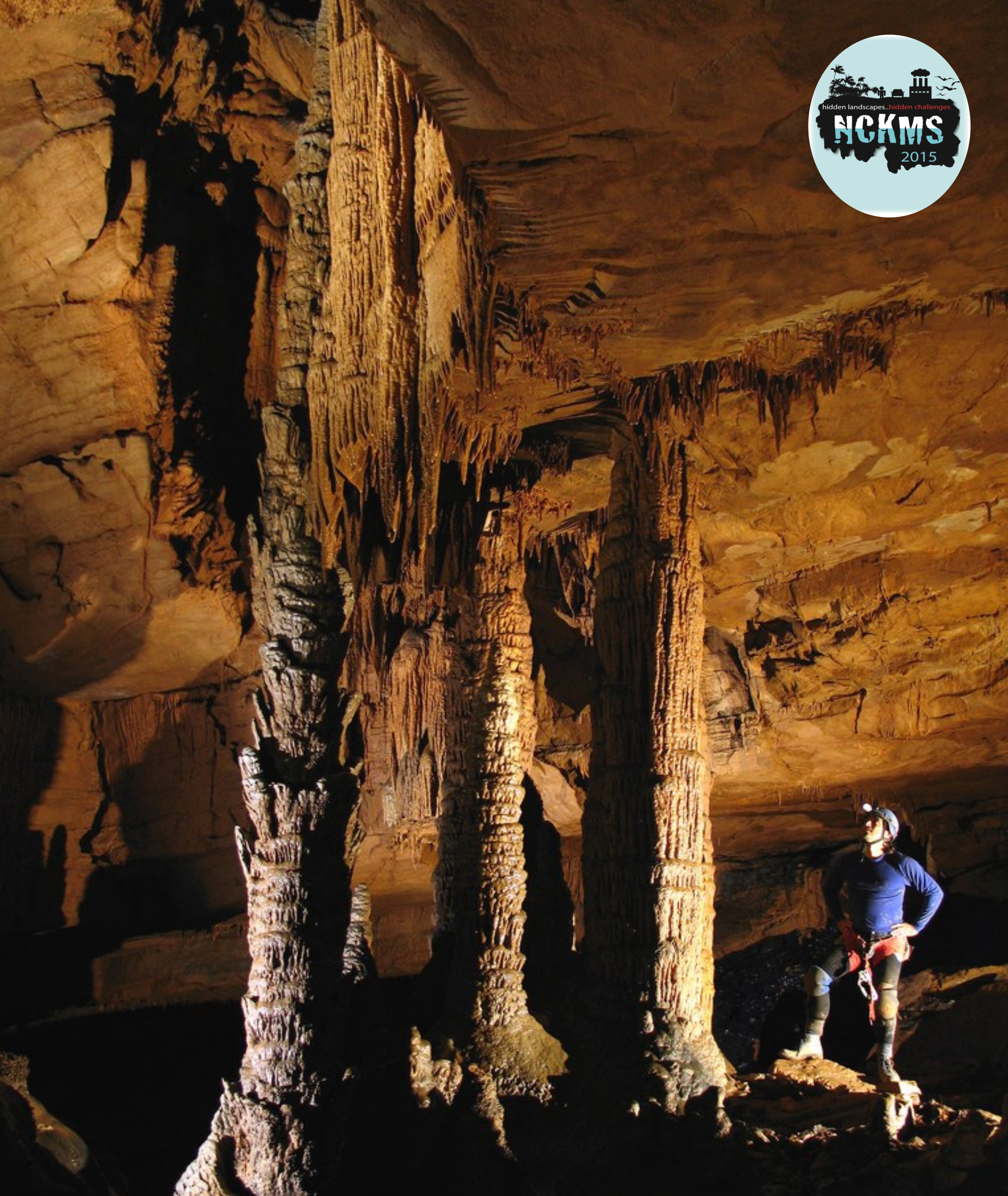

21st National Cave and Karst Management Symposium Proceedings
Hidden Landscapes—Hidden Challenges
Cave City, Kentucky

National Cave and Karst Management Symposium

Proceedings of the Twenty First Conference
Hidden Landscapes—Hidden Challenges

October 19 through 23, 2015
Cave City, Kentucky

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Table of Contents

Biology

Conservation-Education-Outreach-Tourism

Welcome

The theme for this year's symposium is "Hidden Landscapes...Hidden Challenges" which is reflected in the surface and subsurface landscapes of the Mammoth Cave Region and the challenges we face living on and above those landscapes. Mammoth Cave National Park and surrounding areas serve as a natural laboratory for enhancing our understanding of complex cave systems and the associated karst watersheds. Bowling Green, Kentucky exemplifies the challenges of living on karst most notably with the recent Corvette National Museum sinkhole collapse and how those challenges are addressed which is also featured in the remediations associated with the sinkhole.

The 2015 National Cave and Karst Management Symposium has brought special focus on the problems and solutions inherent to living on, managing and protecting not only the Kentucky karst but also to the many other cave and karst areas of the world.

Editor:

Patricia Kambesis

Cave Research Foundation

Center for Human-GeoEnvironmental Studies, Western Kentucky University

Geology/Hydrology
Johanna Kovarik, Chair

Discovery and Management of Georgian Caves

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Georgian caves, as natural phenomena, have attracted many researchers for a long time. They were often mentioned in old Georgian chronicles literary sources (Juansheri-11th century, Rustaveli-12th century, Sulkhan-Saba Orbeliani-17th century, etc.) and also in the works of foreign researchers and the records of travelers (ArkanjeloLamberti-17th century, Diubua De mompere-19th century, Eduard Alpred Martel-20th century, etc.). An especially notable geographer,Vakhushti Bagrationi (18th century) wrote the encyclopedic work "Geography of Georgia,'' in which there are many interesting facts about Georgian karst and caves. It can be said that the Georgian cave survey began during the era of Vakhushti Bagrationi.

The limestone area of Georgia extends along the southern slope of the Caucasus at a distance of 325 km from the Psou River to the east of the Ertso Lake vicinity and vertically reaches about 2,705 m above sea level (Speleologist's Peak).The total karst area is 4,475 sq. km, or6.4% of the whole territory of Georgia.It is estimated that karst formation occurs at a depth that exceeds 4,000 meters. Due to such deep conditions of karst formation, Georgia's mountain karst is one of the unique karst regions on Earth.It can be noted that the first three deepest abysses in the world are located in Georgia's high mountainous, Bzipi and Arabika limestone massifs. The abyss of Krubera, which is the world's deepest cave (2,197 m), was discovered by Georgian researchers in 1960 under the leadership of Professors Levan Maruashvili, Sarma (1,830m), and Ilyuzia-Tovliani-mezheni (1,753m). Therefore, the world's record of karst depth penetration is in Georgia, which was established in the Krubera (Voronja) abyss by the Ukrainian Speleological Association.

The karst and caves are of major importance to Georgia due to both their unique geomorphology and diversity. Many of them have diverse and unique speleothems. Researchers discovered the remains of primitive humans living and traces of their activity in many caves. Kudaro, Tsona, Tsutskhvati, Dzudzuana and Jruchula caves are of world importance as archaeological monuments and need to be managed and protected accordingly. Over the years, scientists atVakhushti Bagrationi Institute of Geography made important discoveries through scientific study of Akhali Athoni, Sataplia, Tskaltubo (Prometheus) and other cave systems. Their research contributed to tourism development of these beautiful karst features, yet more work is needed to full understand and protect the cave systems. Throgh the continued work of researchers at the Vakhushti Bagrationi Institute of Geography, the number of documented caves exceeds 1,500 in Georgia and more work remains to be done.

An Investigation of Groundwater Flow in the Vicinity of Patoka Dam, Indiana: Research to Support United States Army Corps of Engineers Dam Safety Risk Assessment

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Several dams throughout the United States have been built on karst terrains, where especially soluble limestone bedrock has been dissolved to form features such as caves, sinkholes, and underground rivers. In such karst regions, subsurface hydrology can play an integral role in the condition, operation, and safety of dams and should be considered during risk assessment and subsequent dam safety management. Patoka Dam, near Jasper, Indiana, is situated on a well-developed karst landscape/aquifer system, faces significant potential challenges, and recently underwent risk assessment. A groundwater flow investigation using multiple fluorescent tracer tests, analysis of water table elevations, isopach mapping of the Glen Dean Limestone, and spring hydrograph analysis was performed to better understand local groundwater hydrology in the vicinity of the existing water control structures that include the dam, grout curtain, dike, and concrete cut-off wall (Figure 1). The previous 2008 risk analysis identified potential failure modes, one of which was abutment seepage and piping failure of the dike and therefore efforts were focused in this area. Results identified the general local flow direction as south to north and indicate that a limited amount of groundwater is bypassing the control structures in the vicinity of the cut-off wall (Figure 2). Groundwater travel times within the Glen Dean Lime-

Figure 1. Aerial view of study area

stone based on initial dye arrival were are 6 to 15 meters per hour; however, mean groundwater velocities based on quantitative sampling were 2 to 3 meters per hour. Tracer tests, potentiometric surface mapping, and interpretation of geologic mapping helped to delineate the recharge area for Robert Hall Cave Spring (RHCS), a significant groundwater discharge point downstream from Patoka Dam, and confirm the existence of a groundwater divide in the area of the dike. Since lake pool elevation is now at or above the elevation of the Glen Dean Limestone, Patoka Lake is now considered within the drainage basin for RHCS. However, based on spring hydrograph analysis and potentiometric surface variability with pool elevation, it appears that the lake, though it influences flow direction and hydraulic gradient, is a minor contributor to the amount of flow at RHCS. In this case, the lake should be considered a secondary region of the drainage basin in that it is hydrologically connected to RHCS but drainage appears to be largely restrained by subsurface hydraulic control structures. In delineating the RHCS basin, with an important groundwater divide, reviewing potentiometric surface variability, and spring discharge as it relates to pool elevation, it could be concluded that groundwater flow in the vicinity of the dike is diffuse and/or minimal, and therefore the likelihood and extent of groundwater pathways may be decreased. However, it should be noted that karst landscapes are dynamic and all results should be viewed as a 'snapshot in time' rather than a description of a static system. This groundwater investigation has offered a clearer characterization of the hydrogeology within the vicinity of Patoka Dam and provided some insight into the function and geometry of the local karst network that could potentially provide subsurface pathways for internal erosion of unconsolidated dam materials and affect the integrity of the dam and/or dike structures. The research as presented is intended to assist managers at Patoka Dam in additional intrusive and expensive geologic investigations, increase certainty in the risk assessment of potential failure modes related to the karst environment in which the dam operates, and inform dam management.

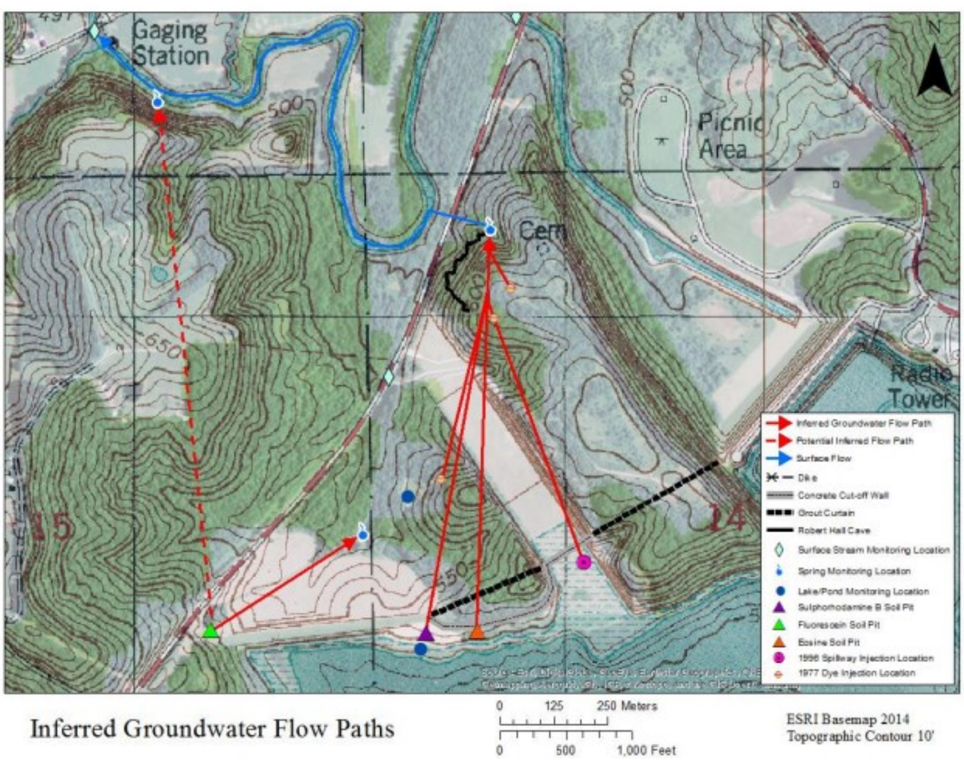

Figure 2. Inferred groundwater flowpaths from all traces

Quantitative Dye Studies to Evaluate the Spill Response System for Mammoth Cave National Park

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Mammoth Cave National Park, an International Biosphere Reserve since 1990, is the world's largest cave with over 400 miles of surveyed passages and a cave ecosystem that is linked to the surface through groundwater recharge. Groundwater, the major component of the cave's formation by causing erosion and dissolution of limestone, still plays a vital role in the continued geomorphic processes that form the cave and its ecosystem. However, the same hydrologic processes that form the cave, make the karst system vulnerable to contamination. With over 500,000 visits per year, it is expected that occasional accidents and spills will occur on the surface. Recharge areas without storm filters and containment basins risk exposing the cave ecosystem to spilled contaminants. The objective of this study was to determine if two temporary small check dams impede chemical transport from the surface into the cave.

The check dams were approximately 2 feet high, 2:1 slopes, and located 100- and 500-feet below tracer release point. Three quantitative tracer studies tests were conducted to test the effectiveness of the check dams. The presence and absence of the check dams were the main variables in the studies. The tracer release point chosen was from a potential contamination source on the surface and the dye was monitored at upper and lower cave passages.

The surface flow channel used in this study was approximately 1,500 feet in length from the tracer release point to the sinkhole. Rhodamine WT-20 dye was released in August, October, (2014) and January (2015) in conjunction with either the onset of storm runoff or as the storm was winding down. Prior to each dye release, the absence of dye was verified by monitoring waters in the cave streams a minimum of three consecutive storms before releasing the dye. The monitoring equipment was placed in the upper and lower cave passages, Cataracts and Cascade Hall area in Silliman Ave, respectively.

Continuous monitoring from June, 2014, through January, 2015, was accomplished using two portable field fluorometers. Additional monitoring for the second tracer study was achieved using 12 passive charcoal sampling devices. For the first test on August 31, 2014, the rainfall depth was a 2.4 inch rain event and 180 milliliters (mL) of Rhodamine were released on the rising limb of the storm runoff. The two check dams were still in place along the surface flow routes. There was a tracer breakthrough in the upper cave passage 9.7 hours after the dye was released. Sixteen hours after the time of the release, approximately half of the recovered dye (center of mass) had moved past the monitoring station in the upper cave passage (Cataracts). The total amount of dye accounted for was approximately 4 mL out of the 180 mL released, which is less than 3% of the tracer used in this study.

We were unsuccessful at detecting any dye in the lower level because of bad placement of the second fluorometer. The second test was initiated on the evening of October 13, 2014 during a 2.1 inch rain event. Both check dams had been removed for this study to estimate the amount of time it would take for the dye to reach the cave with no obstacles. Also, 12 passive charcoal samplers were placed in a variety of locations in the lower level of the cave. Rhodamine dye (600 mL) was released in the rising limb of the storm runoff. During this study it took 4 hours for the dye to be detected in the upper cave passage (Cataracts).

The total amount of dye accounted for via concentration and discharge was 262 mL out of the 600 mL released (43%). Although the fluorometer in the lower cave passage failed to detect any dye again, there were positive tracer results at 5 of the 12 passive sampling locations. Therefore, the fluorometer in the lower cave passage was moved to one of the locations with a positive hit before starting the third tracer study. In the final tracer test on January 3, 2015, 600 milliliters of Rhodamine were released on the declining limb of the storm (a 0.7 inch storm) and was detected in the upper cave passages within 50 minutes. Approximately 38% of the dye was accounted for in the upper cave passage. Trace amounts were detected in the lower level approximately 3.5 days later. Furthermore, subsequent storms produced additional tracer data in the upper cave passage that accounted for another 7% of the dye used in the study. The maximum tracer amount recovered was 288 mL of dye which was 45% of the total amount of dye released. Additional dye detections in subsequent storms had not occurred in the previous two tracer studies. The tracer peaks associated with successive storms after the third study were probably because of the timing of the tracer release in the receding portion of the storm runoff, resulting in tracer transport stalling along the flowpath. Overall, these studies demonstrated that placing the two small check dams along the surface flowpath resulted in lengthening the time-of-travel from 2 hours to 16 hours. It also reduced the amount of dye entering the cave by 90%. Lastly, the third study showed that a chemical released in the last quarter of a storm, may be transferred faster into the cave than chemicals released in the rising limb, with a portion prone to temporary storage.

Additional work is needed to account for the remaining tracer and to better understand the transport and storage mechanisms.

Acknowledgement: The 12 passive charcoal samplers were analyzed by the Crawford Hydrology Lab at Western Kentucky University, C. Salley and L. Bledsoe, analysts.

National Corvette Museum Microgravity: The National Corvette Museum

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On February 12, 2014 a collapse opened beneath the "Skydome" of the National Corvette Museum in Bowling Green, Warren County, Kentucky where several classic Chevrolet Corvettes were on display. The incident garnered global media attention, bolstered by dramatic security camera footage showing eight of the Corvettes dropping into the void. In the hours following the event, EnSafe personnel mobilized to the site at the request of Museum management to work with Western Kentucky University (WKU) representatives in initial assessment of the collapse feature. EnSafe also provided support in evaluating potential environmental and safety concerns at the Skydome during initial response activities.

Based upon EnSafe's experience evaluating subsurface karst features and application of geophysical methods, microgravity was recommended as a relatively low cost, high resolution method to evaluate the extent of the void and aid in identifying other potential karst features beneath the Skydome. Other approaches/methods (e.g., ground-penetrating radar, electrical resistivity, seismic refraction, air hammer drilling) were considered but eliminated for reasons ranging from depth or resolution limitations to safety issues associated with potential subsurface instability.

Ultimately the Skydome was evaluated using three investigative methods implemented sequentially: water jet drilling (during micropile installation for structural stabilization), a microgravity survey, and cave mapping, with excellent correlation of findings among the various datasets. EnSafe was responsible for designing and conducting a microgravity survey, interpreting and presenting the resulting microgravity data, and contributing a team member to enter and map the cave after the microgravity data were collected.

Potential Application of Hugelkultur to Increase Water Holding Capacity of Karst Rocky Desertified Lands

Megan Laffoon, Dr. Albert Meier, Dr. Chris Groves

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Globally, desertification has been identified as one of the most pressing environmental problems due to its impact on agricultural productivity and water availability (Conceição and Mendoza 2008). Desertification is defined as "land degradation… resulting from various factors, including climatic variations and human activities" (Reynold *et al.* 2007). As a result of erosion and vegetation loss, the ability of these areas to sustain life is degraded. Although climate change has been shown to influence rates of land degradation, there is a stronger correlation with human activities (Harriman 2014). While the majority of desertification takes place in arid and semi-arid environments, this is not always the case. *Karst Rocky Desertification* (KRD) refers to areas where the soil loss has created extensive surface exposures of limestone bedrock, particularly widespread through the vast karst area of rural southwest China (Yuan, 1997)

In undisturbed karst systems, the epikarstic zone in the vicinity of the soil/bedrock interface can provide significant storage of shallow water resources. When the soil is lost, precipitation can immediately percolate through the bedrock into deeper, less accessible areas of the aquifer. Without the soil to hold water at the surface, plants and in turn human populations can face desert-like conditions even as groundwater flows beneath.

The Southwest China Karst, once well known for areas of old growth forest, covers 540,000 km^2 of land with several provinces in southwestern China, principally Sichuan, Chongqing, Guangxi, Guizhou, Hunan and Yunnan. Large-scale deforestation and slash and burn cultivation transformed the rural countryside, leaving it vulnerable to degradation (Yuan, 1997). As a consequence, extensive areas have developed KRD and the impact of human activity is indicated as the primary driving force (Wang et al., 2004; Xu *et al.* 2013).

Poverty is widespread in KRD affected areas. Increasing environmental pressure due to population growth and poor agricultural practices on vulnerable soil on karst slopes exacerbates the cycle: poverty to population growth to environmental degradation (Tang and Xia, 2001). Current research efforts focus on breaking the cycle of degradation.

A conjunction of the words "permanent" and "agriculture," the term "permaculture" first originated in a collaborative effort between David Holmgren and Bill Madison to describe an "integrated, evolving system of perennial or self-perpetuating plant and animal species useful to man" and as integrated design science (Mollison and Holmgren 1978). In essence, permaculture is intentionally designed through species selection and overall structure to mimic natural environmental relationships in order to sustain a community.

In the current study, we examined one variation within the permaculture system called *hugelkultur,* an etymologically German word meaning "mound culture." In his book, *Sepp Hotlzer's Permaculture,* Holtzer first describes these raised beds. Hugelkultur beds are made to imitate natural nutrient cycling found in wood decomposition and the high water holding capacities of organic detritus, while also improving bed structure and drainage properties. The beds are, in essence, large, layered piles of woody debris or other detritus under a layer of soil (Holtzer 2011).

We propose that the high organic matter content of the hugel beds will demonstrate a higher water holding capacity (WHC), and enhance soil development, in a way that may show promise as a potential method to help alleviate problems of KRD.

Methods

Soil samples were taken from hugels at three different locations in Bowling Green Kentucky, which has a karst landscape in ways similar to that of parts of Southwest China, beginning in April 2015. We sampled biweekly with a 1.5 cm diameter soil corer. Hugel cores, unless halted by wood, were taken to 30 cm. To determine the amount of water held in a water saturated plot of desertified land, samples were taken on land with similar characteristics to KRD sites i.e. an area dominated by exposed bedrock in Bowling Green, Kentucky.

Soil cores were placed in Whirl-Pak sampling bags and weighed on an electric balance, and then transferred into a paper bag. The samples were then prepared to be oven dried overnight at 120 ^{o}C. The samples were then reweighed to determine changes in soil moisture.

We used a modified formula for the volume of a cylinder to determine the volume of each hugel. Using the wet and dry weights to ascertain grams of water present per volume of sample core, we multiplied the volume of the hugel of origin by the amount of water per volume of soil core to estimate the amount of water present in each hugel.

To project the amount of water that could be held in a 1 hectare field with hugels, if hugels were built to widths corresponding to each test hugel and a footpath of equivalent width was left in between each hugel, the water present per volume of soil core sample was multiplied by the volume of a hypothetical 100 meter long hugel and the number of such hugels that could be built in a hectare. A similar formula was applied to the desertified samples.

Precipitation data was obtained through Kentucky Mesonet (http://www.kymesonet.org).

Results

Over the course of three months, the water levels in the hugels stayed consistently high; the fluctuation in moisture reflected precipitation levels (Figure 1). The saturated sample taken on KRD land showed M = 7.74 ± 2.5 *SD* cm of soil depth and was estimated to hold 154,000 kg/Ha. When compared to the mock desertified area, the hugeled plot demonstrated a much higher WHC M = 955,084 ± 51,038 *SE* kg/Ha. Even through the dry weather periods, hugels contained more water than that held in a water saturated KRD plot.

Discussion

Although hugels required a large amount of initial input of organic material (soil, compost, logs), they can be used for years afterward as a lower maintenance agricultural system. This study suggests that hugel construction could greatly increase water stored on KRD lands (Figure 1). One Ha of hugels con-

Location (Lat/Long)	Sample Name	Date Established	Source Material
36.972450, -86.462412	UUH1	May 2013	Onsite trees and soil, hay and leaves
	UUH2	May 2014	
36.979561, -86.416342	EBH1	March 2014	Nearby trees, aged firewood, onsite soil

Table 1: Hugel location and details

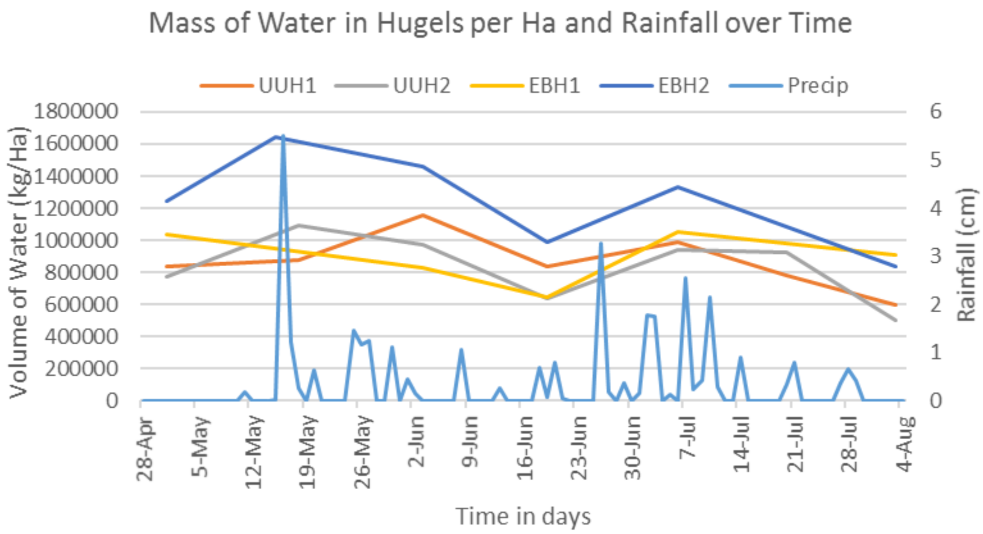

Figure 1:Mass of Water in Hugels per Ha and Rainfall over Time

To project the amount of water that could be held in a 1 hectare field with hugels, if hugels were built to widths corresponding to each test hugel and a footpath of equivalent width was left in between each hugel, the water present per volume of soil core sample was multiplied by the volume of a hypothetical 100 meter long hugel and the number of such hugels that could be built in a hectare. A similar formula was applied to the desertified samples.Precipitation data was obtained through Kentucky Mesonet (http://www.kymesonet.org).

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Discussion

Although hugels required a large amount of initial input of organic material (soil, compost, logs), they can be used for years afterward as a lower maintenance agricultural system. This study suggests that hugel construction could greatly increase water stored on KRD lands (Figure 1). One Ha of hugels contains 3 to 10 times more water than a flat plot of desertified land. In the same amount of land, farmers would be able to store and use more water, and use less irrigation, than if they depended on traditional row cropping. This has potential implications for future productivity of agricultural in areas affected by KRD.

Samples from December 2013 provide a better demonstration of the benefits of hugelkultur using building methods of the sampled hugels more closing mimic the conditions in China. Those hugels were constructed using wood, mulch and limited soil obtained on site. Even with minimal treatment, samples taken from the hugels contained an average of 59% water by gram while the samples from the control, flat land plots, contained 33% water per gram. Unfortunately these hugels were transferred to another owner and destroyed.

In order to be applied in the KRD areas in southwestern China, hugelkultur needs to be effective in several arenas: practical building methods, agricultural yield, and WHC. This study demonstrates its effectiveness in WHC, and research on the yield qualities of hugels is currently being studied. As for construction practicality, flexibility in building materials and the possibility of self-propagation through on-hugel tree cultivation increase the accessibility of productive hugelkultur systems. These systems could be established on the outskirt of rural villages impacted by KRD using available soil in combination with assorted organic matter. Trees could be planted into these hugels along with other indigenous edible or economically valuable plants to create a sustainable, profitable system.

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Isotopic Evolution and Epikarst Mixing in a Telogenetic Karst System: Implications for Contaminant Transport and Groundwater Movement

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There exists a limited understanding of hydrogeologic flow and contaminant transport within karst aquifers, particularly in the epikarst zone, which is highly susceptible to natural and anthropogenic contamination, such as agricultural runoff, due to the interconnected nature of the surface and subsurface. Understanding the storage, flow, and transport dynamics through the epikarst is fundamental to protecting and managing the water quality and quantity of karst aquifers. The epikarst is often where contaminants are located and also where mixing can occur between meteoric and groundwater sources.

Approximately 25% of the world's population relies on karst aquifers for potable water. Currently, federal and state water quality regulations do not recognize karst aquifers as unique entities with enhanced vulnerability to contamination. The National Pollutant Discharge Elimination System (NPDES) allows the US Environmental Protection Agency (USEPA) to regulate point source discharge (factory, house, etc.); however, non-point discharge (e.g. agriculture, forestry, mining, construction, etc.) is more difficult to monitor and regulate. Karst aquifers, especially in south-central Kentucky underlie vast agricultural areas and as such are subject to a broad spectrum of natural and anthropogenic contaminants. These aquifers feed local surface water bodies (rivers and lakes) that are relied upon for recreation, food, water supply, and income. Many surface water bodies in south-central Kentucky are under water quality study for harmful algal blooms, *Escherichia coli* (*E. coli*) loadings, and excessive nutrients (nitrogen, phosphorus). Proper understanding of how these contaminants are introduced to the karst aquifer and the subsequent transport is critical to reducing contamination and improving future water quality.

Crumps Cave in Warren County, south-central Kentucky, is a shallow epikarst cave underlying a large agricultural region near the town of Smiths Grove. The Crumps Cave Preserve, owned and managed by Western Kentucky University, encompasses an approximately 200 meter diameter sinkhole and the entrance to Crumps Cave. Crumps Cave consists of approximately 2050 meters of surveyed passage and averages a depth of approximately 15-20 meters below the surface. This epikarst cave offers a "snapshot" into the evolution and mixing of waters between the surface and the deep regional aquifer more than 45 meters below the surface.

While few tools exist to study the "black box" nature of epikarst dynamics, stable isotope hydrology offers an effective alternative to traditional karst investigative techniques, such as dye tracing, to evaluate flow dynamics and water-soil-rock interactions across a range of spatial and temporal resolutions, particularly with respect to recharge over long periods. Using stable isotopes of water ($^{18}O/^{16}O$ and $^{2}H/^{1}H$), recharge can be traced from meteoric sources through the epikarst, providing insight to the pathways of recharge, flow, mixing, and transport dynamics across multiple spatial and temporal scales in telogenetic karst systems. A secondary method performing base flow separation of multiple discrete storms was used to quantify epikarst storage by comparing recharge volumes with in-cave waterfall discharges.

During 2011-2013, weekly isotope samples were collected from rainfall and an epikarstic in-cave waterfall in Crumps Cave. All samples were collected in 10 mL screw cap vials with no head space and stored at 4°C. Analysis of all samples was conducted at the University of Kentucky's Earth and Environmental Science (UK EES) Stable Isotope Lab. Using the isotope data, along with 10-min in-cave waterfall discharge, precipitation, and geochemical data, the storm, seasonal, and annual transport dynamics of water through the epikarst were evaluated. Campbell Scientific CR10x dataloggers with pH, conductivity, temperature and pressure transducer sensors recorded 10-minute water geochemistry data and discharge of the in-cave waterfall. In a field adjacent to the cave entrance, an Onset HOBO U30 weather station recorded 10-minute meteorological conditions and precipitation.

