Welcome to San Marcos and NCKMS 2021!

We heartily welcome all cavers, cave owners, cave conservancies, cave managers, cave researchers, cave educators, and cave lovers to the 23rd biennial meeting of the National Cave and Karst Management Symposium (NCKMS), in San Marcos, Texas on 1–5 November 2021. Roughly 20%, or 53,720 square miles, of Texas is karst, including the urban corridor of Waco through San Marcos, south to San Antonio. The last (and only) NCKMS held in Texas was in New Braunfels, in 1989. Our state’s population (and number of caves!) has grown rapidly since then, leading to inevitable management conflicts. Hence our theme ‘Endangered Species, Endangered Caves, Endangered Aquifers’. In beautiful San Marcos, that theme surfaces as clearly as the waters of the karstic Edwards Aquifer: a water source for over 2 million people, source of the culturally and economically important San Marcos River, and habitat for a number of federally endangered species inhabiting caves and springs in San Marcos and beyond. San Marcos is touted as one of the oldest continuously inhabited sites in the Americas. With its college-town character, bars and restaurants, proximity to caves and karst features of the Balcones Escarpment and Edwards Plateau, and abundance of natural areas like Spring Lake and Purgatory Creek, we thought it the perfect location for the 2021 NCKMS.

As is characteristic of symposia past, the 2021 NCKMS features a diversity of presentations, reflected in our interdisciplinary sessions, titled Biology, Collaboration in Karst Knowledge, Geotechnical Solutions in Karst, and Management & Monitoring in Karst. We are particularly honored to be hosting NCKMS during the International Year of Caves and Karst. Our keynote speaker, Dr. George Veni will discuss how the international year is a beginning, and we are confident that the knowledge shared and connections made during the 2021 NCKMS will serve as a springboard for increased exploration, understanding, and protection of caves and karst in the United States and beyond. And few people have more authority to talk about exploration, understanding, and protection than our featured speaker, Dale Pate, a native Texan and Texas State University - San Marcos alum (formally Southwest Texas State University). Dale’s years of experience caving in the U.S. and beyond, and managing karst resources for the National Park Service will provide perspective, and an undoubtedly enjoyable evening.

We are excited to have Austin Water – Balcones Canyonlands Preserve as our host this year! Some other goodies we have lined up include a Monday Social and glass-bottom boat tour of Spring Lake, where karst waters well up from San Marcos Springs to form the head of the San Marcos River, and a tour of nearby Natural Bridge Cavers, site of the Tuesday Howdy Party. We’ll have field trips all day Wednesday, focusing on the hydrology, biology, and land use conflicts of central Texas karst. Some field trip options even include short visits inside non-commercial caves, so please bring your properly decontaminated cave gear. But remember that this is Texas, so even in November a T-shirt and jeans (with knee and elbow pads!) will be sufficient underground clothing. As 2021 is the International Year of Caves and Karst, we have also incorporated public outreach activities during our conference.

So once again, welcome to San Marcos and the 2021 NCKMS!

Planning Committee

Jim Kennedy (Chair, Banquet & Howdy Party Coordinator), Niki Lake (Registration), Michael Cicherski (Treasurer), Nico Hauwert (Field Trip Coordinator), Jerry Atkinson (Proceedings Editor), Ron Ralph (Sponsorship Coordinator, Silent Auction Coordinator), Andy Grubbs (Facilities Chair), Missy Singleton (Program Chair), Bonnie Longley (Catering Coordinator), Ben Hutchins (Program Editor), Benjamin Schwartz (Monday Social Coordinator), Chris Thibodeaux (Transportation Coordinator), Chris Murray (San Marcos Lodging & Attractions), Barbara Attwell (Arts Outreach), Carolyn Fusinato (Media Outreach), Jessica Gordon (Workshop Coordinator), Will Quast (Webmaster), Kris Peña (Webmaster), Ethan Perrine (Exhibitor & Vendor Coordinator), Kori Dunaway (Poster Session Coordinator, Volunteer Coordinator), Leia Hill (International Year of Caves and Karst Coordinator).

Steering Committee

Jim Kennedy (National Speleological Society), Kyle Rybacki (Bureau of Land Management - pending), Scott House (Cave Research Foundation), Gordon Smith (National Caves Association), Pat Seiser (National Cave & Karst Research Institute - pending), Cory Holliday (The Nature Conservancy), Lama Soto (U.S. Fish & Wildlife Service - pending), Johanna Kovarik (U.S. Forest Service), Dave Foster (American Cave Conservation Association), Ben Miller (U.S. Geological Survey), Wil Orndorff (Karst Waters Institute - pending), Gretchen Baker (National Park Service - pending).
Jane Hughson
Mayor

Welcome to San Marcos!

Greetings,

On behalf of the City of San Marcos, I welcome you to our beautiful community for the National Cave and Karst Management Symposium. San Marcos is uniquely positioned as a great location for your symposium; being on the Balcones Escarpment, San Marcos is rich with caves and karst features throughout the northwest part of our city.

The City of San Marcos is delighted to serve as the hosts for this event for visitors from all over our great nation. I hope you will take time to explore San Marcos and discover the delights of a great Texas community.

While you are here, we invite you to enjoy the many amenities of San Marcos including the spectacular Texas Hill Country, our beautiful spring-fed river, our historic downtown, our own homegrown music venues and restaurants and the best shopping opportunities in the Southwestern United States!

I hope you enjoy your time here and encourage you visit San Marcos again soon.

Sincerely,

Jane Hughson
Mayor of San Marcos
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## Schedule of Events

### Monday, 1 November 2021

- **8:00AM - 5:00PM** Registration
  - **San Marcos Activity Center, lobby**
- **8:00AM - 5:00PM** Workshops
  - **San Marcos Activity Center, multiple rooms**
- **4:00PM - 5:00PM** Steering Committee Meeting
  - **San Marcos Activity Center, Multipurpose Room**
- **5:00PM - 10:00PM** Meet-and-Greet Social
  - **Meadows Center for Water & the Environment**

### Tuesday, 2 November 2021

- **8:00AM - 5:00PM** Registration
  - **San Marcos Activity Center, lobby**
- **8:30AM - 9:00AM** Welcome & Introductions
  - **San Marcos Activity Center, Banquet Room**
- **9:00AM - 9:30AM** Keynote Address
  - **San Marcos Activity Center, Banquet Room**
- **9:40AM - 10:10AM** Refreshment Break
  - **San Marcos Activity Center, Banquet Room**
- **10:10AM - 11:55AM** Biology Session I
  - **San Marcos Activity Center, Banquet Room**
- **11:55AM - 1:30PM** Lunch (on your own)
- **1:30PM - 4:30PM** Biology Session 2
  - **San Marcos Activity Center, Banquet Room**
- **6:00PM - 10:00PM** Howdy Party
  - **Natural Bridge Caverns**

### Wednesday, 3 November 2021

- **8:00AM - 12:00PM** Registration
  - **San Marcos Activity Center lobby**
- **8:00AM - 4:45PM** Cave Management Field Trip
  - **San Marcos Activity Center, parking lot**
- **9:00AM - 4:15PM** Austin Wild Cave Field Trip
  - **San Marcos Activity Center, parking lot**
- **9:00AM - 4:20PM** Cave Restoration Field Trip
  - **San Marcos Activity Center, parking lot**
- **9:00AM - 4:30PM** Cave Filling Recognition Field Trip
  - **San Marcos Activity Center, parking lot**
- **9:00AM - 5:20PM** Groundwater Fauna Field Trip
  - **San Marcos Activity Center, parking lot**
- **6:00PM - 8:00PM** Dinner Reception & Presentation
  - **Bracken Cave Preserve**

### Thursday, 4 November 2021

- **8:00AM - 12:00PM** Registration
  - **San Marcos Activity Center, lobby**
- **9:00AM - 12:00PM** Collaboration in Karst Session
  - **San Marcos Activity Center, Banquet Room**
- **12:00PM - 1:30PM** Lunch (on your own)
- **1:30PM - 4:50PM** Geotechnical Solutions Session
  - **San Marcos Activity Center, Banquet Room**
- **5:00PM - 6:30PM** Q&A for Poster Authors
  - **San Marcos Activity Center, hallway**
- **6:30PM - 10:00PM** Banquet and Featured Speaker
  - **San Marcos Activity Center, Banquet Room**

### Friday, 5 November 2021

- **9:00AM - 11:30PM** Management & Monitoring Session
  - **San Marcos Activity Center, Banquet Room**
- **9:00AM - 12:00PM** Management & Monitoring Session
  - **San Marcos Activity Center, Banquet Room**
- **11:30 - 12:00PM** Closing Remarks
  - **San Marcos Activity Center, Banquet Room**
- **4:00PM - 5:45PM** Sixteen Legs documentary film
  - **Texas State University, Alkek Teaching Theater**

### Saturday, 6 November - Sunday, 7 November 2021

- **9:00AM - 5:00PM** Government Canyon Karst Project
  - **Government Canyon State Natural Area**
Detailed Program

Monday, 1 November 2021

**Registration**
501 East Hopkins Street, San Marcos Activity Center, lobby
8:00AM - 5:00PM

**Workshops**
San Marcos Activity Center, multiple rooms

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<tr>
<th>Time</th>
<th>Workshop</th>
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<tr>
<td>8:00AM - 12:00PM</td>
<td>Project Underground</td>
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<td>8:00AM - 12:00PM</td>
<td>Survey &amp; Inventory of Cave &amp; Karst Features</td>
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<td>8:00AM - 5:00PM</td>
<td>Cave &amp; Karst Hydrology</td>
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<td>1:00PM - 5:00PM</td>
<td>Cave Management Considerations for Bats</td>
<td>San Marcos Activity Center</td>
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<tr>
<td>1:00PM - 5:00PM</td>
<td>Developing Stewards: Cave &amp; Karst Management Through Accessible Education</td>
<td>San Marcos Activity Center</td>
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**Steering Committee Meeting**
San Marcos Activity Center, Multipurpose Room
4:00PM - 5:00PM

**Meet-and-Greet Social (includes glass-bottom boat rides on Spring Lake)**
Meadows Center for Water & the Environment
5:00PM - 10:00PM

Tuesday, 2 November 2021

**Registration**
501 East Hopkins Street, San Marcos Activity Center, lobby
8:00AM - 5:00PM

**Welcome, Introductions, & Announcements (by NCKMS Coordinator and Chair)**
San Marcos Activity Center, Banquet Room
9:00AM - 9:30AM

**Keynote Address**
San Marcos Activity Center, Banquet Room
9:50AM - 10:10AM  George Veni - Cave and karst management after the International Year of Caves and Karst

**Refreshment Break**
San Marcos Activity Center, Banquet Room
10:10AM - 10:40AM
Detailed Program (Continued)

**Biology Session I**
Chair: Benjamin Hutchins (Tx. St. Univ.)
San Marcos Activity Center, Banquet Room
(only 1st author listed, see abstracts for full authorship and presenter info)

10:40AM - 11:00AM  
Julian J. Lewis - Monograph of the groundwater isopods of Virginia

11:00AM - 11:20AM  
Nicholas S. Gladstone - Groundwater snail biodiversity and conservation in the United States and Mexico

11:20AM - 11:40AM  
Andrew R. MacLaren - Predicting surface abundance of federally threatened Jollyville Plateau Salamanders (*Eurycea tonkawa*) to inform management activities at a highly modified urban spring

11:40AM - 12:00PM  
Zachary Adcock - Development, validation, and application of an environmental DNA assay to detect federally threatened groundwater salamanders in central Texas

11:55AM - 1:30PM  
LUNCH (on your own)

**Biology Session II**
Chair: Benjamin Hutchins (Tx. St. Univ.)
San Marcos Activity Center, Banquet Room
(only 1st author listed, see abstracts for full authorship and presenter info)

1:30PM - 1:55PM  
Colin Strickland - Austin cave restoration

1:55PM - 2:15PM  
Kara Posso - Military bases may be vital for preserving key components of karst habitat: an evaluation of karst preserves at Camp Bullis, San Antonio, Texas

