explain some observed differences in water chemistry, and we will explore how land use changes may be influencing water quality changes over time.

**Conservation, Management, & Techniques III (9:15 – 9:30 AM)**

**Sharing GIS data layers developed for United States Geological Survey regional water-availability studies**

Westerman, Drew Aaron[*1]

[1] United States Geological Survey, Lower Mississippi-Gulf Water Science Center, 401 Hardin Road, Little Rock, Arkansas 72113, United States

The U.S. Geological Survey (USGS) Water Availability and Use Program is conducting an assessment of water availability throughout the United States to gain a better understanding of the status of our water resources and how changes in water use and climate may affect those resources. Through this effort, multiple layers of Geographic Information System (GIS) data are created to aid in the development of surface-water and groundwater models that represent a resource of interest. The produced GIS data are standalone products and can be used in other projects and to help guide resource-management decisions. Examples of GIS data include the hydrogeologic framework that contains the altitude and thickness of units within regional aquifer systems, county-level water-use data, geophysical profiles of soil conductivity, and potentiometric surfaces of wells screened in an aquifer. The USGS can quickly disseminate the GIS data using customized web applications or the USGS ScienceBase platform.

**Conservation, Management, & Techniques II (3:15 – 3:30 PM)**

**How to upgrade to an LED cave lighting system for under $40,000**

Wiles, Michael E.[*1]

[1] Jewel Cave National Monument, 11149 US Highway 16, Custer, South Dakota, United States

The lighting system of Jewel Cave's half-mile Scenic Tour route has remained virtually the same since the first tour in May 1972. In recent years, technology has matured to the point that an upgrade to LED lights can be accomplished without major renovation, or replacement of the system. Beginning in 2014, the park's maintenance staff began upgrading switches, wiring, and fixtures. This year, most of the 129 incandescent bulbs were replaced with comparable LED screw-in bulbs. The remaining bulbs and 6 mercury vapor lamps will be replaced this winter. The project is being conducted with the goal of keeping things simple, so that the lighting system will be as "bomb proof" as possible. Thus, it does not include high-end bulbs or remote computer control. It will reduce energy consumption and heat input by 80%, and reduce the frequency of changing bulbs. When completed, the upgrade will cost around $35,000 including all labor and materials.

**Geology & Hydrology I (11:30 – 11:45 AM)**

**Estimating the true elevation of cave lakes with surface and subsurface geology at Jewel Cave, South Dakota**

Wiles, Michael E.[*1]; Fiorentino, Eric[1]; Heins, Daniel[1]; Cerrati, Gabriella[1]; Hayward, Erin[1]

[1]Jewel Cave National Monument, 11149 US Highway 16, Custer, South Dakota, United States

In 2014, volunteer cave explorers discovered the first underground "lakes" in Jewel Cave, located in the southern Black Hills of South Dakota. The lakes occur where cave passages intersect the regionally important Madison aquifer. These discoveries provide a unique opportunity to monitor variations in water level within the aquifer, which is especially important because Madison wells are quite sparse in the southern Hills. This new source of information can significantly improve USGS modeling of the aquifer, and establish natural trends within the system. However, the cave survey is not adequate for establishing the true elevation of the lakes. Even though internal loop closures and over 30 radiolocations have been used to control lateral errors, there is no way to confidently control vertical errors. There are thousands of stations between the lakes and the nearest certain vertical control. Therefore, the park is using the known thicknesses of geologic strata and cave levels to estimate the lake levels to within 20 feet (6 m). Although this is an approximation, it provides the best possible estimate, short of an actual observation well, and has shown that the cave survey has drifted more than 50 feet (15 m) lower than the actual depth.

**Conservation, Management, & Techniques III (10:15 – 10:30 AM)**

**Policy communication and the impact of agricultural communities on karst landscapes: an example from Phong Nha-Kẻ Bàng National Park, Vietnam**

Willenbrink, Elizabeth[*1]; North, Leslie[1]; Polk, Jason[1]; Nguyet; Vu Thi Minh[2]

[1] Center for Human GeoEnvironmental Studies, Western Kentucky University, 1906 College Heights Boulevard, Bowling Green, Kentucky, United States
[2] Institute of Geological Sciences, Vietnam Academy of Science, 84 Chua Lang, Dong Da, Hanoi Vietnam