While seasonal and storm pulses showed significant variation associated with changing atmospheric sources, the epikarst waterfall isotope signal remained constant across the dataset. This homogenizing effect implies mixing occurs in the shallow epikarst zone across both short and long time intervals. Previous estimates of baseflow separation of the waterfall indicated that the epikarst storage is potentially two to three orders of magnitude higher than at regional springs, revealing that storage in the epikarst can play a significant role in recharge and as a mixing zone for contaminant transport.

The results found in this study imply contaminants introduced to the epikarst during different seasons could mix at a rate that influences the contaminant signal throughout the year, particularly at baseflow. Contaminants introduced to the system may remain in the epikarst for longer time periods, possibly multiple seasons, and not flush through the epikarst into the groundwater in shorter time spans. This has significant implications for the assessment and execution of water quality monitoring and regulation.

An Analysis of the Lost River Karst Aquifer's Hydrometeorological Response to Storm Events for Flooding and Water Quality Management

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The purpose of this research is to examine storm event induced flooding and hydrometeorological responses in the Lost Rive Karst Aquifer System. In order to achieve this, precipitation totals from Automated Surface Observing System (ASOS), Cooperative Observer Program (COOP), Community Collaborative Rain, Hail and Snow Network (CoCoRAHS), and Kentucky Mesonet (KYMN) weather stations within the same drainage basin were compared to discharge totals from Lost River Rise (LRR) and Blue Hole Four (BHF), both outputs of the Lost River Karst Aquifer. (Figure 1) ASOS and COOP are both automated, quality-controlled weather networks ran by the National Weather Service. KYMN is also automated and quality controlled, but is ran by the Kentucky Climate Center on WKU's campus. CoCoRAHS is a manual, volunteer-based weather network. All of

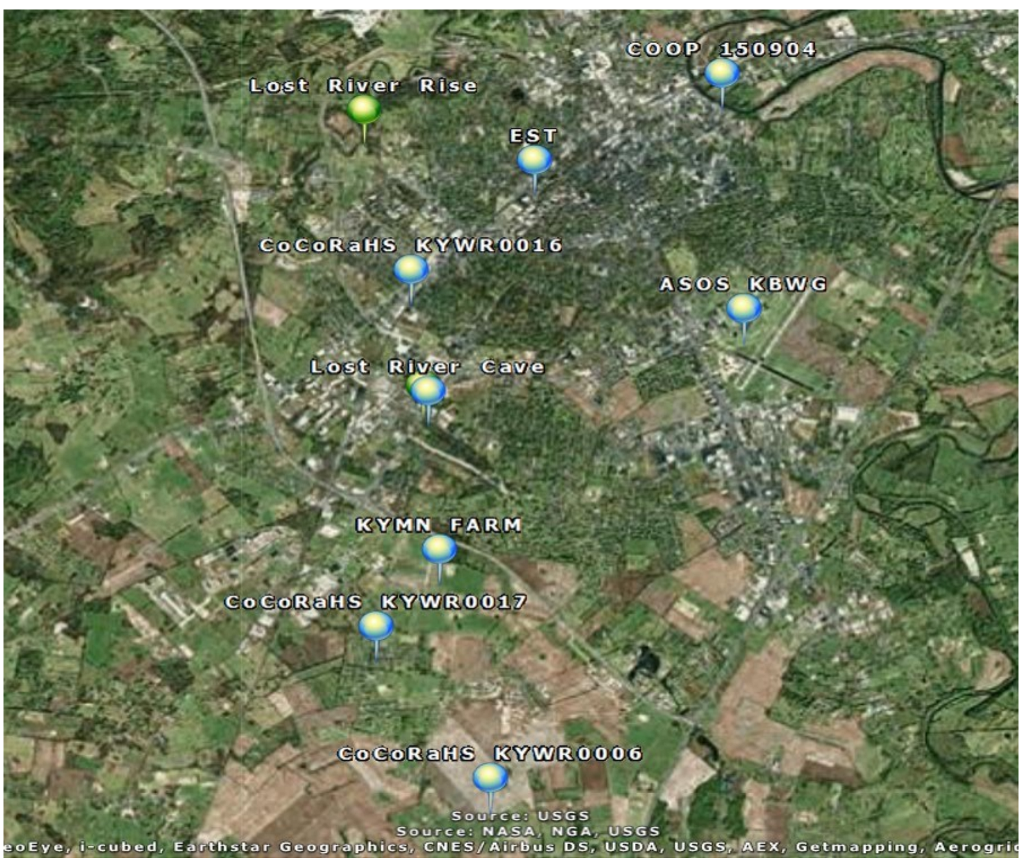

Figure 1 Monitoring locations

the major weather stations that are located in the Lost River Basin were used to make it possible to address the non-homogeneity of precipitation across the basin. Both daily and monthly resolutions were used so that individual storm events could be analyzed, while also focusing on comparison of the larger hydrometeorological responses by comparing those to the baseflow regime. Definite baseflow levels were found at both LRR and at BHF (Figures 2 and 3).

Data were measured and collected for 20 continuous months, with evapotranspiration being accounted for at monthly resolution. HOBOWare and EcoWatch software were used to measure and record data, while SigmaPlot was used for further statistical analysis of storm events to determine predictive flood modeling between the primary output (LRR) and the upstream conduit (BHF). A predictive storm model that helps explain the basin responses in the system to differing storm events was created. The results indicate there are critical thresholds at which the system responds to storm events and that seasonal influences are present. The next step of this research is to pair the geochemical data already being collected with the discharge values, displaying the flux in geochemical composition during storm events. It is also hoped to create a flood mitigation index to better prepare for future flooding events. This research has broader impacts in providing an increased understanding of karst-related hydrometeorological interactions within the Lost River Cave Aquifer System, which pose the threat of flood risk, and possible application to better plan for development in the basin as well as others with similar characteristics.

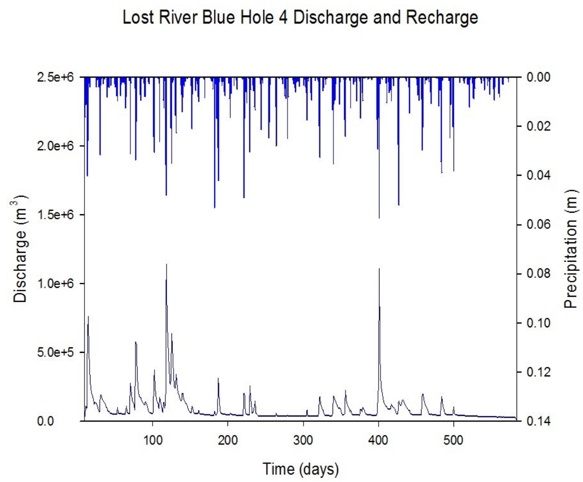

Figure 2 Discharge and Recharge graph for Lost River Blue Hole

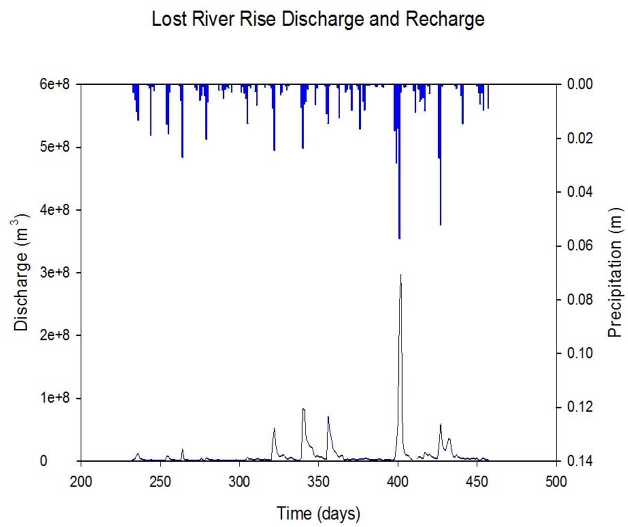

Figure 3 Discharge and Recharge graph for Lost River Rise.

Student Science in the Caverns: Characterizing Drip Water Chemistry at Diamond Caverns, Kentucky

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An investigation of spatial and temporal variations in the chemistry of cave drip waters was initiated at Diamond Caverns, a private show cave near Mammoth Cave National Park, Kentucky during the period May 2007 to July 2008. As part of independent student research projects, undergraduate geology-major students were central to fieldwork, data collection and in the lab analysis, in order to develop both technical experience and critical thinking skills.

Diamond Caverns, as a show cave with a management team that was very supportive of student work and cave researc made an excellent research site due to easy access, security, and the ready outreach opportunities. Because we were allowed to sample during times while the caverns were open to the public, visitors were able to watch the collections and view the collection sites as part of the tours. A goal of the study was to educate the guides in the basics of the collection process so that they could answer visitor questions. A poster showing the process and some results was made available to the management to be placed in the lobby to further the goal of building the relationship between the science and the fun and engagement of the show cave. Tourist caves such as Diamond Caverns offer exceptional locations and opportunities for high-visibility science that are accessible and interesting to visitors curious about the relationship between the natural underground that they are exploring and the overlying surface environment. Many questions they express about the relationships between human activities and water quality and the cave environments could be answered by tour guides using the sample collection points as examples.

Initially, the principal research questions involved a hydrogeochemical study of the H_2O–CO_2–Ca-Mg system in the vadose zone of Diamond Caverns. These specific data and the resulting karst water model were able to shed light on factors influencing the microclimatic and geochemical aspects of the cave. Data from this project add more broadly to the regional understanding of vadose zone geochemistry.

The main objectives of this research were: 1) Physical-chemical characterization of karst waters, and analysis in time and space of parameters such as pH, temperature, CO_2 content, and electrical conductivity; 2) Preliminary evaluation of the relationships between land use, the external atmosphere and soil cover, composition of drip-waters, and the processes of precipitation and dissolution of carbonate minerals and transfer of CO_2, and 3) Involvement of undergraduate students in field research.

Samples were collected approximately every three weeks for 13 months from fifteen sites extending approximately 0.7 km from the mouth of the cave along, or adjacent to, the tourist trail through the cave. The majority of drips came off the end of speleothems, and drip length varied from centimeters to over a meter. After training, the students collected the samples and recorded various parameters within the cave at each site, including CO_2 levels, temperature, rate of flow (drips/minute), and date and time. Water samples accumulated in fixed positions below drips until a minimum of 300 mL was collected. Total volumes of dripwater were measured to estimate rates of infiltration drip at each location. Temperature, pH and alkalinity were measure at the time of or soon after sample collection, All samples were analyzed by the students, again after appropriate training, at the Environmental Research and Training Laboratory (ERTL) at the University of Kentucky. The suite of elements analyzed included Ca, Mg, K, Na, Ba, Sr, Mn, Fe, Ni, Co, Cu, Si, Al, and Zn. These data were used to establish a base composition for dripwaters from Diamond Caverns, identify outlier compositions, and compare these data to both external (above-ground) and cave interior environmental variables. Spatial parameters included CO_2 levels and electrical conductivity, potential groundwater flow paths, and external environmental conditions (e.g. proximity to paved and agricultural areas). There were some complexities involved in establishing a baseline compositions for drip waters, even at a specific site. These included: 1) record drought conditions coupled with a wet winter; 2) complex interactions between meteoric waters and soils and bedrock; 3) variable dissolution and precipitation rates; and 4) evidence of varying source lithologies in the vadose region.

While the initial scientific questions associated with analysis of the dripwaters were of limited use to direct management of the cave, results also ended up showing relationships between surface landuse and drip water chemistry that identified sources of potential, future environmental problems. A detailed cave survey facilitated the comparison of surface features to sampled sites below. Certain elemental abundances, while not at high concentrations (e.g. Cu, Cr, Zn, Fe, Al, Na) were correlated to surface sources of anthropogenic contamination, while elemental ratios (e.g. Ca/Mg and Ca/Sr) were used in conjunction with drip rates to predict which sites were direct conduits to the surface, and which had more complicated vadose zone plumbing. Geochemical variations were compared to meteorological parameters at collected nearby.

Elemental abundances varied over the duration of sampling sometimes by a factor of four or more at a single site. These variations were compared to wet and dry periods, proximity to paved surfaces, drip rates, and lithology. For example, Na abundances and Na/Ca were strongly correlated with areas close to paved surfaces near the cave's visitor's center, roads, and parking lots, perhaps reflecting the use of salt on the roads during winter months. Strong drought conditions in 2007 introduced the possibility of sustained accumulation of heavy/base metals on surface roads and parking areas, which could be washed into the cave during sporadic showers. However, base metal (Zn, Cd, Cu and others) concentrations were a less consistent indicator of overlying paved surfaces than expected. Certain elements (e.g. Ca) did vary with precipitation, as higher Ca concentrations occurred during drier periods while lower Ca concentrations were correlated with wetter periods, particularly near the mouth and at the far end of the trail.

Various elemental ratios (Sr/Ca and Mg/Ca) were used to approximate residence time for waters in overlying lithologies. Higher Mg/Ca in samples near the mouth of the cave suggests stagnation of waters in contact with dolomitic bedrock, while higher Sr/Ca indicate proportionally more calcite water/rock interactions.

This project was designed as a model of a longitudinal study that was executed entirely by undergraduate Geology majors. The students set up a rotation for collecting the samples. They were trained by personnel at the ERTL lab at University of Kentucky and prepared and analyzed the samples under the supervision of technicians there. Each student was able to present different aspects of the research as the project progressed, gaining important experience in disseminating science at professional conferences. These types of studies are ideal for long-term projects, which are difficult to resolve during the limited time available for a graduate student. A series of undergraduates will all gain valuable experience in executing scientific procedures, while contributing to a large data base, also making the entire project more cost-effective by limiting the need for graduate assistantships. The presence of low impact sampling sites increases the value of the visitor experience by demonstrating HOW scientists learn and contribute to the information given by tour guides.

We cannot protect what we cannot understand. Often, groundwater in karst regions and more generally is hidden away and out of site. Sampling directly from caves can give direct access to this often hidden realm. In this case, the next generation of environmental scientists gets a direct insight into the relevant processes in the scientifically appropriate, yet accessible environment of a developed show cave. This setting also presents a natural opportunity public outreach and engagement into environmental science.

Building Resilience against Karst Hazards: A case study of the National Corvette Museum Sinkhole

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Sinkholes are a common part of life in south-central Kentucky, but when a major collapse occurred on February 12th, 2014 at the National Corvette Museum (NCM) in Bowling Green, (Figure 1) residents and the media alike took notice as it received significant attention around the world. The collapse occurred inside the Skydome portion of the building (Figure 2), where eight rare Corvettes fell into the hole that opened in the concrete floor. The Museum immediately began to provide details to the public and made the decision to share information for the sake of transparency and invite help from the community to deal with the unexpected event. Investigation of the sinkhole collapse began immediately while the Corvettes were extracted from the void. Due to the complex nature of the sinkhole's location inside the building and threat of further damage and safety concerns, a multi-disciplinary approach was used to collaboratively bring cave and karst geoscience, geology, engineering, hydrology, construction, and geophysical methods together to investigate and explore the sinkhole and underlying cave passage.

During this time, Western Kentucky University (WKU) worked with the City of Bowling Green, Warren County, and the Museum to disseminate information to the public about the sinkhole. This included educating people that it is not uncommon for landforms like caves, sinkholes, and springs to be found in locations where many people live and thrive everyday. In fact, more than 6,500 sinkholes were reported in the United

Figure 1. The Skydome is located near the contact between the Ste. Genevieve and St. Louis limestones on the Pennyroyal sinkhole plain. Data from the KGS Map Information Service.

States over the last 60 years, with many occurring in Florida, Kentucky, New Mexico, Virginia, and elsewhere. The NCM sinkhole was a less common type of sinkhole, offering a chance to explore and document its investigation and remediation from start to finish.

WKU worked with the City of Bowling Green to provide information through its joint UnderBGKY groundwater awareness campaign, which provided an avenue by which the public could learn more about karst landscapes and the role and formation of sinkholes. To date, the team has created a series of educational resources, including a website, infographics, short videos, and karst visualizations, along with written descriptions of various aspects of living on karst terrains.

There were over 8.5 billion media hits on the NCM sinkhole, which provided an opportunity to engage the public and private sectors in a conversation about sinkhole hazards, including the implications for building codes, insurance, and storm water management in several major karst areas of the U.S. and abroad. Several talks, documentaries, and other events were held to engage the public and interested stakeholders in learning more about karst hazards and their mitigation. Researchers from WKU are also using this trigger to initiate research on ways to learn more about the most effective tools and techniques for educating about karst landscapes, since they are often widely misunderstood.

Through collaborative work within the NCM sinkhole team, a thorough and ro-

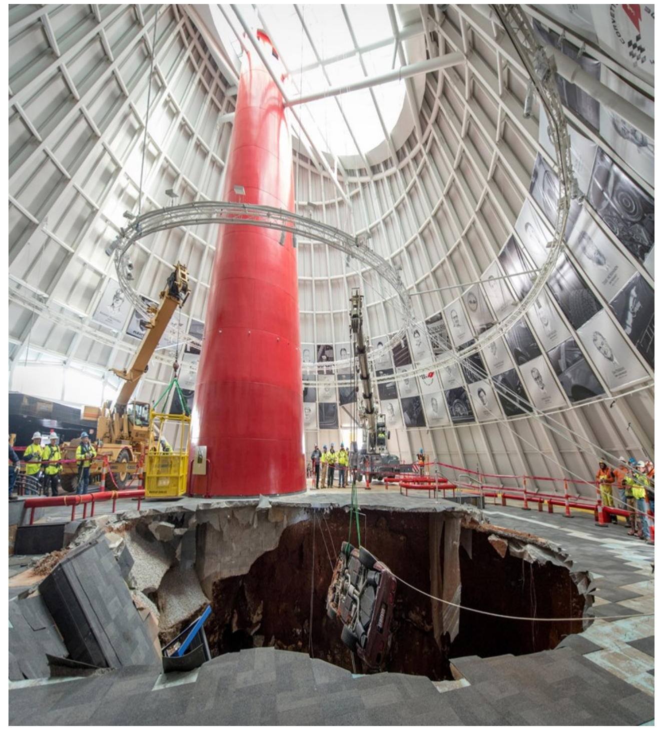

Figure 2, Collapse at Corvettte Museum Skydome

bust investigation of the sinkhole collapse has provided additional data about its formation, impacts, and remediation.

WKU is working with the Museum and an outside consultant to develop a highly detailed, unique, interactive educational exhibit about the sinkhole and karst landscapes that will provide visitors an opportunity to experience firsthand how sinkholes form and get accurate scientific knowledge about karst landscapes.

Collectively, this has highlighted the importance of collaborative karst geotechnical investigations to better understand and remediate karst hazards, such as sinkholes, and the

Analyzing possible influences in Karst Regions Contributing to Harmful Algal Bloom Occurrences in Freshwater Lakes

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HABs, or harmful algal blooms, are occurring in lakes in central Kentucky, which is a large karst region. These HABs consist of blue-green algae (cyanobacteria), which can bloom in high enough densities to pose a threat to human health and ecosystems through the production of cyanotoxins. During the year of 2013, several Kentucky lakes and reservoirs were placed under water quality advisories by the United States Army Corps of Engineers (USACE) in regards to high cell count densities of cyanobacteria, per World Health Organization (WHO) guidelines. Both Nolin River Lake and Rough River Lake (Figure 1) were placed under advisory. These lakes play important roles for the local communities as sources of water, recreation, income, and flood control as well as serving as the communities' economic centers. The HABs pose a threat to these communities, yet little has been done to study their formation or spatial distribution, particularly within the context of karst groundwater inputs. Interestingly, these lakes have had HABs form in winter months, a rare occurrence. This winter bloom phenomenon has not yet been studied, though understanding why it occurs is

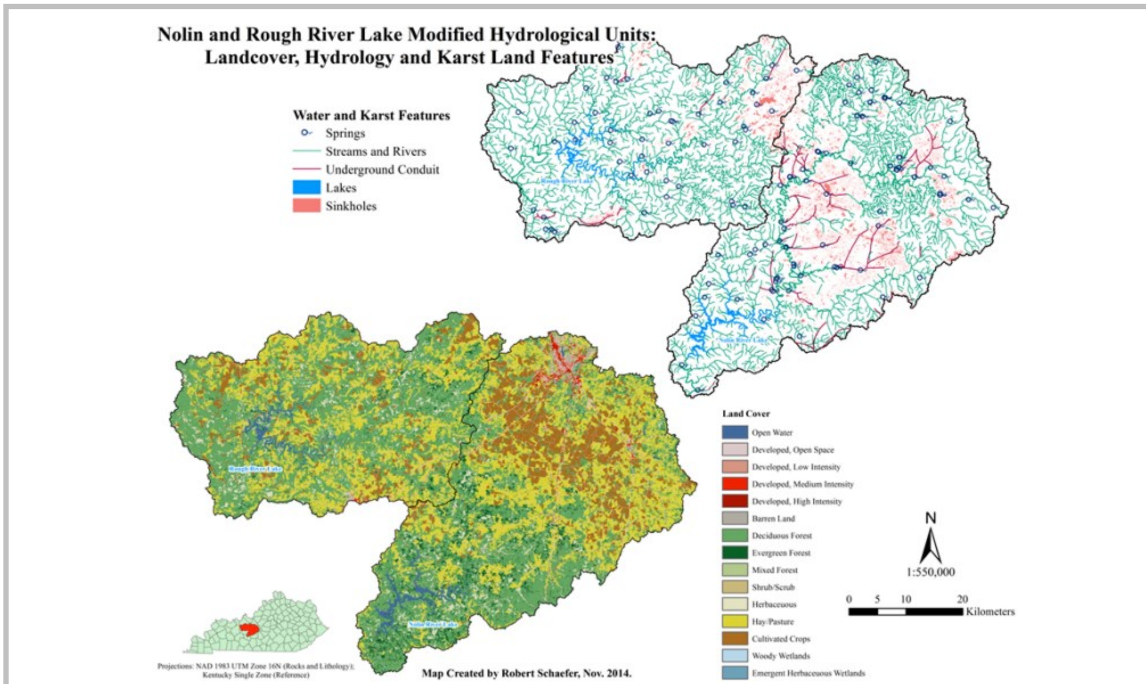
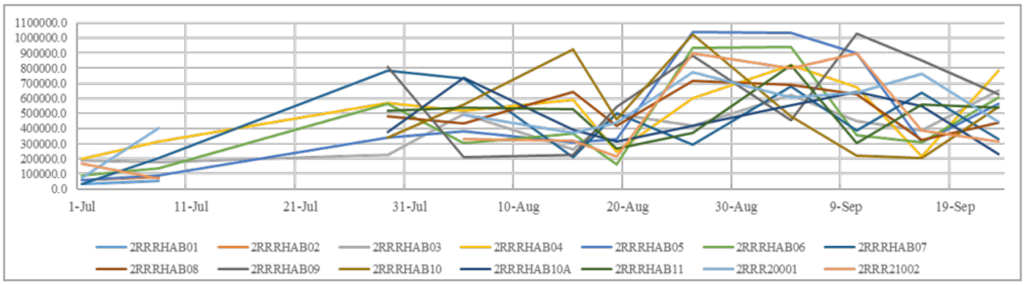


Figure 1: Maps representing the A) land coverage and B) hydrology and karst land features of the modified USGS hydrological units. A) The units have similar land coverage percentages; however, Nolin River Lake's unit has more dense clusters of urban development (data from USGS 2011, 2013). B) Note that the surface water features in the sinkhole plains are very limited. Also, the underground conduit paths are generalized and not representative of the true course. They were found with die tracing (data from KGS 2003, USGS 2013). Included is a reference of the area (denoted in red) is included in the middle map of Kentucky (data from Tiger/Line 2010, USGS 2013).



Cyanobacteria Cell Counts at Nolin River Lake (July – December 2013)

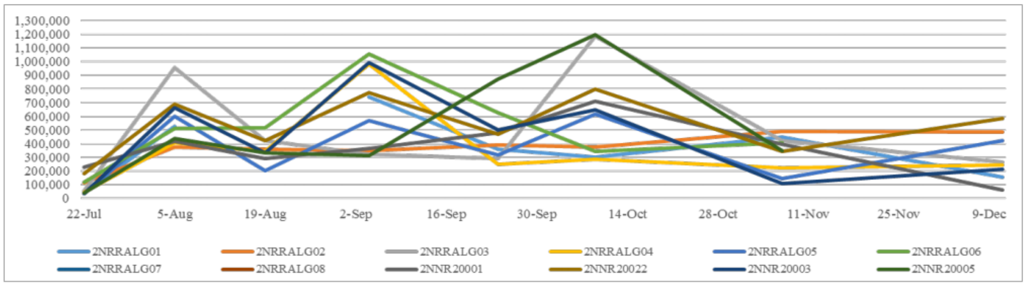


Figure 2: The cell count data collected during 2013 for each lake. The graphs show HABs occurring throughout the seasons, including winter. A dangerous bloom is one that has a cell count over 200,000 cells/mL, by WHO standards.

important due to the health threats presented by these HABs. The USACE monitored the cyanobacteria cell counts in the lakes for the last two years, but the lakes were sampled on different schedules and different selection criteria were used to select the sample sites. Currently, monitoring is being done on a bi-weekly basis for multiple parameters, which include pH, SpC, temperature, nutrients, and N isotopes with sampling sites near karst inputs. Together, these data will be used with the existing data in a GIS to spatially analyze the possible karst influences on HAB occurrences in the two lakes being studied. A spatial analysis of the historic sample sites and cell count data for 2013 were entered into a geodatabase and examined utilizing the inverse distance weighted average tool from Desktop or ArcGIS 10.2.2. Results indicate possible contributions from karst groundwater inputs may be contributing to the timing and occurrence of HABs in these karst influenced lakes, particularly in the winter. Further qualitative analysis using GIS analysis involving the landuse, hydrogeology, and population densities surrounding the lake when paired with the historic bloom data revealed interesting results (Figures 1 & 2). The peaks of the blooms seem to correlate with certain landuse practices that may have an effect on their occurrence. These blooms are seemingly occurring during time periods in which karst influenced groundwater is the likely source of nutrient contamination. The nutrient laced karst groundwater also maybe the cause of the winter blooms.

Figure 2: The cell count data collected during 2013 for each lake. The graphs show HABs occurring throughout the seasons, including winter. A dangerous bloom is one that has a cell count over 200,000 cells/mL, by WHO standards.

Contaminant Mapping and Refugia: Hidden River Cave, Kentucky

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Hidden River Cave has a long history of exploitation as a power and water resource, as a tourist attraction and as the recipient of industrial waste and untreated municipal sewage, culminating in metal contamination, eutrophication and anaerobic conditions in the cave stream in the late 1970s. Upgraded treatment and construction of a trunk sewer in the early 1980s relieved the cave of the contamination, and water quality was restored along with the remarkable return of a variety of cave fauna, particularly the blind cave crayfish (*Orconectes pellucidus*). The geography of the contamination and recovery indicated that much of the recovery arose from a relatively pristine upstream tributary (Wheet River) that apparently acted as a refugium when much of the cave was contaminated.

The catchment area of the Hidden River Cave has been gradually industrialised in subsequent years, and the blind crayfish populations have reportedly declined or been eliminated in response to undocumented contamination events. In collaboration with the America Cave Museum and American Cave Conservation Association, the annual Kentucky field course from the University of Western Ontario has undertaken a longitudinal survey of cave contamination, with the objective of identifying contaminant source and pathways, and possible amelioration and protection. Narrative accounts of pollution episodes were used to loosely characterise the contaminant and its source tributary or inlet. The cave upstream of the entrance was surveyed for blind crayfish populations and evidence of contaminant residues. Water samples were collected from inlets and stream transects and analysed using spectrofluorometry (synchronous scans at delta lambda 20 and 90 nm). Fluorescence spectra were smoothed and normalised to the median fluorescence intensity ($I(med)_\lambda$ by wavelength ($I(norm)_\lambda = Log(I_\lambda / I(med)_\lambda)$) such that relatively high contamination was indicated by values > zero, and relatively clean water by values < zero. Specific fluorescence peaks also indicate particular fluorophores implying the contaminant source.

The narrative, observations and water quality revealed ongoing chronic and acute contamination associated with specific inlets and channels in the cave. These are summarised in table 1. Some contaminants were observed every year and are classified as chronic, others were delivered as on-off episodes and are characterised as acute likely a rising through accidental spills, although residues were often persistent. Other acute events were repeated suggesting more routine release. The annual survey method prevented accurate time demarcation of contamination episodes.

The nature of the contaminant was used to establish a putative land use, while the location and distribution was used to define a likely surface catchment area. Assuming a fairly direct link between the surface and underlying contaminant source allowed prospecting for the respective land use using Google Earth and Streetview. These sites were then investigated in the field to test the inferences arising from mapping.

A number of distinctive, but relatively low impact contaminants proved easy to track down. For example a trail of mulch debris running from the bin into an adjacent sinkhole draining into the headwaters of

Similarly, the plastic beads (#1, commonly called nurdles) are stock material used in plastic forming and injection molding. They were largely found downstream of "Main Corridor", the tributary that had carried the historical sewage effluent into the cave. A major plastic packaging plant lay immediately south of the inlet sinkhole, with a line of stock hoppers arrayed in the catchment area of the sinkhole. No runoff control or filtration protection was evident. An accidental spill of the plastic beads is inferred to have been washed or carried in runoff into the adjacent sinkhole and into the cave.

The organic waste events (#3, reported as foul smelling effluent with LNAPL blobs) are found in the Wheet River, but have an impact on all downstream reaches of the cave river. Various industrial plants occupy the upper Wheet River catchment, but the most likely source is a regional wastewater treatment plant established to handle waste from a bakery and condiments factory. The plant removes grease and solids (that are carried away by truck), digests the high BOD waters and passes the partically treated water to the regional sewage treatment plant. The Google Earth historical imagery reveals that this plant was created around 2008, but has expanded with the addition of runoff control and a waste lagoon in 2011. Informal narrative accounts indicate that excess load or mechanical failure lead to release of untreated or partially treated waste. Before construction of the lagoon, this waste would have entered a closed depression upstream of the Wheet River headwaters. Even after construction of the lagoon, field inspection has revealed collapses in the floor, and any waste entering the lagoon is left to discharge to the sinkhole, albeit at a reduced rate. Plans have been made to line the lagoon to reduce the risk of collapse.

The cave stream is lost under breakdown in the midsection of the cave, but a number of inlets convey contaminants that are seen in the downstream river. The most egregious source of contamination is a 6" drainage well that is inferred to open on the surface where it drains a pre-mix concrete operation. Streetview imagery reveals the forecourt of the plant being hosed down with runoff draining towards the well. Field inspection shows trucks being washed with contaminated runoff draining into the drainage well. The on-site settling pond is not functional.

The waterfall inlet has very distinctive contamination with steady flow (regardless of drought conditions), very low ambient fluorescence and odor of chlorine implying a drinking water source, but with the persistent presence of a distinctive fluorescein peak (512nm). The most likely source for this is a nearby carwash. Streetview and field inspection reveal runoff entering a drain that is inferred to soak away into groundwater. Various fluorescent dyes are used in Car wash soap solutions to increase the apparent brightness of the finish.

Oil and fuel contaminants in other inlets through the midsection of the cave may be from local garages, or a somewhat chaotic recycling yard that drains into a series of collapsing sinkholes.