2:15PM - 2:40PM  
Riley S. Drake - Monitoring microbial communities for cave conservation

2:40PM - 3:05PM  
Colin Strickland - Central Texas cave life

3:05PM - 3:30PM  
Refreshment Break

3:30PM - 4:40PM  
Biology Session Breakout

**Howdy Party (includes cave tour)**
Natural Bridge Caverns (shuttle from Activity Center departs at 5:00PM)
6:00PM - 10:00PM

**Wednesday, 3 November 2021**

**Registration**
501 East Hopkins Street, San Marcos Activity Center, lobby
8:00AM - 5:00PM
Detailed Program (Continued)

Field Trips
San Marcos Activity Center, parking lot
8:00AM - 5:20PM

8:00AM - 4:45PM George Veni - A cross section of cave & karst management: show caves, preserves, & private property
9:00AM - 4:15PM Rich Zarria & Mark Sanders - South Austin wild cave tour: management to protect cave ecosystems
9:00AM - 4:20PM Drew Thompson - Cave restoration on the urban frontier
9:00AM - 4:30PM Nico M. Hauwert - Finding caves in north Hays County: recognition of caves in an environment of widespread filling
9:00AM - 5:20PM Benjamin Hutchins - From recharge to rivers: groundwater fauna sampling across flowpaths

Dinner Reception & Presentation
Bracken Cave Preserve (field trips will proceed directly to reception and return to Activity Center afterwards)
6:00PM - 8:00PM

Thursday, 4 November 2021

Registration
501 East Hopkins Street, San Marcos Activity Center lobby
8:00AM - 12:00PM

Collaboration in Karst Knowledge Session
Chair: Devra Heyer (NCKRI)
San Marcos Activity Center, Banquet Room
(only 1st author listed, see abstracts for full authorship and presenter info)

9:00AM - 9:20AM Katarina Kosič Ficco - Cavers and karst scientists: the bridge to the underground
9:20AM - 9:40AM Jessica Gordon - Optimizing cave and karst management through collaborative outreach
9:40AM - 10:00AM Patricia Seiser - Instigating a cultural shift in cave and karst management
10:00AM - 10:20AM Dave Jackson - Creating a brighter future: teaching conservation with CaveSim
10:40AM - 11:10AM Refreshment Break
11:10AM - 12:00PM Collaboration in Karst Knowledge Session Breakout
12:00PM - 1:30PM LUNCH (on your own)

Geotechnical Solutions in Karst Session
Chair: George Veni (NCKRI)
San Marcos Activity Center, Banquet Room
(only 1st author listed, see abstracts for full authorship and presenter info)
Detailed Program (Continued)

1:30PM - 1:50PM  Mark Sanders - Ventilating high CO2 xaves
1:50PM - 2:10 PM  Drew Thompson - The sinkhole stabilization of the Blowing Sink Research Management Area
2:10PM - 2:30PM  Robert K Denton Jr. - The use of morphologic character analysis to determine sinkhole risk for solar site development
2:30PM - 2:50PM  Kemble White - Cambria Cavern discovery and mitigation; a case study in urban karst management
2:50PM - 3:10PM  Refreshment Break
3:10PM - 3:30PM  Wil Orndorff - Mountain Valley Pipeline: karst issues in Virginia 4 years into construction
3:30PM - 3:50PM  William Whitehead - SUAS karst survey: using drones to augment human pedestrian survey
3:50PM - 4:10PM  Adam Majzoub - Delineation and characterization of gypsum karst geo-hazards in the Delaware Basin of west Texas: A case study using electrical resistivity tomography
4:10PM - 4:50PM  Geotechnical Solutions in Karst Session Breakout

Q&A for Poster Authors Session
San Marcos Activity Center, hallway
5:00PM - 6:30PM
(only 1st author listed, see abstracts for full authorship and presenter info)

Banquet, Upcoming Symposia Announcement, & Featured Speaker
San Marcos Activity Center, Banquet Room
6:30PM - 10:00PM
Featured Speaker: Dale Pate

Friday, 5 November 2021

Management & Monitoring in Karst Session
Chair: John Hickman (SCCI)
San Marcos Activity Center, Banquet Room
(only 1st author listed, see abstracts for full authorship and presenter info)

9:00AM - 9:20AM  Nico Hauwert - Widespread cave filling in Austin
9:20AM - 9:40AM  Jimmy Valdez - Karst impact management scheme for cave sites in the Cayo District, Belize C.A.
9:40AM - 10:00AM  Gretchen Baker - Comparing cave climate during COVID closures vs open times at Lehman Caves
10:00AM - 10:20AM  David Yan - Effects of visitation patterns on carbon dioxide concentrations within Carlsbad Cavern
10:20AM - 10:40AM  David Woods - How much land does it take to protect a cave?
10:40AM - 11:00AM  Mitchell Berger - The acquisition and protection of Clarksville Cave: a tale in five parts
11:00AM - 11:30AM  Refreshment Break
Detailed Program (Continued)

Closing Remarks
San Marcos Activity Center, Banquet Room
11:30AM - 12:00PM

Sixteen Legs documentary film free viewing
Texas State University - San Marcos, Alkek Library Teaching Theater
(Parking available at the Texas State University - San Marcos Edward Gary Street Garage. See campus map for details.)
4:00PM - 5:45PM
Texas premier!

Saturday, 6 November - Sunday, 7 November, 2021

Government Canyon Karst Project
Government Canyon State Natural Area, 12861 Galm Road, San Antonio, TX 78254
9:00AM - 5:00PM
Find, explore, survey, and inventory caves and karst features on 12,000 acres of Balcones Fault Zone.
Weekend camping is available.
Interested persons must contact the project coordinator, Marvin Miller in advance at mlmiller@gvtc.com.

Photo by Peter Anderson-Sprecher
Workshops

**Workshop 1: Project Underground | 8:00AM - Noon**

**Description:** Project Underground is a K-12 environmental education curriculum and activity guide focused on caves and karst through the topics of geology, biology, and history. Learn methods to educate about the world beneath our feet in this workshop. Formal educators (classroom) and non-formal educators (nature centers, parks, camps) are encouraged to attend. Hands-on activities are required. This is not a passive lecture. Participants will receive an activity book and certificate at the end of the workshop.

**Instructors:** Christine Walkey is the Project Underground national coordinator

**Prerequisites:** None

**Location:** San Marcos Activity Center

**Cost:** $20.00 (for Project Underground activity book)

**Workshop 2: The survey & inventory of cave & karst features | 8:00AM - Noon**

**Description:** Baseline resource inventories and annual monitoring are two of the most important, if not the most important, activities in cave and karst management. They inform the “what and where” component of the cave and karst resource strategy and allow one to gauge the effectiveness of management decisions/actions through time. This short course will cover the design and execution of baseline inventories and annual monitoring activities as they apply to cave and karst resources. The course will also explore various methods to derive more understanding and visualization of cave data and surface/subsurface karst field data. 25 person limit.

**Instructors:** Kyle Rybacki is the Bureau of Land Management’s Cave & Karst Subject Matter Expert where he oversees program administration, training, and provides technical assistance to BLM field staff and foreign governments. Kyle enjoys helping others learn and grow, and utilizes inquiry-based learning supplemented by hands-on activities. Kyle has a BS and MS in Geology & Geophysics from the Missouri University of Science & Technology, formerly the University of Missouri – Rolla, and a dual-title Ph.D. in Geochemistry and Astrobiology from Penn State.

Pat Kambesis is Associate Director for Science and Exploration at the Center for Human GeoEnvironmental Studies at Western Kentucky University. She is an instructor for the Department of Earth, Environmental and Atmospheric Studies at WKU and is faculty for the WKU/Mammoth Cave National Park Karst Field Studies program where she teaches courses in cave and karst data collection, data management and visualization, and Geographical Information Science. She holds a BS in Biology from University of Illinois, a BS in Geology from Southern Illinois University, MS in Geoscience from WKU and a PhD in Earth and Atmospheric Sciences from Mississippi State University. She also is a registered GIS Professional (GISP).

**Subject:** Resource inventory, data management & visualization

**Skill level:** Non-technical specialist

**Equipment:** Laptop

**Outcomes:** Participants will leave with an understanding of how to design and execute resource inventories of caves and karst features. Basics of data management and visualization of data will also be covered.

**Location:** San Marcos Activity Center
Workshops (Continued)

Workshop 3: Cave management considerations for bats | 1:00PM - 5:00PM

Description: Bats have long been associated with cave habitats, but throughout history this association has not always benefited these cryptic mammals. In fact, our cave-dwelling bat species have suffered some of the most catastrophic population declines. Fortunately, we now have a far better understanding of the complexities in underground environments and their importance to bats. We begin with a glimpse of the variety of underground environments and how to determine their suitability to different bat species at all stages of their life-cycles. Bat natural history and the history of cave exploration and human use is combined to highlight the important biological implications of cave study and protection. Case studies of cave conservation are presented which will illustrate many of the successful efforts to balance human and bat needs on the landscape. 20 person limit

Instructors: Janet Tyburec (Bat Survey Solutions, www.batsurveysolutions.com) is an experienced author, educator, photographer, presenter, and wildlife biologist specializing in environmental and nature studies, especially addressing bat conservation and research. Works in various settings: lecture halls, classrooms, and outdoor field locations. She has decades of experience in the development, coordination, and management of multi-day trainings, workshops, and field surveys. She brings excellent attention to detail, reporting, organization, and budgeting to every project. Since 1992 Janet has organized, conducted, and instructed at nearly 200 workshop venues, personally training over 2,800 students on research skills for studying and managing bat populations across North America in addition to conducting field trainings and research worldwide.

John Chenger (Bat Conservation and Management, www.batmanagement.com) has over 20 years of experience in the field of wildlife conservation and research. He is currently President of Bat Conservation and Management, Inc. (BCM), a company he formed in 1998 to supply wildlife agencies and the general public with remarkably successful artificial bat roosts. His company provides consulting services on numerous wildlife survey and mitigation projects, and produces custom field-gear for the survey and monitoring of bats and other wildlife. He has directed and participated in numerous projects including over 600 cave identifications, individual and regional cave and mine surveys, karst hydrology studies, summer woodland bat mist net surveys, and Allegheny woodrat surveys to determine presence, population size, and habitat use. He has conducted abandoned mine habitat assessments, fall harp trapping surveys for bats, echolocation call analysis, ground and aerial radio telemetry coordination, harp trap and artificial roost design, and bat-friendly gate design. Since 2004 he has been a recurring instructor at training workshops offered by Bat Conservation International, Bat Conservation and Management, and Bat Survey Solutions, offering a comprehensive curriculum designed to train serious students, consultants, and land managers in the current research and management techniques for the study of bats. He has served as a Sub-Region Coordinator within the National Cave Rescue Commission. He has previously designed and implemented six simultaneous public educational programs at the commercial cave Laurel Caverns (Farmington PA), in addition to overseeing the interpretive staff and publishing a book on the history, geology, and biology for this summer attraction. Before becoming involved with bat conservation, John was a professional studio and field photographer, skills that continue to be utilized to this day.