Karst landscapes are vulnerable to human influence, especially agricultural development. Interconnectedness between surface activities and subsurface environments make karst landscapes especially susceptible to soil erosion and water contamination. The likelihood of these two phenomena happening increases when agricultural intensification, irrigation, or fertilizer application occurs. In order to mitigate the negative consequences of agriculture on karst landscapes, increased implementation of policy to regulate human activities and increased communication of these policies is needed. This study occurred in Phong Nha-Kẻ Bàng National Park, Vietnam, a UNESCO World Heritage site dominated by the oldest karst landscapes in East Asia, extensive agricultural communities, and mediocre success in protecting its karst terrain. Interviews, observation, and GPS analysis were used to analyze the effectiveness of policy

communication and karst protection in the Park. It was found that karst protection policy in the region is minimally communicated and, when communicated, often delivered in the wrong way to the wrong individuals. Despite the known harm agriculture causes to karst landscapes, intensification, irrigation, and the use of fertilizers still occurs frequently and is often supported by government officials. Policy and karst landscape information is concentrated among park officials and rarely presented in an informal setting, leaving those in most frequent contact with the karst landscape—the farmers—without any information on the vulnerability of karst terrain to agriculture and the subsequent impacts on human and biological health. In analyzing the situation in Phong Nha-Kè Bàng, general conclusions on policy to protect karst terrain in agricultural regions can be drawn. The communication of karst science and the implementation of policy to protect the landscape must be presented both formally to governing officials and local representatives and then passed down through informal networks to general citizens. Through these means, karst protection can successfully implemented.

# Poster Presentations

The list of posters is arranged in alphabetical order by the first author of the presentation. An asterisk (*) identifies the author that is presenting the poster. Abstracts are also available on the Symposium website.

**Enhancements to a bat-friendly cave gate design for increased security**

Adams, Rachel Estee*[1]; Schroeder, R.C.[2]; Slay, Michael E.[3]

[1] Department of Ecosystem Science and Management, Texas A&M University, 400 Bizzell Street, College Station, Texas, United States
[2] RCS Metal Fabrication, 2066 Pony Peak Road, Timbo, Arkansas, United States
[3] Arkansas Field Office, The Nature Conservancy, 601 North University Avenue, Little Rock, Arkansas, United States

Bear Hollow Cave, located in Bella Vista, Arkansas, has been managed by The Nature Conservancy since its donation to the organization in 1998. It is home to various species of bats, salamanders, and cave-adapted organisms, including the endangered cave crayfish, *Cambarus aculabrum*. Unfortunately, the site has also been the location for illegal dumping, vandalism, and trespassing. A steel pipe gate was installed by Arkansas Game and Fish Commission in 1994 to protect the cave and its fauna prior to the development of the Agency Guide to Cave and Mine Gates that provides guidance and specifications on constructing bat-friendly gates. The existing gate was frequently damaged via broken locks, cut bars, and an attempt at removal using heavy machinery. In 2015, we deconstructed the existing gate and installed a bat-friendly version. Because of prior heavy vandalism, we enhanced the bat-friendly design by adding several layers of protection. The enhancements included reinforcements to the 1.5 by 1.5-inch angle iron stiffeners and a redesign of the lock box to include a dummy lock. For each pair of stiffeners, one was filled with gravel and concrete, while a freely spinning stainless steel rod was enclosed in the other. During attempts to cut horizontal bars, the internal rod will spin against a saw and the concrete-gravel mixture will dull the cutting blade. The reinforced angle iron was sealed with a flat piece of metal, constructing sturdy triangular horizontal beams. Finally, the functional lock was placed above a fake lock, to reduce potential damage to the true lock. Since construction, we have visited monthly to check for vandalism. A few attempts to dig under the cave gate were observed but were thwarted. The improved design has proven successful at preventing vandalism and unapproved access, ensuring the safety of the fragile cave organisms and environment.

**Blanchard Springs Caverns and a billion points of light**

Hocut, Tamara*[1]; Jurney, David[2]

[1] Ozark-St. Francis National Forests, PO Box 427, Jasper, Arkansas, United States
[2] Ozark-St. Francis National Forests, 605 West Main, Russellville, Arkansas, United States

The Center for Advanced Spatial Technologies (CAST) and the Ozark-St. Francis National Forests entered into a cooperative agreement to do a complete 3D point cloud survey scan of all the visitor facilities and cave tour. Because the infrastructure of the Blanchard Visitor Information Center and Caverns was developed in the late 60's and early 70's, there is a need to look at infrastructure updates that look at safety, energy conservation, protection of geologic features, protection of threatened and endangered species, and the preservation of heritage sites. New technology available today allows for detailed mapping of the visitor center and the caverns so that appropriate updates can be planned. This mapping also helps resource professionals with research and modeling that will help with the preservation of this very unique site that is the home of threatened, endangered, and sensitive species.