Kneebuster contamination presents problems as this tributary has served as an important refugium and educational resource. A blob of DNAPL was observed in 2008, with dead crayfish on top. The most recent event occurred in summer 2015, when an oily black ooze entered from a side passage, eliminating all crayfish from the passage. These episodes are interpreted as "legacy" contamination sequestered in sediment deposited in the 1970s. Unfortunately, these materials retain their potency through many years

The final source of contamination is a small inlet that exhibits slimy overgrowths and a persistent peak at 410nm suggesting laundry brighteners in domestic sewage. The source of such contamination cannot be narrowed down, although the regional trunk sewer runs just overhead of this point in the cave.

The sinkhole plain topography means that surface runoff will inevitably drain into sink points in their respective closed drainage basin, with any ponding bypassed by construction of enhanced injection wells or bedrock soakaways that ensure recharge of unfiltered water. There is little prospect of taking surface runoff elsewhere. However, many of the sources of contamination could be ameliorated if not prevented by construction of runoff controls such as screens or oil-grit separation tanks. This does not appear to have been a priority, although many industries are keen to establish their environmental responsibility, and would likely support such protection.

Improving Stormwater Treatment Efficiency Based on Runoff Properties at Mammoth Cave National Park.

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_*Acknowledgement: Thomas Byl*[1,3]

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Mammoth Cave National Park is the home of the longest cave and one of the most biologically diverse cave species and biotic cave communities in the world. With more than half a million visitors are attracted annually, anthropogenic contaminants from human activities,and vehicle traffic and development can be carried by storm runoff into groundwater and into the cave. , and Contaminants in the storm runoff can threaten the aquatic habitat of rare and endangered species. The objectives of this research waeres to determine the amount and sources of major pollutants, analyze the treatment efficiency of the current stormwater treatment system, and provide improvement solutions to increase the stormwater treatment efficiency.

In this research, preliminary sampling was performed to get a betterrief understanding of the storm runoff. Natural and simulated storm samples were collected and analyzed with grab sampling. YSI datasondes equipped with specific conductivity and turbidity probes was also used to optimize the sampling strategy. The result from preliminary sampling indicated that most of the dissolved constituents and suspended solids were accumulated during the dry period and carried into the drainage system during the first-flush of storms. Based on this observation, passive first-flush samplers were designed, constructed and installed at the storm drain inlets. Concentration of pollutants collected from the samplers between 2011 and 2013 were used in regression analysis to determine the correlations between pollutants from storm runoff and the surrounding environment of different locations. Range of concentration of three major pollutants determined from first-flush samples are as follows.: Zzinc concentrations ranged from 0.0 to 0.72 mg/L and copper concentrations ranged from 0.9 to 31.4 mg/L. Zinc and copper are commonly found in vehicle tires, brakes pads, aged rood, and drainage pipes. These two pollutants are also abundant in the nature, but they are toxic at high concentrations. Quaternary ammonia compound (QAC) concentration rangeds from 0.071 to 0.206 mg/L, and it is can be found int detergentcleaners, sanitizer, Lysol®,WNS biosecurity stations (2011-13) and disinfectants in RV recreational vehicle sewage tanks.

Data compiled from several sites and storm events were used to run regression correlations based on the length of dry period between precipitation eventss and, the basin size and contaminants. A strong correlation was found between the length of dry periods and the increase in specific conductivity, as well as, and the concentration of copper. It should be noted that tThe correlation does not imply cause and effect. However, it is reasonable to assume long dry periods allow greater accumulation of potential dissolved solids such asand heavy metals from the parking lot runoff. The amount of zinc and QAC in the first-flush samples and the basin sizes also showed a strong correlation in which both the amount of zinc and QAC increased with the increase in basin size. This correlation can be explained by the land- use distribution of the targeted basins that are consisted of mainly parking lots and developmentwalkways. The increase in human and vehicle traffic and on the development impervious surfaces increased the potential and the amount of contaminants to be carried by storm runoff.

Currently, a stormwater filter system is used for treatment of storm runoff at Mammoth cave National Park. The system was designed in 2003. The main treatment mechanisms of the system involve filtration and adsorption of pollutants with filter materials or adsorbents in the filter cartridges, and filtration of debris by hydrodynamic separators. The suggested lifespan of the treatment system before maintenance by the manufacturer is about 2 years. This research studied the treatment efficacy of the adsorbents, ZPG® and determined the lifespan of the treatment system based on local conditions. The filter material, ZPG®, consists of Zeolite, Perlite, Granular Activated Carbon (GAC), and is collected from the Stormwater Management StormFilter® for this study. Each sorbent has its specific treatment strengths, and a combination of media can constitutes a more effective configuration than single media, and to meet a wide range of treatment goals.

BThe batch method was used in the experiment to determine the adsorption isotherms, rate and capacity of ZPG®. Adsorption of Cu(II) and Zn(II) were found to fit the Langmuir Adsorption model which indicates that the adsorption of Cu(II) and Zn(II) are by filtration with the micro-sized pores in ZPG™ and cationic exchange with the metal ions on the surface of ZPG.™ The adsorption of Cu(II) and Zn(II) were found to have rapid initial rate and became stable within 24 hrs which indicated that the adsorption rates decrease with time. These results can be explained by the competitive effects between metal ions in the solution. Once the adsorption site is occupied, it will not be available for further adsorption. For QAC adsorption, it wais found to fit the Freundlich Adsorption model which indicates that the adsorption process is mainly by filtration and intermolecular attraction forces between QAC and ZPG™. Multilayers of QAC form on ZPG™ which agreed with the experimental results that percentage of QAC removal increases with the increase in initial QAC concentration. The increase in amount of QAC bound onto ZPG™ increase the available improves the surface area for adsorption. Adsorption capacity of Cu(II), Zn(II) and QAC was found to be 8.83×10^{-3} mg/g, 0.256 mg/g, and 8.93×10^{-2} mg/g respectively. With the annual loads estimated from the runoff studieswith the capacities, 2 year precipitation intensity and average pollutants concentrations found from field water samples, the lifespan of ZPG™ was estimated to be at least 2.82 years based on the performance of Zn(II) adsorbed onto ZPG™.

The result from the filter material tests indicated that the efficacy of the filter systems decreased with time. The decrease in efficacy also followed withmay be due to leaves clogging of the filter flowpath. Furthermore, organic some pollutants can be washed off by strong intense flush events because of the weak intermolecular force. Problems also found at the hydrodynamic separators in which large amount of leaves andplant debris detritus were accumulated which caused clogging of drainage pipes every deciduous seasonimpaired flow, especially in the fall. Because of the short lifespan and high maintenance cost and frequency, an alternative treatment solution should be considered for future stormwater systems. EPA indicates that biorRetention pondsarea is an ideal stormwater management BMP for parking lotsin conjunction with storm filters may provide the better service and increased life spans. Bioretention areas utilizes soils, and both woody and herbaceous plants to remove pollutants from storm runoff by sedimentation, soil adsorption, natural degradation, and plant adsorption. The removal effectiveness of different pollutants with this method are found to be 43-97% for copper, 64-95% for zinc, 52-67% for total kjeldahl nitrogen, and 92% for ammonium. Bioretention utilizes the natural area to treat stormwater, which saves construction, filter material, and maintenance costs. The approximate construction cost suggested by EPA is about $6500 for each bioretention area.

Disclaimer: Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government or Tennessee State University.

The Origin of Jewel Cave and how it supports cave management decisions

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Introduction

With over 175 miles of passages, Jewel Cave is the third longest cave in the world. This paper documents the intimate relationships between the cave and present-day geologic structure, contacts, and topography. It presents a conceptual model for further investigation of the origin Jewel Cave.

Principles of Cave Development

Carbonate caves typically form in three stages: 1) fracturing, 2) phreatic dissolution, and 3) vadose enlargement. Vadose activity only occurs after the cave drains and begins to pirate surface streams – something which didn't occur in the Black Hills area. Moreover, the dissolution of caves depends on the existence of a natural mass transfer system. Movement of mass from location to another requires: 1) a solute (limestone), 2) a solvent (acidic solution), 3) a transport medium (groundwater), 4) a continuous flow path, and 5) an energy gradient (elevation difference between recharge and discharge areas).

Geomorphological Framework

Jewel Cave stays in the upper 250 feet of the Pahasapa Limestone, which is locally 430 feet thick. Its passages strongly correlate with the modern surface topography: they are large and mazy beneath the hillsides, but diminish in size and complexity as they approach the drainages; so the processes that shaped the topography must also have been responsible for forming the cave at the same time.

Also, the cave exhibits a strong correlation with the geological structure, as it exists today. Hell Canyon is aligned with the axis of a south-plunging syncline, and the cave itself wraps around a curved strike, dipping toward the plunge of the syncline.

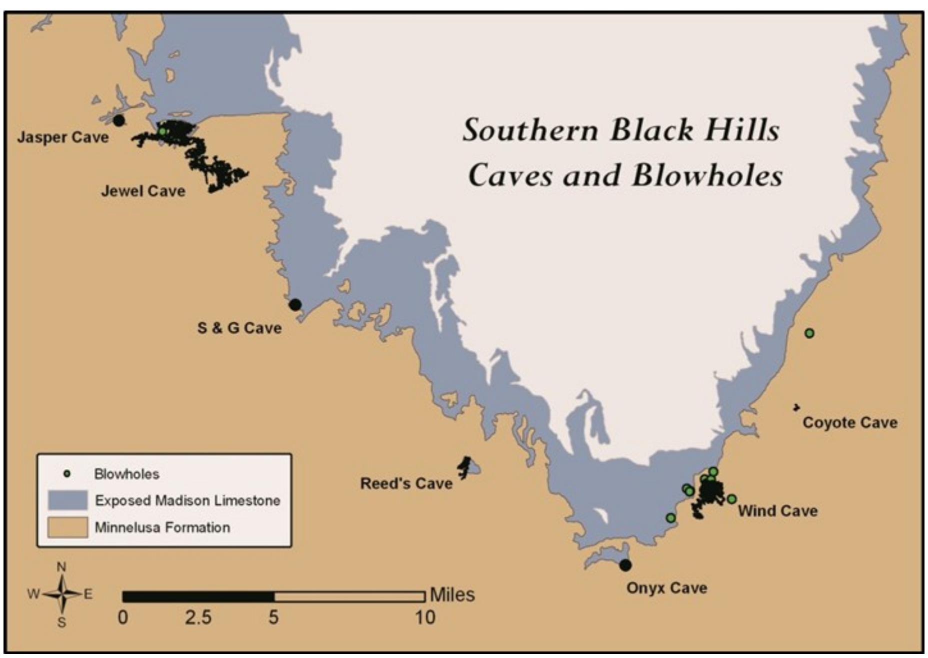


Figure 1 - Large caves are found only beneath the Minnelusa cap.

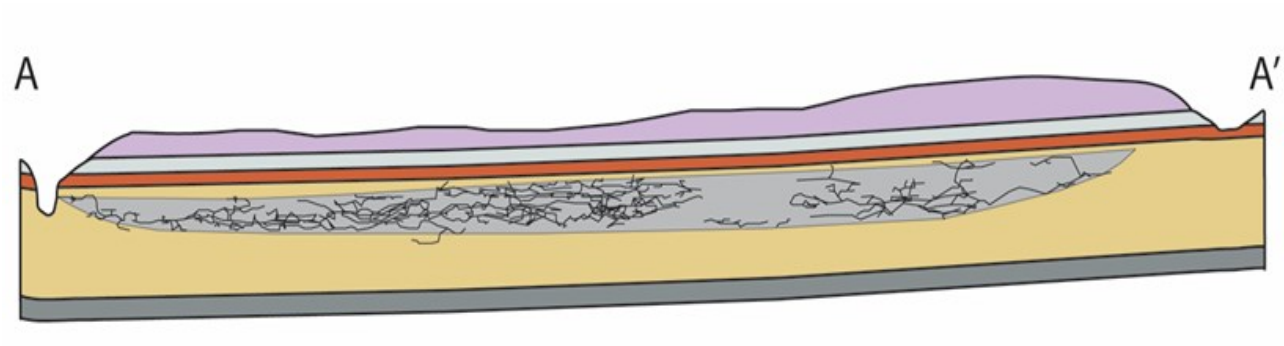


Figure 2 - Cave passages form a lens shape that thins where it approaches surface drainages.

Additionally, nearly all cave passages in the southern Black Hills lie beneath a Minnelusa cap (Figure 1), so it is obvious that the Minnelusa once played a role in forming the passages. There no large caves (remnants of large cave systems) in the uncapped portions of limestone, and none are greater than 500 feet in length. Therefore, the large cave systems could not have formed until *after* the Minnelusa cap eroded back to its present configuration.

Finally, the shape of the solutionally enlarged fractures is a lens that thins out as it approaches the surface drainage at each end (Figure 2). Throughout the Black Hills, it is common for cave passages to diminish in complexity and rise up when they approach surface drainages.

Paleohydrology

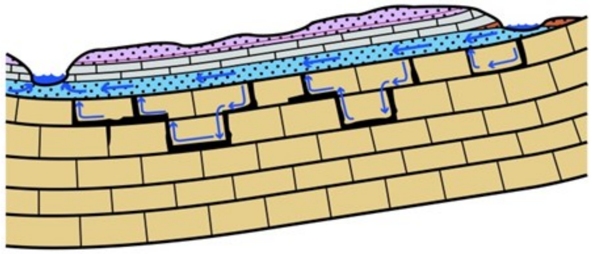
The Englewood Limestone underlies the Pahasapa, but the lower 15 feet is actually impermeable red shale, which prevents water rising from below. The presence of 15 feet of red shale above the Pahasapa precludes the direct infiltration of meteoric water into the fractures of the Pahasapa. However, a 40-foot subunit of permeable Minnelusa sandstone rests on top of the Pahasapa Limestone. A 50-foot subunit of Minnelusa limestone with interbedded clastics lies immediately above, and is overlain by the basal shale of a third Minnelusa subunit. Based on literature, the basal sandstone is assumed to have a permeability of about 10%, and could have served as an initial confined aquifer, supplying water to the developing cave system. It outcrops at Pass Creek and Teepee Canyon – assumed recharge areas, and at lower elevations in Lithograph and Hell Canyons – assumed discharge areas.

Carbonic acid is assumed to be the solute. Because the sandstone aquifer was confined, the carbonic acid wouldn't lose its aggressiveness through degassing. Therefore, it could maintain full aggressiveness over the entire distance from recharge to discharge. Additionally, the effective permeability of sandstone is 3-6 times greater than the cave-sized permeability in the limestone. So the dilution of the acidity in the sandstone, caused by the depleted water returning from the limestone, would be minimal.

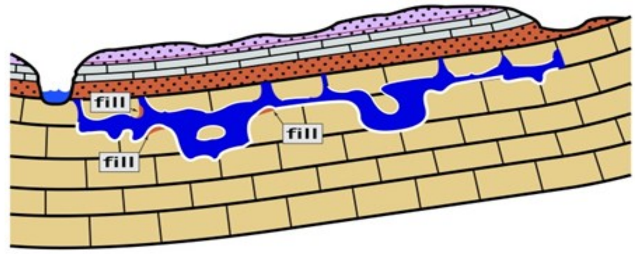
Sequence of Events

Stage 1 - Because the sandstone is much more permeable than the initial state of either limestone (above or below), the water would first flow almost exclusively through the sandstone. However, it could circulate down into the discontinuous fractures in the Pahasapa Limestone, and back up into the sandstone, as long as it emerged at a point of lower energy gradient. (See figure 3a.)

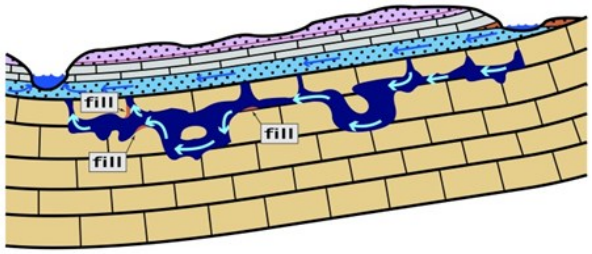
Stage 2 - The discontinuous nature of the fractures would result in isolated cells of dissolution, which would begin to coalesce as the nascent cave passages were enlarged. The basal Minnelusa sandstone would sometimes collapse into the still-developing cave passages. (See figure 3b.) This model anticipates the fill entering contemporaneously with cave development,



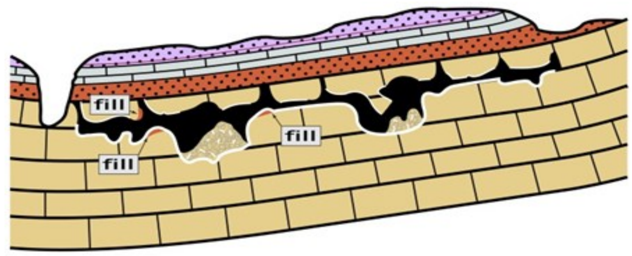
3a- **Stage 1** of cave development



3b - **Stage 2** of cave development



3c - **Stage 3** of cave development



3d **Stage 4** of cave development

Figure 3. Stages of cave development

rather than 300 million years earlier, so the fill is best described as *neofill*, rather than *paleofill*.

Stage 3 - Once Hell Canyon (and Lithograph Canyon) had cut all the way through the sandstone aquifer, the sandstone would drain and stop functioning as a confined aquifer, and the water remaining in the Pahasapa would be essentially stagnant. Unenlarged fractures may have slowly drained water from the cave. Once air entered the aquifer, the water would begin to degas. This would cause cave water to become supersaturated, and precipitate the ubiquitous calcite spar on cave surfaces. (See figure 3c.)

Stage 4 - As the water drained, buoyancy was removed, and many of the larger rooms collapsed into piles of breakdown. (See figure 3d.) With further draining, air connections became more integrated, and barometric air flow became more prominent.

Timing

Using known physical parameters and estimating hydrological and chemical properties, a calculation estimates 1.1 million years as the minimum amount of time for the cave to form. The deposition of calcite spar essentially marked the end of cave development. A pair of U/Pb dates at suggests that the spar began forming later than 26 ma, probably around 15 ma. Since the $CaCO_3$ equilibrium is controlled by dissolved CO_2, once the CO_2 was removed, the precipitation would have become irreversible, and might have taken only a few hundred years. Depending on the nature of the older dated substrate, the cave could have formed as recently as 15 million years ago.

Orthoquartzite clasts are found along the western and southern flanks of the Black Hills, but no local source has been found. The clasts are scattered across 1,500 square miles around western and southern flanks of the Black Hills, from 7,000 to 3,700 feet elevation. They crosscut several stratigraphic units, so are one of the newest features of the landscape. Three clasts have been found in Jewel Cave. One is beneath, and therefore older than, the spar. This supports a geological recent origin for the cave.

Conclusions

The model is geomorphically compatible with surface and cave features. It explains the development of cave passages with 1) no direct recharge from meteoric water, 2) no hydrothermal recharge from below, and 3) no paleokarst origins. The cave could have formed in as little as 1.1 million years, as recently as 15 million years ago.

Biology
Jerry Lewis, Chair

Managing the spread of *Pseudogymnoascus Destructans* and conserving Bats threatened by White-Nose Syndrome in North America

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Bats in North America face numerous challenges, including habitat loss, climate change, environmental contamination, and energy development, but none is as immediate a threat to multiple species as white-nose syndrome, a fungal disease that is responsible for unparalleled rapid declines in bat populations. White-nose syndrome (WNS) was unknown to science before discovery in New York in January 2007 (Blehert *et al*. 2009). Since that time the disease has spread to at least 26 states and five Canadian provinces, and the fungus causing the disease, *Pseudogymnoascus destructans* (*Pd,* Lorch *et al.* 2011), has been documented in three additional states: Minnesota, Mississippi, and Oklahoma (see current map: www.WhiteNoseSyndrome.org). Genetic analyses indicate the fungus is likely not native to North America and that human activity may have led to its introduction. *P. destructans* may have originated in Europe where the fungus has been detected on 13 bat species, 11 of which have been confirmed with WNS based on our current case definitions. There have been no documented deaths of European bats from WNS, however.

From what appears to be a single point of introduction to North America, *Pd* has spread rapidly, propagated largely by bat-to-bat or bat-to-environment-to-bat contact. Human-mediated transmission also may have contributed to the spread based on the potential for the fungus to be carried between caves on clothing or personal gear (USGS 2009), the ability of the fungus to remain viable for long durations in the absence of bat hosts (Lorch *et al*. 2013, Hoyt *et al*. 2014), and conspicuous longer distance jumps to heavily visited caves before detection at large bat hibernacula close by. The fungus infects torpid bats resulting in physiological and behavioral impacts, often leading to mortality. Population declines exceeding 90% have been documented in affected hibernacula during winter surveys (Turner *et al.* 2011), and corroborated by estimates of colony size and activity during summer. The international response to the disease has been rapid, and has resulted in considerable advances in our understanding of the pathogen and the disease to the extent that we are beginning to see progress in the development of potential tools and strategies designed to better manage *Pd* and the impacts of WNS on bats.

In the United States, WNS research, management, and conservation activities are coordinated through a common collaborative strategy outlined in: *A National Plan for Assisting States, Federal Agencies and Tribes in Managing White-Nose Syndrome in Bats* (USFWS 2011). The U.S. national plan is mirrored in Canada by a sister plan: *A National Plan to Manage White-Nose Syndrome in Bats in Canada* (CWHC 2015). Despite the advances made in our understanding of the mechanics of this epizootic, including pathology, transmission, dynamics, and ecological requirements of *Pd*, the best tools currently available are still those

Table 1. Bat species on which white-nose syndrome (WNS) has been confirmed based on approved case definitions, or on which at least one individual has tested positive for *Pseudogymnoascus destructans* (*Pd*) using molecular identification techniques

	Positive for WNS	***Pd* Present**
North America		
	Big brown bat (*Eptesicus fuscus*)[1]	Eastern red bat (*Lasiurus borealis*)[2]
	Eastern small-footed bat (*Myotis leibii*)	Southeastern bat (*M. austroriparius*)
	Gray bat (*M. grisescens*) ***endangered**	Silver-haired bat (*Lasionycteris noctivagans*)[2]
	Indiana bat (*M. sodalis*) ***endangered**	Rafinesque's big-eared bat (*Corynorhinus rafinesquii*)[2]
	Little brown bat (*M. lucifugus*)[1]	Virginia Big-Eared Bat (*C. townsendii virginianus*) ***endangered**
	Northern long-eared bat (*M. septentrionalis*)[1] ***threatened**	
	Tri-colored bat (*Perimyotis subflavus*)[1]	
Europe		
	Greater mouse-eared bat (*M. myotis*)[3]	Whiskered bat (*M. mystacinus*)[5]
	Daubenton's bat (*M. daubentonii*)[4]	Lesser mouse-eared bat (*M. oxygnathus*)[6]
	Bechstein's bat (*M. bechsteinii*)[4]	
	Natterer's bat (*M. nattereri*)[4]	
	Brandt's bat (*M. brandtii*)[4]	
	Geoffroy's bat (*M. emarginatus*)[4]	
	Pond bat (*M. dasycneme*)[4]	
	Northern bat (*E. nilssonii*)[4]	
	Barbastelle (*Barbastellus barbastellus*)[4]	
	Brown long-eared bat (*Plecotus auritus*)[4]	
	Lesser horseshoe bat (*Rhinolophus hipposideros*)[4]	
1 - Blehert et al. 2009; 2 - Bernard et al. 2015; 3 - Pikula et al. 2012; 4 - Zukal et al. 2014; 5 - Martinkova et al. 2010; 6 - Wibbelt et al. 2010		

that reduce the risks of human-mediated transmission of the pathogen and reduce disturbance to bats during hibernation.

In North America, seven bat species have been confirmed with WNS, and five additional species have been detected carrying *Pd* (Table 1). *P. destructans* is a psychrophilic (cold-loving) fungus that grows best in cool, wet conditions (growth range between ~ 1 and 19°C, Verant *et al*. 2012). Such conditions are common for caves and mines across the continent (Perry 2013), and hibernating bats in every state may be found using these same cool and humid conditions. Like most fungi, *Pd* produces spores and hyphae (filamentous

Table 2. Evidence and supporting publications or sources providing evidence that human actions may contribute to the spread of *Pseudogymnoascus destructans* (*Pd*) and affect survival of bats affected by white-nose syndrome (WNS).

Evidence	**Supporting publications and reports**
Pd can persist and grow in the absence of bats.	Lindner et al., 2011; Lorch et al., 2012; Lorch et al., 2013; Peuchmaille et al., 2011a; Reynolds et al. 2015
Spores of *Pd* can remain viable outside of subterranean environments.	Puechmaille et al., 2011b; Hoyt et al. 2014
Spores of *Pd* can cling to clothing and footwear and can be inadvertently transported out of contaminated sites.	J. Okoniewski, unpublished data; H. Barton, unpublished data; USGS - National Wildlife Health Center, unpublished data
Pd may be present on bats or in bat roosts without being visibly detectable.	Dobony et al., 2011; Langwig et al., 2015
Spread of *Pd* may be slowed by geographic or biological barriers to bat movements that may not be barriers to human movement.	Miller-Butterworth et al., 2014
Repeated and/or prolonged human disturbance during hibernation is detrimental to bats, especially bats already stressed by WNS.	Boyles and Willis, 2009; McCracken, 1989; Mohr, 1972; Reeder et al., 2012; Thomas, 1995; Tuttle, 1979
If done correctly, current decontamination procedures have a high probability of significantly reducing the risk of spreading viable *Pd*.	Shelley et al., 2013

vegetative growth), and is capable of asexual reproduction through spores and hyphal fragmentation. The spores can persist for extended periods in suboptimal conditions, including wide temperature and humidity ranges (Lorch *et al.* 2013). Fungal material can adhere to substrate, fur, hair, clothing, shoes, etc. (collectively referred to as "fomites"), and thus, can be moved large distances by bats, humans, or other carriers. As a consequence, human visitation to caves and mines increases the risk of contributing to the spread of WNS to uncontaminated areas through inadvertent transport of *Pd*. The containment strategies developed for WNS include: 1) cleaning and treating (hereafter, decontamination) of gear, clothing, footwear, and any other surfaces that might have been exposed to *Pd* and may subsequently come in contact with hibernating bats or their habitats, and 2) the reduction or prevention of opportunities for people to encounter, transport, and transfer *Pd* spores or vegetative structures to bats or naïve environments.

The U.S. Fish and Wildlife Service developed guidance for decontamination procedures (Decontamination Protocol, 2008) as well as recommendations for regulation or restriction of human activities likely to pose a risk for spreading *Pd* (Cave Advisory, 2009). These documents were developed in consultation with state and federal partners that would later join together formally under the collaborative national response plan. The national plan provided further support for the importance of containment strategies for managing infectious agents, and describes the ways in which universal precautions are implemented to reduce incidence of disease by preventing infections and breaking chains of transmission. The Decontamination Protocol has been revised regularly in response to research results that further our understanding of the compounds and procedures known to effectively kill spores of *Pd* (e.g., Shelley *et al.* 2013), and to include a wider variety of applications. The Cave Advisory has also been reviewed regularly, and has been the focus of considerable discussion within the WNS response community, but had not been formally revised until recently (revision under final review). While some have questioned the risks associated with human-mediated spread of *Pd*, the weight of scientific evidence in support of these protocols and recommendations continues to grow (Table 2). Additionally, members of the WNS Steering Committee have agreed to endorse the most recent versions of the two documents as national guidance, so they now represent an agreed upon set of recommendations from state, federal, and tribal agencies engaged in the national response. Updated versions of the National Decontamination Protocol and National Recommendations for Managing Access to Subterranean Bat Roosts (replacing the Cave Advisory) will be released in coming months.

Dedication and commitment of the many individuals, institutions, and government agencies who have engaged in this issue and lent their support has produced both great progress in our understanding of WNS and ability to respond to it, and significant contributions to broader scientific advancement. Healthy bat populations contribute to strong ecosystems and provide beneficial ecosystem services, thus our efforts to control and reduce the impacts of WNS on North American bats is of the highest priority.

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Strip Adaptive Cluster Sampling with Application to Cave Crickets

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Adaptive cluster sampling (ACS) is a strategy for sampling rare populations and can provide more precise estimates for population means and totals than other designs such as simple random sampling (SRS). Adaptive sampling responds in real-time to conditions on the ground and allows sampling effort to increase where clusters of observations of interest occur. This is a case study involving cave crickets in Mammoth Cave National. We used strip ACS, a 2-stage extension to standard ACS designs, to estimate population sizes of these rare endemics and considered both the practical and statistical performance of these approaches relative to SRS. We demonstrate its practical implementation and briefly discuss issues such as plot set-up and data management, computation of population estimators and confidence intervals.

Monitoring in-cave Resources with Reduced Impact and increased Quantitative Capacity: Developing Photogrammetry Methodologies for in Cave Environments

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Introduction

Photogrammetry is a methodology developed to use photographs in order to accurately measure the size, location, and context of 3D objects (Mikhall et al. 2001). The use of photogrammetry is becoming an increasingly popular tool to document geologic resources. Most uses of this technique have occurred in surface environments with very few studies documenting resources in low-light, sub-surface environments. Those that have been conducted in cave environments often involve use of other related technologies, such as Terrestrial laser scanning (Lerma et al. 2010) to develop these 3D models. These added methodologies increase cost, need for technical expertise, and amount of gear needed to document resources. Photogrammetry, as a stand alone methodology, holds the possibility of decreasing the impact while increasing the quantitative nature of both research and monitoring efforts within cave environments if it's limitations can be mitigated. Here we present developing techniques for performing photogrammetry in the unique conditions of caves in order to improve our ability to document and monitor resources in these environments.

Figure 1: Image of an entrance area photogrammetry set up at GRCA. To reduce the amount of equipment brought into the cave, the authors use trekking poles and caving lights to illuminate the site.

Methodology

The National Park Service has been leading the efforts to adapt these methodologies for in-cave use. Recent software developments allow for reduced field equipment in order to create accurate 3D models, however dark and damp conditions can hamper the quality of the model output (Tsakiri et al. 2007). In order for photogrammetry to provide the necessary information, these two factors need to be addressed. Newer digital cameras can minimize the impact of dampness on the final model, however lighting needs to consistent and bright to provide the data necessary for the software. Additionally, the remote nature of many in cave sites, means lightweight and compact options are necessary to provide this lighting. At Grand Canyon National Park, modifications to minimize weight while maximizing light have included using common caving/hiking equipment to reduce the weight of materials brought into the caves (Figure 1). Trekking poles are often used as light stands and caving lights are used in conjunction with lightweight video lights to maximize the amount of light available. To further adjust for reduced light in the cave environment, cameras are set to a slower shutter speed, with a wide focal range, set on a timer, and placed

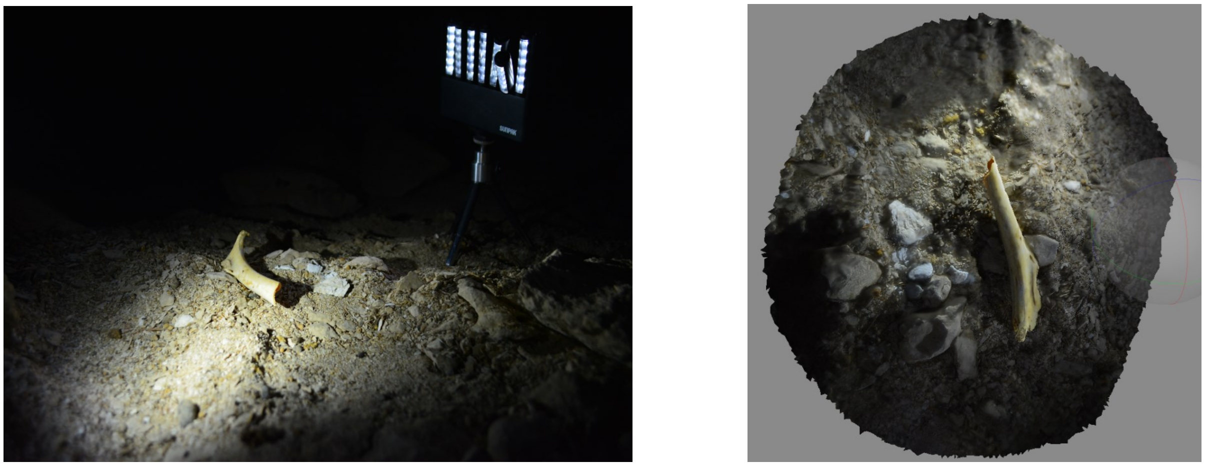

Figure 2: Proximal tibia photographed in cave is illuminated using a lightweight, portable video light (above). Resulting 3D model of the tibia (right).