Skill Level: Any

Location: San Marcos Activity Center

Outcomes: Identifying suitable caves for hibernation and maternity sites using internal and external surveys.
Workshops (Continued)

Workshop 4: Developing stewards: cave & karst management through accessible education | 1:00PM - 5:00PM

Description: How do we develop future stewards of cave and karst resources? This workshop will explore the idea of management through the development of education programs that will build future stewards of cave and karst resources. Participants will further look at how to build an accessible program from its infancy to completion so that educational outreach is accessible to all audiences. This will be an interactive workshop mixing both small group discussions and whole-group activities to enable participants to freely discuss issues they are having as cave and karst managers and to develop solutions through discussion and reflection. 50 person limit

Instructors: Brad Barker has been an avid caver since 2007, enjoying both horizontal and vertical cave exploration. Brad is currently serving as a member of the Education Division of the National Speleological Society to help further develop their educational outreach programs. He has a Masters of Teaching and Learning and is currently a K-12 educator working with Deaf/Hard-of-Hearing students in Northeast Georgia. Brad is currently in his eleventh year as an educator and has taught middle school English, social studies, and science, as well as high school science. Additionally, he has worked with students who are English language learners in grades K-8. During a sabbatical from teaching, Brad worked for the National Park Service as an Education Technician at Badlands National Park with a focus on educational outreach, managing educational grants for use with local tribal students, social media, and Section 508 compliance for accessibility. During this time, he completed the Foundations of Accessibility certificate program from Eppley Institute for Parks and Public Lands to further develop his knowledge and skills in creating accessible programs and content for all park visitors. The focus on accessible outreach and education are close to Brad’s heart because he has an adopted son who is deaf. When Brad began looking for ways to share his love of the outdoors with his son, he found that there was little content that was truly accessible.

Brad has led workshops in the past with Legacy Environmental Education in Alabama bringing education on caves and karst to teachers so they could then return to the classroom better equipped to teach their students about these unique environments. While helping with these workshops, Brad focused on ways to demonstrate the importance of karst groundwater and human impacts in these environments. Brad also led trips underground for the participants to help them not just know of caves from literature and film but to experience these environments firsthand. As an educator, Brad values experiential learning and developing ideas through critical thinking.

Subject: Stewardship, Educational Outreach, Accessibility

Skill Level: Any

Equipment: Note-taking equipment (pen/pencil or electronic device) and management plan for cave or karst resource (optional but beneficial). The instructor would appreciate participants sharing their management plan (emailed to brad.barker@muddycaver.com), if applicable, so the course can be further refined to best match the participants’ needs.

Location: San Marcos Activity Center

Outcomes: 1) Understand the value of investing in youth and adult programming for educational outreach; 2) Explore and practice various educational techniques and strategies for engaging an audience and improving understanding of cave and karst environments; 3) Identify resources available for use in educational programming; 4) Define accessibility and gain a better understanding of accessibility issues and how they apply to best practice; 5) Reflect on current education outreach activities and evaluate their success; 6) Best practices for accessibility for those with disabilities; 7) Understanding of how to make content accessible to all audiences; 8) Understanding and identifying accessibility issues at managed cave or karst area and how to increase access/understanding to those with disabilities.
Workshops (Continued)

Workshop 5: Cave & karst hydrology | 8:00AM - 5:00PM

Description: Karst terrains and underlying caves are part of the hydrologic cycle. Karst has many unique aspects that are commonly misunderstood by non-specialists. This workshop will discuss different conceptual models to better understand the karst hydrologic cycle from rainfall to sinkholes and caves to springs. Several tools will be discussed that are useful to help better understand and manage these unique environments including water quality monitoring parameters and frequency, water quality instrumentation, use of tracer (dye) testing to delineate spring sheds, and general discussion of geophysics in karst settings. 25 person limit.

Instructors: Geary M. Schindel, P.G. President, National Speleological Society and Texas Professional Geologist with more than 40 years of experience as a karst hydrogeologist working on CERCLA, RCRA, and source water protection programs.

Dr. Mustafa Saribudak, P.G. President of Environmental Geophysics based in Austin, Texas. He has more than 30 years of international experience in geophysics. On the last 15 years, he has conducted more than 200 geophysical surveys for the environmental, engineering, and oil and gas industries and real estate developers.

Alf Hawkins, P.G. Associate with Environmental Geophysics for more than 28 years and has more than 40 years of experience working in the field of geology, airborne and marine geophysics. He has worked nationally and internationally in environmental, oil & gas, and mineral exploration areas.

Subject: Karst Hydrology, Cave and Karst Management, Tracer Testing, Water Quality Monitoring, Geophysics

Skill Level: This program is directed toward the land and cave resource managers with a basic understanding of earth sciences.

Location: San Marcos Activity Center

Outcomes: Participants will come away with a better understanding of the hydrologic cycle and how it applies to the resources they manage. They will have an overview of the tools available to monitor water quality, relationship of surface activities to the subsurface, delineation of cave and spring sheds, and use of geophysics in the karst environment.
Field Trips

Trip 1: Cave restorations on the urban frontier | 30 person limit

Trip leader: Drew Thompson, Biologist, Austin Water Balcones Canyonland Preserve Program

Synopsis: See the City of Austin’s cave restoration and stabilization projects of the past decade in South Austin. Our urban karst landscapes have taken many hardships throughout its recent history from deforestation and overgrazing to the purposeful filling in of caves and sprawling urban expansion. Witness firsthand the City of Austin’s efforts to reopen and restore our valuable resources increasing clean water recharge, healthy biological habitat, and creating a safe environment to educate the public about the benefits of caves and their contribution to the Edwards Aquifer.

Logistics: Group size will be limited to 30 people. We will depart promptly at 9:00AM from the San Marcos Activity Center, returning at 5:00PM. Lunch will be provided so packing one’s own is not required. All lights, helmets, and pads will be provided for those who would like to enter the caves. Personal cave gear will not be allowed to enter the cave in efforts to reduce the chance of cross contamination and possible transfer of WNS. All sites require a short to moderate walk on easy terrain. Comfortable hiking shoes, a reusable water bottle, (drinking water will be provided), and sun protection are highly suggested. Details are preliminary and subject to change.

Details: The caves of South Austin are plentiful and contribute directly to the Barton Springs segment of the Edwards Aquifer. They are very rich in biodiversity being home to numerous karst obligate species and resident troglobiophiles. Once often seen as unwanted and unnecessary burdens in the past by landowners and developers, the City of Austin has gone to great lengths to correct the negative effects by restoring these important ecosystems and recharge features to a healthy and manageable state. By means of excavation, stabilization, and re-vegetation, these neglected treasures now have a second chance. On this field trip we will visit 11 major sinkhole/cave restorations conducted by City of Austin staff under the supervision of Dr. Nico Hauwert. Sites will include a visit to the William H Russell Karst Preserve, (a 200 acre plot previously known as the Blowing Sink Research Management Area), where we will visit the stabilized entrances of Sinky Dinky, William’s Well, Wyoaka, Brownlee, Winter Woods, and Blowing Sink Caves. We will then visit the Goat Cave Karst Preserve to see Wade and Hideout Caves. From there we will take a trip into the entrance portion of Grassy Cove Cave (an easy hands and knees crawl through a nicely decorated passage). We’ll then make our way to the Lady Bird Johnson Wildflower Center to visit the entrance portions of Wildflower Cave (a decently sized room used as underground Classroom) and LaCrosse Cave (a multi-level room used as an underground classroom). During the field trip we will go over site history, biology, geology, excavation methods and techniques, and the obstacles that we overcame to achieve our goals.

Itinerary
(Start & end at San Marcos Activity Center | 9:00AM - 4:20PM)

9:45AM - 12:00PM: William H Russell Karst Preserve (45 min drive): Sinky Dinky, Williams Well, Wyoaka, Brownlee, Winter Woods, & Blowing Sink Caves
12:00PM - 12:30PM: Lunch at William H Russell Karst Preserve
12:40PM - 1:10PM: Goat Cave Karst Preserve (10 min drive): Wade Sink, Hideout Cave
1:15PM - 2:15PM: Grassy Cove Cave (5 min drive): Grassy Cove Cave
2:20PM - 4:20PM: LBJ Wildlife Center (5 min drive): Wildflower Cave, LaCrosse Caves
6:00PM - 8:00PM: Bracken Cave Preserve (1 hr 15 min drive): Tour, presentation & catered reception.
8:50PM: Return to San Marcos (50 min drive)
Field Trips (Continued)

Trip 2: From recharge to rivers: groundwater fauna sampling across flowpaths
20 person limit

Trip leader: Benjamin Hutchins, Ph.D., Biologist, Edwards Aquifer Research & Data Center

Synopsis: See representative/important groundwater fauna sites in the San Marcos area as we move from the Contributing Zone of the Edwards Aquifer down a flowpath that even takes us off of the karst but never outside its influence to see aquatic habitats, management issues, and sampling techniques for rare groundwater species.

Logistics: Due to a need to get up close and personal to see sampling techniques and groundwater invertebrates, group size will be limited to 20 people. We will depart promptly at 9:00AM from the San Marcos Activity Center, returning at 5:00PM. Lunch will be provided. No special gear is needed (we will not be going in caves), but some sites require a short walk. Comfortable hiking shoes, a water bottle, and sun protection are suggested. You will have the option of getting your feet wet, but water should be avoidable. Details below are preliminary and subject to change. Although we will be sampling for groundwater organisms, successful capture is not guaranteed.

Details: The Edwards Aquifer is a global hotspot of groundwater biodiversity. It is also a critically important water source for large, metropolitan areas. This results in substantial management conflict, but also novel conservation approaches. We will visit a diversity of sites within 35 minutes of San Marcos to see different segments of the aquifer system, including the contributing zone (where surface waters flow onto the recharge zone), the recharge zone (where surface water sinks to recharge the aquifer), the confined zone (where Edwards limestones are overlain by non-karstic lithologies), Edwards springs, and Edwards-dependent surface streams. Specific sites include: Jacobs Well (an iconic spring and underwater cave in the contributing zone), Freeman Ranch (a working ranch in the recharge zone, operated by Texas State University), Ezell’s Cave (a historic and biologically important cave in the recharge zone), the San Marcos artesian well (a flowing artesian well in the confined portion of the aquifer and the most bio-diverse groundwater site in North America), Comal Springs (the largest Edwards spring and habitat for several federally protected species), and the San Marcos River (a culturally and biologically important river fed by the San Marcos Springs). At each site, we will briefly discuss the hydrogeologic setting and salient management and conservation issues. In more detail, we will introduce sampling strategies for collecting aquatic subterranean organisms without physically entering caves.

Itinerary
(Start and end at San Marcos Activity Center | 9:00AM – 5:20PM)

9:35AM - 10:25AM: Jacobs Well (35 min drive): Contributing Zone, hydrogeology, conservation, SCUBA assisted bio collection
11:00AM – 11:50AM: Freeman Ranch (35 min drive): Recharge Zone, plankton hauls and bottle trap sampling in open boreholes
12:05PM – 12:25PM: Ezell’s Cave Preserve (15 min drive): Balcones Fault Zone, Texas Cave Mgmt. Assoc. History
12:35PM – 1:00PM: Lunch at San Marcos Artesian Well (10 min drive)
1:00PM – 2:30PM: San Marcos Artesian Well: Confined Zone, artesian well history and ecology, drift net sampling, lunch
3:00PM – 4:00PM: Comal Springs (30 min drive): Endangered species, EAHCP, drift net and cotton lure sampling
4:20PM – 5:20PM: Guadalupe River (20 min drive): Gravel and water chemistry as an extension of karst habitat, Bou-Rouch pumping
6:00PM - 8:00PM: Bracken Cave Preserve (30 min drive): Tour, presentation & catered reception.
8:50PM: Return to San Marcos (50 min drive)
Field Trips (Continued)

Trip 3: South Austin wild cave tour: management to protect cave ecosystems
20 person limit

Trip leaders: Rich Zarria & Mark Sanders, Biologists, Austin Water Balcones Canyonlands Preserve

Logistics: Group size will be limited to 20 people. Lunch will be provided so packing one’s own is not required. All lights, helmets, and pads will be provided for those who would like to enter the caves. Personal cave gear will not be allowed to enter the cave in efforts to reduce the chance of cross contamination and possible transfer of WNS. Crawling/stooping through cave passages is required in some caves. Comfortable hiking shoes and a reusable water bottle (drinking water will be provided) are highly suggested. Details are preliminary and subject to change.