**Analyzing the risk of bedrock collapse sinkholes in Bowling Green, Kentucky**

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[2] Department of Biology, Texas State University, San Marcos, Texas, United States

Sinkholes occur throughout the state of Kentucky and particularly in the southcentral part, as indicated by the occurrence of the highest density of sinkholes in the state. The most common sinkhole-type in southcentral Kentucky is the cover collapse, which occurs in the soil or other loose material overlying soluble bedrock. Bedrock sinkhole collapses, which are considered rare, occur when the ceiling of a cave collapses, exposing the cave passage to the surface. On geologic time scales of cave formation and degradation, bedrock collapses are much more common as indicated by the 350 cave entrances in Warren County, Kentucky. However, Bowling Green, Kentucky, has seen two major bedrock collapse sinkholes within the past 16 years, as well as smaller bedrock collapses that have not received the same attention. In both cases, the bedrock collapses are associated with the development of human infrastructure. The purpose of this study was to determine the risk of bedrock collapse sinkholes as anthropogenically-induced geohazards in Bowling Green, Kentucky. Methods and data utilized included remote-sensing, cave and karst mapping, local geologic mapping, isopach mapping of overburden, and hydrogeologic information and data, all incorporated into a GIS. The results of the study showed that all recent bedrock collapses were associated with human infrastructure development. The GIS highlights areas that have the potential for bedrock collapses that would result in damage and loss of infrastructure.

## Characteristics of bats at a cave in eastern Oklahoma: spring emergence and fall swarming

Robbins, Lynn W.[1]; Armstrong, Kory M.[1]; Light, Nathanael R.[*1]; Stark, Richard C.[2]

[1] Environmental Solutions & Innovations, Inc., 3851 S. Jefferson Avenue, Springfield, Missouri, United States
[2] U.S. Fish & Wildlife Service, Tulsa, Oklahoma, United States

Data presented here represent four sampling periods (two fall swarming and two spring staging) that will be used to estimate changes in the overwintering populations of Northern Long-eared Bats (MYSE), Tri-colored Bats (PESU), and Gray Bats (MYGR) in a single cave system in the Ozark Plateau National Wildlife Refuge (OPNWR) in Adair County, Oklahoma. This cave system has 11 known entrances, three of which are the areas of interest for this survey. The cave system was negative for *P. destructans* in winters 2013–2016, but positive in spring 2016. Data from bats at the hibernaculum were compared to data collected on the landscape during the July 2013 Bat Blitz from the same general area. Bats were captured at three cave entrances in the OPNWR during the nights of 29 & 30 September 2015, 5 & 6 April 2016, 28 & 29 September 2016, and 20 & 21 March 2017, using harp traps at cave entrances and mist-nets strategically placed around those same cave entrances. All equipment, traps, poles, nets, cloth bat bags, and processing gear were new or decontaminated following USFWS protocols. MYSE and MYGR were banded with uniquely numbered forearm bands. Previous winter surveys of this cave system counted <50 MYSE. Although we captured over 1,500 individuals, many individuals were seen inside and around the cave entrances and we stopped the surveys each night long before the bats stopped their activity. We estimated >1,000 individuals of MYSE during each survey period. A cold front passed through on the second night of the fall 2015 survey, and the activity of PESU increased to a point that we took down the nets and traps. A small number of MYGR are known to use the cave during the summer and it is likely that these MYGR leave this cave for other hibernacula. There were significant differences in mass between summer and fall and between spring and fall for both MYSE and PESU as they emerge from or prepare for hibernation, but no significant differences were observed in MYGR. This may occur as fall bats are in transit or have not departed for their hibernacula and future mass increases. At this time, we do not know if the sex ratio for MYSE in the spring 2016 and 2017 survey (>95% male) represents the hibernating population or if the females departed prior to our survey. Low numbers of MYSE captured in spring 2017, are likely weather related and due to unseasonably warm weather and not related to WNS.

## Cave Research Foundation: cave and karst management in the Buffalo National River

Sapkota, Kayla[*1]

[1] Cave Research Foundation, 270 Casey Lane, Dover, Arkansas, United States

The Buffalo National River flows freely from west to east for roughly135 miles and is one of the few remaining undammed rivers in the lower 48 states. The river was brought into the National Park System in 1978, providing over 94,000 acres and offers floating, hiking, camping, and other

outdoor activities for people of all ages. The Buffalo National River is home to over 500 cave and karst features, including lengthy caves, small shelters, pits, and more. The Cave Research Foundation (CRF) has worked for decades in the Buffalo National River under a scientific research and collecting permit. The purpose of the CRF work in the Buffalo National River is to provide baseline data on caves and other karst features within the park boundaries. Included in this task are the location of caves, cartographic surveys, and baseline biological monitoring, with a special emphasis on monitoring for White Nose Syndrome. In order to maintain easily accessible and searchable records of the many cave and karst features contained by the Buffalo National River, a sophisticated, yet broadly comprehensible database was created initially populated by existing, historic records and files. It is regularly updated with new and enhanced information. This poster details the ongoing work by the CRF in the Buffalo National River and provides details for salient discussions among conference-goers.