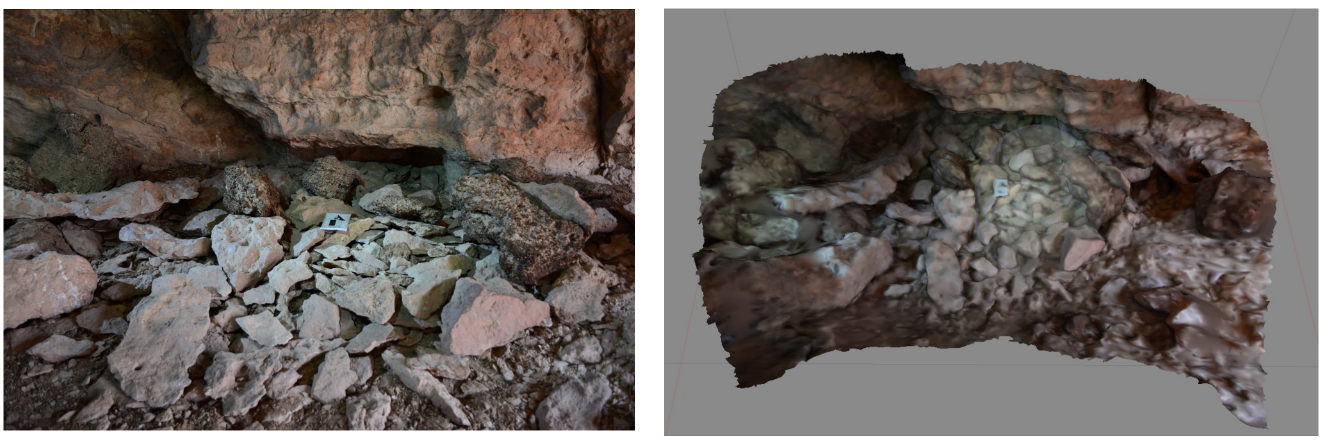

Figure 3: Photo of a monitoring site in GRCA (left). Resulting 3D model of this monitoring site (right)

on a tripod to reduce camera movement. In order to collect enough data for the models, a minimum of 30 photos are taken for small, individual objects (see Figure 2) and 50 or more photos are taken for larger monitoring sites (Figure 1 and 3).

Results

Examples of preliminary in-cave methodologies have been used to produce models of paleontological resources (Figure 2), archeological artifacts, and as a method for establishing quantitative photo monitoring (Figure 3) . Additional models have been created for resources in Oregon Caves National Monument.

Conclusion

Due to the inherent nature of conducting research in caves within a national park setting, it is preferred to leave all resources in-situ while still providing as detailed documentation of these resources as possible. Additionally, long-term monitoring is often necessary to determine the impact of human use and improve protection of these resources. Photogrammetry provides a means of quantifying this change over time by comparing models created at different time periods to determine differences in preservation and protection of these resources. These methods are relatively low impact, when compared to typical resource-focused studies, such as paleontological digs, and provide a means of documenting impacts and change over time that is much more quantitative than standard photo monitoring efforts. Additionally, the lightweight nature of these developing methodologies provide a means of getting high quality data while increasing feasibility and minimizing impacts of data collection in remote cave environments.

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Karst wreckage: Subterranean fauna as collateral damage

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In the course of our consulting work we have encountered the aftermaths of too many catastrophic events, where subterranean communities were destroyed and species driven to the brink of extinction. Some of these disasters are limited to relatively small geographic areas, while others cut swaths across our landscap

Not one, but two, catastrophes have occurred at Indiana University (IU) on the Bloomington and New Albany campuses, where insecticides annihilated entire groundwater communities.

At the main campus in Bloomington, Jordan Hall (the biology building) was built over a spring used as the water supply for laboratory studies of cavefish by Dr. Carl Eigenmann. A community of subterranean invertebrates lived in the spring, e.g., Jordan's groundwater isopod (*Caecidotea jordani*), but the community composition will never be known since the habitat was poisoned to eradicate termites invading the building. Specimens of the endemic groundwater amphipod *Bactrurus cellulanus* were not discovered in the university collection until long after the community was eradicated, and the species was extinct at the time of its description in 2001. On the campus of IU Southeast in New Albany the groundwater isopod *Caecidotea teresae* and an undescribed amphipod *Stygobromus* met a similar fate from insecticides.

Those events only touched geographic pinpoints, but other disasters involving chemical poisoning stretched across larger karst landscapes. At the Dickson, Tennessee landfill tetrachloroethylene (TCE), an industrial solvent, was dumped on karst and poisoned an entire groundwater ecosystem (we were involved as part of the Natural Resource Defense Council's (NRDC) team of expert witnesses). Called by some the "Poster child for environmental racism", the TCE was released into the groundwater supply for a small, predominantly black community in a county that is over 95% white. The toxic chemicals in the water produced cancers that inevitably killed people.

The site of the NCKMS 2015 in Cave City, Kentucky sits atop the groundwater basin of Hidden River Cave, where over the past century the cave and its fauna have suffered from the effects of massive groundwater degradation (Lewis, 1996). In the 1960's the cave's main stream received the effluents of the Cave City and Horse Cave sewage treatment plants, including waste from a metal plating plant and creamery. After the development of a regional sewage treatment facility water quality improved markedly, but the report of the rebirth of Hidden River (Lewis, 1993) was probably premature. The sewage worms that once lined the edge of the Hidden River are gone, but the Southern cavefish (*Typhlichthys subterraneus*) and cave crayfish (*Orconectes pellucidus*) seen today by visitors on the cave tours only occur in significant numbers at the confluence of a relatively unpolluted tributary with Hidden River. New research (Lewis et al., 2015) showed that the fish and crayfish emerge into the main river from a side passage called Blindfish Alley, then disappear downstream from the confluence (figure 1). There the animals apparently succumb to toxins, e.g., residual heavy metals in the substrate remaining from years of receiving plating plant effluent. A pollution event in the spring of 2015 killed much of the fauna in Blindfish Alley, demonstrating that no place in the system is safe.

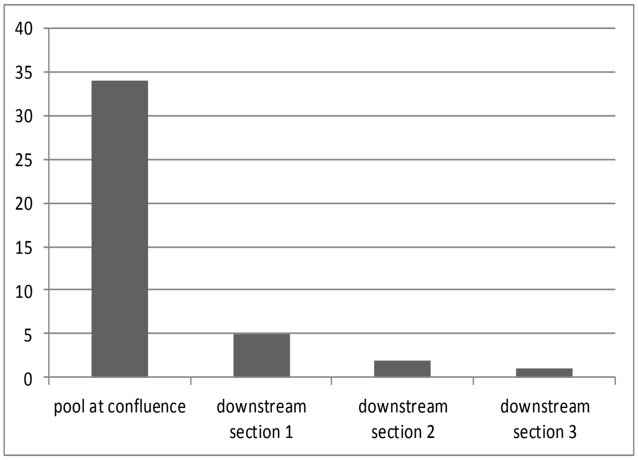

Figure 1. Results of a census of total numbers of the Southern cavefish (*Typhlichthys subterraneus*) and cave crayfish (*Orconectes pellucidus*) in the main stream in Hidden River Cave on 30 September 2014. Most of the animals occurred in a large pool at the confluence of the Blindfish Alley and the main stream. The histogram shows the abundance of the fauna at the large pool at the confluence, then the disappearance in the next three sections of the stream over a distance of about 500 feet (Lewis, et al., 2015).

In the southeastern Indiana karst the ordnance industry wreaked havoc with the karst environment. Lewis (1995) described operations at the Indiana Army Ammunition Plant (INAAP), where starting during World War II nitrocellulose propellants were manufactured by combining nitric acid with cotton. The waste product of the process was nitric acid laden with explosive nitrocellulose particulates and other toxic chemicals like sulfuric acid, nitrobenzene and aniline. This effluent was discharged into the environment at an average rate of 22,500 gallons/minute, at a temperature of 80° F and pH of 2.3. Released into Jenny Lind Run, the limestone floor of the creek was entrenched by the acid as much as 8 feet deep and 10 feet wide. The effluent spread through underground channels, enlarging existing caves and creating new ones where none existed before. Needless to say, no cave animals can exist in rivers of nitric acid and the subterranean fauna was extirpated.

In the adjacent counties from INAAP, the U.S. War Department created the Jefferson Proving Ground (JPG), where starting in 1941 a great variety of ordnance was tested: ranging from artillery rounds to rockets, almost anything that could be shot, dropped or thrown on a battlefield was tested there. At the peak of activity, 175,000 rounds per month were fired at JPG. In addition to conventional weapons, from 1984-1994 100,000 depleted uranium (DU) tank penetrator rounds were fired. Despite recovery operations over 150,000 pounds of DU remained on the impact fields, along with 1.5 million rounds of conventional unexploded ordnance (UXO).

After JPG was closed in 1995, over 50,000 acres containing UXO was dedicated as the Big Oaks National Wildlife Refuge (BONWR). A bioinventory of caves, springs and wells on BONWR by Lewis and Rafail (2002) showed that some sites were devastated by ordnance impacts and UXO contamination. A follow-up project in 2015 to conduct cave stream censuses compared cave communities in UXO and DU impact fields with others in relatively unaffected areas. Results indicated that Isaiah Irwin Cave had been damaged by ordnance impacts and the cave stream community was sparse, mostly comprised of surface species. Stream communities in other caves within the impact fields were unaffected, as were those outside of ordnance testing areas (figure 2).

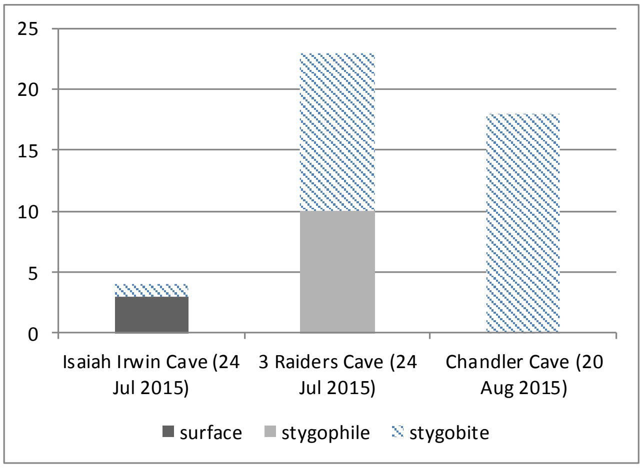

Figure 2. Histogram of cave stream censuses indicating total numbers of animals in three sites at BONWR. The fauna of Irwin Cave, contaminated by UXO, is sparse and mostly comprised of non-cavernicolous species. Despite being in the DU area, the fauna of 3 Raiders Cave is diverse and appropriate for the area. Chandler Cave is in an area little affected by UXO contamination (Lewis and Lewis, 2015).

To summarize, the scars are irreparable: entire subterranean communities poisoned by toxic chemicals; karst landscapes with acid entrenched streams, pocked with shell craters and caves collapsed by explosions. Entire cave faunas extirpated by sewage, heavy metals and other toxic cocktails. In some caves varying degrees of recovery has occurred through re-colonization by some subterranean species (Lewis, 1996). In tragedies like the Dickson, Tennessee landfill the NRDC obtained millions of dollars in mitigation, but money does not restore lives nor create quick fixes for the environment. The only solution seems to lie in the axiom “those who cannot remember the past are condemned to repeat it” …to prevent catastrophes before they happen.

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The Extirpation of a Population of the Endangered Illinois Cave Amphipod (*Gammarus acherondytes*) by an Exotic Species:

The Wednesday Cave Debacle

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The Illinois Cave Amphipod (ICA or *Gammarus acherondtyes*) is an obligate inhabitant of cave streams of southwestern Illinois. This crustacean was listed as a federal Endangered Species in 1998 due to the encroachment of civilization into its habitat-cave streams with gravel substrates. In 1998, the range of the species encompassed four cave systems in Monroe County and one in St. Clair County, although the population in the latter had been extirpated by septic pollution of the groundwater. After listing, The Nature Conservancy commissioned a project to identify new populations of the endangered species. This project resulted in the discovery of several additional cave populations distributed through four groundwater basins where the species was not previously known (Lewis, et. al 2003).

The United States Fish and Wildlife Service (USFWS) recovery plan for this endangered species required periodic population monitoring. We conducted the population monitoring that was done about every 3 years in one or more caves within all of the known groundwater basins where the ICA still occurred. Locations with larger populations took precedence over those with smaller, less important populations.

One of the new sites for the ICA was Wednesday Cave, a 30 foot long cave in the Annbriar Spring Groundwater Basin. Despite a diverse aquatic community including *G. ancherondytes*, monitoring of Wednesday Cave was eclipsed by the much larger population in Reverse Spring Cave, also in the Annbriar basin. Wednesday Cave was thought to be a fairly protected population, since the cave was a small "side passage" of the Annbriar Groundwater Basin, less susceptible to pollution than the groundwater trunk stream. Wednesday Cave's population was monitored as a second tier site, due to its potentially protected habitat and smaller population.

The first sign of problems at Wednesday Cave occurred during a visit on 6 July 2001. As we walked down the steep sinkhole slope to the entrance, we smelled a strong phenolic odor, characteristic of the polydesmid Greenhouse Millipede, *Oxidus gracilis.* This species was thought to have originated in Japan (Hoffman, 1999), but now occurs in North America and is rapidly becoming a noxious exotic species in caves. Once we crawled through the body-sided hole and slid down the breakdown slope to a walking height passage, we encountered the small stream with a gravel substrate flowing across the cave floor. Twenty feet into the cave, the stream fell from a rimstone dam three feet high, beyond which was a broad pool spanning the passage to the cave's end. On that day it was impossible to avoid crawling over dozens of the millipedes, many of them in copulating pairs. The millipede swarm covered the floor; every surface of the riparian zone and every piece of gravel above water. We crushed hundreds of them while progressing through the cave, resulting in a smell so great that we wondered if it might be toxic to the ICA.

As incredible as this may sound, polydesmid millipedes are known to swarm in numbers so great that they stop trains (Marek and Sierwald, 2014). Every year we receive inquiries from cavers who have sighted one of these swarms of chestnut colored, inch long Greenhouse Millipedes covering the floor and walls of some cave. The odor arises from a chemical compound secreted from dorsal glands on the millipedes, contains phenol (which is toxic as well as soluble in water), hydrogen cyanide and benzaldehyde (Habermehl, 2012).

On the next trip, in October 2007, we found a healthy population of the ICA with nine of the amphipods in a transect of 10 linear feet in length (table 1). We also discovered that the farm on which the cave was located was for sale and informed Diane Tecic, the Regional Heritage Biologist for the Illinois Department of Natural Resources (IDNR). Based on the importance of the endangered species population in Wednesday Cave, the large tract containing Wednesday Cave was purchased by The Nature Conservancy and subsequently transferred to IDNR as a state nature preserve. The habitat of the ICA seemed secure.

Concerns about the toxicity of the millipede swarms in Wednesday Cave were overshadowed by more pressing concerns during our population census visit in 2011: the entrance had disappeared under mud washing down the sinkhole wall. Using a GPS location and our recollection of the site, we identified the entrance and dug it open. Sliding down the muddy slope, we saw that most of the gravel in the stream had disappeared under the mud. Only one ICA was found in the census. The community diversity had fallen from seven species in 2007 to four in 2011. State and federal officials were notified of the problem and the need for immediate action. Safe from groundwater pollution, and seemingly unharmed by the exotic millipedes, the ICA was under attack from an exotic species outside of the cave.

The culprit? Bush Honeysuckle. Of the 14 species of honeysuckle in Illinois, 13 are exotic species not native to the state (all in the genus *Lonicera*). Four of the exotics are bush honeysuckles and have in common a height of 15-20 feet, paired flowers and fruit, hollow stems and long, dark green lance-shaped leaves (Haupt, 2015). These honeysuckles out-compete native plants and create mono-culture hedges in forests. Allelopathy, i.e., the production of chemicals toxic to other plants, has been demonstrated in *L. maackii* (the dominant species in the area around Wednesday Cave) and is suspected in others (Gould and Gorchov, 2000).

Three years passed. Entering the sinkhole on 9 August 2014 we fought our way through a tangled understory of Bush Honeysuckle, with few other plants on the bare soil of the forest floor. We came prepared for the worst and carried a shovel with us. It proved necessary as the entrance was buried even deeper than before under mud slumping, a result of the Bush Honeysuckle

Table 1. Population censuses of a 10 foot (3 meter) transect in Wednesday Cave, Monroe County, Illinois between 2007 and 2014 (Lewis and Lewis, 2014).

	Gammarus acherondytes	*Gammarus troglophilus*	*Caecidotea brevicauda*	*Caecidotea packardi*	*Sphalloplana hubrichti*	*Physella sp.*	*Bactrurus brachycaudus*
13 Oct 2007	9	10	11	1	1	1	1
26 Mar 2011	1	14	14	0	1	0	0
9 Aug 2014	0	24	66	0	0	0	0

crowding out native plants that would normally retain the soil. The picture in the cave was even grimmer. The stream habitat had been reduced to mud and leaves. The Illinois Cave Amphipod was gone, and only two species remained, an isopod and an amphipod which occur in caves as well as surface streams in the area.

Wednesday Cave had been purchased with the hope that it might serve as a refugium for the Illinois Cave Amphipod. Unlike Reverse Stream Cave, Wednesday Cave as a relatively small in-feeder of the Annbriar Groundwater Basin, was not susceptible to disturbances to the trunk stream of the groundwater system. It was believed that if the main stream suffered a significant environmental insult, it could be repopulated by the ICA population in the relatively isolated Wednesday Cave, protected in a dedicated state nature preserve.

Unfortunately, the stewardship of the land was not up to the task, and the Illinois Cave Amphipod was extirpated by sedimentation of the critical gravel habitat. Now the cave is buried under the mud…a "million dollar mud-hole"… abandoned to one of the few things perhaps still interested in using the cave…Greenhouse Millipedes.

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Genus-wide assessment of *Bactrurus* (Amphipoda: Crangonyctidae) informs conservation and management of groundwater habitats

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The genus *Bactrurus* is comprised of eight species of eyeless subterranean species found in caves, springs, and other shallow groundwater habitats across twelve states the Midwestern United States. We re-evaluated patterns of distribution in this genus and reviewed threats in the course of reassessing the NatureServe global and state conservation ranks and conducting the first IUCN Red List conservation status assessments for each species. We examined land cover and human population density within 2.5 km buffers around each occurrence. Four species (*B. angulus*, *B. cellulanus*, *B. speleopolis*, and *B. wilsoni*) are known from ≤3 localities and very restricted distributions. Dominant land cover varied among the eight species. For the possibly extinct and single-site endemic *B. cellulanus*, land cover was dominated by developed lands (86.8%), Land cover around the three *B. angulus* occurrences is dominated by forests (58.3%), but pasturelands are also common (15.3%). Fecal coliform enrichment may contribute to degradation of groundwater habitat of this species. Land cover for *B. speleopolis* and *B. wilsoni*, was also dominated by forests (62.7% and 44.0%, respectively), but pasture (24.6% and 29.0%, respectively) and developed (9.9% and 7.9%, respectively) land cover were also common, suggesting a variety of human impacts on these rare species. Of the four species that are more widely distributed, land cover for *B. mucronatus* (88 sites) is heavily dominated by cover classes representing human modification, including croplands (68.8%) and developed lands (16.6%). Only *B. pseudomucronatus* is little affected by human activities, with 85.6% of its cover in forest. Combined human altered lands (developed, pasture, crops) comprise 89.2% and 90.6%, respectively, of the land cover for two species (*B. cellulanus* and *B. mucronatus*), 43.0 -46.1% for three species (*B. brachycaudus*, *B. hubrichti*, and *B. wilsoni*), 23.1-24.6% for two species (*B. angulus* and *B. speleopolis*) and only 11.15% for *B. pseudomucronatus*. These data suggest a wide range of impacts and vulnerability across species, pointing towards the need to develop management strategies aimed at conservation at the species level instead of at the generic level. Based on both NatureServe and IUCN Red List conservation criteria, half of the *Bactrurus* species are at significant risk of extinction, while the other four species are wide-ranging and not currently threatened.

White-nose Syndrome response at Mammoth Cave National Park

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Since it was first identified in the United States in 2006, white-nose syndrome (WNS) in bats has become an important issue in the management of caves and bats at Mammoth Cave National Park (MACA). First the threat of its arrival and later its actual arrival and effects have led to interventions with both the visiting public and researchers, restrictions on access to colonial bat roosts, increased monitoring of bat populations, support of scientific studies, and upgraded interpretation on bats, wildlife disease, and public health. Table 1 contains a timeline of activities and responses related to WNS that the park has undertaken.

The most visible response to WNS at MACA has been the interventions with visitors to prevent first human-caused arrival of the fungus in the park (before Spring 2014) and later (after April 2011) visitors potentially leaving with the fungus after a tour (or research). This is a very important aspect of WNS response at MACA, since over 400,000 people visit caves at the park each year. Beginning summer 2009 park staff screened cave visitors to prevent accidental introduction of the fungus by visitors. Screening methods included public announcements, pre-tour briefings by guides, and printed posters in the Visitor Center. Visitors were asked if they have been in a cave since 2005. If so, they are asked about whether they were wearing or carrying things that have been in a cave. If they had things that had been in a cave, park staff worked with them to reduce the potential for bringing in fungal spores. Measures that were taken included decontamination, bagging items, or disallowing items from the cave. This type of pre-visit screening ended in spring 2014, when bats in major tour areas of the cave were found to have WNS.

Starting April 2011, when WNS was first identified in Kentucky, MACA began requiring visitors to walk over a biosecurity mat after taking walking tours of the cave. This measure was taken to reduce the possibility that MACA visitors could take the fungus away from the cave with them, even before it had not been detected in Mammoth Cave. The biosecurity mats consisted of a 12-foot run of outdoor carpet (to physically remove dirt and spores) followed by a six-foot-long wet walkover mat with a cleaning solution. From April 2011 through September 2012, the walkover mats used a Lysol solution. In September 2012, the park stopped using Lysol solution mats, because the use of Lysol in mats was deemed to be off-label use. From September 2012 through June 2013, the park used only the twelve-foot lengths of plastic outdoor carpet to physically remove spores from the soles of shoes. The carpet was decontaminated daily to kill spores that might accumulate on it. In July 2013 MACA began using a Woolite solution in the walkover mats. This solution will help clean spores from shoes, it is also deemed safe for contact with people's skin and can be used on footwear.

Intervention for people on caving tours is more intense. Visitors on those tours are required to use park supplied gear that is only used on park. Their shoes undergo a

Date	Response or existing activity modifications
May 2009	Colonial bat roosts closed year-round (except approved WNS and bat research); Decontamination required of incoming gear for researchers
June 2009	Screening of incoming tour visitors and intervention (decontamination, disallowing items, etc.). Park WNS intervention station and displays start
Winter 2009-10	Enhanced monitoring of caves for WNS, biennial counts of *Corynorhinus* hibernation roosts
August 2010	Begin requiring decontamination between caves and after cave trips for researchers
January 2011	Park releases original WNS Response Plan
Winter 2010-11	Enhanced monitoring of caves for WNS, biennial counts of *Myotis* hibernation roosts, no evidence of WNS seen
April 2011	KY (non-park) site confirmed with WNS; Tours began post-visit decontamination with walk-over mats containing Lysol solution
Winter 2011-12	Enhanced monitoring of caves for WNS, biennial counts of *Corynorhinus* hibernation roosts
August 2013	Tri-colored bat swabbed during fall trapping at Colossal Cave tests positive for Pd. Analysis occurred after WNS found on park. First evidence of Pd on park.
Sept. 2012	Post tour walk-over mats changed to dry carpet due to restrictions on Lysol use
Fall 2012	Filming for NPS series on bats and WNS on park
January 2013	WNS confirmed at park in Long Cave
Winter/Spring 2013	WNS found in all six colonial *Myotis* hibernation sites known on park. Biennial counts of *Myotis* roosts show normal count numbers and no evidence of increased mortality.
July 2013	Post tour walk-over mats changed to Woolite solution; Filming on park for Battle for Bats: Surviving White Nose Syndrome.
Winter 2013-14	Enhanced monitoring of caves for WNS, biennial counts of *Corynorhinus* hibernation roosts; WNS identified in three largest *Corynorhinus* hibernation sites (in other species); WNS located on some park cave tour trails; prior cave visitation screening of incoming visitors ceases
Spring 2014	Increased human bat contacts on cave tours. Increase training and preparation on human-bat contact and rabies issues.
March 2014	AP and WKYU stories on WNS impacts at park
Sept. 2014	Filming of bat research and WNS discussion for CW Network
Fall/Winter 2014-15	Develop enhanced human-bat contact procedures with Public Health Service and state assistance
Winter/Spring 2015	Biennial counts of *Myotis* roosts indicate significant decreases in little brown, Indiana, and tri-colored bat counts. Numerous dead and dying tri-colored bats recovered along Historic Tour Route. Elevated bat-human contacts and rabies intervention. Increased bat surveillance. WNS at all tour entrances.
February 2015	Louisville, Bowling Green, and Glasgow stories on WNS impacts at park
April 2015	Relaxed decontamination procedures between Pd+ sites on park
May 2015	Seasonal (summer) reopening of WNS+ hibernation sites for research and education

Table 1 – Timeline of Mammoth Cave National Park WNS-related Activities and Responses

more thorough cleaning than those of people on walking tours.

Although even prior to WNS all 400+ caves in Mammoth Cave National Park were closed to human access except via ranger-led tours, research permits, or special use permits. WNS did cause some changes in access restrictions to caves on the park. Prior to WNS response, colonial bat hibernacula on park were closed in the winter and maternity colonies were closed during the summer to protect bats when they were in sites. In spring 2009, all colonial bat caves on park were closed to access for all activities except those related to WNS and bat research. In May 2015, access restrictions were eased on sites that are known to have WNS or the fungus that causes it. These sites reverted to their previous seasonal closures, since there is no longer a danger that off-season visitation will introduce WNS to these sites.

WNS has also led to gear restrictions for park caves. Beginning in May 2009 people entering caves under research and special use permits have been required to decontaminate all gear using current approved national decontamination protocols before entering park caves. In August 2010 decontamination requirements were added between caves on the park (if they are visiting multiple ones) and after visiting park caves. In April 2015, decontamination requirements between caves were eased to allow gear to go between WNS+ sites on park without decontamination. The park continues to require decontamination following cave trips before going to any cave off-park and before visiting any parkcave with unknown WNS status.

With over 400,000 people taking cave tours each year, MACA has a great opportunity to inform people about the importance of bats and the threat posed to them by WNS. Before WNS, information on bats was part of our interpretive message, but since WNS that messaging has increased greatly. People are informed about WNS and bats at the beginning and end of every tour. The post-tour walk over the biosecurity mat provides an important message that WNS is an important threat, and that people have a role in keeping it from spreading. Sometimes visitors have even had the opportunity to see bats with WNS symptoms along tour routes. The park has also participated in numerous media projects on bats and WNS. These have included national and regional television programs, video productions, and print and web media stories.

Additional bat and WNS related messaging became necessary at the park beginning in Spring 2014. WNS caused unusual bat numbers and behavior near toured cave entrances at the park. This led to increased bat-human contacts on cave tours. The increases affected both visitors and park staff. Several people required rabies post-exposure inoculations as a result of bat-human contacts. The park assisted by a NPS Disease Outbreak Investigation Team developed a series of responses including improved messaging and increased monitoring for unusually behaving bats.

When WNS arrived in the northeast United States, many agencies lacked significant baseline data on healthy bat populations. Beginning in 2009, MACA increased surveillance and monitoring of its bat roosts (both hibernacula and summer roosts) to gather baseline data, detect the arrival of WNS, and to document potential population changes. This monitoring includes biennial hibernation counts, summer emergence counts, and summer acoustic mobile transects. Disease surveillance includes regular entrance checks of bat roosts, targeted winter visits to bat roosts to check for signs of WNS, and cave entrance acoustic monitoring. In 2014 the park added additional monitoring for dead and dying bats along tour routes in response to concerns about bat-human contacts.

Biennial hibernation counts of colonial *Myotis* sites in 2015 showed significant decreases in several bat species. Preliminary counts indicate little brown bat (*Myotis lucifugus*) declines slightly above 80%, Indiana bat (*Myotis sodalis*) declines of nearly 80%, and tricolored bat (*Perimyotis subflavus*) declines near 70%. On the other end, gray bat (*Myotis grisescens*) and Rafinesque big-eared bat (*Corynorhinus rafinesquii*) numbers continue to be stable or increasing on park as of this year. Mist netting on several projects suggest that northern long-eared bats are greatly decreased on the summer landscape in the park in 2015.

The park has also supported a wide range of bat and WNS related research by NPS scientists, researchers from other federal agencies, and from academic researchers. Some of these studies have been supported through access to sites, assistance with sample collection, or direct staff assistance in research. Other studies have been funded by the NPS to assist in gathering information needed for management of affected bat species and caves. These studies have included work on such topics as bat physiology; roosting behavior; WNS fungus prevalence and distribution;, decontamination techniques; bat and insect distribution and abundance before and during WNS outbreak; and bat condition going into hibernation and coming out (pre- and during WNS outbreak).

WNS and its effects have led to a dynamic management environment for parks with caves, and in particular for parks with large show cave operations. The need to prevent the spread of WNS tempts managers into simply closing sites to prevent people from coming in contact with the fungus (or to prevent them from introducing it to places it has not previously been found). However, the opportunity to provide strong messaging on bats and the threat that WNS poses to them also provides a drive for managers. At Mammoth Cave, we believe that strong intervention with both visitors and researchers can sufficiently reduce the threat to allow access while protecting bats and caves.