Details: Tour of South Austin Cave Preserves that are ecosystems for rare cave species and serve as educational/recreational resources for thousands each year. Each has different entrance security measures to protect the cave and the public, depending on site specific conditions. There are efforts to establish sufficiently large karst preserves to protect cave cricket foraging areas and water source areas to sustain cave ecosystems. Several decades ago, a large maternity bat colony in Goat Cave was eliminated by a cave gate in response to concerns from a new growing neighborhood. Once trash and ranch fill were removed from Wildflower and LaCrosse Caves, their ecosystems are rebounding including nutrient providing bats and cave crickets, despite the shared use with up to 2 thousand school kids and other explorers each year.

Itinerary
(Start and end at San Marcos Activity Center | 9:00AM – 4:15PM)

9:40AM - 10:50AM: Grassy Cove Cave (40 min drive)
11:00AM – 12:45PM: Whirlpool Cave (10 min drive)
1:00PM – 1:45PM: Lunch at LBJ Wildflower Center (15 min drive)
1:45PM: 2:45PM: LBJ Wildflower Center: La Cross & Wildflower Caves
3:00PM – 4:15PM: Goat Cave Karst Preserve (15 min drive): Goat Cave
6:00PM - 8:00PM: Bracken Cave Preserve (1 hr 15 min drive): Tour, presentation & catered reception.
8:50PM: Return to San Marcos (50 min drive)
Trip 4: Finding caves in north Hays County: recognition of caves in an environment of widespread filling | 30 person limit

Trip leaders: Nico M. Hauwert, Ph.D., Professional Geoscientist, Balcones Canyonland Preserve Program Mgr.

Logistics: There are opportunities to enter caves during this trip and helmets, headlights, and knee pads will be provided for safety and to reduce the risk of spreading white nose syndrome.

Details: This field trip examines common reasons why most caves were filled across the area and provides tools for recognizing filled caves. A common misconception is that caves are found open and can readily be identified by a geologist trained in karst terrains. The reality is that caves were widespread filled for a variety of reasons that will be examined in this field trip. Caves known today generally were excavated by cavers. Caves, especially when filled are generally not identified prior to development of sites, and are more likely discovered during construction or later catastrophic collapse. However, features that are highly likely to be caves can be identified by experienced cave stewards, through geophysics, surface contour maps, LIDAR and occasionally on aerial photographs. Where caves are filled actual discovery of caves and understanding its importance necessitates excavation. How historical practices affected recharge to aquifers, potential groundwater contamination, flooding, habitat for wildlife, education/recreational resources, historical records archived in cave deposits, and loss of heritage features for the public to experience. This trip will also examine sinkhole morphology and the geologic factors affecting cave development and cave density. This trip is dedicated in memory of Bill Russell, my mentor in finding caves and one with an amazing record for finding concealed caves.

Itinerary
(Start and end at San Marcos Activity Center | 9:00AM – 4:30PM)

<table>
<thead>
<tr>
<th>Time</th>
<th>Location</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:15AM – 10:00AM</td>
<td>Texas State University (15 min drive)</td>
<td>Academy Cave that extends beneath Texas State University.</td>
</tr>
<tr>
<td>10:30AM – 11:30AM</td>
<td>Dahlstrom Ranch (30 min drive)</td>
<td>Examine common ranching practices including trash filling of sinkholes, filling of caves to prevent damage to livestock, and plugging of sinkholes to create stock ponds.</td>
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<tr>
<td>11:30AM – 12:30PM</td>
<td>Lunch at Dahlstrom Ranch</td>
<td></td>
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<tr>
<td>1:00PM – 1:40PM</td>
<td>Onion Creek Water Quality Protection Lands (30 min drive)</td>
<td>Examine creek swallet caves on Onion Creek.</td>
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<tr>
<td>2:00PM – 2:15PM</td>
<td>Hoskins Hole Cave (20 min drive)</td>
<td>Examine 80 feet deep Hoskins Hole shaft. This cave was partially filled with trash and restored.</td>
</tr>
<tr>
<td>2:30PM – 4:30PM</td>
<td>Hudson Water Quality Protection Lands (15 min drive)</td>
<td>This former ranch was proposed for a 1,400 home development utilizing organized sewage system effluent infiltration. No caves were identified in the submitted geologic assessment. An 8-day assessment allowed by court order utilizing teams of cavers and geologists identified 140 significant features including 7 caves, 5 likely filled caves or sinkholes, and 3 large-internal drainage sinkholes. The site was acquired by the City of Austin for preservation.</td>
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<tr>
<td>6:00PM - 8:00PM</td>
<td>Bracken Cave Preserve (1 hr 15 min drive)</td>
<td>Tour, presentation &amp; catered reception.</td>
</tr>
<tr>
<td>8:50PM</td>
<td>Return to San Marcos (50 min drive)</td>
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Field Trips (Continued)

Trip 5: A cross section of cave & karst management: show caves, preserves, & private property | 29 person limit

Trip leader: George Veni, Ph.D., Executive Director, National Cave & Karst Research Institute

Logistics: The group will travel in two 15-passenger vans. Lunch will be provided at the Cibolo Center for Conservation. No caving equipment is needed. A camera, comfortable hiking shoes, and a reusable water bottle (drinking water will be provided) are suggested. One stop will involve crossing a shallow stream (typically 10-20 cm deep) so consider crossing barefoot or in sandals and bringing a small towel. Details are subject to change. Rain is not expected but could require a change in some destinations.

Details: Many styles of cave and karst management occur to fit their diversity and needs. The styles also vary according to the type of ownership and general land use. This trip spotlights three styles of ownership/management. It will first visit a small, lovely, privately owned show cave where management is focused public access, education, and safety. Next is a public nature center with an attached private nature preserve where natural resource protection is the primary focus, followed by public education/access and research. The final stop is on a privately owned ranch trying to protect over 150 years of family stewardship from now rapidly encroaching suburban development. The trip is designed for people interested in contrasting landscape-wide and site-specific approaches to cave and karst management.

Itinerary
(Start and end at San Marcos Activity Center | 8:00AM – 4:45PM)

9:15AM – 11:30AM: Cave Without A Name (75 min drive): Show cave management and methods for trail, lighting, tourist management, public education, and vandalism.

12:00PM – 1:00PM: Lunch at Cibolo Center for Conservation (30 min drive)

1:00PM – 3:00PM: Cibolo Center for Conservation: Tour the adjacent Cibolo Preserve and caves and karst features along Cibolo Creek. Discuss water quality challenges from an upstream sewage treatment plant, neighboring urban developments, and the naturally evolving karst landscape that is capturing the stream and depriving water to the downstream riparian area.

3:45PM – 4:45PM: Honey Creek Cave (45 min drive): Visit the entrance of Honey Creek Cave, Texas’ longest cave, and the headwaters of its namesake Honey Creek. Discuss state and private efforts to protect this pristine riparian area, one of the few left in Texas, from proposed suburban development that may degrade water quality of surface runoff and groundwater through the cave.

6:00PM - 8:00PM: Bracken Cave Preserve (45 min drive): Tour, presentation & catered reception.

8:50PM: Return to San Marcos (50 min drive)
Oral Presentations

The list of oral presentations is arranged in alphabetical order by the first author.
An asterisk (*) identifies the presenting author.

Development, validation, and application of an environmental DNA assay to detect federally threatened groundwater salamanders in central Texas
Adcock, Zachary (zca3@txstate.edu)*1,2
1. Texas State University, Department of Biology, 601 University Drive, San Marcos, TX 78666
2. Cambrian Environmental, 4422 Packsaddle Pass Suite 204, Austin, TX 78745

The molecular detection of DNA fragments that are shed into the environment (eDNA) has become an increasingly applied tool used to inventory biological communities and to perform targeted species surveys. This method is particularly useful in habitats that are difficult or not practical to physically survey. Central Texas Eurycea salamanders are species of concern throughout most of their distributions and can inhabit both surface (e.g., springs) and subsurface (e.g., aquifer) aquatic environments. Subsurface surveys are challenging, and the detection of salamander eDNA in water samples is an appealing survey technique for these situations. Here, we develop, validate, and apply an eDNA assay using quantitative PCR for Salado Salamanders (E. chisholmensis), Georgetown Salamanders (E. naufragia), and Jollyville Plateau Salamanders (E. tonkazae). These three species are federally threatened and constitute the Septentriomolge clade that occurs in the northern segment of the Edwards Aquifer. We demonstrate that the assay is specific to the target taxa and amplifies Septentriomolge eDNA from salamander positive water and known-occupied field sites. We did not detect Septentriomolge eDNA at any sites with historically rare detections or in second order creeks downstream of occupied sites. We explore the effects of site and sample covariates on these results, and we discuss future research needed to refine this method and understand its limitations before practical application and incorporation into formal survey protocols for these taxa.

Comparing cave climate during COVID closures vs open times at Lehman Caves
Baker, Gretchen (gretchen_baker@nps.gov)*1

In March 2020, Lehman Caves in Great Basin National Park closed to tours and stayed closed until May 2021, a total of over 400 days. During this time, the cave lights were primarily left off except during some staff work in the cave (approximately 30 days). Visitation decreased from about 33,000 to about 50 people. Before, during, and after this closure, hourly temperature and humidity data loggers collected data at several locations in the 3-km long cave. Periodic carbon dioxide levels were recorded as well. At the site of the main transformer in the cave, during the summer three-month period, the average temperature was 10.9°C during the closure and 13.1°C with limited tours. Humidity changed from an average of 100% during the closure to 94.4% with limited tours. Carbon dioxide levels near this area showed a daily increase of 300 to 400 ppm in late July and early August 2021, with 7 daily tours. The maximum usually occurred in mid-afternoon, with a minimum at about 0800. Temperature at this nearby location showed an increase of 0.1°C during each day in early August with tours, with a minimum temperature at 0700 or 0800. A remote part of the cave shows no temperature or humidity change during this time period. This unexpected cave closure allowed for cave baseline conditions to be documented, as well as giving the Park a better understanding of how tours impact parts of the cave environment.

The acquisition and protection of Clarksville Cave: a tale in five parts
Berger, Mitchell (m.berger@necaveconservancy.org)*1
1. Northeastern Cave Conservancy, PO Box 254, Schoharie, NY 12157

Ask cavers whose formative caving years were spent in the northeastern United States, “which wild cave was your first?” and the answer that you will hear more often than any other is: Clarksville Cave. Located in Albany County, New York, this roughly 4,800 foot long cave with five entrances boasts one of the longest histories of any cave in the state, with exploration dating back at least as far as 1811. Today, it is the centerpiece of the Northeastern Cave Conservancy’s most popular and well-known preserve.
Oral Presentations (Continued)

The story of how the NCC's Clarksville Cave Preserve came into existence and has grown into what it is today begins in earnest in 2001, and this twenty year tale has not yet reached its conclusion. While each of the NCC's other cave preserves has entered its portfolio in a single acquisition, the Conservancy first purchased a sizable portion of Clarksville Cave with one entrance in 2004, and has been steadily working to acquire and protect more of the cave ever since. Each opportunity to expand the preserve has presented itself under unique circumstances, some relating to a fatality, rescues and rescue trainings, foreclosures, friendly neighbors, and neighbors who've become deeply involved with the NCC. We will explore each chapter in the NCC's ongoing journey to protect the entirety of this very special cave, with the hope that other groups seeking to protect more of a cave system they currently hold a portion of may glean some ideas to help make that dream reality.

The use of morphologic character analysis to determine sinkhole risk for solar site development
Denton Jr., Robert K (robert.denton@terracon.com)*1; Joshua David Valetino1
1. Terracon, Suite 170, 19955 Highland Vista Drive, Ashburn, VA 20147

Construction in karst terrains can present a challenge to development, and the solar energy industry has become increasingly aware of the potential impact to both site infrastructure, human health, and the environment that may result from the mismanagement of construction activities at solar sites. These impacts include development of new karst features or accelerated growth of existing features, damage to water supply wells and springs, and potential negative impacts to the habitat of stygobiont taxa.