Conservation-Education-Outreach-Tourism
Pat Seiser, Chair

Conservation and touristic use in *Ballet* Cave, Brazil: history, present situation and future outlook

Luciana Alt and Vitor Moura

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Ballet Cave is among the most important archaeological and speleological sites in *Minas Gerais*, Brazil. The *Ballet* style[1] can be one of the oldest rock art styles identified in South America, with relative dating of at least 10,500 AP (Neves et al., 2012)[2]. *Ballet* Cave is about 150m long, and is located in the Private Reserve of Natural Heritage - PRNH *Fazenda Bom Jardim*[3], which in turn, is part of the Environmental Protection Area *Lagoa Santa* Karst. In 2002, the infrastructure project and its installation were carried out, as well as an extensive conservation work on the cave, which comprised the restoration of rock art panels. This "nationwide first" project was coordinated by Helen David, speleologist, PhD in conservation and restoration. This article presents the results of this study and the current situation of the site and the future prospects.

Visitation and Conservation Project at *Ballet* Cave/ 2002

Ballet Cave, well known in the region, received unplanned visitation until the end of the 90's. Unfortunately graffiti covered practically every smooth and accessible surface, including rock art panels (Figures 1A & B), cave walls, ceiling and speleothems. These graffiti were made with different materials and techniques, especially coal, clay, chalk, and incisions. In the 90's a barbed wire fence and gate were installed in order to protect the cave. But that was not enough to stop the vandalism. At the beginning of the new millennium, the cave conservation status was pitiful. There was a significant amount of scattered garbage, many broken speleothems and cattle feces covered large areas of the floor. At that time, besides the graffiti, several changes on the pictorial panels were found, i.e. nests and hives of insects, animal droppings, mineral deposits (probably caused by successive applications of water to "enhance" the visual quality of the paintings), dust accumulation (possibly consequence of trampling over sedimentary layers), as described by David & Moura (2002). To protect *Ballet* Cave and other human and natural heritage places, the creation of PRNH *Fazenda Bom Jardim* was mandated by environmental agencies, and among other actions, a Visitation and Conservation Project for *Ballet* Cave/ 2002 that was coordinated by Helena David.

The Visitation and Conservation Project at *Ballet* Cave was implemented in 2002. The first steps were the cave survey, the impact mapping, and the detailed photographic survey of rock art panels and all surfaces to be be restored. The photos were taken before, during and after conservation actions (Figure 2). Another important step was the implementation by the project coordinator, of solubility tests on different types of substrata (rock, speleothems). These tests enabled the development of tech-

[1]This style is characterized by elongated human figures, with male and female nominees, arms raised, head and mouth often elongated and open

[2]Relative dating obtained for *Ballet* Style figure found in *Lapa do Santo*, *Matozinhos*, by the Laboratory of Human Evolution Studies team, led by Walter A. Neves.

[3]Owned by LafargeHolcim S/A.

Figure 1A- Partial view of pictorial panel in *Ballet* Cave. Photo: LA / VM

Figure 1B– Main rock art panets seen from the wooden platforms. Photo: LA/VM

niques for removal of different types of graffiti, dirt, insect nests, and animal excrements. Temperature and relative humidity measurements were made throughout the process, in order to understand the dynamics of the cave microclimate and to avoid any changes over that. The conservation work lasted about four months, and only three people[4] were involved. It was a painstaking job, done with minimum impact techniques and control measures to safeguard the integrity of the cave environment and archaeological heritage The second phase of the project was the planning and installation of the infrastructure. For protection of the archaeological sediment, a wooden platform was installed at the cave entrance zone and the access inside the cave was restricted[5]. Some signs were installed in addition to strategic locations, posting warnings or interpretive content to guide visitors. The platform is made of removable pallets. They were put together with flexible joints and directly supported on the cave floor. The installation process didn't call for any excavation or disturbance in the sedimentary layer, thus not causing irreversible damages to the archeological site. The pallets provide a smooth surface, comfortable and safe for visitors. All of that entails a better view of the rock art panels as well as it serves a better conservation of the site. Moreover this solution can be easily removed in the case of future archaeological excavations. The platforms protect the archaeological sediment from compaction and disturbance caused by trampling, avoiding the dispersion of fine particle matter, and its subsequent deposition over pictorial panels. The use of pallets made the project feasible, due to the reduced cost of installation and maintenance.

Present situation

Nowadays *Ballet* Cave receives about 600 visitors per year, mostly students. They enter the cave in groups up to 15 people, guided by a LafargeHolcim S/A employee. The cave is included in a broader preset visitation program. This visitation program lasts about two hours and includes other human and natural heritage places within PRNH *Fazenda Bom Jardim*. Visitation is held from Monday to Friday and must be booked online, 10 days in advance. A 150m wooden walkway was recently installed on the hillside forest between the dirt road access and the entrance of the cave.

Apparently, there was a significant re-

[4] Helena David, Vitor Moura and Luciana Alt.

[5] The access is allowed only to conduct scientific research and monitoring activities.

Figure 2 - Example surface with graffiti in *Ballet* Cave in 2001, in 2002 after Conservation Project and in 2015. Photos: VM

covery on the hillside forest in relation to the situation observed in 2002, so much so that the barbed wire fence is now better camouflaged by vegetation. The conservation status of the cave, in general, is now a lot improved. Now because of the platform fewer intrusive footprints are observed, indicating that most visitors have respected the installed infrastructure. Furthermore, it was observed that there were rare new graffiti. This attests to the theory that the existence of a large number of graffiti attracts new graffiti, and also shows that the cave management has been effective.

It should be noted that from time to time, the conservation interventions over graffiti made with incisions techniques, need to be monitored and maintained. For example, after 13 years of completion of the Visitation and Conservation Project, some points where the techniques used to camouflage incisions already need to be revised because the filler material was apparently removed by sheer natural processes i.e. stream air, circulation of small animals, etc. In some places, insect nests began to form over the rock art and other surfaces. When this kind of nest is formed over the rock art panels, their removal can be critical and cause damage to the pictorial layers and should be performed only by specialists.

Future outlook, suggestions and recommendations

The good condition observed in 2015 in *Ballet* Cave attests to the management qualities, and because of that, it is possible to think about the expansion of the visitation circuit within the cave. In addition to rock art, the cave possesses other attractions, such as a main hall that contains historical evidence of saltpeter extraction. This main hall also contains the remainders of recent archaeological excavations. Given the importance of *Ballet* Cave it could well be included in regional touristic circuits and could be opened on weekends, without prior appointment, in order to expand the audience to the larger public.

Currently there is no monitoring program applied to the cave. Is its recommended the monitoring of cave fauna dynamics be developed in order to evaluate the possible interference of the installed infrastructure. This action is important, for example, to assess the impact of introduced construction materials over cave fauna. It is recommended to carry out an annual photographic monitoring over rock art panels and other surfaces of the cave. This type of monitoring helps to identify and record possible changes (speleothems breakage, graffiti, insect nests, animal dung deposition, etc.). These monitoring actions call for the planning of immediate conservation actions. A monitoring system is an important tool for pointing out the need to review any management and surveillance actions, or even to attest to their effectiveness.

Acknowledgements

This article is a tribute to Helen David, who introduced us to the world of cave conservation, and instilled into us a strong awareness about the fragility of these environments. She showed us the need to seek for minimum impact techniques. We acknowledge Jose Duarte from Lafarge-Holcim S/A for allowing and supervising our visit to *Ballet* Cave. We also acknowledge André Alt for reviewing the English translation.

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Making Cave Lint Camps a Success

Gretchen M. Baker and Ben Roberts

Great Basin National Park, Nevada

One consideration of cave management for show caves is how to maintain the natural cave beauty while allowing for thousands of people to visit the cave each year. Each person who enters the cave brings a bit of dust and debris on their shoes and leaves hair and lint from their clothes. Over time, a sheen of lint and dust often covers many of the cave speleothems and walls. The lint can have many adverse effects on the cave, including providing an artificial food source, dissolving speleothems, providing unnatural odors, and marring the aesthetics of the cave (Horrocks and Ohms 2006).

Many show caves hold periodic lint camps in an effort to remove this buildup, calling for cavers to come help remove lint and other debris that have accumulated in the cave due to human visitation. Cave lint camps have gained popularity since the first one held at Carlsbad Caverns in 1988 (Jablonsky 1992). They have been held at many caves with volunteers coming from near and far. Due to the cumulative nature of impacts from lint and dust, continued lint camps are critical to restoring and maintaining caves in as natural a form as possible.

Horrocks and Ohms (2006) provide recommendations on how to hold a successful lint camp, including identifying areas to be cleaned, techniques to be used, advertising widely, securing lodging, and offering training. These are excellent guidelines, and we build on these recommendations to share how they can be used to provide educational opportunities for both cavers and non-cavers.

About 30,000 people visit Lehman Cave in Great Basin National Park, Nevada annually. The trail in Lehman Cave is often narrow, wending through tight passages and next to columns, shields, and other cave formations. Despite being remote, Lehman Cave lint camps have repeatedly attracted volunteers. Over eight lint camps have been held in the last two decades, with over 200 volunteers and over 3,000 volunteer hours. In 2015, two lint camps were held to accommodate all of the interested volunteers (Figure 1). How has a very remote area, three hours to the nearest shopping mall and over two hours to the nearest interstate, attracted these people?

The Lehman Cave lint camps have been marketed not only to grottoes, but also to the general public. Quite a few people who saw Lehman Cave on a cave tour and heard about

Figure 1. Participants in the February 2015 Lehman Cave lint camp.
NPS Photo by G. Baker.

Figure 2. Some of the tons of sand removed from Lehman Cave during lint camp to restore the natural cave features. The sand is left from trail building many decades ago. NPS Photo by G. Baker

Figure 3. Volunteers of all ages help at the Lehman Cave LInt Camp, helping to ensure that the cave will be looking its best for the next generations. NPS Photo by G. Baker

the perils of lint from an interpretive ranger wanted to come back for a lint camp so they could give back to the cave. In addition, the lint camps have benefited greatly from social media. The park used Twitter and Facebook to spread the word about events. These posts were quickly shared with others and have resulted in quite a few people coming to lint camp who otherwise wouldn't know about the event.

Recent media coverage has helped to engage even more people. Stories in *National Parks Traveler* and *the Los Angeles Times* have reached wide audiences. The stories concentrate on why people come to lint camp, and these stories have encouraged others to volunteer their time to help the cave.

In addition to removing lint and dust, lint camp volunteers have helped remove tons of debris left from trail-making efforts (Figure 2). These restoration efforts have been especially popular as original cave floor is uncovered. Some volunteers take ownership in the project—or rather, a small part of the cave—as they yearn to discover how the cave originally looked. In 2015, the park also had an archeologist attend the lint camp to help identify objects found next to the trail. Nails, coins, and a pool hall token were found, as well as additional historic signatures. Participants were keen on making the next archeological discovery.

Keeping volunteers happy can be accomplished in a variety of ways. They do a variety of tasks, from dusting to digging to removing algae near lights; they work in various areas of the cave. Free housing allows cavers and non-cavers to mingle and even try furniture caving, a popular event. One of the biggest perks of a Lehman Cave lint camp is being allowed to see some of the off-trail areas, including the renowned Talus Room, the largest room of the cave. It was closed during the 1980s due to rock fall, so is now rarely visited. In addition, some volunteers help park staff conduct White-nose syndrome monitoring for bats during internal winter cave visits and gain additional experience caving.

The National Park Service is charged with attracting the next generation to participate in park activities. The lint camps have helped greatly with that. In 2014, half the participants were under age 25. It is common for more experienced cavers to help the younger helpers learn the best cleaning strategies (Figure 3).

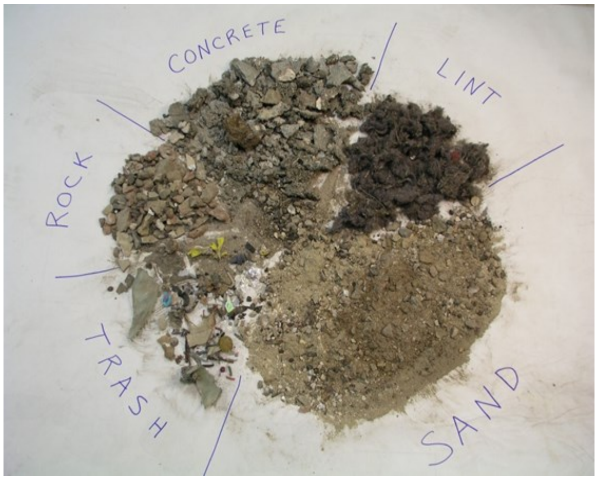

Figure 4. Breakdown of debris removed from the cave during a lint camp. NPS Photo by S. Thomas.

Lint camps are an excellent way to not only maintain a cave in a more pristine state, but also to attract stewards that will want to help keep the cave that way.

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Karst and Coastal Development: A Digital Cave Survey Tool for Municipal and Tourism Planning in Quintana Roo, Mexico

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Abstract

Cave exploration and survey in the northeastern karst of Quintana Roo reveals an increasingly complex network of dry and underwater caves. Over 1500 kilometers of underwater and dry cave passage is documented within a developing coastal region earmarked for municipal and touristic growth. Both urban and tourist hubs maintain a complex relationship between the demands for public infrastructure, prudent use of undeveloped lands, and the sensitive character of the region's karst environment. As coastal municipalities and tourist resorts grow in the region, encounters with dry and underwater caves, karst windows, and a widespread karst aquifer occurs with increasing frequency.

Government and non-governmental agencies can invite local speleological survey groups to share geo-referenced cave survey data or cave mapping products to assist in planning for future regional growth. Revealing cave passage and entrance locations creates a problematic arena for survey groups. Sensitive cave survey data may drift through layers of government bureaucracy reaching land speculators, resort developers, and perhaps even lawbreakers searching for historical antiquities. Vulnerable landowners in possession of desirable karst windows may also suffer uninvited scrutiny by municipal agents.

We propose an alternative method in sharing geo-referenced karst survey data as defined by cave areas. A geo-referenced survey software plot is analyzed by our QEXF software, producing a buffered Google Earth software KML file displaying user defined boundaries for a cave. Survey plot and entrance Global Positioning System locations are removed from the KML file. Cave surveyors control sensitive data while allowing the public to produce reasonably accurate cave area maps within the Google Earth software environment.

Introduction

The Riviera Maya, originally named as the Costa Turquesa, was once a backwater collection of small fishing collectives, coconut plantations, and cattle cooperatives. Slash and burn farming and subsistence hunting on this karst plain supplemented the diet of what was a modest and retiring community. Located on the eastern coast of Quintana Roo Mexico, this region has grown to become a prime destination for world tourism. Resorts, modern highways, and urban centers have developed within a narrow coastal zone of mangrove and scrub jungle that accommodates a collection of fragile fresh water drainage zones. Over many years speleologists, cave divers, hydrologists and ocean divers have collected diverse sets of complimentary data supporting the concept of this area's broad and shallow aquifer drainage region.

The Quintana Roo Speleological Survey (QRSS) archives these observations and cave survey data. Today we find the most common ecotourism activities include an increased use of wild dry and underwater caves. Those activities are becoming an integral part of the local tourism industry. Municipalities and public services continue to grow in order to support the burgeoning

Figure 1. Google Earth KML Cave Line Plot Image

Figure 2**.** Google Earth KML Cave Area Image

tourism base. As the coast develops, QRSS receives many requests for cave locations and survey data from local governments, land developers, and environmental groups.

Georeferenced cave survey data or cave plot and KML file facsimiles are generally not suitable media when distributing information about the underground karst environment with the public (Figure 1). Survey data in this form is often misinterpreted, leading the public and government officials to reach false assumptions about cave and the aquifer environments. In the wrong hands cave location data have encouraged surface excavations into existing underwater cave passage for ecotourism companies.

Methods

A georeferenced survey plot file compiled by Compass Cave Survey Software. The operator edits the QEXF Parameter file before the Compass plot file is analyzed by QEXF software. Parameters include the size of the cave area buffer centered on the basic survey line plot. The cave plot can remain in the buffered zone or be removed. Color buffers may be ignored or added to indicate a range of exploration dates. The buffer zone may be transparent, or absent with just an outline. QEXF will process the Compass plot file though defined user values creating a simple Google Earth KML file (Figure 2). The QEXF KML file is bitmap-based; all cave georeferencing is removed.

Discussion

The QEXF program has been used with success on many occasions. Responding to requests for cave survey information are straightforward. Permission to disclose survey data information from groups who have shared data with the QRSS is not required. Landowners will continue to have issues with land developers and municipality offices should their property contain a significant karst window(s).

CAVEMONITOR – Monitoring Show Caves of Romainia

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Romania hosts spectacular karst areas with many caves holding the potential to become touristic attractions. While the number of caves opened for tourism is still low, in the last years there is a trend of opening new caves for tourism or re-fitting old show caves by using new lighting technologies and construction materials. In the last 4 years only, 5 new caves were opened for tourism and a couple of others are currently being under consideration for development. However, at a national level there are no management protocols enforced to monitoring changes in show caves and none of the caves opened to tourists have any such monitoring.

The CAVEMONITOR project started in the summer of 2014 and aims at establishing a robust protocol of monitoring the impact of tourist traffic upon the biotic and abiotic elements in show caves and to apply it as a pilot-study. The protocol includes monitoring of physical and chemical parameters of the caves (from air, water, speleothems, sediments) as well as the biological ones (population densities, the evolution of biodiversity hot-spots, air microbiology) in relation to the touristic traffic. The study should establish: (a) the extent to which the frequency and volume of the tourist traffic affects the monitored parameters; (b) required measures to ensure a physico-chemical equilibrium of the cave air and water and preserve cave's attractions; (c) limitations required in order to preserve cave biodiversity and to avoid the input of allochtonous elements such as lampenflora; (d) identify potential health risks to both cave personnel and tourists related to radon levels.

The project includes 5 show caves from the Southern and Western Carpathians and and one laboratory cave used as a reference site. The project includes the monitoring of the number of visitors and groups frequency, paralleled by the monitoring of the main physico-chemical parameters of the air (CO^2, temperature, RH) and drip and condensation waters (drip rate, temperature, conductivity, pH, water chemistry). Meteorological parameters are monitored using automated weather stations located in the close vicinity of all caves. We also monitor the vertebrate (Chiroptera) and invertebrate populations from caves, as well as the microbiological composition of the air, water and sediments. To assess speleothem vulnerability to the changes in chemistry of condensation or percolating waters calcite precipitation stations are installed and periodical measurements of stable isotopes ($d^{18}O$, $d^{13}C$) are carried out on both precipitated calcite and dripwaters. Radon concentrations are measured using both active and passive instruments.

The project will: (i) establish a robust monitoring protocol to be applied to all show and protected caves; (ii) establish threshold values for the tourist carrying capacity such as to allow for the preservation of the subterranean environment; (iii) create reliable technical solutions for monitoring the cave environment, including remote monitoring and online data transfer; (iv) establish a set of basic principles to be en-

[1]CAVEMONITOR is a research project funded under the SEE financial mechanism with the number 17SEE/2014. The team consists of 24 researchers from the "Emil Racovita" Institute of Speleology in Bucharest and Cluj, the University of Bergen (Norway), and the "Babes-Bolyai" University in Cluj.

Fig.ure 1: Location of the monitored caves in Romania.

forced by the management plans of show caves pending on their morphology or the type of touristic traffic; (v) issue a set of preventive measures and instructions to be followed by the personnel and stakeholders of the show caves.

A total number of 35 monitoring stations have been installed in the 6 caves under observation (Figure 1). We are using both automated fixed stations, where sensors are connected to a central datalogger and mobile stations consisting of a combination of low-cost dataloggers that are functioning independently to each other.

A variety of sensors and dataloogers available on the market have been tested for their performance and robustness. In this report we discuss the performance and difficulties related to different sensors and cave conditions as seen after 6 months of measurements. We also present preliminary data showing the influence of lighting regimes and human traffic on the environment of the caves in different settings.

Cave Management and Restoration Efforts at Coronado National Memorial, Hereford, AZ

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Coronado National Memorial is one of the most southern National Park units in the United States and the largest of the 29 Memorials (Figure 1). The Memorial is located in the southern portion of the Huachuca Mountains in the Mexican Highland section of the Basin and Range Province. The Huachucas are one of 40 mountain ranges in the borderlands named “sky islands.” These mountain ranges received the name because they resemble islands that rise above the grassy sea. There are seven located caves within the Memorial and possibly three other unlocated caves. Only three are of substantial size, with Coronado Cave being the largest. The remaining four features are extremely small and likely have little or no interest for the general public. The Memorial is bounded by Montezuma Pass to the west, Bob Thompson Peak to the north, and a 3.3 mile-long southern boundary marking the US-Mexico international border.The geology of Coronado National Memorial, in southeastern Arizona, spans more than one billion years with a rich history including mountain building events, rifting, periods of shallow

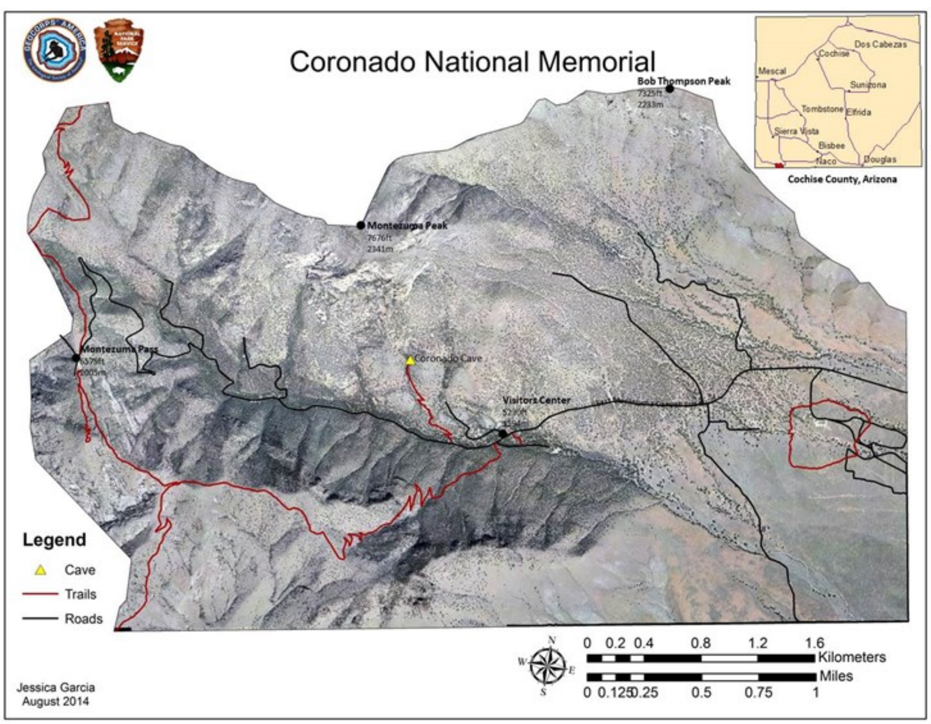

Figure 1. Coronado Park Boundary showing roads, trails, location of Coronado Cave and peak/feature elevations.

seas, and supervolcanoes. These events created a diverse geologic landscape composed of Permian limestone, Mesozoic and Tertiary volcanics, and Quaternary deposits. Karst features formed 15,000-10,000 years ago by phreatic conditions, leading to the dissolution of the limestone. Coronado Cave, formerly known unofficially as Montezuma's Cave, Montezuma's Treasure Vault, and Geronimo's Cave until the mid-1980s, not only attracts present day visitors but served as an attraction to miners during the 1800s. Its spectacular size and once pristine speleothems captivated its visitors. Unfortunately, most of these formations have been advertently or inadvertently destroyed. Due to concerns that other caves may be subject to similar types of vandalism and for visitor safety, Coronado Cave remains the only cave resource open to the public. Intact speleothems are rare. Speleothems found within the cave include: cave popcorn, drapery, chandelier, stalactites, stalagmites, moonmilk, flowstones, rimstone, columns, soda straws and helictites. Other cave features include gypsum boxwork and scallops. Mathematical derivation calculated that water flowed at a rate of less than 24 feet per minute. Today the cave is mostly ephemeral; water is usually only observed during monsoon season. Coronado Cave consists of one large room that is 180 meters long by 6 meters high by 20 meters wide, with a narrower portion near the center of the cave's length, and three narrow crawlways which can be seen in the Coronado Cave map (Figure 2).

Geologic resources have primarily been passively managed since the Memorial's inception, with the most well-known feature, Coronado Cave, operated as a "wild" cave without permits. Due to the detrimental effects of vandalism to Coronado Cave and a need for more scientific information about other geologic features in the Memorial, an overhaul of the cave management program was initiated in 2014 and

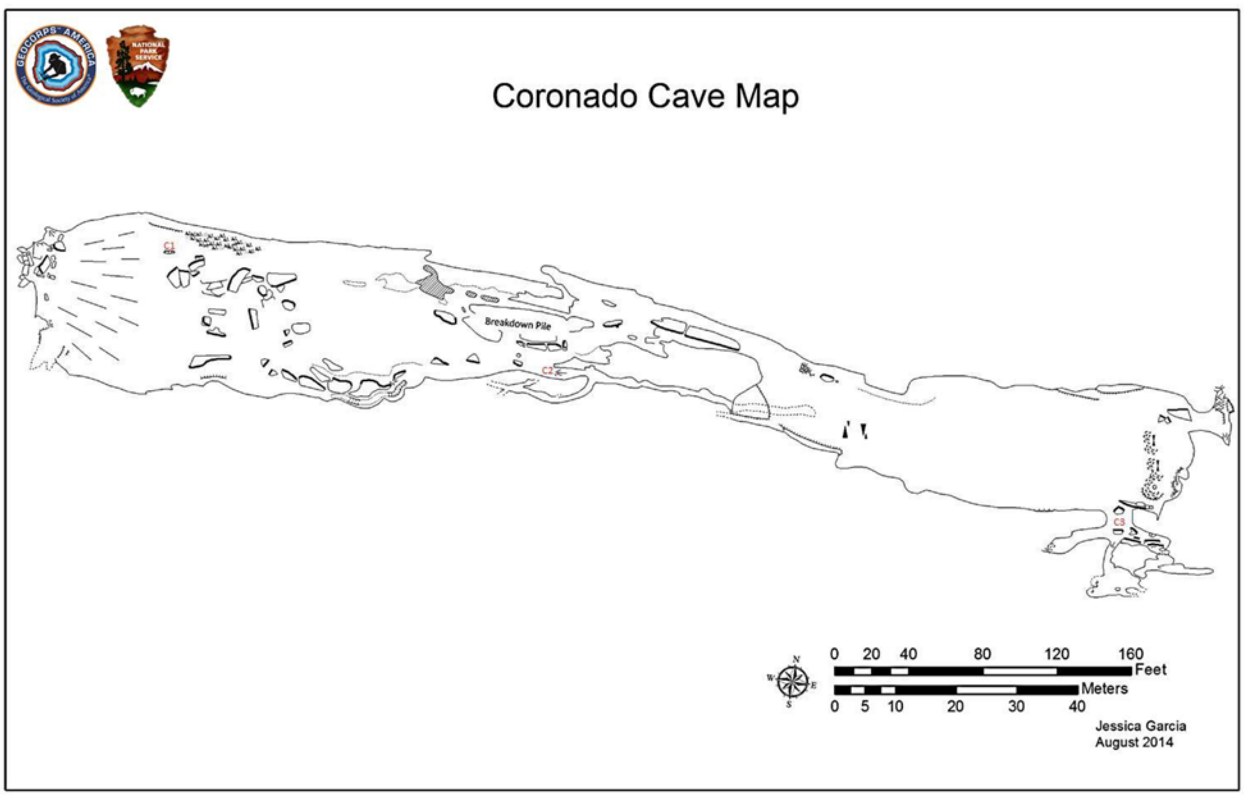

Figure 2: Coronado Cave map with crawlways located in red.

Figure 3: Graffiti and post-remediation efforts

has been developed and implemented over the last year. The two most prevalent destructive activities by visitors to Coronado Cave are littering and graffiti vandalism (Figure 3). Remediation efforts began in July 2014 with systematic removal and documentation of trash and graffiti. By April 2015, park staff, SCA interns, GeoCorps America interns and Boy Scout volunteers had meticulously scoured the cave and removed 45.53 lbs of trash in a total of 91.5 work and volunteer hours. Successful graffiti remediation by park staff occurred throughout the year using nondestructive techniques and materials.

Graffiti remediation and trash removal will continue into the foreseeable future. Over time, trends in littering and graffiti prevalence can assist with further cave management actions. The cave management plan has also been updated to enhance monitoring activities and meet current management objectives. This effort has resulted in a more robust management program, which now includes updated management objectives; protocols for monitoring and remediation; a cave safety protocol; updated cave maps; collection of anthropological and meteorological data; information about possible unknown caves through reconnaissance efforts; and the creation of education and outreach materials for training park staff and improving public interpretive programs. This endeavor has served the mission of the National Park Service by enhancing the preservation of park caverns for the enjoyment of future generations.

"An Education is Not All Derived From Textbooks": A Century of Interactions Between Mammoth Cave and Western Kentucky University

Chris Groves[1], Deana Groves[2], and Weldon Hawkins[3]

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South central Kentucky's Mammoth Cave System is by far the most extensive known cave system on Earth. The cave and landscapes that overlie it have been designated not only as a US national park, but also by the United Nations through UNESCO as both a World Heritage Site and an International Biosphere Reserve to codify their global significance. In addition to the unique natural landscape, there has been a rich human history in the area for at least 10,000 years and within the cave itself for more than four thousand.

Just 50 km to the southwest is Western Kentucky University (WKU) in Bowling Green, which including various precursor institutions has had numerous interactions with the cave system and its proprietors for more than 100 years. These relationships have been remarkably synergistic, for example providing the University with a nearby, world-class learning environment while offering the cave managers, particularly in recent decades, the expertise of faculty and student scholars (and cavers) in interpreting the cave system, landscape, and associated resources.

Early interactions included many school field trips to the cave. Among the earliest of these were trips in the early 1900s from the Potter School for Young Girls. In the same era, students entering the Bowling Green Business College "on the Seventy Dollar Scholarship" who paid "for same at time of entering" were offered a free trip to Mammoth Cave with all expenses paid including

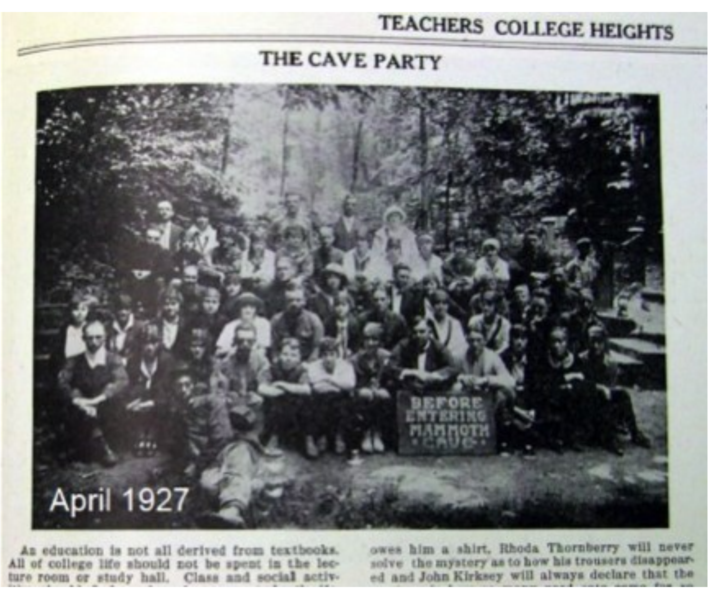

Figure 1. Students from the Western Kentucky State Normal School and Teachers College, a precursor to WKU, at the Historic Entrance to Mammoth Cave in 1927.