Prior site studies have often depended on the subjective evaluation of individual features by a karst specialist. However, at large sites (>1000 acres) with high concentrations of dolines and ponors, the analysis of the risk these features present is time-consuming and often inaccurate. To address this, we have been developing a method using morphometric character analysis in an attempt to reduce subjectivity in karst feature evaluation. The process involves an initial desktop review to identify suspect karst features, followed by a field survey during which feature risk is determined based on the systematic coding of documented characters including: 1) the presence of an open throat, 2) parapet characteristics, 3) degree of soil raveling, 4) drainage leading to the karst feature, and 5) presence and quality of vegetation. Each karst feature is assigned a risk category where the recommendations detail approaches for each karst risk level. We then work with project engineers to assist in designing appropriate measures intended to minimize the impact to planned infrastructure and the karst resource.

Monitoring microbial communities for cave conservation
Drake, Riley S. (rileydake@gmail.com)*1,2,3; Emily Tencate2; Ramon Armen2; John Dunham2
1. Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139
2. Fort Stanton Cave Study Project, 1 Whispering Winds Trail, Placitas, NM 87043
3. Cave Exploration Society Inc, Medford, MA 02155

Fort Stanton Cave in Lincoln County is the 10th longest cave in the United States. With the discovery of the Snowy River Passage in 2001, it has emerged as one of the most scientifically significant caves in the West. We used 16s rRNA and genomic DNA sequencing to analyze the composition of microbial communities present in Crystal Lake, the terminal sump located at the end of the Snowy River passage. Compared to the low concentration of microbial cells expected in an oligotrophic cave environment, Crystal Lake had a high concentration of microbial cells. We suspected that some of the microbes in Crystal Lake may not be cave resident microbes, and sought the possible surface origins of these microbes. Specifically, we took samples at the resurgence, further upstream in the cave, and from nearby surface water sources which are known or suspected to flow into Fort Stanton Cave, including the suspected insurgence at Eagle's Mouth. This study established a robust baseline for both the resident microbial community in Crystal Lake and its expected relationship with nearby surface water. We present this case study as a proof-of-concept for the feasibility and cost-effectiveness of microbial monitoring for cave conservation. Microbial monitoring through sequencing has become increasingly accessible through the advent, evolution and commercialization of next-generation sequencing (NGS) technologies. We discuss practical applications and limitations for monitoring microbial communities in caves.
Oral Presentations (Continued)

Groundwater snail biodiversity and conservation in the United States and Mexico

Gladstone, Nicholas S. (ngladstone@pape-dawson.com)*1; Matthew L. Niemiller2; Benjamin Hutchins3; Benjamin Schwartz3,4; Alexander Czaja3, Michael E. Slay6; Nathan V. Whelan7

1. School of Fisheries, Aquaculture, and Aquatic Sciences, Auburn University, Auburn, AL 36849
2. Department of Biological Sciences, The University of Alabama in Huntsville, 301 Sparkman Drive, Huntsville, AL 35899
3. Edwards Aquifer Research & Data Ctr., Texas State University San Marcos, 601 University Drive, San Marcos, TX 78666
4. Department of Biology, Texas State University San Marcos, 601 University Drive, San Marcos, TX 78666
5. Faculty of Biological Sciences, Juárez University of the State of Durango, Gómez Palacio, Durango, Mexico
6. The Nature Conservancy, Arkansas Field Office, 601 North University Drive, Little Rock, AR 72205
7. Southeast Conservation Genetics Lab, Warm Springs Fish Technology Center, United States Fish and Wildlife Service, Auburn, AL

Among the many taxonomic groups to successfully adapt to life in groundwater habitats are freshwater snails. However, snails that inhabit groundwater systems are generally understudied because of sampling difficulty and lack of taxonomic expertise. We conducted a literature review to assess the biodiversity, geographic associations, current threats, conservation and management activities associated with each species, and current environmental policies that may offer protections for groundwater snails. We identified 39 species among several taxonomic families that have been described from karst regions across the United States and Mexico, representing one of the most biodiverse subterranean fauna. Owing to the often short-range endemicity and proximity to a range of anthropogenic disturbances such as increased sedimentation, groundwater extraction, or physical alteration of subsurface passages, most groundwater-restricted snail species are at elevated extinction risk. Of the 39 known species, 32 have been assessed as imperiled under NatureServe criteria and 10 species have been assessed as threatened under International Union for Conservation of Nature (IUCN) criteria. However, only three species are federally listed in either the U.S. or Mexico, and current laws regulating wildlife and water pollution at the state and federal level may not adequately provide protections for most groundwater snails. Since groundwater systems will be increasingly manipulated and relied upon for human water demands, we advocate for increased study of this diverse groundwater fauna so that conservation efforts can continue to be enhanced.

Optimizing cave and karst management through collaborative outreach

Gordon, Jessica (jessica.gordon@austintexas.gov)*1; Cait McCann*2

1. City of Austin, Watershed Protection Department, P.O. Box 1088, Austin, TX 78767
2. City of Austin, Wildland Conservation Division, 3621 Ranch Road 620 South, Austin, TX 78786

What can organizations do to optimize cave and karst management and outreach efforts? Synergistic collaborations provide opportunities to leverage resources to enhance and expand community engagement. We will explore the opportunities and challenges which exist when nonprofits and government agencies work together, share best practices that we have developed, and highlight examples of how partnerships offer a model for others to more effectively manage karst resources and engage the public in conservation. We will provide an overview of our Cave Collaboration Committee, which consists of representatives from multiple City departments, state agencies, caving organizations, and local cave managers. Members from each of those stakeholder groups met to address their concerns and operational needs, first forming a simple agreement about training requirements for guides and total numbers of visitors to each cave per year to minimize the impact on caves with endangered species as we increase the number of educational tours. The collaboration quickly evolved into a way of organizing annual training for interpretive guides and teachers in cave biology, geology, and safety. The partnership continued to yield more collaboration, including the reintroduction of large-scale public education efforts like the Austin Cave Festival (with over 3,000 participants), art projects, cave rescue training, and shared educational resources. In just a few years, previously unconnected cavers and land managers from across the city developed much closer relationships and coordination, resulting in improved protection of endangered species habitat, more meaningful and informative cave visits for the public, and stronger emergency action plans.
Oral Presentations (Continued)

Widespread cave filling in Austin

Hauwert, Nico (nico.hauwert@austintexas.gov)*1

1. City of Austin, Balcones Canyonlands Preserve. 3621 South FM 620, Austin, TX 78738

The filling of caves has been widespread practice in Texas over the last 200 years. The reasons given included keeping water at the surface for mills, stock ponds and other surface water supplies, eliminating fall hazards for livestock and people, disposing of ranch trash, mitigating perceived poor air quality, disease and habitat for undesired animals, increasing marketability for development, creating water-quality ponds, eliminating surface disturbance associated with restoration, and protecting the groundwater from surface contamination. While numerous studies equate “increasing yield” of a landscape to increasing runoff to streams, in Central Texas it is advantageous to infiltrate runoff for groundwater recharge, reduced flooding, and sustained spring flows. The effect of historic widespread filling of caves and sinkholes have contributed to increasing flooding risk, reduced habitat for cave species including rare and endangered invertebrates and bats. Cave restoration also can provide important educational and historical resources.

The majority of known caves in Travis County required excavation and documentation by local cave volunteers associated with local branches of the National Speleological Society and Texas Speleological Survey since the 1950’s. Since 2013, the City of Austin has hired and contracted cavers. Because the scope of restoring caves can be a large effort, the number of trained cave excavators and annual investment are limited, and filled caves can be challenging to detect, revealing of new caves occurs at a slow pace. Caves, some of which are very extensive, continue to be discovered each year in the Austin area.

Creating a brighter future: teaching conservation with CaveSim

Jackson, Dave (jacksonndmit@cavesim.com)*1 ; Tracy Jackson1

1. CaveSim LLC, 13 Kreg Lane, Manitou Springs, CO 80829

Education of the public is a crucial component of efforts to conserve species, caves, and aquifers. In the short term, education about specific conservation initiatives builds support among the public for these initiatives, helping citizens to understand the importance of conservation work and the role that the public can play in assisting with conservation. In the longer term, more generalized conservation education helps inspire students to consider careers in science and conservation, and inspires young people to take a stand for conservation. Since 2010, the authors have traveled around the United States with a mobile conservation education program. The authors and their team of staff and volunteers teach K-12 students about conservation of caves, groundwater, and a variety of species including bats and invertebrates. The program has educated approximately 40,000 children in 19 states, and the authors often collaborate with local, state, and federal agencies to bring the program to under-served and rural populations. The authors will share numerous examples of collaboration between government agencies and their organization (CaveSim) with the aim of inspiring future collaborative initiatives. The authors will also illustrate how they have aligned the CaveSim program with state education standards to make it easier to bring conservation education into public schools.

The Agency Guide to Cave and Mine Gates, a 12-year history

Kennedy, Jim “Crash” (cavercrash@gmail.com)*1

1. Kennedy Above/Under Ground LLC, 304 West Mockingbird Lane, Austin, TX 78745

Before White Nose Syndrome siphoned away all cave conservation funding, a small group of experts was focusing on protecting the most critical bat roost habitats in the United States. Utilizing state-of-the-art cave gate designs and placement based on bat ecology and the study of cave microclimates, this information rapidly became the “industry standard”, adopted by the National Park Service, US Forest Service, US Fish and Wildlife Service, The Nature Conservancy, and many state land management agencies. In order to convey those concepts and practices in simple language to the agency folks making the decisions and providing the funding (and writing the RFPs), the most active gaters developed this handy guide. New modifications and innovations meant that the Guide has been periodically revised, with the latest occurring just in time to be released at this Symposium. We cover some of the features of the Guide, plus show some recent examples of the styles of gates featured therein.
Cavers and karst scientists: the bridge to the underground
Kosič Ficco, Katarina (katarina.kosic@dcr.virginia.gov) *1; Wil Orndorff2; Thomas Malabad3
1. Virginia Dept. of Conservation & Recreation, Natural Heritage, Karst Program, 8140 Cumberland Gap Rd, New Castle, VA 24127
2. Virginia Dept. of Conservation & Recreation, Natural Heritage, Karst Program, 1580 Oilwell Road, Blacksburg, VA, 24060
3. Virginia Dept. of Conservation & Recreation, Natural Heritage, Karst Program, 231 Price St., Blacksburg, VA, 24060

Several centuries of karst research support the idea that appropriate management, protection, and research of karst landscapes require a holistic, karst specific approach. It is also commonly understood that karst specific scientific knowledge is not necessarily attained by common geological or hydrological studies. Nonetheless, karst related positions at federal, state, and local governmental levels, and in private practice, are often occupied by scientists with very limited knowledge, training or experience in karst science. Such individuals are often willing to learn from and collaborate with the cave and karst community. If the willingness to learn is absent, or the network of karst specialists unknown or inaccessible, then a significant knowledge gap may persist, reducing our understanding of karst resources and hampering efforts to protect them. By proactively cultivating a practice and culture of collaboration between the karst community and various stakeholders such issues can be mitigated.

Two cases illustrate the effective inclusion of cavers and karst scientists into decision making and evaluation of karst resources on public lands. Cavers and karst scientists are collaborating with the United States Forest Service to survey caves and karst of the Bridger-Teton National Forest. Beneath Virginia’s Jefferson National Forest, cavers are working with paleontologists from state, federal, and private sectors to extract an intact Pleistocene cat skeleton from a remote vertical cave. In both cases, effective communication between collaborators helped prevent alienation of project partners that could have resulted in detrimental impacts to both the research projects and the already vulnerable cave and karst resources.