Figure 2. A recent group of WKU students at the Historic Entrance to Mammoth Cave (photo by Chris Groves).

"railroad fare, cave fare, and hotel fare to and from Mammoth Cave." An article from 1927 describing the benefits of such excursions to the cave (Figure 1) correctly claimed that "An education is not all derived from texbooks."

Many early trips involved multi-day excursions. While some of these were by train between Bowling Green and the cave, at least in some cases the boys would make the 100-kilometer round trip on foot accompanied by horse-drawn wagons loaded with girl students who, while riding ahead of the boys, would sing songs to encourage (or taunt) and provide energy to their walking colleagues. A camping trip along the Green River after one such cave trip was described as having festivities occurring to a level "not seen since the celebrations of the Danes on the morning after the slaying by Beowulf of the sea-monster Grendel."

In 1925 explorer Floyd Collins was trapped while exploring Sand Cave within the current bounds of Mammoth Cave National Park, and a large rescue effort ensued. For several days rescuers could carry food to Floyd who was stuck not far from the entrance, but they were unable to free him from a tight squeeze where he had been trapped by a ham-sized rock that had slipped and pinned him in place. After a collapse between Floyd and the entrance made subsequent visits to him impossible, it became a race against time to free him, and a shaft

Figure 3. 2004 Signing ceremony for the Mammoth Cave International Center for Science and Learning, Including Ms. Lujuana Wilcher, Park Superintendent Ron Switzer, WKU Pesident Gary Ransdell, and Senator Mitch McConnell (photo by Chris Groves).

was initiated to reach the passage where he could be freed. Among the men who strained for days to dig through the rock to reach Floyd was the WKU football team, and the sheet signed by the players as they arrived on the scene can still be seen on the wall of a local museum of Floyd Collins artifacts at the office of Dr. Tim Donnelly in Bowling Green

In 1980 the Karst Field Studies Program at Mammoth Cave National Park was established by at WKU by Dr. Nick Crawford as a unique opportunity to study cave and karst topics at the university level. These courses continue today and have been taught by a number of the world's leading experts in their respective fields or of the cave itself, a partial list of whom includes, in addition to Dr. Crawford, the likes of Will White, Art Palmer, Patti Jo Watson, Stan Sides, Roger Brucker, Tom Barr, Derek Ford, and Horton Hobbs.

Class field trips still continue regularly to the cave (Figure 2), and in recent decades several departments have developed interactions at the cave including professional funded research, graduate thesis and undergraduate research projects, and extensive educational experiences within, in the close vicinity of, or closely relevant to MACA. The Park-related graduate research emanating from WKU has been extensive and wide ranging, with numerous thesis studies focused on biology (19 completed), hydrogeology (9), water quality (6), geochemistry (7), cultural geography and policy (4), atmospheric science (3) and others in folk studies, remote sensing, and environmental education. One MS thesis from WKU's Department of Communications even used Bormann's (1972) fantasy theme method to examine dominant rhetorical visions and communities that emerged from the 1925 tragedy of Floyd Collins.

For decades students with an interest in cave exploring have been attracted to WKU's karst studies programs because of the connections to exploration in south central Kentucky including Mammoth Cave and there is also a history of interactions between WKU and the Cave Research Foundation (CRF), with three current and former WKU faculty and staff having served as CRF Presidents. Numerous WKU students have also served as seasonal or permanent guides as well as scientific and management positions at Mammoth Cave and other national parks, and indeed other federal agencies.

The Mammoth Cave International Center for Science and Learning was established in 2004 (Figure 3) as a cooperative initiative between the Park and WKU, one of 17 such centers operating within the national park system. The Center facilitates Park-related research and environmental education to a wide range of students and scientists, as well as implementation of citizen science programs.

The future is bright for such mutually beneficial interactions to continue on into the future. New on tap for fall 2015 is the first time offering of a WKU Honor's Program Colloquium simply called *Mammoth Cave National Park*.

Reference

Bormann, E.G. "Fantasy and Rhetorical Vision: The Rhetorical Criticism of Social Reality" (1972). *Quarterly Journal of Speech.* 58: 396-407.

Modeling Cave Temperature to Prioritize the Assessment of Over-winter Cave Use by Bats in Grand Canyon National Park

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Division of Science and Resource Management
Grand Canyon National Park

Introduction:

Winter ecology of bats in the American Southwest is largely under-studied. In Arizona 16 bat species are believed to overwinter, however hibernacula information exists for only 10 sites in the state, of which seven are located in northern Arizona. Grand Canyon National Park (GRCA) contains more than 375 caves and hosts 22 species of bats, nine of which are species of conservation concern. Currently little information exists regarding caves in Grand Canyon, including cave climatic conditions and winter use by bats. With the westward advance of white-nose syndrome, it is increasingly important that land managers and conservation biologists in the Southwest identify and monitor bat hibernacula. Beginning to answer the fundamental questions associated with winter activity of bats in the Southwest is a crucial first step in managing the onset of white-nose syndrome, which is predicted to arrive by 2021.

White-nose syndrome has affected several species of bats throughout North America, including the big-brown bat (*Eptesicus fuscus*), a bat native to Grand Canyon, as well as several species of *Myotis* which have closely related species that are found within the park. Due to the remote nature of caves within GRCA, it is a challenge to access all caves in the park, let alone identify the most likely caves for winter bat use. Here we present methods used to model temperature ranges throughout GRCA using physical properties of the landscape including vegetation cover, slope, and elevation. By modeling these variables, cave locations which best fit known bat hibernation temperatures and ideal *Pseudogymnoascus destructans (P.d.)* growth temperatures were identified, thus providing a list of high-priority caves that are recommended for inventory and monitoring prior to the arrival of white-nose syndrome to the region.

Methodology

A cave temperature model was created to assist with prioritization. Since insufficient data is available from caves within GRCA, data from 12 caves in Sequoia and Kings Canyon National Park (SEKI) was used to create a series of regression models to determine the relationship between average annual cave temperature and a series of environmental variables. Initially, five variables were included in the full regression model: number of entrances, average entrance elevation, average entrance slope, average entrance aspect, and vegetation cover at the entrance. Number of entrances was determined from cave inventories; slope, aspect, and elevation were calculated using the 10-meter DEM of the area using ArcGIS 10.2; and vegetation data was reclassified from existing vegetation maps into three categories with assigned quantitative values: (1) shrub/grassland, (2) open canopy, and (3) closed canopy. A step-wise removal of variables was then conducted, removing the least significant variable and re-running the regression model. Akaike's Information Criterion adjusted for sample size (AICc) was then run on all models to determine the best fit model (Table 1). The model using elevation, slope, and vegetation classes was shown to be the best fit model, 1.8 times more likely than the second best fit

Model	AICc	Akaike wt	r2	p
ent+elev+slope+aspect+veg	72.7207	0.0567	0.8078	0.0067
elev+slope+aspect+veg	69.7850	0.2461	0.8282	0.0018
elev+slope+veg	68.5354	0.4597	0.8238	0.0006
elev+veg	70.5422	0.1685	0.7643	0.0006
elev	72.3315	0.0689	0.6922	0.0005

Table 1: Results of AIC model selection showing sample-size corrected AIC value (AICc), relative likelihood of each model (Akaike wt), the coefficient of determination (r^2) of each model, and the significance level (p) of each model. The

model. This model was found to account for 82% of the variability in average cave temperature.

The model equation was then input into the raster calculator to model cave temperature in Grand Canyon:

Temperature = [67.077 – (0.0027 x Elevation Raster) + (0.0848 x Slope Raster Value) – (3.616 x Vegetation Raster Value)]

The result of this model showed a predicted cave temperature throughout the park. These results were then spot checked using the two available temperature records in GRCA caves, resulting in an error of less than 0.5 °C at both caves. Cave locations were overlayed onto the created temperature raster and temperature values were extracted for each cave location. Caves with temperatures matching the ideal growth range of *P.d.* (12.5 – 15.8°C) were identified. A literature review was conducted to explore the range of hibernacula temperature for the 16 species of bats that could be potentially hibernating in caves in Grand Canyon. To find caves where both *P. destructan*s and hibernating bats were most likely to overlap, the temperature range at which these two layers intersected was selected. Additionally, caves were selected whose predicted temperatures were below the ideal growth range of *P.d.* to increase the likelihood of finding hibernacula.

Results:

The resulting raster dataset provided values for temperatures across our study area and ranged from approximately 8.5 – 17° C; temperatures were subsequently predicted for 364 caves throughout the park (Figure 1). The literature review of the hibernation temperatures resulted in a range from -10 to 21°C. The majority of literature revealed that bats do not commonly hibernate at temperature above 10°C. Seven caves were identified within both the ideal temperature range for *P.d* and within the bat hibernation temperature range of 10-14°C; three caves were below the ideal temperature range of *P.d* and ≤ the 10°C hibernation temperature (Figure 1). All ten caves are labeled as priority for inventory and monitoring by park managers.

Discussion:

The westward spread of white-nose syndrome across North America has prompted the proactive study of bat hibernacula in areas of potential outbreak locations. These include the countless cave systems of Grand Canyon National Park. High species richness, high visitor traffic, and the complex canyon environment, provide the perfect opportunity for the potential occurrence and spread of *P.d* and white-nose syndrome, leading to the possible future decline

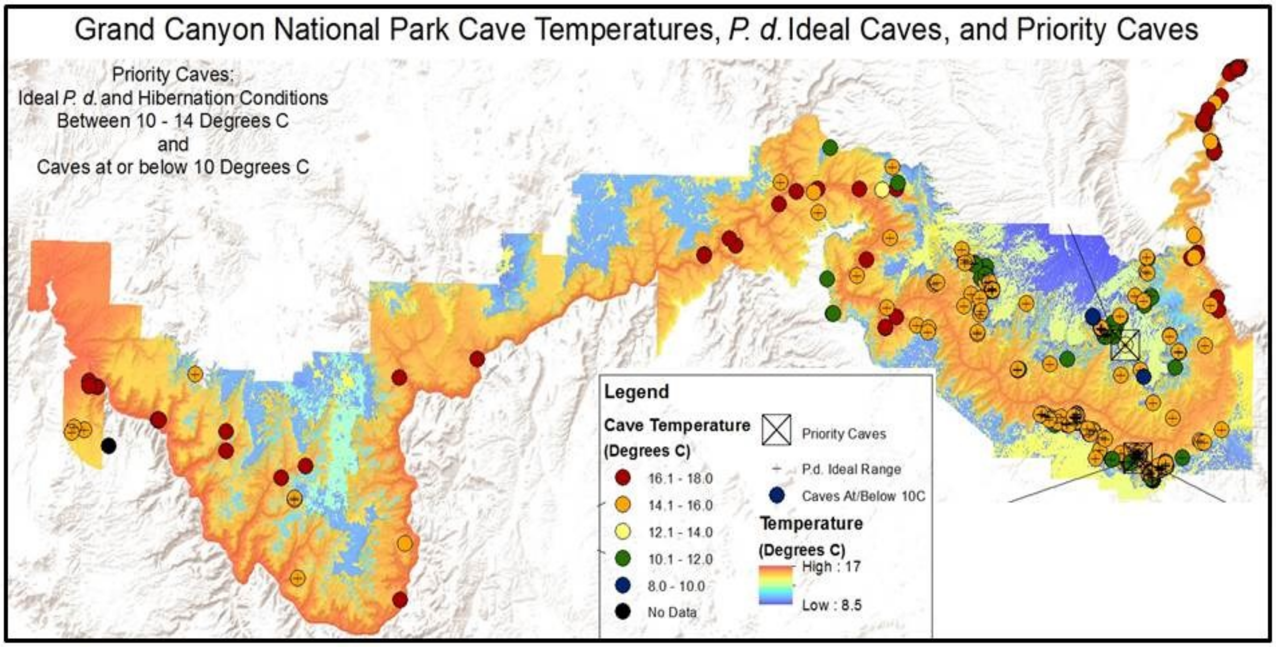

Figure 1: Modeled temperature (°C) map of Grand Canyon National Park, Arizona. Cave location and associated temperatures (n=364), Pseudogymnoascus destructans ideal caves (n=211), and priority caves for survey (n=10) are shown.

in the park's bat populations. The temperature model developed in this study predicted cave temperatures and will provide park natural resource managers a prioritized starting point for surveying the 375+ caves currently recognized in Grand Canyon. Beginning in the winter of 2015, Grand Canyon Physical Science and Wildlife staff will collaboratively survey these high-priority caves which will involve: monitoring cave temperature and relative humidity; conducting hibernacula surveys; and setting up passive acoustic monitoring stations at six identified hibernacula to monitor winter bat activity. The data collected will help inform and improve our current cave temperature model and will begin to expand the knowledge of winter ecology of bats in the Southwest in the absence of white-nose syndrome. Furthermore, continued monitoring of these sites will assist park managers in identifying potential outbreak locations and hibernaculum sites, ultimately leading to the conservation and protection of bats in Grand Canyon National Park.

White Nose Syndrome Decontamination Video for Canada

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Canada

White Nose Syndrome (WNS) is confirmed in five eastern provinces of Canada. The disease has impacted many bat populations and resulted in three species being listed as endangered under the federal Species at Rick Act. The listed species are: Little Brown Myotis, Northern Myotis and Tri-Coloured Bat.

A review of what instructional videos were available, on the internet as of January 2015, demonstrating the correct techniques to decontaminate clothing and equipment for WNS revealed a limited selection.

A National Plan to Manage White Nose Syndrome in Bats in Canada (revised February 2015, http://www.cwhc-rcsf.ca/docs/BatWhiteNoseSyndrome-NationalPlan.pdf) has a Communication and Outreach Technical Working Group. One of this group's goals is: Distribute recommended standard practices and procedures that reduce the risk of geographic spread of WNS in North America.

Parks Canada Agency and Canadian Wildlife Health Cooperative (CWHC) developed a 15 minute instructional video that was managed by a commercial film production company. The recognized method with the use of hot water as the primary decontamination agent was chosen. Complete testing results of chemical products available in Canada and their effectiveness for WNS decontamination were not available at the time of video production. The full Canadian decontamination protocol of the CWHC is found at http://www.cwhc-rcsf.ca/docs/WNS_Decontamination_Protocol-Jun2015.pdf Reference is made to this protocol several times during the video advising viewers to check there for updates and additional detail like the decision making tool.

The primary audience of the video is park staff, cave researchers and recreational cavers. Although it is assumed that bat researchers will be fully aware of WNS decontamination protocols, this video may offer them reminders or tips.

The video has been designed and produced with Canada's two official languages kept in mind. Therefore all narration is added after field shooting. The primary public distribution point will be the Parks Canada YouTube site, https://www.youtube.com/parkscanada

The Missouri Cave Database

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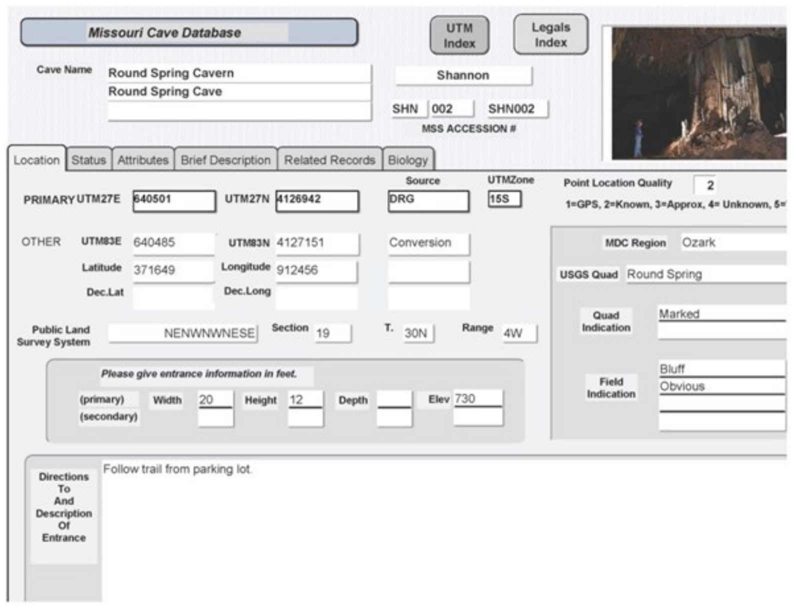
Abstract:

The Missouri Cave Database (MCD) is an outgrowth of a 50-year effort by the Missouri Speleological Survey to document cave and karst information in the state. The present database was initiated as a small effort in the late 1980’s and eventually incorporated thousands of records from the old Cave Catalog, a joint effort between the MSS and Missouri DNR. Today the database has expanded into a relational database with 7,000 main records representing cave entrances. A faunal table contains nearly 19,000 records; additional descriptions, trip reports, and other materials comprise yet another 11,000 records; and records of maps on file contain another 3,500 records.

Today the database is maintained by MSS in cooperation with Cave Research Foundation (CRF). Major funding has come from a variety of public agencies, plus the MSS and CRF. The presentation will be in the form of a demonstration of the working database.

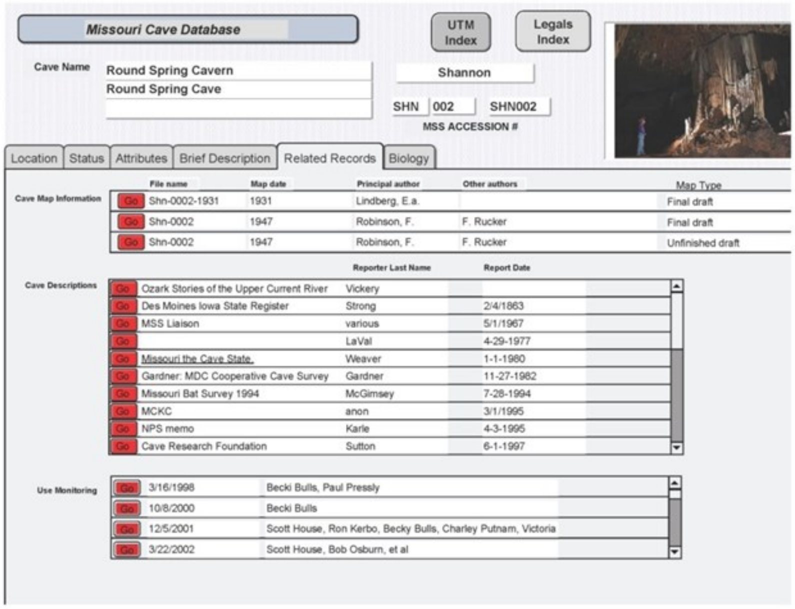


Entry Table for MSS Cave Database

The Missouri Cave Database (MCD) is a relational database managed by the Missouri Speleological Survey (MSS) in cooperation with a variety of other organizations and agencies. It contains information on nearly 7000 caves in the state.

The MCD is an outgrowth of early attempts to computerize the listing of caves in Missouri. Original paper lists were printed into a “catalog” beginning in the late 1950’s. This was replaced in ~1964 with a computerized cave listing. The “fields” (categories, really) were simple text with no search capabilities. Eventually this was ported over to a slightly more advanced system where simple searches on county names were made possible.

As micro-computers came about, the need for more search capabilities became obvious. Categories became fields and searches were possible. A prototype was developed on Apple computers, using National Park Service caves as the data set. In time, the old text fields of the main dataset, written in arcane languages, were broken and imported into different programs. Eventually



Related records in the MSS Cave Database

the superiority of one of these programs became obvious and further development of the alternatives was abandoned.

The MCD is written in FileMaker Pro, a cross-platform program known for the ease of programming and use. The MCD is easy to use and yet powerful at the same time. Import functions are powerful and simple. This allows multiple people to work on aspects of the data and reimport the revised material into the main database. The import functions also allow for simple importation of locational data revised in other programs, such as GIS, and then brought back into the main database.

Purchase of the "Advanced" version of the software allows the data manager to export data sets as runtimes, suitable for use by anyone with a 64 bit machine. This enables us to distribute runtimes containing subsets of the data. For example, the Mark Twain National Forest gets a subset that contains information only on caves within the Forest, which amounts to something over 700 caves or roughly 10% of the total within the state. All of the large public agencies in the state cooperate, in one form or another, with the MCD. While primarily a volunteer effort of the MSS, additional funds for the development and maintenance of the database have come from National Park Service, U.S. Forest Service, Missouri Department of Natural Resources, and Missouri Department of Conservation. Other public entities cooperating in the sharing of data include the Department of Defense (Corps of Engineers and Ft. Leonard Wood). St. Louis County Parks, and City of Perryville. Private entities such as the L-A-D Foundation (owner of nearly 200,000 acres) also cooperate in sharing data and supporting expansion of the database. Cave Research Foundation (CRF) has provided financial support, software, and office space for the data manager.

The Missouri Cave Database has served as the model for databases elsewhere including Mammoth Cave National Park KY, Buffalo National River AR, and a new database for the Illinois Speleological Survey.

Brief Description of the Tables:

There are currently seven tables with six relationships tying them together. A database design report in HTML format is available for anyone interested. Most of the tables are linked by using a cave's MSS accession number, e.g. SHN139 – three letters for the county and then a sequential number within the county.

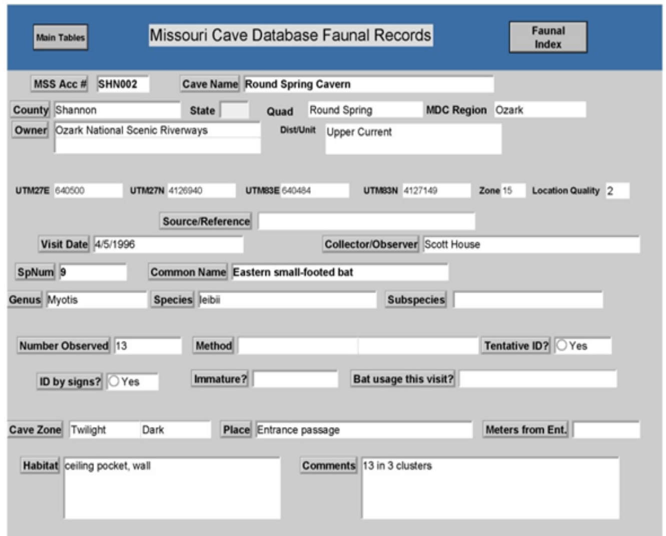
The Main Table contains 65 fields and approximately 7000 records. The fields include several locational fields, simple attribute fields such as geologic unit, ownership, status, length, cultural notes, etc. Using this table alone, one can sort out (for example) all of the caves on a certain quad that are owned by a certain agency that are more than X length or in Y geologic unit. The Main Table has several pages and layouts to it, terms that will mean little to most people. Also included are portals or gateways into the related tables. The 7000 records represent caves or disparate entrances to the same cave.

The Maps Table contains 14 fields and over 3500 records. This is not a link to the gigabytes of digitized cave maps but rather an index to existing cave maps on file with the MSS. The 3543 records each stand for a sheet of a cave map; most are single sheets. However, this table could be exported and act as a link if someone wished to program such a beast.

The Reports Table contains 15 fields and approximately 11,000 records. These records are individual entries from cave files reports, grotto newsletters, emails, professional reports, etc.

The Faunal Table contains 42 fields and nearly 19,000 records. Each record represents a species occurrence in a particular cave on a particular date. For example, ten pipistrelle bats in Cave X on Y Date is one record. As MSS cooperators dig into old reports this number is rapidly increasing. Regular monitoring of caves is also adding a great many records. Again, this information can be easily exported for use in GIS or other applications.

The Species Table contains 22 fields and over 1100 records. This is a reference table used by the faunal table to insert specific information on a certain species. These two tables are linked via a species number. The 1100 records represent different species noted from Missouri caves. Extinct species are included.



Species records , Missouri Cave Database

The Use Monitoring Table contains 24 fields and, so far, less than 50 records. This table exists to track monitoring of caves. Information from other databases will be imported into this table; the monitoring database for Ozark Riverways has over 1500 records that will be imported and linked to the main table.

A Do List table currently has 8 fields and 1100 records. This is a trial table that may or may not be continue. Consider it under development. If the concept does not work, it will be removed.

National Forest Cave and Karst Management Plans— The need to include "Hotw to" Wording

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Abstract

A significant number of National Forests have caves and karst, but very few National Forests have personnel whose primary duties are to support and manage that cave/karst resource. Most of the National Forests have managers that have caves and karst among their assigned duties, but many other duties that are higher on the priority list. Additionally, there is entropy associated with normal changes in personnel assignments and new staff coming onboard. Many of these same Forests have established caver communities that can support in the transitions and tasks.

Forest level cave and karst management plans need to include wording that not only provide the legal mandates and policies, but the also the management parameters for the five primary user groups of caves; the Forest managers, for profit companies whose actions affect caves and karst, researchers, recreationalists, and the organized caving community that help with the cave management and tasks. These cave and karst management plans need to provide clear concepts and structure that can be understood by diverse user groups and training levels. These guides also need to include Forest specific examples to help the "new-to-caves" manager effectively come up to speed.

A cave/karst recommendations document has been written for Forest managers who have little allocated staff for caves /karst management. The document uses the authorities (CFRs) and Forest Service Manual (FSMs) sections as the foundation to implement in a management in a uniform manner. There are short, Forest specific sections addressing the individual Forest's resource. The documents are located at: http://centralarizonagrotto-cavemanagement.webstarts.com/. Recommendations for five forests are presented along with the bibliography and revision log.

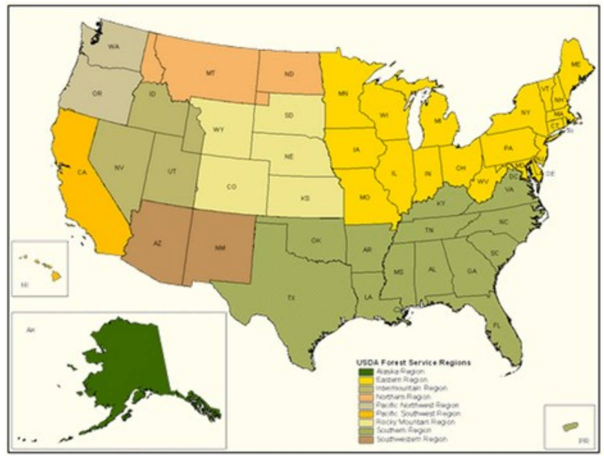

Figure 1. Forest Service Region

Introduction

In the nine regions there are 155 National Forests and 20 National Grasslands. Most of the Forests have caves and karst. Very few have Forest level cave management plans. Figure 1 shows the forest regions and Table 1 shows number of forests within regions[1] with

[1]http://www.fs.fed.us/wildflowers/regions/
[2]http://www.fs.fed.us/maps/forest-maps.shtml

Area of U.S.	States	National Forests in Region *	Cave Resource Specialists in Region
Northern	ID, MT, ND	12	?
Rocky Mountain	CO, KS, NE, SD, WY	18	?
Southwestern	AZ, NM	11	2
Intermountain	ID, NV, UT, WY	13	1
Pacific Southwest	CA, HI	17 + 2 "Other areas"	1
Pacific Northwest	OR, WA	18 + 5 "Other areas"	2
combined with Eastern region	n/a	n/a	n/a
Southern	Southern and SE states	36	?
Eastern	Eastern and northcentral states	13	?
Alaska	Alaska	2	0
Washington Office	All	155	1

Table 1 Number of forests within regions

an estimate of cave resource specialists[2] that have a working knowledge of caves and karst. There are a few more.

There is an ongoing flow of forest personnel changing locations with transfers, promotions, and retirements. With forest level cave/karst management plans, transferring personnel at the district level have the same working document. When personnel move between forests or to the regional level, very similar, approved documents will greatly reduce the learning curve and getting up to speed time.

This is beneficial for both those forest personnel that are familiar with caves and karst, and forest personnel starting positions where caves and karst are on their list of responsibilities, but the employee has little background in this area.

Having forest level cave/karst management plans benefits the four other forest user groups:

- For profit companies whose actions affect caves and karst (Egs. timber and grazing) will have consistent parameters for the businesses.
- Cave researchers have consistent criteria for the research process across multiple forests.
- Caver support (Egs. NSS, CRF) have the same working criteria for projects and supporting the cave management.
- Recreational spelunkers have an easy access to caving ethics on the forest.

The forest level cave management plans need to include clear, practical wording to be useful.

Recommendations for Cave and Karst Management

The document has been compiled using multiple sources besides the CFRs and FSM; the previous USFS cave and karst management coordinator documents, Jim Nieland's XYZ Cave Management Plan, and individual cave and forest level cave management plans.

The document contains:

- Authorities
- Forest Service Manual and handbook Direction
- Cave and Karst Management Policies and Objectives
- Extent of the Resource – Individualized for the Forest
- General Administration and Public Involvement
- Cave Management Categories
- A cave evaluation and classification system
- Cave inventory procedures
- The Significant Cave Nomination Process including nomination forms, and Finding/Decision Form signed by the Forest Supervisor.
- Cave management techniques
- Cave ethics (do's and don'ts)
- Research guidelines

- Monitoring categories
- For cave files, what is kept in the Master File and what is allowed in the Public File
- Management guidelines and techniques for karst
- Cave Entry Permit
- Terms and Definitions

The document provides the "how to" information that allows application for specific projects. For example when a cave has been nominated for Significance, the steps and responsibilities are listed when the Forest Supervisor signs the Finding/Decision for the cave to receive permanent significant status.

Cave Management Categories

There are two management categories of caves on National Forests; Generally Known Caves and Lesser Known Caves. This is a root consideration for how the Forest determines the management.

Category 1: **Generally Known Caves**

- Highly Developed (trails/lights/parking), directed access
- Developed Natural (parking/signage), directed access
- Natural (little/no improvements), no directed access

Category 2: **Lesser Known Caves**

- Primitive, no directed access
- Sensitive and Pristine, no directed access

There are several advantages having these two categories:

- Current conditions and the general knowledge base are considered up front.
- Classification of the cave (Preserve, Permit, Non-Permit, and Directed Access) can be applied where needed.
- Management policies can be made for the caves in each category. Individual cave management plans address more specific needs.

Research Guidelines

There are guidelines addressing the steps from the proposal submittal, techniques, deliverables, and resource degradation.

File Management

There are federal restrictions on information may be publicly available. The **Master File** contains complete information on the cave including the cave management plan. The **Public File** contains non-sensitive information including any closure orders, key checkout/return policy. For example, the Public File helps the person at front desk with what information can be discussed during key checkout and return.

Karst Management

Mitigating unnecessary surface destruction in karst areas is an ongoing awareness problem. There are guidelines to help reduce the impact of surface operations on the subsurface karst ecosystems while still extracting the surface resource. Three examples include:

- Grazing: Locating salt stations away from karst features. The unnecessary disturbing of the surface upstream of recharge entry points causes unnecessary siltation and impact.
- Timber harvesting: In upstream areas of karst features, do not use tracked vehicles in the drainages, and fell trees away from the drainage. Avoid throwing slash into karst features.
- Non-hard-surface roads: Avoid karst features and avoid road runoff going into karst features.

Unfortunately, lack of awareness is a primary enabler to bad practices.

Significant Cave Nomination Forms

After the initial surge of Significant Cave nominations in 1994, new nominations have become rare. The nomination forms have been updated to include submitter email address, cave GPS location and other information that was not readily available at that time.

Also included are cave inventory forms. These help with the "things to think about" when inventorying the cave.

Management and Monitoring Categories

Several monitoring categories are discussed to provide an acceptable tool box for the given caves being considered. Some of the areas include:

- Trip size limits
- Trip limits
- Visitor registers
- Photo monitoring
- Signage
- Gates
- Maps
- Trails

Before a cave gate is installed a closure order and at least an interim cave management plan is needed. This has been a long, ongoing problem with cave gates. The gates are put on but follow up management parameters are not written down.

Forest Specific Wording

There are four areas in each document that contain Forest Specific wording.

- The **Title Pages** currently use "Recommendations for XYZ Cave and Karst Management". When approved by each Forest the title pages would change to "XYZ Forest Cave and Karst Management Plan".
- **Extent of the Cave and Karst Resources** – This contains a high level description of the caves and karst on the particular forest. For example, some Forests have large areas of active karst while other Forests do not. Some Forests have lava tubes.
- The **cave numbering system** contains **examples** of the forest being addressed.
- A forth area addresses karst. Some Forests have large karst areas. Other Forests do not. For the Forests without large karst areas a reduced karst management Appendix J has been created to reduce the unnecessary burden.

These forest specific items make the implementation local and less abstract. The remainder of the cave and karst management guides is the same for all of the Forests.

Forest Plan Integration

Updating each National Forest Plan is a long and involved process. If the Forest plan references (linked) to the Forest's cave and karst management guide, the process of updating the can be achieved with considerably less overhead.

In Arizona in the last two years we have achieved getting these links into the Forest Plans for four National Forests. A fifth Forest is currently updating their Forest Plan and the link is expected.

Areas of Discussion

The Recommendations for National Forest Cave and Karst Management has not yet been approved by a national forest. The costs associated with achieving approval have become more and more restrictive due to budget issues. The budget issues are expected to become more prohibitive.

However, having forest level cave and karst management guidelines provide the tools for forest personnel to substantially leverage their time through the use of volunteers. The cave guide provides the working structure for individuals and groups to proactively address the caves through Challenge Cost Share agreements and Volunteer contracts.

Conclusions

- Forests with significant caves need Forest level cave and karst management guides.
- There are very few cave resource specialists in the National Forest system.
- Personnel "new-to-caves" are assigned cave management as one of their responsibilities.
- Recommendations for cave and karst management is available at http://centralarizonagrotto-cavemanagement.webstarts.com/
- The management guidelines need to be understandable to multiple user and training groups. The guidelines provide tactical direction for day-to-day activities.
- The cave and karst management guides need to be linked in the Forest Plan.

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A modern gate for Ezells Cave

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Abstract

Ezells Cave is one of the most biologically diverse caves in Texas, yet has had a tragic history of mis-management. Early attempts at protection excluded the bat colony which provided important nutrient input to the cave's ecosystem. In March of 2015, a new bat-friendly gate was finally installed with the help of many volunteers and donors.

History

Ezells Cave (Figure 1), in San Marcos (Hays County), Texas, has a long and colorful history. It was first discovered by land surveyor Greenberry B. Ezell around 1870, and purchased by him in 1893. He operated it as a show cave for a short time, even building a small boat for touring the Lake Room. (TSS 2015)

The cave fosters a rich ecosystem, with 116 species recorded so far (TSS 2015). Blind, cave-adapted salamanders, *Eurycea rathbuni* (Texas Blind Salamander) (Figure 2), have been noted in the cave almost from the beginning. These salamanders are neotonous, and have been collected from only seven locations in the small Purgatory Creek basin, including Ezells Cave. As such, they

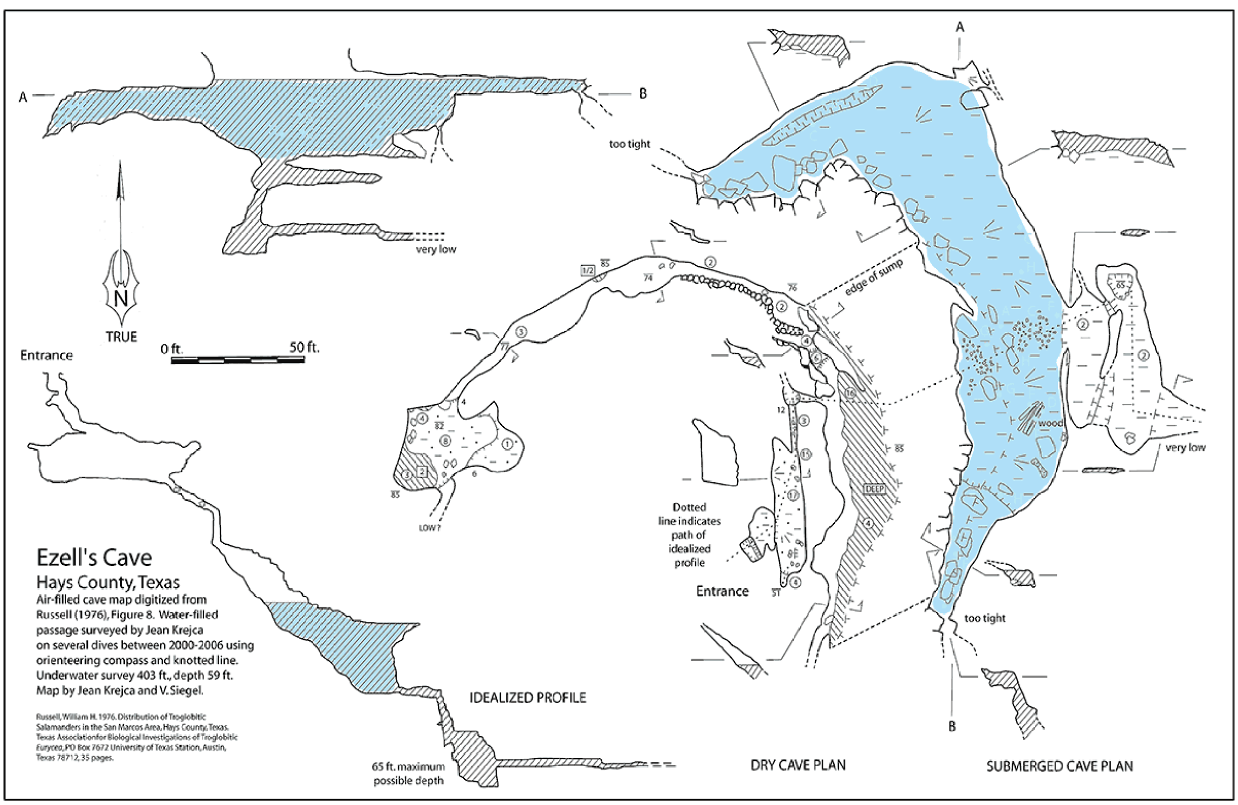

Figure 1. Map of Ezell's Cave by Jean Krejca and Vickie Siegel

are listed as Vulnerable on the IUCN Red List of Endangered Species (Hammerson and Chippindale 2004). The US Fish and Wildlife Service listed it as Endangered on 11 March 1967 (Udall 1967).

The rich biodiversity and rarity of the salamanders and other aquatic species initiated early conservation efforts. It was visited by NSS President Charles Mohr (a cave biologist) (Figure 3) around 1948, who collected and photographed a blind salamander and wrote about his adventure in *The Caves of Texas* (Mohr 1948). In 1955, the Texas Herpetological Society (THS) purchased an easement from the then-landowner, Truman T. Saltonstall, to protect the salamanders. The THS then built a brick wall inside the entrance fissure to support a chain-link fence, believed to still allow bat entry while keeping out unauthorized humans. Neither was true. Vandals cut through the fencing almost weekly to enter the cave and collect salamanders. This was eventually replaced with a 12"x12" steel bar grid gate, but this did little to deter vandals and the cave was essentially left unprotected. (TSS 2015)

Figure 2. *Eurycea rathbuni* Credit: Jean

Figure 3. Charles Mohr at Ezell's Cave entrance Credit: unknown

The owner of nearby Wonder Cave (a show cave), T. J. Mostyn, bought the cave from Saltonstall in 1962, and covered the entrance with a solid steel plate. This alarmed biologists, who attempted to get The Nature Conservancy (TNC) to purchase the property. However it was sold yet again as a house lot. Eventually, on 27 September 1967, TNC was able to purchase the cave with the assistance of the Southwest Texas Grotto. The solid "gate" was promptly removed, and illegal entry began anew. TNC bought an adjacent property with a dilapidated house, renovated it, and installed a caretaker to keep an eye on the cave. Bats had not yet recolonized the cave after the disastrous closure efforts, although two experiments in transplanting bats from nearby caves were attempted by Texas Tech University in 1970. (TSS 2015)

In 1971 the National Park Service designated Ezells Cave as a National Natural Landmark. And in 2004, TNC transferred ownership to the Texas Cave Management Association (TCMA). Sometime between the purchase by TNC and transfer to TCMA, a new gate was built, involving a solid concrete platform and round tubular bars.

(Figure 3) A chain-link fence was also installed around the perimeter of the cave entrance. Water monitoring equipment was installed by the Edwards Aquifer Authority, which holds a conservation easement to the cave. Vandalism attempts continued, and bats have not returned.

The Modern Era

Recognizing the biologically-unfriendly nature of the entrance gate, biologist (and TCMA Preserves Committee Chair) Jim Kennedy petitioned the TCMA to remove it and replace it with a bat-friendly cupola-style gate. Cavers Ben Hutchins and Andy Gluesenkamp, both biologists working for Texas Parks and Wildlife Department, helped secure a Landowner Incentive Program (LIP) grant to cover the cost of materials and tools. TCMA solicited additional donations from cavers and other organizations, and succeeded in raising a total of $15,853. Donors all had their names welded on the finished gate bars. An 8' x 12' cupola-style gate was designed by Kennedy, (Figure 4) and constructed on 8 and 15 March 2015 by 29 cavers. There were 282.25 person/hours recorded during the construction, and another 63.2 hours for driving. This resulted in a volunteer value of $9013.20. The project was featured in the *San Antonio Express-News*, *San Marcos Daily Record*, and *The University Star* from nearby Texas State University in San Marcos.

Figure 3. Concrete gate at Ezcell's Cave
Credit: Jim Kennedy

Figure 4. Jim Kennedy measuring gate
Credit: Logan McNatt

TCMA still has to remove the old concrete-and-round-bar gate, which will require jack-hammers, rock saws, and cooler weather than has been available since March. Even with the effort, it is uncertain that the bats will recolonize the cave. Surrounding habitat has altered, with houses appearing in former ranchland. But as the author asserts, it is a guarantee that bats would not return unless the old gate was replaced. And as a conservancy dedicated to protecting karst and promoting best management practices, TCMA's preserves should be models of good management, not embarrassing failures. Only the future will tell if these recent efforts are successful.

Acknowledgements

Much of the history and biology of Ezells Cave was taken from the extensive files of the Texas Speleological Survey. The regating project was spearheaded by Ezells Preserve Manager Ron Ralph, who expertly herded the cats. We also thank the donors and sponsors, particularly Texas Parks and Wildlife Department, John Schneider, Edwards Aquifer Authority, Michael Portman, Charles Goldsmith, Fritz Holt, Sam Wayne Young, John Brooks, Julie Jenkins, William K. Davis, Randy McNatt, Ned Fritz, Tom Florer, Aubrey Burnett, Owen Burnett, Marlie Hussing, Bexar Grotto (San Antonio), and the University of Texas Speleological Society (Austin). Finally, thanks go out to TCMA for all the hard work and forward-thinking efforts on behalf of Texas karst.

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The National Forest Service Cave and Karst Program in 2015

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The United States Department of Agriculture Forest Service (Forest Service) manages caves, karst systems, and associated resources on over 780,000 square kilometres of public land. Approximately 531,815 square kilometers (205,335 square miles) of bedrock known to host caves and karst systems occur on National Forest System (NFS) lands. Known caves and karst areas occur in over 100 National Forests and Grasslands, and over 2,200 significant caves have been identified to date. The management of these resources is mandated by the Federal Cave Resources Protection Act (FCRPA) of 1988 and other federal acts, and is guided by the Code of Federal Regulations (CFR) and the Forest Service Manual (FSM). The goal of the Forest Service National Cave and Karst Program is to protect and maintain the biological, geologic/mineralogical/ paleontological, hydrological, cultural, educational, scientific and recreational values of caves and karst resources.

Since the last National Cave and Karst Management Symposium in 2013, the Forest Service National Cave and Karst Program has moved forward with several key efforts. The Minerals and Geology program updated the Forest Service handbook chapter with direction on cave safety protocol, including information on cave rescue as well as vertical caving. National courses and regional workshops have occurred to train Forest Service employees in caves and karst management and more are planned agency-wide. The program developed guidance to assist forests in forest plan revisions, and is working to connect with forests individually to ensure that caves and karst are considered in these updated plans. Finally, Minerals and Geology created national internal communication tools to facilitate broad understanding within the agency concerning all aspects of the program. At the forest level, forests are working to nominate and designate new significant caves, with forests adding caves to the list from the Pacific Northwest Region and the Rocky Mountain Region in 2015.

One of the main goals of the Forest Service National Cave and Karst Program is to strengthen relationships with key partners at the national, regional, and forest level through facilitation and education. Partners from Cave Research Foundation, the National Speleological Society, and Bat Conservation International have mapped, cleaned, restored, documented, monitored, and studied our caves with skill, passion, and dedication. Over the past 10 years, Forest Service cave and karst managers have utilized GeoCorps America internships to accomplish cave and karst resource work in the field including: creating databases, conducting field inventories, mapping subsurface resources, and educating visitors. More than 20 interns have worked on forests from Alaska to West Virginia specifically with the cave and karst program, with other interns working with cave and karst resources as part of their duties. With limited budgets and diversified duties of resource managers, the assistance received from all of our partners has allowed a great quantity of work to be accomplished furthering the cause of cave conservation.

A Multidisciplinary Project for Sustainable Management Planning in Karst, Chiapas, Mexico

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Forest Service staff through the Office of International Programs has worked with the Reserva de la Biosfera Selva el Ocote in Chiapas, Mexico since 1993. The joint effort began to focus on the Rio la Venta canyon in 2010, a key area for conservation within the reserve. Surface water is scarce in el Ocote due to karstification, so the canyon and river provide important habitat for the riparian vegetation and many rare and endangered biota. However, karst systems are particularly vulnerable to overexploitation and pollution due to their high hydraulic conductivity and points of rapid infiltration. A multifaceted and sustainable approach for management is necessitated by the complex hydrology of karst systems and the easily impacted nature of its resources. The Forest Service Office of International Program has supported this multidisciplinary project to assess and address current and potential environmental issues for the largest sub-catchment of the Rio la Venta watershed as a foundation for creating sustainable management strategies in the canyon.

A level one assessment spatially depicted and quantified human disturbance in a GIS based on information from a wide range of stakeholders and field surveys. The assessment also mapped areas of vulnerability to groundwater contamination. Results from the assessment show the area to be fairly pristine, with minimal environmental disturbance. The majority of the study area is classified as moderately vulnerable to groundwater contamination; however areas of high vulnerability exist. Current threats to the ecosystem stem from local practices related to residents' daily water use, agriculture, and animal husbandry. The reserve lacks the ability to enforce regulations and large areas of private land exist within the sub-catchment, so the assessment concluded that top-down management approaches are unsustainable. Drawing from the final model created by cross-referencing disturbance with vulnerability, the project created and implemented water quality monitoring and karst education projects incorporating local residents in the areas of concern. Future work includes similar assessments of other subcatchments within the larger Rio la Venta Watershed including continued dye trace studies, and development of a water budget through partnerships with local universities.

Caves and public use in the Southern Espinhaço Mountain Range, Brazil

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Introduction and objectives

Caves are fragile, complex and low resilience environments however caves provide unique scientific, educational and recreational opportunities for visitors. These uses, without proper management, can severely impact or even destroy the attributes that provide such opportunities. Many of these resources are not renewable, and in these cases the damage is irreversible. There are some caves with established public use, still incipient in the southern portion of the Espinhaço Mountain Range. Among the main observed uses, we highlight the sporadic visitation of rare beauty speleological sites (Figure 1), the religious use (Figure 2) and the practice of adventure sports (climbing, rappelling and others). None of the identified caves are actually prepared to receive such activities, as it has no speleological management plan developed in any cave in the area. This instrument allows the development of appropriate planning, control and monitoring of public use activities. These caves are therefore vulnerable to the impacts arising from uncontrolled visitation as speleothem breakage, graffiti, trash disposal, fauna alterations, sediment perturbation, etc. (Figures 3 and 4).

The central objective of this work is to identify and analyze the current status of public use in the caves of the area. This identification involves a great responsibility, since the mere disclosure of a list of caves, or photographs showing the great beauty of the underground environment, can stimulate the use of caves that are not prepared for such activities.

Methodology and results

The identification of caves with public use established in the Southern Espinhaço Mountain Range was conducted through literature review, consultation with CECAV (Brazilian Caves Research and Protection Federal Agency) database, interviews with

Figure 1 – Entrance of Salitre cave, in quartzite rock. Site of numerous opportunities for public use and environmental interpretation.

Figure 2 – Entrance of Capela Velha cave with a rock cross on the floor. Photo: Luciana Alt and Vitor Moura.

Figure 3 – Gentio cave, in marble, showing graffiti in the foreground and sediments with traces of intense trampling. Photo: Luciana Alt and Vitor

Figure 4 – Lapa Santa cave passage showing garbage disposal. Photo: Luciana Alt and Vitor

researchers and extensive consultation on the internet websites. The study included 13 municipalities in the area and identified 33 caves with public use or which were promoted as tourist attractions. In the field it was found that 14 of these caves had higher propensity to public use and received greater pressure by this activities. The Figure 5 shows the main caves identified during the work and its location in relation to protected areas in the Southern Espinhaço Mountain Range. The environmental analysis divided the analyzed caves into four groups of attributes: (I) caves whose main attraction is prehistoric archaeological sites, (II) caves with religious use, (III) caves whose main attraction are historical archaeological sites and (IV) caves with recreational use. In some caves these attributes are overlapped, representing a challenge for speleological management activities.

Conclusions and recommendations

This work identify that the population poorly absorbs scientific and environmental values linked to speleological heritage. This can be explained by the lack of specific educational activities in the area. Much of the public use activities identified in the Southern Espinhaço are sporadic visits for recreational purposes. The public in general misunderstands the dense and complex layers of environmental information commonly stored in caves. As example, the public did not apply proper value in one archaeological site associated with a cave because this information is not included as part of their life, education and nowadays culture.

It was noted that some caves are being promoted, irresponsibly, as tourist attractions. The historical-cultural heritage housed by these caves is very fragile and extremely relevant, being vulnerable to vandalism. Until they are properly prepared to receive visitors these caves should not be promoted, under penalty of losing, irreversibly, his heritage.

This work sets an important step, and despite the limitations in time and sampling, the results reached depth in analysis and can effectively contribute to the future planning of the public use of the caves in the area. From the acquired knowledge, it is recommended that effective actions must be carried for protection and enhancement of speleological heritage of the area. The main actions required are: increase knowledge regarding the speleological heritage, creation of more protected areas including caves with public-use demand, promote educational programs and perform cave management plans. Some of these actions are in progress, such as the Salitre Cave management plan, in Diamantina, but there is still a long way to go.

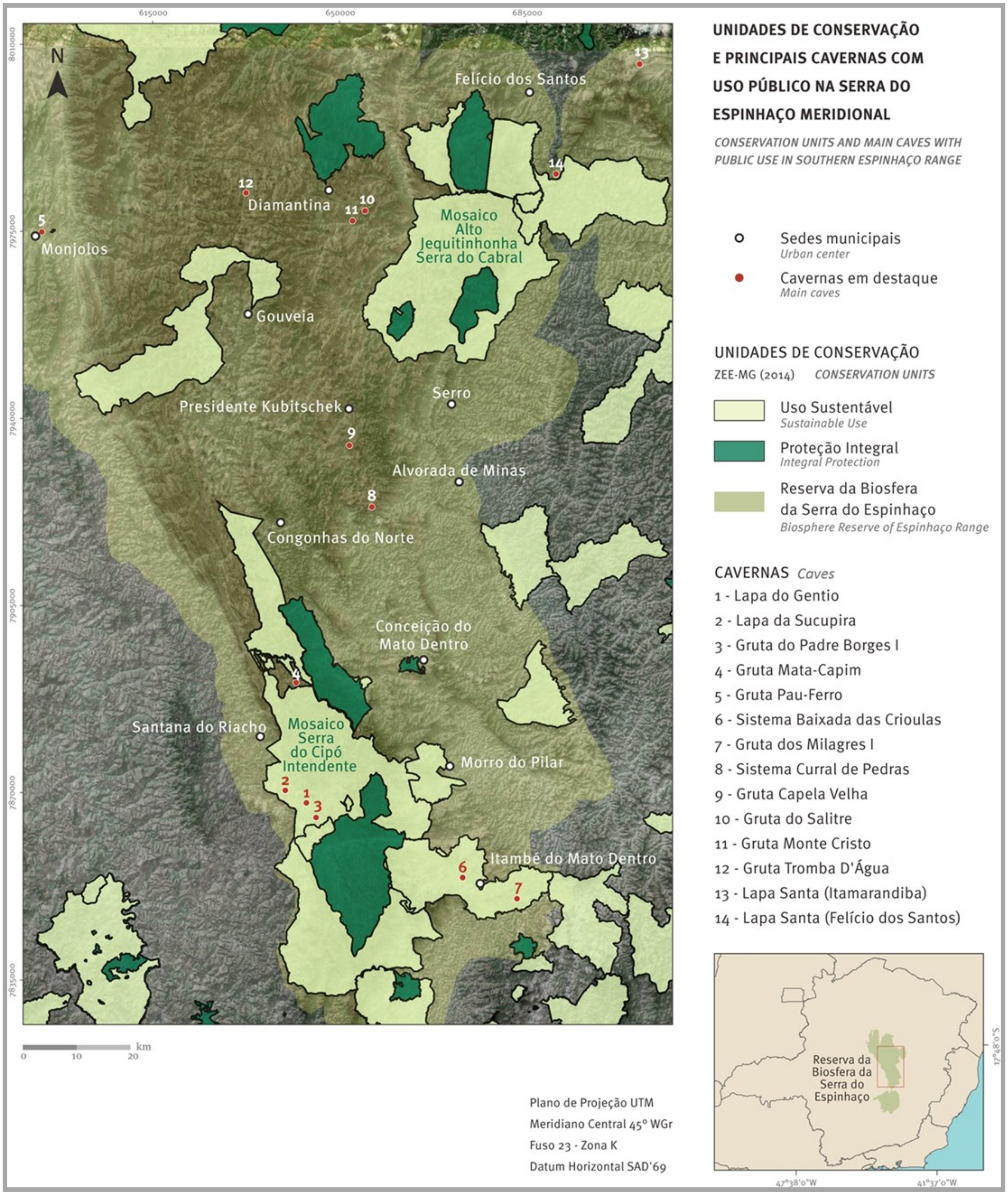

Figure 5—Map showing the main caves with public use and protected areas (conservation units) limits in the Southern Espinhaço Mountain Range area

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Can Monitoring of Microorganisms from Show Caves be used in Human Impact Assessment?

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The problem of tourist impact on caves has received special attention mainly considering the physical phenomena, surpassing by far the very few studies on the microorganisms that are brought by tourists inside the caves and their effect on cave environment (except for some few special situations). Our study intends to be novel in different aspects by taking into consideration microbial monitoring for a longer period of time and considering the relationship to different environmental features, including the geometry of the general development of the touristic sector, the number and type of openings, temperature, air relative humidity, CO_2, and number of particles in the air. A simple method was used by exposing RIDA@COUNT plates to cave air and pools water and counting the number of microorganisms at 24 hours intervals for 5 days. The mediums were for Total aerobic, Yeast & Molds, E. coli/Coliformes and Enterobacteriacaea. The number of Enterobacteriacaea and Coliformes was small for air samples and more significant for some of the water samples, while the number of Total aerobic and Yeast & Molds was significant in all cases. We will discuss the differences between caves and between stations inside each of the four studied caves where monthly sampling was undertaken. We also discuss the usefulness of this method in the assessment of human impact in show caves and the need for an integrated monitoring of show caves.

How Cavers Became Allies Instead of Adversaries at Mammoth Cave National Park

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Introduction

The overall story of the Cave Research Foundation's (CRF) formative years has been told by Phil Smith and Red Watson (1981) and by Roger Brucker and Red Watson (1976). However, there is an element to this story that has not been discussed, and another aspect of this story that has not been emphasized. First, cavers and park administrators did not and maybe could not understand each other very well, and second, a park service employee gave crucial advice to the cavers that helped them gain acceptance by the park.

Having joined CRF in 1973, and first worked with the National Park Service (NPS) as a seasonal guide at Jewel Cave National Monument starting in 1974, I have gained some perspective into the respective cultures of the NPS and CRF.

A Basic Misunderstanding

One reason for the initial poor communication is that cave explorers and Mammoth Cave National Park (MCNP) administrators did not understand or appreciate each other's priorities and motivations. Park administrators had their hands full managing tour operations, a visitor center, campgrounds, picnic areas, a hotel concessioner, roads, ferries on Green River, utilities, hiking trails, fire fighting and more within over 50,000 acres of land (this is not a complete list of responsibilities). They would view cave explorers from Ohio as somewhat eccentric young enthusiasts who wanted to do something risky in the park. The entrapment and death of Floyd Collins had occurred only 30 years before, and this was not the kind of notoriety the park wanted or needed.

Park administrators and cavers had a common interest in park caves, but of course the interest came from different angles. In order to explore caves in or near the park, the cavers had to plan trips far in advance, and travel hundreds of miles from home. They saw that NPS staff lived right on top of or near park caves, yet did not explore them. To cavers, this was inconceivable! (Yes, hear that just like in the Princess Bride movie). Here are a couple of stories about these cavers that illustrate the depth of their desire to explore.

In the early 50s, Phil Smith and Roger McClure were students at Ohio State University. They met Jim Dyer, who had moved up to Ohio after retiring from being Manager of Floyd Collins Crystal Cave. Phil and Roger decided that caving in Kentucky was for them, but they had no car. So they packed up kits in duffel bags, and hitchhiked to Mammoth Cave! One time they did not get to Cave City until the wee hours, so the few cars passing by would not pick them up. The only solution to their problem was to walk the nine miles to Mammoth Cave with the duffels on their backs! The manager at the Mammoth Cave Hotel would let them spread their sleeping bags on the porch so long as they packed up before guests started coming downstairs. On one of these hitchhiking trips to Mammoth Cave it was bitterly cold, so the manager let them sleep on the lobby floor. They befriended some of the Guides, who loaned them Coleman lanterns so they could better see Dixon Cave. To park administrators, living in their comfortable homes on top of the cave, the idea that anyone would go to such great lengths in order to explore holes in the ground would be, well, inconceivable!

Here is another story, after the establishment of CRF, but it too shows that these cavers would do whatever it took in order to get underground in Kentucky. Back in 1964-65, Stan Sides would skip out of medical school classes at University of Missouri in Columbia on Friday afternoon, and catch a Greyhound bus to St. Louis with his duffel of cave gear, sleeping bag, etc. First and second year med school had Saturday classes until noon, so there was considerable risk in cutting classes due to possible pop quizzes.

Red and Patty Jo Watson would pick him up at the bus station in their VW Microbus, and then drive to Flint Ridge. Typically, Patty Jo would ride in the back with their daughter Anna while Stan drove. This allowed Red to sit in the front passenger seat where he would cradle a portable typewriter in his lap so he could type out letters as they rolled down the highway. Red was President of the Cave Research Foundation at the time and there was much to do. This was of course an avocation as both he and Patty Jo were professors at Washington University, which left little spare time. As Red would near completion of a letter, he would ask Stan what town was coming up. Then he would finish the letter for mailing at that town's Post Office.

They would arrive late in the evening or the early wee hours, and get to bed in the little building CRF called the Spelehut or the back bunkhouse, depending on availability. Saturday would be consumed by a long cave trip that lasted well into the night. Sunday was a time for writing trip reports and packing up muddy cave gear for the return drive. Red and Patty Jo would take Stan back to the bus station in St. Louis for the long ride back to Columbia, followed by a late walk home

Figure 1. Flint Ridge cavers attend the 1955 NSS Convention. From left to right are Jim Dyer,Tony Vanderleeden, Roger Brucker, Joan Brucker, Philip Smith, Beverly Bixler, David Jones, Roger McClure, and Jacque Austin.

Photo likely by Bill Austin.

with his duffel of dirty cave gear. Monday morning early saw Stan back in class for his medical studies. This routine happened several times a year. Now it is about 50 years later, and Stan is still active with CRF.

When Adversaries Worked Together

Adversaries can of course become allies in extremis, and during the 1954 Crystal Cave expedition there was a forest fire, which expedition cavers helped the park to put out (Lawrence and Brucker, 1955). Another example where the adversaries worked together was in the case of a man trapped in a cave near Sulphur Well in 1955 (Brucker & Watson 1976). The park was contacted for help, who in turn asked Bill Austin, Manager of Crystal Cave, to help. Bill used a car jack and boards to raise heavy slabs of rock off of Mr. Fancher and save his life (Roger Brucker, personal communication). These incidents with positive outcomes may have helped to soften hard feelings between cavers and park staff where that existed.

A Crucial Bit of Advice

Central Ohio Grotto cavers had no luck getting permission from MCNP to explore and map caves in Flint Ridge. The cavers tried rebranding themselves as the Flint Ridge Reconnaissance, a special project of the National Speleological Society (NSS). This way, their stature was elevated from being a bunch of cavers from Ohio to an arm of a national organization (Figure 1). To build credibility, a group of the cavers attended a December 1955 American Association for the Advancement of Science meeting, and Brother Nick Sullivan, then president of the NSS, presented a paper by Roger Brucker on the Flint Ridge Caves(Brucker & Watson 1976). With this elevated status, negotiations with the park could potentially be more successful, and a national organization could also talk with NPS officials at the Washington and Regional levels. At times it seemed like progress was being made, but then permission would still be denied. Part of the difficulty was the strained relationship between the park and Floyd Collins Crystal Cave owners. The week long NSS Expedition in Crystal Cave in 1954 put these two organizations in the same folder, as far as the park was concerned.

Figure 2. Ranger Joseph Kulesza in uniform at Mammoth Cave National Park. Photo courtesy of Mary Jo Veluzat, his daughter.

Park Ranger Joseph Kulesza (See Figure 2) understood this problem and advised the cavers to establish a science-based organization (Brucker and Watson 1976). Ranger Kulesza had spent a lot of time playing cat and mouse with explorers going into park caves illegally, and perhaps realized the futility of this situation. According to Dr. Stan Sides, Joe Kulesza was the first park employee to realize that cavers were best managed as partners and allies. He had a genuine interest in the discoveries being made by cavers, and was park superintendent when the Flint Ridge Cave System and Mammoth Cave were connected in 1972. Cavers formed a good relationship with Mr. Kulesza. For example, Stan Sides would visit Joe Kulesza at his home after a CRF expedition to give him the news of any discoveries. Here is another touching example: Roger Brucker visited Mr. Kulesza just before he passed away. They had worked together for many years, and Roger told me that after he left the nursing home, he wept.