Monograph of the groundwater isopods of Virginia
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A monograph (in preparation) of the groundwater isopods of Virginia encompasses over 50 species found in caves, springs, seeps, wells and drain tiles. Twenty of these species are being described as new to science, mostly narrow endemics. A large percentage of the karst-associated biodiversity is in springs, not caves. We emphasize the importance of sampling springs, frequently passed over by biologists in favor of entering the caves discharging the water. In Virginia the cave and spring fauna are interwoven into a complex evolutionary fabric and evaluating both helps our understanding of how the subterranean obligate fauna fits into the bigger picture. Two of the karst species are listed as federally endangered or threatened, and a third is being evaluated for placement. Critical review of past records of these and other Virginia isopod species leads to the seemingly obvious conclusion that one should enlist the best taxonomic expertise available. Much Virginia material has been identified by folks who weren’t isopod specialists, resulting in mis-identifications, confusion and the need to re-visit. Likewise, we have found molecular work is critical for recognition of cryptic species. Traditional morphological taxonomic characteristics alone are not always sufficient for species delineation, resulting in significantly underestimated species diversity. However, in most cases other morphological characteristics vary consistently between species in such a way that once a species is recognized, determinations based on morphology can be made. A by-product of the molecular work is the discovery of more syntopy than previously recognized from morphology alone.
Predicting surface abundance of federally threatened Jollyville Plateau Salamanders (*Eurycea tonkawae*) to inform management activities at a highly modified urban spring

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Urban Expansion has contributed to the loss of habitat for range restricted species across the globe. Managing wildlife populations within these urban settings present the challenge of balancing human and wildlife needs. Almost the entire range of Jollyville Plateau Salamanders (*Eurycea tonkawae*) is embedded in the Austin, Cedar Park, and Round Rock metropolitan areas of Travis and Williamson counties, Texas. Among *E. tonkawae* occupied sites, Brushy Creek Spring has undergone some of the most extensive anthropogenic disturbance. Today the site consists of small groundwater outlets that emerge in the seams within a concrete culvert underlying a highway, yet salamander persist within this system though they are rarely observed. Here, we predict the occurrence of salamanders within the surface habitat of Brushy Creek Spring in response to accumulated rainfall using generalized linear models. Our results indicate that while rare, salamanders do occur within this modified habitat. Additionally, we present evidence of reproduction, recruitment, and subterranean movement by *E. tonkawae* throughout this site. Information on the conditions that result in salamander observation at this site should be used to schedule site management, maintenance, or repair, when the occurrence of salamanders is not predicted to be likely.

Delineation and characterization of gypsum karst geo-hazards in the Delaware Basin of west Texas: A case study using electrical resistivity tomography

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The Delaware Basin, a major subdivision of the Permian Basin located in west Texas and southeastern New Mexico, contains abundant and diverse karst features within the Permian aged Castile Formation, a major evaporite unit within the region composed primarily of gypsum/anhydrite. Common expression of karst in area includes sinkholes, exposed solution enlarged fractured bedrock, solution cavities, and caves of polygenetic origin. Recent infrastructure development related to oil and gas activity in the Permian Basin has increased encounters with karst related hazards. Land reconnaissance surveys conducted during the fall of 2015 and summer of 2016 documented karst features adjacent to a major thoroughfare in Culberson County, Texas.

Two-dimensional electrical resistivity surveys were conducted to characterize and delineate karst features that were not readily apparent on the surface. Preference was given to sites where subsidence or road degradation due to karst were apparent. Two sites are presented where a multi-electrode, direct current resistivity survey using a dipole-dipole array was conducted parallel to the road. Data was reduced using EarthImager-2D (Advanced Geosciences, Inc.) to create two-dimensional pseudosections of the subsurface. Detected anomalies were interpreted as zones of increased suffusion, fractures, solutional conduits, and stratral leaching. This non-invasive geophysical method was shown to be effective at detecting subsurface karst features with no apparent surface expression. The findings suggest that two-dimensional electrical resistivity surveys can provide valuable information for infrastructure projects in high karst geo-hazard areas.

Mountain Valley Pipeline: karst issues in Virginia 4 years into construction

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In 2018, construction of the Mountain Valley (MVP) and Atlantic Coast (ACP) 42 inch, 1400 PSI natural gas pipelines began in Virginia across the Appalachian Ridge and Valley, where karst is extensively developed in Paleozoic carbonate bedrock. Sinking streams, sinkholes, caves, and springs are common. Each project developed karst hazard assessments and

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mitigation plans, and used dye traces to inform monitoring. Permitting issues delayed both projects. Dominion canceled ACP in July, 2020, while MVP continued and is over 90% completed. State agencies are working with landowners to constrain possible sources of continued turbidity at a spring hydrologically connected to sinkholes that in 2018 received sediment from a now-completed section of MVP. Much remaining construction is on karst, and at stream crossings where permits are pending. Delays in project completion increase environmental risk; the four-mile section along Sinking Creek Mountain (Giles County) is in its fourth year of construction. Monitoring for potential impacts at two springs draining this section continues. In February 2019, nine meter-scale sinkholes were discovered in an area blasted but not trenched in 2018, and where karst pinnacles had been excavated during grading. Project opponents characterized this area as an unroofed cave. Virginia Department of Conservation and Recreation (VDCR) staff considered the sinkholes likely the result of fines raveling into blast voids, and pipe installation here in 2021 exposed no caves. MVP is working with VDCR to protect any newly discovered karst features, and funded the purchase of the Salamander Cave Preserve by the Southeastern Cave Conservancy.

Military bases may be vital for preserving key components of karst habitat: an evaluation of karst preserves at Camp Bullis, San Antonio, Texas

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Joint Base San Antonio Camp Bullis has established Karst Preserve Areas for management of 83 significant caves on the base, including 32 caves known to contain endangered species. In 2021, Zara Environmental LLC evaluated Karst Preserve Areas for the 32 endangered species caves plus two other caves based on recommendations for karst preserve design published by the U.S. Fish and Wildlife Service. The land use and management specific to Camp Bullis is uncommon in today’s urban landscape and presents some unusual considerations for karst preserve assessment. Abiotic and biotic components of the karst ecosystem associated with each cave were assessed, resulting in a spectrum of low quality to high quality rankings for each cave preserve. Of the 34 caves assessed, one cave preserve ranked as low quality, two preserves ranked as low to medium quality, nine preserves ranked as medium quality, seven preserves ranked as medium to high quality, and 15 were ranked as high quality preserves. The uncommonly high number of medium to high quality preserves reflects that there is a low density of urban development and a high density of caves on the base, which enables many Karst Preserve Areas to overlap, creating large contiguous preserve areas that exceed U.S. Fish and Wildlife Service standards for karst preserve size.

Ventilating high CO2 caves

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Many caves in the Austin area have high CO2 levels during the summer and early Fall, making access for management difficult if not impossible especially for tasks that require long exposure times such as cave excavation work. Ventilating caves with portable air blowers has been a relatively cheap and effective tool to allow such access. Staff was able to determine how effective ventilating was at reducing CO2 levels, and how long levels remained low, so therefore, how frequent ventilation was needed for various caves of various depths and sizes.

Instigating a cultural shift in cave and karst management

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Cave management has been and still is an evolving field across the country and worldwide. The same is very true within the National Park Service. Each new NPS National Cave and Karst Program Coordinator adds their personal spin, while keeping true to the original purpose of protecting, conserving, and promoting our cave and karst national treasures.

I’ll discuss the challenges I face on a weekly basis addressing the lack of knowledge, missing information, and the need to
reach out to the caving community to find out about NPS cave and karst resources. These challenges forced me to re-evaluate my thinking about how cave and karst resource data is managed as well as recognizing the need for a massive cultural change in the thinking of the NPS cave and karst community. A conceptual framework has been developed and is in the process of being implemented. As the NCKRI, Director of Cave and Karst Management Sciences I see the beginnings of a new chapter in how the “Feds” manage cave and karst resources data.

Austin cave restoration
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1. City of Austin, Balcones Canyonlands Preserve. Reicher Ranch 3621 South FM 620 Rd, Austin, TX 78738

Historical widespread filling of Central Texas caves has left many features obscured by trash and fill, often resembling trash dumps rather than caves. There is much restoration work needed to return these caves to their original states. Restoration produces an increase in habitat for rare species, improves recharge to the aquifer and provides educational opportunities for the public and the next generation of cave conservationists. There are many examples of caves in the Austin area that have been negatively impacted either by filling, by being built over or by vandalism. Some of these include Midnight Cave, Dead Dog Cave, Salamander Mountain Cave and District Park Cave. One of the saddest aspects of this widespread degradation of Central Texas caves is that these caves are home to an extremely diverse community of cave fauna. One of the factors that supports this diverse community is the ability of nutrients from the surface to enter the subterranean environment. Cave crickets play a critical role in this by transporting nutrients into cave systems in the form of their eggs, their own bodies, and from their nutrient rich dropping which feed fungus and bacteria that provide food for springtails, millipedes, and other cave organisms. Cave entrances are biologically important since they are the portals allowing nutrients from the surface to enter the nutrient deficient cave ecosystem. I will give detailed histories of some previous and ongoing Austin cave restoration projects. These include Wildflower Cave, LaCrosse Cave, Grassy Cove Cave, and Persephone Caverns.

Central Texas cave life
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Starting at the entrance, and traveling deeper, I will show the amazingly diverse community found in Central Texas caves. Through macrophotography and videography, I shed light on these seldom seen subterranean organisms. The cave-loving troglophiles feel right at home in the moist, stable underground ecosystem. And even though they could survive on the surface, they prefer the conditions below. Some of these include frogs, toads, salamanders, spiders, and snails. The ecologically important trogloxenes are the main source of nutrients entering many Central Texas caves. These part-time cave dwellers include mammals such as raccoons, opossums, bats, and the biggest contributor, though smallest in body size, are cave crickets. Large groups of roosting cave crickets provide abundant nutrients from their eggs, their bodies and from their droppings which feed fungus and bacteria that feed other cave organisms such as springtails, millipedes, and other cave organisms. The cave obligate troglobites have become so adapted to the stable, near 100 percent humidity environment, that they can no longer survive on the surface. Some of their adaptions include slower metabolism, and longer lifespans than surface relatives. Other adaptions are a loss of eyes and pigmentation, elongation of legs and antennae, and increased vibratory and olfactory senses. These include troglobitic harvestmen, millipedes, pseudoscorpions, and spiders. In cave streams, pools, and the aquifer live the stygobites, the obligate ground water fauna.

The sinkhole stabilization of the Blowing Sink Research Management Area
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1. City of Austin, Balcones Canyonlands Preserve. Reicher Ranch 3621 South FM 620 Rd, Austin, TX 78738

In 2013, Dr. Nico Hauwert of the City of Austin's Watershed Protection Department, along with team of City cave specialists and Zara Environmental, proceeded to implement a plan to stabilize five of the major karst features on the Blowing Sink Research Management Area in South Austin. With the decades old shoring becoming greatly distressed, we found ourselves with no other options other than watch the entrances to these caves collapse in on themselves over time or to excavate to
Oral Presentations (Continued)

bedrock and erect a permanent and more ecofriendly solution to these threatened karst features. Despite confronting many obstacles and restrictions many departments of the city came together along with contractors and volunteers to help make this vision become a reality and a cave restoration success story.

Karst impact management scheme for cave sites in the Cayo District, Belize C.A.

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Twenty percent of the world’s total surface area consists of karst terrain, which provides 20 to 25% of the drinking water to the world’s population. As a result it is important to protect these fragile sites such as sinkholes and caves. These karsts sites serve as sensitive indicators to the overall health of an ecosystem. However, often they are exploited as natural parks and show caves where humans cause intentional and unintentional destruction. In Belize, while there are numerous cave formations throughout the landscape, only a few are available for tourism purposes. The result of this study indicates that there is the need for proper development of policies and guidelines that will protect the integrity of the few cave sites open to the public. In Central America and the Caribbean, cave monitoring is very unusual and considered a low priority and a result, the objective of this paper was to use the quantified human impacts on show caves in Belize using the karst disturbance and provide proper regulations that need to be implemented based on results. The convenient sample method was used to select the Barton Creek, Actun Tunichil Muknal and Nohoch Che’en Caves as study sites. The degree of impacts to cave formations (speleothems) and erosion was collected through an observation process by physically visiting the three cave sites. The karst disturbance index was applied with moderate confidence levels to assess the impacts caused by human activity at the selected caves. This research is vital for understanding the state and condition of cave sites in Belize and institute policies that will provide protection for these karst environments in Belize.

Cave and karst management after the International Year of Caves and Karst (Keynote address)

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The International Year of Caves and Karst was established by the International Union of Speleology (UIS) to reach and teach the world about the many benefits and challenges of living with caves and the karst landscapes in which most occur. The theme of the Year is “Explore, Understand, Protect,” because exploration is necessary to conduct the research needed for the understanding required for proper and sustainable protection and management. At the time of this writing, 241 organizations have joined the UIS and organized 305 International Year activities around the world. Many more are planned. But what happens after the International Year?

The International Year of Caves and Karst is a beginning. It is not the goal. Connections are being made this year with local to international governmental bodies. The is the first step. Our next steps are to build those connections into relationships. With a relationship, your information will not only be welcomed, but requested. From there identity specific, realistic, and achievable actions, and work to make them realities. Understand where compromise may be needed and what cannot be compromised. Continue to educate and invigorate the public, including scientists and educators who are not familiar with caves and karst. As they learn how caves and karst are relevant to them, they will become natural partners. Their support will multiply globally. Caves will become places to respect, “karst” will be seen as a critical part of our environment, and funds and support for further exploration, understanding, and protection will grow.

Cambria Cavern discovery and mitigation; a case study in urban karst management

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In the early morning hours of February 8th, 2018, residents of a neighborhood north of Austin, Texas were awakened by the sound of “thunder.” Hundreds of tons of the ceiling of a previously undetected cavern had collapsed, taking with it portions of Cambria Drive, the adjacent sidewalk, and underground utilities. Approximately 750,000 gallons of water washed directly into the Edwards Aquifer as the nearby water tower emptied itself through the ruptured water main. By first light commuters and school kids encountered a yawning void in the earth expelling a column of water vapor into the frosty sky. Fortunately, neither sewer nor natural gas utilities were compromised and no one was harmed. This presentation documents the aftermath and the eight-month process of protecting the cave, the aquifer, and associated habitat for threatened and endangered species, while restoring full function to the neighborhood. The exploration and mapping process is discussed, as well as the development of site protection measures, regulatory compliance strategies, occupational safety measures, and the cave closure engineering and construction plans.

SUAS karst survey: using drones to augment human pedestrian survey

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Karst survey is traditionally performed by pedestrian reconnaissance, walking transects spaced evenly across the area of interest. Small unmanned aerial systems (sUAS) are used to augment the human portions of survey by photographing the land surface at regular overlapping intervals, using photogrammetry to produce a digital surface model, which is reviewed in a 3-dimensional analysis by a qualified karst expert. SWCA Environmental Consultants have performed dozens of these reviews, producing a data recovery, analysis and reporting system that reduces the amount of survey time, but increases the quantity and quality of data collected. The flight systems, analysis, and review steps taken by SWCA to produce a karst survey comparable to pedestrian survey will be presented.

How much land does it take to protect a cave?

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2. Tumbling Creek Cave Foundation

The protection of significant caves often requires more than control of the cave entrance. Complex connections with the surface can be unique to each cave and will dictate the amount of land needed to adequately protect cave resources. As the most biodiverse cave west of the Mississippi River, and habitat for multiple species of conservation concern, Tumbling Creek Cave has been a focal point for karst studies by the Ozark Underground Laboratory for over half a century. The many conservation achievements at Tumbling Creek Cave are the result of numerous studies aimed at understanding the hydrogeological nature of the cave system and the fauna within. Many of those achievements have occurred by improving land use on the surface. The story of cave protection efforts at Tumbling Creek Cave can provide a framework for cave managers when determining how much land is needed to protect a cave.

Effects of visitation patterns on carbon dioxide concentrations within Carlsbad Cavern

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Carlsbad Cavern, as a renowned show cave, faces potential hazards to its natural resources due to human visitation. Exhalation from visitors leads to elevated levels of CO2 in the air within the cave, which could pose a significant threat to human life and to the sensitive cave environment. At high concentrations of CO2, the human body suffers a multitude of negative physiological effects, cave speleothem experience slowed growth or even dissolution, and the resident flora and fauna could have their habitats disrupted. Thus, the National Park Service seeks to develop an improved understanding of the driving mechanisms behind CO2 levels in the cave. In this study, we investigated the relationship between human visitation patterns and elevated CO2 levels throughout seasonal shifts and the lifting of COVID-19 visitation restrictions. We used Wöhler
CDL 210 devices to continuously monitor CO₂ levels at 3 key locations within the cave. The CO₂ data was compared against visitation data obtained from ticket sales and a TRAFx Infrared Trail Counter. We conclude that human visitation is strongly correlated to the daily average CO₂ range and that the effects of visitation on CO₂ levels experience a short time delay. The results of this study suggest that future visitation policy at Carlsbad Cavern may need to be designed to limit the amount of CO₂ buildup and prevent the degradation of the cave environment.
### Poster Presentations

The list of poster presentations is arranged in alphabetical order by the first author.
An asterisk (*) identifies the presenting author.

#### Void inspection and mitigation in drilled shaft foundations

Beatty, Heather*¹, ²; Michael Machacek³; Adrian Martinez²; Lucas Short²; Ben Engelhardt²; Zach Lanfear²

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Previously undetected karst features are commonly encountered during construction within the Balcones Fault Zone in Central Texas. To balance the needs of infrastructure support and aquifer protection, construction projects located within karst recharge zones should include procedures for void response and mitigation. Among the procedures can be details for void mitigation in drilled shaft (DS) foundations. The Austin District of the Texas Department of Transportation (TxDOT) has revised their standard practices to include example void mitigation details which were first applied during the Mopac Intersections project in Travis County. Details for small and medium sized voids were made from combining state guidance for the protection of sensitive features on the Edwards Aquifer and the project’s general excavation methods. Input was sought from project engineers and local geoscientists who partnered with TxDOT. Large sized voids required feature-specific mitigation planning. Optimal down hole video results required that standard inspection procedures be followed to identify voids. The contractor received training in the procedures and conducted DS inspections. Professional geoscientists confirmed voided zones and sound bedrock at the base of DS. A tight-fitting ring on steel casing was used to minimize loss of concrete into a void. Bridge DS at La Crosse Avenue had the most voids. Post construction integrity tests showed mitigation was successful despite having massively voided zones. This best practice presentation draws from a project that included new bridges and retaining walls in karst terrain. Such projects involve engineering and geoscience work, the safety of the public, and the environment.

#### Counting cave shields: a Lehman Caves study

Hill, Morgan (mhill@blm.gov)*¹; Gretchen Baker²

2. Great Basin National Park, 100 Great Basin National Park, Baker NV 89311

Lehman Caves, located in White Pine County, NV, has been open to the public as a show cave since 1885. The cave has been federally protected since 1922, leading up to its incorporation into Great Basin National Park in 1986. Thousands of visitors each year make the trip to Lehman Caves to experience its rich history and many beautiful features. One such feature found in Lehman Caves, cave shields, are a unique and rare type of speleothem. Park lore estimates around 300 cave shields exist within the cave, but an extensive investigation of the shields had not been conducted. In early 2020, a geoscientist-in-the-park partner found, measured, and documented every visible cave shield in Lehman Caves. Results of the study indicate a total of 504 cave shields in Lehman Caves, possibly more than any other cave on earth. Additionally, it was discovered that multiple morphologies of cave shields may exist, dependent on bedrock jointing and fracturing. This integrated study within Lehman Caves provided a better understanding of the quantity and distribution of the shields and postulate how they grow and develop, filling a critical information gap for the park.

#### Is trapping success in Texas blind salamanders (*Eurycea rathbuni*) influenced by season, aquifer level, or precipitation?

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The Center for Conservation and Research at San Antonio Zoo (CCR) conducts research and conservation projects that focus on rare and endangered species and ecosystems, both locally and internationally. The Texas blind salamander (*Eurycea rathbuni*) is restricted to the San Marcos pool of the Edwards Aquifer and is federally listed as endangered. The Center for Conservation and Research at San Antonio Zoo and the United States Fish and Wildlife Service have been collecting...
salamanders to bolster research and captive assurance colonies, respectively. Research goals include development of breeding and husbandry protocols, gathering morphometric data, pathogen screening, and obtaining genetic material for ongoing population genetics studies.

Trapping success of this species is highly variable, and little is known about the influence environmental conditions may have on trapping results. We seek to explore how environmental factors such as seasonality, rainfall, and aquifer levels may influence trapping success.

Data collected from 2016 to present, has been compiled from seven sites where traps or driftnets were utilized. In addition to trapping data, San Marcos historic rainfall records provided by NOAA, and information on aquifer levels from the Edwards Aquifer Authority will also be analyzed. These comparative analyses of relationships among environmental factors and trapping results are forthcoming, and may provide insight on preferred environmental conditions, salamander activity, and improvements to existing trapping protocols.

Conservation and endangered species management in Williamson County
Renner, Joshua D. (josh.renner@wilco.org)*1; Sarah Moody1; Laura Schweitzer1
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The Williamson County Conservation Foundation (WCCF), formerly known as the Williamson County Karst Foundation, was formed in December 2002 for the purpose of providing for conservation and perhaps the eventual recovery of endangered and threatened species in Williamson County. The Foundation is overseen by a seven-member Board of Directors, including two Williamson County Commissioners. As the administrator of the Williamson County Regional Habitat Conservation Plan (WCRHCP), the WCCF partners with the county and developers to streamline endangered species permitting while advocating for responsible development and providing holistic conservation. The WCCF oversees the monitoring and management of over 50 caves on over 1800 acres of karst preserves. The United States Fish and Wildlife Service (USFWS) recognizes 5 Karst Fauna Areas (KFA) benefiting Texella reyesi and Batrisodes texanus that are a part of the WCCF preserve system while another 2 KFAs are currently proposed. Future endeavors of the Foundation include continuing to fund monitoring and research of Eurycea naufragia and Eurycea chisholmensis and expanding karst preserve acreage and KFAs in the county.

Development of a geology trail: a subglacial landscape; Clarksville Preserve, New York State
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Northeastern Cave Conservancy (NCC) programs are focused mainly on the conservation of caves and karst, inclusive of geological research oriented toward public education. The Clarksville Preserve is widely used by schools, colleges, scouts, cavers, and the public. While numerous websites provide general information, NCC outreach may be bolstered via a user-friendly program designed to generate interest in surficial geologic features through correlation with underlying cave features. To this end, the NCC is developing a 1,200-meter geologic trail.

This paper provides detailed descriptions and photographs of seventeen interpretive stops, each being designed to be accessible via smartphones using customized QR codes. Individual stops are designed for trail users to envision karst resources within the context of an evolving landscape, with emphasis on how karst features developed beneath glacier ice during early deglaciations. Trail stops highlight massive overland flow beneath 150-meter-thick stagnant glaciers pressed against Wolf, Cass and Bennett Hills to the south, with water depths ranging up to 3 meters. Subglacial meltwaters cascaded over cliffs, down wide channels, carved a deep gorge, and roared into joints - forming shafts, canyons, and tubular conduits within 1,500-meter Clarksville Cave. Together, these conduits served as a major subglacial drainageway, with flow coalescing from dozens of surficial inputs over thousands of years under thinning ice. Through time, the levels of subterranean conduits dropped as meltwater downcut through the Onondaga limestone, ending with a succession of stream-borne glacial sediments and cobbles. Subglacial inflow to the cave is now absent, resulting in an underfit hydrologic flow regime.
Poster Presentations (Continued)

Monitoring air quality in caves with a butane lighter
Sanders, Mark (mark.sanders@austintexas.gov)*1; Colin Strickland1; Drew Thompson1
1. City of Austin, Balcones Canyonlands Preserve, Reicher Ranch 3621 South FM 620 Rd, Austin, TX 78738

In lieu of expensive air quality monitors, for decades cavers have used cheap butane lighters to gauge whether it is safe to enter caves. Past studies comparing effects to the flame of a butane lighter under different levels of oxygen have been the basis for why butane lighters have been considered a useful tool by so many cavers.