By taking Mr. Kulesza's advice and forming a science-based organization called the Cave Research Foundation in 1957, the cavers put some apparent distance between themselves, the NSS, and Crystal Cave management. As Ranger Kulesza predicted, this science-based organization did reach an agreement with the park to survey and explore caves on Flint Ridge. That was in 1959 and the foundation is still supporting research of many kinds including cartography of park caves.

Concluding Thoughts

Park administrators, law enforcement rangers, and non-guide cave explorers went through some difficult years characterized by poor understanding, poor communications, and lack of agreement. Ultimately though, with some crucial guidance from Ranger Joseph Kulesza, the Cave Research Foundation was established and agreement was reached. This initially rocky relationship has been mostly positive in the intervening decades. In 2013, the relationship between Mammoth Cave Guides and non-Guide cavers came full circle when CRF fielded the first all-NPS Guide exploration and survey team during the October CRF Expedition (Olson, 2014). Finally, in Red Watson's satirical "Jaws" spoof called "Maws" (Watson 1976), cavers and park staff at Big Cave National Monument are lampooned equally. At the conclusion of the story though, "Ranger K" and the "Speleologist" are allies, which is a good and fitting end.

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Introducing the Junior Cave Scientist Program

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NPS Cave & Karst Program Coordinator

National Park Service

Beginning in the summer of 2014, the Geologic Resources Division (GRD) of the National Park Service successfully developed a Junior Cave Scientist booklet (Figure 1) and badge (Figure 2) as part of the NPS Junior Ranger Program. Overcoming several setbacks and other problems, the team of Limaris Soto, Joe Camacho, Jim Wood, and Dale Pate completed the booklet by early 2015 and received 20,000 printed copies of the 24-page Junior Cave Scientist booklet by mid-April 2015. Through a chance encounter, Joe Camacho recruited Paloma Hernando, an art student at the University of Colorado at Boulder to draw a stunning illustration for the front cover. In a similar vein, Limaris Soto worked with and modified a drawing provided by the talented Beth Fratesi to create an image that became the center point for the program's badge. Unlike most of the Junior Ranger program badges, this badge is wooden with wording and the illustration etched into the wood by laser.

The Junior Cave Scientist booklet is designed for kids of all ages and covers a number of topics in a fun way. Using the booklet, kids learn: the definition of caves and karst, that cave scientists are also known as speleologists, how to be safe, how to take care of the incredible, yet fragile resources found in caves, about the different types of caves and the mineral decorations known as speleothems, about the categories of animals that are found in caves, and get to take a look at a few of them including microbiology and bats. They also get to play a board game that takes them through the different zones found in a cave, they learn more about myths that surround bats and about White-nose Syndrome, the deadly disease that is killing millions of hibernating bats. As they make their way through the booklet, they learn of fossils and paleontology along with archeology. And last, but certainly not least, they learn of karst and groundwater, sinkholes, the ease at which pollution can contaminate regional aquifers, and how their actions can help preserve and protect caves and karst landscapes.

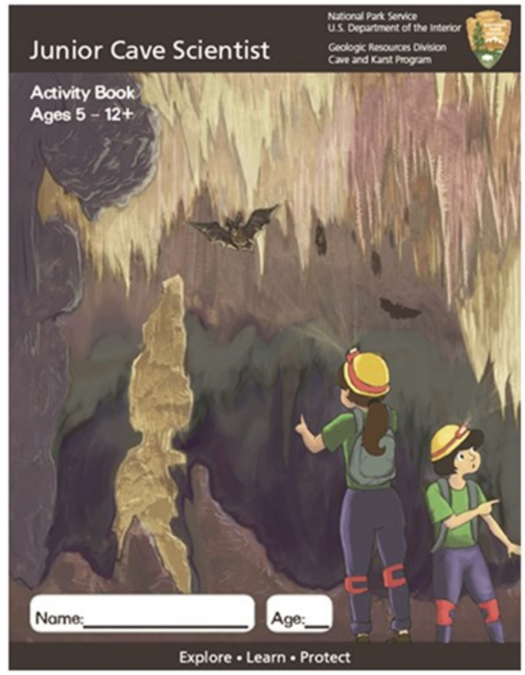

Figure 1. Junior Cave Scientist booklet

These booklets are available in printed form, but also can be downloaded from our webpage in a high-quality .pdf or in a lower -quality .pdf. We also look forward to having a Spanish version available this coming year. Visit our webpage at: go.np.gov/jrcavesci

Initial reaction to this booklet and badge has been very positive. As of this writing (September 11, 2015), we have distributed approximately 12,000 booklets to

22 parks, 1 region, and 1 Washington office within the NPS, 2 other federal agencies, 1 state park, 1 private show cave, 3 grottos and the national office of the NSS, 1 girl scout group, and 3 elementary schools. The distributed booklets so far have been sent to 25 states, Washington DC, and Guam.

Please help spread the word. These booklets are available to any group, school, grotto, or individuals for their use in helping educate the public about the values of cave and karst resources. Junior Cave Scientists pledge to explore magnificent and beautiful caves, to learn about caves and karst systems and the work that speleologists do, to protect our national parks and the things that make caves and karst areas special, and to enjoy the national parks and share what they have learned with their friends and family.

Figure 2 Junior Cave Scientist badge

Long-Term Protection for Carlsbad Cavern

Dale L. Pate

NPS Cave & Karst Program Coordinator

National Park Service

Development began initially as an effort to harvest bat guano from the Bat Cave portion of Carlsbad Cave in the early 1900's. Few remnants of this initial development are evident today. One of the guano miners, Jim White, took the opportunity to explore much of the cave during the next number of years. Jim White's discoveries became legendary and generated much publicity. By 1923, Carlsbad Cave National Monument was created by proclamation by President Calvin Coolidge. Over the following 70 years, development on top of the cave grew sporadically to give the visiting public easy access to the cave and to make it easier for the NPS to manage the cave as well. This development (Figure 1) included a maintenance facility, visitor center, parking lots, buried gasoline tanks, employee housing, and a host of other infrastructure needed to facilitate visitor access. The last major building effort was part of Mission 66 construction projects that added, among other items, 12 3-bedroom apartments, a new larger visitor center, a large seating area at the cave entrance for watching the bat flight, and an addition to the elevator shaft that added two larger elevator cars to accommodate larger groups of visitors. This infrastructure was placed directly on top of the cave without knowledge of the potential impacts that could result in damage to the cave itself.

Beginning in 1992, money was sought to begin an infiltration study that would help the NPS better understand the connections between the surface and the cave. Funded by the NPS Water Resources Division in 1994, Colorado School of Mines was awarded a contract to complete this study. This project produced a master's thesis by Mark Brooks in 1996 and a final report in 1997. The report documented high concentrations of aluminum, zinc, total organic carbon, and nitrates that were found in drips and pools in a number of locations throughout Carlsbad Cavern. Much of this high concentration was also found to be related to chronic, relatively low-level releases from specific surface locations. Additionally, the report discussed the likely potential for a variety of accidents, spills, and leakage scenarios that threatened water quality and public health from sewer line leaks and spills, gasoline spills and vehicle fires that would lead to contaminated runoff from parking lots and road segments; and spills, leaking tanks, fires, and other accidental releases from the maintenance yard and other structures.

By 1996, Carlsbad Caverns National Park released its new General Management Plan that among other items, directed the park to complete a Development Concept Plan (DCP) based on the Infiltration Study results. The thesis completed in 1996 determined infiltration pathways from surface runoff into several locations within Carlsbad Cavern.

By 2002, the DCP titled *Carlsbad Cavern Resource Protection Plan and Environmental Assessment (EA)* had been completed with a signed FONSI (Findings of No Significant Impacts) by the Superintendent and Regional Director. This plan and EA considered alternatives that would:

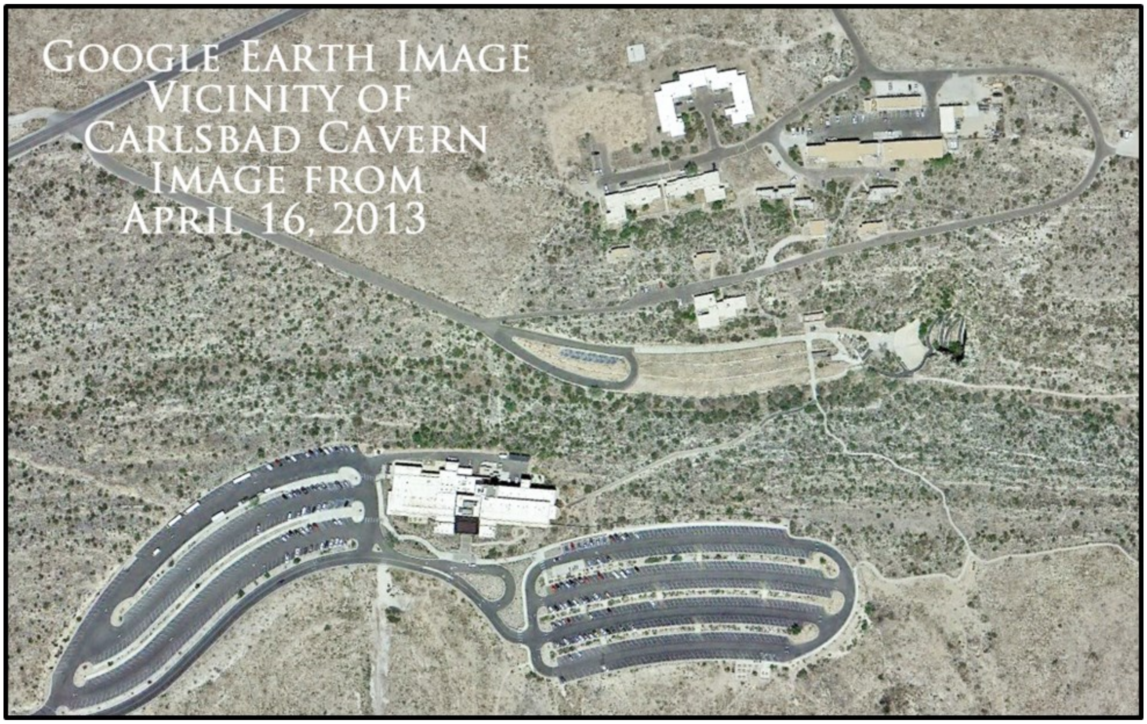

Figure 1 Structures in the vicinity of Carlsbad Cavern

- Eliminate pollution sources above the cave such as fuel storage, paved areas, maintenance operations, and park residences;
- Restore natural infiltration above the cave;
- Reduce catastrophic threats from spills, vehicle fires, and structural fires;
- And, implement mitigation measures to protect natural resources and the public where threats remained.

Out of three alternatives provided, the Park Preferred Action and Environmentally Preferred Alternative selected to remove the most threatening sources of contamination and mitigate potential contamination from remaining facilities. The major infrastructure changes were as follows:

- **Buried Outfall Sewer Line Replacement -** The buried outfall sewer line that ran from the Visitor Center to the east for over 1-mile before turning south and running off of the escarpment on the surface to the Evaporation Ponds located off the escarpment was identified as a critical problem. This gravity-fed line dated from the 1930s to the 1950s. Portions of the lines were still clay pipe with newer steel pipe being used from work done in the 1950s. Much of the system was designed to overflow and had routinely overflowed and spilled for a number of years. This line was long overdue for replacement. In 2004, this sewer line was replaced with an above ground line that ran directly off of the escarpment. Once off of the top of the cave areas, the line was buried and emptied into re-lined evaporation ponds.

- **Gas Pumps and Buried Tanks Removed** - Identified as a potential problem, the park removed gas pumps along with their buried tanks from the maintenance yard in 2008.

- **Bat Flight Parking Area Changes** – Identified as a serious, long-term problem, this parking lot dates from the 1920s and sits directly over the Main Corridor in Carlsbad Cavern. This lot accumulated oil, fuel, antifreeze, and other heavy metal contaminants from the thousands of cars that annually parked in this lot. Additionally, the lot collected runoff from some housing and administrative buildings. The design of the lot funneled contaminate-laden water directly into Bat Cave Draw and quickly into the cave. Other concerns included bus and auto fumes and noise that were drawn down into the cave entrance and was identified as significantly detracting from the natural setting of the entrance. In 2010, most of this parking lot was rehabbed leaving historic walls in place, planting native plants in much of the recovered area, and building a new turn-around for dropping people off to walk to the cave entrance and containing a few handicapped parking places.

- **Parking Lot Filters – Oil and Grit Separators** – In an effort to remove contaminants from parking lot runoff, oil and grit separators were placed in various locations on remaining parking lots around the Visitor Center. The grade of the two upper, large visitor parking lots was changed to funnel water to the south off of the escarpment, which also received oil and grit separators. These separators were installed in 2010.

- **Removal of Mission 66 Housing** – Mission 66 housing was also considered a long-term chronic contamination point. These were 12 3-bedroom apartments built in two large structures in the early 1960s. These apartments housed a number of permanent employee families with a number of vehicles parked throughout the year. Contaminant sources included clogged sewer lines and day-to-day uses and activities that released various types of materials onto the ground above the cave. These structures at the time were not considered historic and did not represent the 1926-1942 Period of Significance for structures built directly on top of the cave. In 2010, one of the large structures holding 6 3-bedroom apartments was removed returning the area to natural conditions.

Summary

It took 18 years to formulate ideas and develop projects to better understand the surface to cave connections at Carlsbad Cavern that led to implementation of the final products mentioned above. The process to affect the completion of these projects is testament to the scientific integrity of the studies and the ability to use existing laws to develop public planning documents that are designed to protect the incredible natural resources such as Carlsbad Cavern. The end result is that we have better understanding of processes that affect Carlsbad Cavern and have removed or mitigated structures and processes to provide long-term protection for the cave. There is still much work to do but we've started the process. More things to consider for the future include: establish a new maintenance facility off of the limestone escarpment at or near White's City; install oil and grit separators and other filtering devices on remaining parking lots and roads in the current maintenance, office, and housing areas; build new resource offices and housing area for seasonal and volunteer workers along with the new maintenance facility or locate in the town of Carlsbad; remove the east pod of the Mission 66 apartments and the last few remaining non-historic buildings; remove propane from use in housing, offices, and other structures if at all possible; and find a better solution for the location of the park generator and buried diesel tank that is currently located on the north side of the visitor center immediately adjacent to Bat Cave Draw.

Cave and Karst Resource Management on Joint Base San Antonio-Camp Bullis

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This paper will focus on the history and management practices of the cave and karst resources by the Department of Defense (DoD) on Joint Base San Antonio-Camp Bullis (JBSA-CB) as defined by the Biological Opinions (BO) and Integrated Natural Resource Management Plan (INRMP). This will include management of 112 known caves. 29 of these caves contain known endangered karst invertebrate species including in cave biological monitoring, cave cricket exit counts and Red Imported Fire Ant (RIFA) monitoring and treatment. An additional 42 caves and karst features are managed for endemic and state threatened species and require RIFA inspections and treatments. Three karst features are used as control sites for the RIFA program. This paper will present the history and details of the cave resource management program at JBSA. We have over 20 years of one of the most intensive programs in the Federal Government and an extensive database of resources that is unparalleled.

JBSA-CB is an approximately 28,000 acre military training facility located in Bexar and Comal Counties outside of San Antonio, Texas. JBSA-CB has worked with the United States Fish and Wildlife Service (USFWS) for over 20 years to protect and conserve three federally listed endangered karst invertebrate species twelve endemic karst invertebrate species and one state threatened, cave adapted vertebrate species. The cave and karst management program is among the most thorough and detailed program of its' kind to study and manage these cave and karst related species. The amount of data collected is enormous and will take years to analyze. Analysis of this data allows JBSA-CB to work with the USFWS to take proactive, adaptive management strategies in research and management of these species and their habitat while optimizing the military training mission. Sykes Act (1960) requires military installations to assess property for natural resources. When significant natural resources are determined an Integrated Natural Resource Management Plan (INRMP) must be undertaken to manage all natural resources identified.

JBSA-CB has been a military reservation for over 100 years. It lies in the rolling hills of south-central Texas in a mostly scrub oak and juniper forest. Several significant natural resources have been identified in the INRMP. The significant natural resources identified on JBSA-CB related to cave resources include groundwater significance and endangered species.

JBSA-CB lies within the Edwards Aquifer Recharge and Contributing zones. JBSA-CB has 112 known caves and approximately 1500 karst features identified. The southeast corner of the installation is part of the Edwards Aquifer Recharge zone along with Cibolo Creek in that runs across the installation from west to east in the extreme north of the base. The rest is the Contributing Zone that runs toward the recharge zone but with an abundance of caves and karst features this area also contributes water to the Glen Rose-Trinity Aquifer. JBSA-CB is one of the ideal places to study the relationship between these two aquifers.

JBSA-CB is home to three federally listed endangered karst invertebrate species. Management of these species is based upon the Bexar

County Karst Invertebrate Recovery Plan. JBSA-CB has adopted some adaptive management strategies implementing some variance from the recovery plan. The INRMP is a document that requires signature from installation command, the USFWS and the state natural resource agency, Texas Parks and Wildlife Department (TPWD).

JBSA has identified two areas of potential impact to federally listed endangered species, both of which are related to the cave and karst management program at JBSA-CB. The oldest of these Biological Opinions (BO)s entitled "Military Mission and Associated Land Management Practices and Endangered Species Management Plan (ESMP) for the U.S. Army's Camp Bullis in Bexar County, Texas." This document essentially defines the management strategies for the three endangered karst invertebrate species as well as two endangered bird species.

JBSA has also completed a BO on Edwards Aquifer Groundwater Use. The Edwards Aquifer Is a sole source aquifer for the City of San Antonio and surrounding region. It also is the source of most of the springs in Central Texas, including San Marcos, Hueco, and Comal Springs. These springs are the source or provide significant water to some of the most significant rivers in the State of Texas. These springs also provide habitat to several listed endangered species. The "Groundwater BO" determines the amount of water that JBSA is allowed to pump from the Edwards Aquifer and has resulted in the "Critcal Period Management Plan for Edwards Aquifer Water Use at JBSA".

Both of these BOs are a result of section 7 consultations with the USFWS as required under the Endangered Species Act (ESA)

Cave Diveres as a Resource for Cave Management

Mark Wenner

Karst Terrain Explorers

With WNS looming in most states, federal and state authorities closing down caves faster than we find them, liability for divers and property owners on a climb, cave divers feel that they need to reach for some solutions. My goal in Mammoth, and with State and Federal agencies has been to help create procedures aligned with some already existing protocols, helping to set the foundation for safe projects; which in turn educates the authorities and public to our successful efforts through results. Cave divers are a huge resource to public and private sectors, so we need to send that message out, as loud and clear as possible. We do that by establishing and following proven procedures and methods of operation, strong organization, high standards and cooperation with other groups and entities. This has allowed us to undertake some complicated projects with good results.

Cave Conservation and Restoration Couse in Brazil

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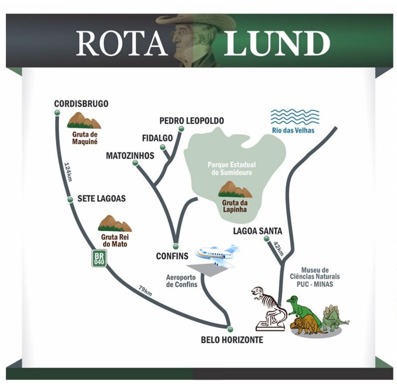
Introduction

Several Brazilian show caves are in areas protected for environmental, historical, and cultural significance. In some cases, evidence of anthropogenic impact in popular tourist caves spans more than 100 years of public use. Cumulative consequences of infrastructure installation, maintenance, and visitor-flow operations include graffiti, trash, construction rubble, broken speleothems, stained formations, and disturbed sediments. Cave management plans describe the resulting detrimental impacts to fauna, habitat, and microclimate (Alt, Moura NCKMS 2013). The urgent need to implement conservation activities with on-going monitoring, mitigation, and restoration in these fragile, Brazilian cave environments stimulated coordination of the first International Cave Conservation and Restoration Course in Brazil.

Held during April 2014 in Brazil's southeastern state of Minas Gerais (Figure 1), we designed the Course to introduce current best techniques, philosophy, and ethics with daily hands-on cave projects. Students used theoretical and practical activities to produce tangible restoration progress on two heavily visited show caves, Gruta do Maquiné and Gruta do Rei do Mato. Augusto Auler of the Instituto do Carste (Brazilian Karst Research Institute) in cooperation with corporate sponsor Anglo American Mining Company invited Jim Werker and Val Hildreth-Werker to collaborate with Luciana Alt and Vitor Moura in conducting the seven-day training. The Course, an important step toward initiating conservation actions set forth in management plans for both caves, was enabled through environmental compensation laws and cave protection legislation established after 1988, and is one of Brazil's pioneering initiatives in karst outreach and restoration.

History, Impacts, Motivation

Gruta do Maquiné, located in the highlands of Minas Gerais, is a popular national



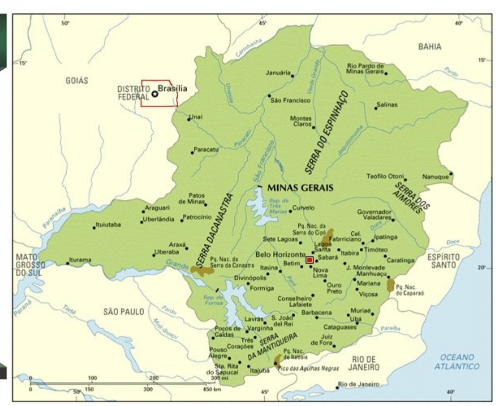


Figure 1 Location maps

destination renowned for paleontological discoveries made during the 1830s by accomplished Danish scientist, Peter Wilhelm Lund. Famed twentieth-century Brazilian novelist, João Guimarães Rosa, who was born in the nearby small town of Cordisburgo in 1908, described the magical chambers and beautiful speleothems of Maquiné. About a century ago, Maquiné became an important tourist site and the first Brazilian cave developed for organized visitation; and in the late 1960s, also the first to install an electric lighting system. This show cave is one of the most visited commercial caves in Brazil and receives about 50,000 visitors per year.

A second show cave named Rei do Mato lies about 50 kilometers from Maquiné, near the city of Sete Lagoas. State and municipal agencies organized commercial tourist visitation in the 1980s and installed walkways and stairs. The walls of Rei do Mato protect a splendid mutli-level chamber filled with speleothems of rare beauty.

Administered under the supervision of the State Forestry Institute, both caves are in protected areas and operate through public-private management partnerships. The State Tourist Board of Minas Gerais implemented a national advertising campaign promoting the Peter Lund Museum and three show caves including Maquiné, Rei do Mato, and another touristic cave, Gruta do Laphina, as destinations on a regional tourist route known as Rota Lund (Lund Route) along highways north of the major city of Belo Horizonte.

Both cave operation units began implementing resource management plans written by Alt and Moura in 2009/2010. These plans include detailed studies and diagnoses of environmental impacts, provide recommendations for visitor activities, document concerns regarding installed infrastructure, and propose measures to reduce harmful consequences by improving infrastructure and mitigating negative-impact activities (EIF 2010). In addition to historic and contemporary signatures, graffiti, trash, broken speleothems, and debris from development, Alt and Moura describe a variety of specific problems such as iron stains on speleothems, metal flaking from walkway degradation, accumulations of iron plates under the catwalk, and deteriorated wood left from old walkways in Rei do Mato, as well as compacted soils, disturbed sediments, undelineated visitor pathways, questionable handholds, and other concerns in Maquiné.

Between 2009 and 2013, cave managers began to implement a few of the proposed conservation advances, but progress was slow and sporadic. For example, installations of LED-based lighting systems began to replace old high-voltage lamps. With many issues described in the management plans, and little remediation initiated at the cave sites, the Instituto do Carste partnered with Anglo American Mining in applying federally mandated environmental compensation fees to support the first International Course on Cave Conservation and Restoration. The main objective of the Course was to provide hands-on training in identification, mitigation, and control of environmental impacts linked to tourism and public visitation.

Brazil's First Cave Conservation and Restoration Course

To reinforce the conservation-management processes of these two show caves, Course directors defined three objectives: 1) train and engage conservation stewardship; 2) initiate mitigation and monitoring projects; 3) and motivate ongoing restoration progress.

A pioneering initiative in Brazil, the first International Course on Cave Conservation and Restoration is a milestone for future cave conservation and restoration activities in the country. The intent was to train, motivate, and


Students worked in small groups, identifying anthropogenic impacts in Gruta do Maquiné and creating impact maps for their assigned areas

Course participants spent a day collecting trash in Maquiné, completing the tasks by sorting the garbage to determine what activities generated the waste—thereby discovering the need to improve communication of protocols regarding infrastructure maintenance and visiting tourists. Trash sorting in the parking lot blossomed into spontaneous art statements using objects found in the cave passages. Lata lixo is Portuguese for trash can!


Discussion and testing of the best techniques for removing the thick lint layer covering speleothems in Rei do Mato included mindful protocols for wildlife and minimum impact techniques. Participants gained valuable hands on experience in a variety of restoration tasks. Photos Luciana Alt, Val Hildreth-Werker

establish practical experience to enhance ongoing advances. Delivered by Val Hildreth-Werker and Jim Werker who authored the NSS manual titled Cave Conservation and Restoration (2006), coordination and logistics of the Course counted on the expertise of Luciana Alt and Vitor Moura, who coordinated and authored the 2009/2010 Management Plans for both caves, Maquiné and Rei do Mato (EIF 2010).

During the seven-day Course, all theoretical and practical activities were carried out in the facilities and caves of Maquiné and Rei do Mato. Lectures, discussions, demonstrations, and group assignments filled the week with conservation management activities. Following classroom presentation and discussion of theoretical concepts, we assigned small teams with daily hands-on cave projects involving resource assessment, impact analysis, decision-making, planning, group dynamics, consensus building, and execution of cave management tasks. The seven-day schedule enabled participants to spend many hours each day in small groups, literally planning and executing a variety of in-cave conservation-management projects. Student teams took our classroom theories and restoration methods directly into the caves, used the information we presented to identify problems, plan strategies, make decisions, and then performed actual hands-on application of the tasks. As projects became more complex, participants adapted plans and techniques to better fit the specific situations they encountered. The Course provided opportunity for in-depth analysis, application of decisions, and fine-tuning of skills.

Through an application process, 27 students were selected to attend this first Course. Skills and backgrounds of those selected were very diverse. Some represented federal, state, and private environmental protection agencies; others were long-time interpretive guides from the two caves. We had archaeologists who worked in federal as well as academic venues; lawyers representing environmental agencies; a few members of the caving community; and some mining company officials. Other applicants fill a waiting list for the second course, which is planned for this coming year.

Classroom information and practical in-cave activities gave students technical training for performing current best practices in caves based on the foundation of *primum non nocere*—first do no harm. Drawing from current best practice concepts published in *Cave Conservation and Restoration* (Hildreth-Werker and Werker 2006), the Course curriculum covered techniques, philosophy, and ethics of cave management. We include the word *current* in front of best practices, as a reminder to stay abreast of new studies and use science-based information to continually improve and redefine standards and practices in cave conservation (Spate, et al.1998; Hildreth-Werker 2006).

Tangible Outcomes

Participants accomplished much impressive conservation work in the two protected tourist caves during the Course week. Teams identified, documented, and initiated restoration projects addressing some of the conservation concerns described in the cave management plans. All students gained tangible field experience in resource assessment, identification of conservation issues, impact mapping, low-impact caving ethics, cave cleaning, special attention for historic materials, lint debris removal, speleothem restoration, lampenflora control, trail delineation, historical and cultural marking analysis, contemporary graffiti removal, and visitor routing to enhance safety and mitigate impact. The week of instruction, discussion, and practical training inspired participants to propose follow-up programs for continuing the work initiated through the Course.

Following the Course, participants employed in various federal, state, and private cave-resource management positions created new minimum-impact protocols for work in their respective scientific disciplines. Results include new protocols for cave archeologists and biologists. These documents represent tangible positive outcomes of the philosophical discussions, technical methods, and impact-reducing ethics presented during the Course. On the other hand, proposed plans for continuing conservation and restoration projects in the caves have not been implemented. Much still needs to be done; we will design our next course to stimulate continued training and especially motivate ongoing annual restoration events.

Brazil's first International Course in Cave Conservation and Restoration is an important initiative for karst outreach and instigates new pathways forward in the protection and conservation of caves.

Acknowledgements

We extend gratitude to the Anglo American Mining Company and their supportive representatives, to our friends and colleagues from Instituto do Carste, Chico Mendes Institute for Biodiversity Conservation, National Center for Research and Conservation of Caves, Gruta do Maquiné, Gruta Rei do Mato, and all the cave sites we visited. We appreciate the opportunity to participate in Brazil's conservation management and karst outreach.

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Cave Research Projects Help Promote Diversity in the Geosciences

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Data from the National Science Foundation indicates that the geosciences have lower ethnic and racial diversity than any other science, technology, engineering and mathematics (STEM) discipline. Increasing the diversity of the geoscience workforce will benefit the discipline by providing scientists with different backgrounds, approaches and perspectives. A diverse geoscience workforce is essential to helping society understand and respond to increasingly complex geoscience issues, especially with regards to topics of concern for different racial, ethnic and cultural groups.

This paper reviews how a partnership between Tennessee State University (a minority serving institution), the U.S. Geological Survey, and Mammoth Cave National Park engaged students in scientific research and increased the number of students pursuing employment or graduate degrees in the geosciences. The projects focused on water resources in a karst terrain, such as parking lot runoff and filter efficiency, groundwater recharge and chemical transport, quantitative tracer studies, karst hydrology model development, geophysical logging, emergency spill response, geochemistry and geomicrobiology. These projects used a variety of geoscience tools and methods, including field data collection, geographic information system, chemical and biological analysis, hydrologic instrumentation, modeling and experimentation.

Twenty-two students (12 male, 10 female) participated in karst research projects from 2007 to 2015. They represented majors in environmental engineering, mathematical, chemistry and biological sciences. Each of the 22 students completed significant research and presented their results at a regional or national conference. Of the 22 student researchers, three are still undergraduates, two accepted jobs after completing their bachelors, 16 went on to masters programs with thesis projects that emphasized earth science themes, and four students continued into Ph.D. programs (three geoscience majors and one physics major). Of the fourteen students that have completed their academic studies, all but four are currently employed in the geoscience or environmental engineering profession.

When the students were asked what influenced them to pursue a career in the geoscience profession, the overwhelming response was their research experiences that exposed them to earth and environmental scientists. The research experience demonstrated the relevance of the discipline, such as water quality studies and environmental protection. The research and professional meetings also provided an opportunity for the students to learn of employment opportunities, make professional connections, and feel like they could make a difference pursuing a career in geosciences. Another benefit of the student research was the financial assistance, which reduced the need to work off campus. It is clear from these results that engaging underrepresented students in geoscience research projects helps promote diversity.

Acknowledgements: The authors thank Bobby Carson, Rickard Toomey, III, Rick Olson, Steve Kovar, Larry Johnson, and Sarah Craighead of Mammoth Cave National Park; Mike Bradley of the U.S. Geological Survey; Lonnie Sharpe and Roger Painter of Tennessee State University for support and assistance with student research projects over the years.

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