In an attempt to verify past results, City of Austin Balcones Canyonlands Preserve staff utilized 2 different CO2 meters, the Vaisala Data Logging CARBOCAP GM70 Handheld CO2 Meter and the Telaire 7001 CO2 meter, taking measurements in caves with high CO2 levels, staff was able to determine impacts to the flame of a butane lighter under varying levels of CO2.

Increased thunderstorms across the Southern Great Plains – beneficial or harmful to karst dependent organisms?
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Using 30–50-thousand-year-old stalactites from Williamson County caves, Maupin et al. (2021) found that thunderstorms in the Southern Great Plains of the United States are increasing in intensity and frequency. Assessing changes in storm characteristics under different climate scenarios remains highly uncertain due to limitations in climate model physics. They analyzed oxygen isotopes from the stalactites to assess past changes in thunderstorm size and duration. Storm regimes shifted from weakly to strongly organized on millennial timescales and were coincident with well-known abrupt climate shifts during the last glacial period. Current analysis suggests that thunderstorm organization in the Southern Great Plains is strongly coupled to changes in large-scale wind and moisture patterns. These changes in circulation may be used to assess future predictions and paleo-simulations of mid-latitude thunderstorm climatologies.

The analysis of past climate regimes encapsulated within stalactites may give clues regarding future macroscale rainfall scenarios across the Southern Great Plains and more specifically, rainfall across the karstic landscape of Texas with the assumption of a rapidly warming climate. On its face, the potential for increased rainfall across this region may prove beneficial for terrestrial organisms that depend on a saturated atmosphere in karst voids (i.e., troglobites) or those species reliant upon a permanently wetted aquifer (e.g., stygobites). However, stronger thunderstorms capable of dropping large amounts of rain within a short duration may not be beneficial if flooding negatively impacts the subterranean ecosystem. We explore potential impacts to subterranean fauna with the assumption that a hotter Texas is a wetter Texas.
Texas caves have developed from a highly diverse range of geologic conditions. To date, nearly 6,500 caves plus an additional 8,000 springs and karst features have been documented across the 171,875 km² of karst in Texas. Although the caves and karst of the eastern Edwards Plateau and Balcones Escarpment are particularly relevant given our theme of endangered species, caves, and aquifers, all nine karst regions in the state have their own unique attributes and management challenges. To provide context for this year’s symposium theme and field trips, we provide here an overview of the karst regions of Texas. The following descriptions are from Smith and Veni (1994).

Balcones Fault Zone (BFZ): The BFZ is narrow and runs south from Dallas to San Antonio, then turns west and nearly reaches Del Rio. It contains thick-bedded to massive Cretaceous limestone and some dolomite beds. Abundant faults, all related to Miocene-age structural activity, are generally downthrown toward the Gulf of Mexico. Joints are more numerous and determine the orientation of most caves. Major caves form by groundwater which flows parallel to the BFZ and discharges at distant and large artesian springs. Vertical caves, some quite deep, route vadose water to deep phreatic groundwater conduits. The BFZ is closely related to but separated from the Edwards Plateau by a strip where the Edwards Group limestones have been eroded away. Some of the highest cave densities in the state occur in the BFZ although it is also the region that has been most thoroughly investigated.

Edwards Plateau (EP): The EP is a broad, gently rolling upland locally incised by few, moderate-size streams. It is one of the largest continuous karst areas in the United States. Cretaceous limestone with some dolomite dip gently to the south and southeast, with fractures related to regional uplift rather than local faulting and folding. Many caves, some quite extensive, are confined to small vertical intervals, either by lithology of the confining beds or by still-stands of nearby rivers. Vertical caves are less common. The EP can be divided into subregions, principally on the basis of stratigraphy and hydrology.

Devils River Trend: This narrow band of very thick-bedded to massive limestone is not easily correlated to laterally adjacent formations and appears to be the result of carbonate bank construction that lasted through most of the Middle Cretaceous. Vertical caves are common in the western section. In the eastern section, vadose flow is relatively recent, so most caves are old, large, high-elevation, phreatically-formed rooms and passages.

Maverick Basin: Thick-bedded limestone sequences are separated by the thin-bedded shaley limestone of the McKnight Formation. Most caves are limited vertically by lithology, and groundwater outlets were apparently at the bases of the upper and lower sequences. Passage orientations are determined by the local hydraulic gradient and are weakly guided by fractures.

Central Edwards Plateau: Cavernous rocks become progressively thinner to the north, but in the southern part of the subregion, caves attain significant vertical extent. Particularly in the north, stream incision into the soluble carbonates is younger, and fewer well-integrated caves have formed.

Stockton Plateau: The deeply incised Pecos River separates the Stockton Plateau from the rest of the Edwards Plateau. The Pecos and Rio Grande have provided outlets for groundwater at the base of the thick, soluble limestone sequence and have promoted development of some of ‘Texas’ deeper caves.
Lampasas Cut Plain: Although cavernous limestones are not more than 25 m thick, laterally extensive caves have developed in the broad uplands. Abrupt eroded edges of the uplands are limits to cave development. Most extensive caves are small-diameter conduits. Erosional exposure of some caves suggests that most pre-date current incision.

Isolated Edwards Outliers: Erosional remnants of the Edwards Plateau encircle much of the plateau. To the north and west, caves are small and apparently unrelated to caves in neighboring outliers. Long caves in this subregion result as foci of groundwater flow or maze development. In the southeastern portion, most caves are also small and recently formed. Larger caves are generally relics of hydrologic regimes that pre-date incision of the plateau margin.

Lower Glen Rose: The lower member of the Cretaceous Glen Rose Formation is a thick-bedded to massive fossiliferous limestone that contains many of the longer caves in Texas. It is exposed along the most deeply dissected southeastern margin of the Edwards Plateau. Caves may end in sumps or sediment fill draining into the Edwards Aquifer, or display long, dendritic stream systems draining into local rivers. Caves are strongly guided by fractures, and many were initiated as routes for stream piracy across meanders or between drainage basins.

North Texas: Cretaceous and Pennsylvanian-Permian age thin limestone beds with rare thick limestone banks provide limited opportunities for speleogenesis. Known caves do not have much lateral or vertical extent.

Llano Region: This structural basin contains Paleozoic rocks, including very thick carbonates of Cambrian and Ordovician age that are exposed along its outer margin. Abundant normal faulting and related jointing provide numerous avenues for dissolution. Cavern development may be vertically extensive. Dissolution-widened fissure systems are abundant in places where jointing is pervasive.

Permian Reef: The Capitan Reef is well-known to geologists and speleologists as the host rock for Carlsbad Caverns and related caves in New Mexico. In Texas, the same carbonate reef/bank rocks are exposed in the Guadalupe, Sierra Diablo, Apache, and Glass Mountains. Relatively few caves are known. This may be in part due to inadequate exploration, but also because of the very high geomorphic position with respect to groundwater relative to the Carlsbad area. It may also suggest that little deep-seated hydrogen sulfide gas rose to mix with groundwater, as occurred at Carlsbad.

Block-faulted Ranges: The basin-and-range province includes far west Texas and parts of the Big Bend area. Several carbonate rock units are exposed in many of the mountainous, block-faulted ranges and are thus bounded by steep, near-vertical, normal faults. Caves are guided by jointing related to abundant faulting. Few caves are known, in part, because of difficulty of access and distance from population centers. Few known caves are extensive.

Gypsum Plain: The gypsum of the Permian Castile formation contains numerous caves in high density. With very low relief and few outlets for infiltrating groundwater, most of the caves begin small and become smaller. A few are moderately long where groundwater can apparently exit to a deeper zone or to a surface valley. A few caves appear to result from artesian flow from the underlying sandstone. Even though the Castile is up to 530 m thick, the low portion is predominantly anhydrite, and only about the upper 30 m is gypsum. Hydration is partly responsible for irregular jointing of the gypsum. Salt beds at depth are being removed by dissolution and result in broad subsidence sinkholes on the surface.

Northwest Texas: Permian-age gypsum beds up to 7.6 m thick are interbedded with shale and dolomite. Erosion through the Blaine Formation provides an outlet for groundwater that infiltrates its upland exposures. Where the distance from sink to outlet is long, caves are also long if not blocked by collapse or cut by erosion. Some caves form as cut-offs across the bends of surface drainages. Artesian salt springs also rise through the gypsum, the result of deep solution of salt beds in the evaporite sequence.

Most of the above information remains accurate since written in 1994. The one significant change is the greater understanding of hypogenic karst aquifer development in Texas. Hypogenic processes are now recognized in most regions, notably the Balcones Fault Zone, Edwards Plateau and all its subregions, Permian Reef, and Gypsum Plain. For details, see Stafford and Veni, (2018).

References:


San Marcos Attractions

The San Marcos Convention and Visitors Bureau is one of our Prietella-level co-sponsors, so we hope you get a chance to visit some of our local attractions. A great place to start planning your visit is with San Marcos virtual brochures available at http://www.toursanmarcos.com/visitor-information/brochures.html. We’ve listed some of our favorite attractions and activities here. Map on the following page.

The Meadows Center Glass Bottom Boat Tours & Wetland Walk (featured during Monday evening Social):
Glass bottom boat rides on Spring Lake provide views of the San Marcos Springs, and the surrounding areas has a wetland board-walk and interpretive center.

Wonder World Cave & Park:
Wonder Cave is a developed fault-controlled cave, and the surrounding surface area has an “Adventure Park” with petting zoo, train ride, observation tower, and more.

Outlet Mall:
San Marcos is home to a San Marcos Premium Outlets mall. There are 145 luxury and name brand stores located along I-35 interstate highway and only 10 minutes from the San Marcos Activity Center.

Sunset Bowling Lanes:
Family-friendly 24-lane U.S.B.C. sanctioned lanes with concessions and happy our.

Movie Theaters:
Enjoy a movie at Starplex 12 Movie Theaters or Springtown Center (which includes in-theater dining, arcade, bowling alley & reclining seats.

Skate Park:
The City of San Marcos has a free skate park near the Activity Center. Bring your own wheels or just sit back and enjoy the show.

Disc Golf Courses:
Courses within a short drive from the symposium include: Texas State University (21 hole), Flying Armadillo (18 hole), University Heights (9 hole)

Public Library:
The newly renovated and expanded San Marcos Public Library is next door to the activity center

Texas State University - San Marcos Campus:
Stroll through campus to enjoy attractive architecture, landscaping, and library (with excellent views from the top floor and the Wittliff Collection of Southwestern art)

Kayaking & Tubing the San Marcos River:
Bring your own or rent from the San Marcos Lion’s Club or other area providers. See endemic, federally-endangered Texas wild rice and other native species in clear, spring-fed water. The San Marcos Riverwalk allows for an easy walk back to numerous entry options in town.

City of San Marcos Parks & Trails:
The City of San Marcos has many miles of trails and over a 1000 acres of park space. Many of the green spaces contain karst features and scenic trails. Trails can be found all around town and along the river. Some of our favorite options include Upper Purgatory Creek Natural Area, Prospect Park, Ringtail Ridge Natural Area, and Spring Lake Natural Area.
Sixteen Legs free Texas premier viewing

Join us on the beautiful Texas State University - San Marcos campus for the free Texas premier viewing of the documentary Sixteen Legs. In celebration of the International Year of Caves and Karst, the organizing committee of the 2021 National Cave and Karst Management Symposium is hosting this free, public viewing of the award-winning 2016 documentary. The film documents the reproductive ecology of Australian cave spiders, and touches on themes of hope and survival. The film will be playing at the Alkek Library Teaching Theater (see campus map for details). Parking is available at the Texas State University - San Marcos Edward Gary Street Garage. Doors will open at 3:30PM and the film will start promptly at 4:00PM.

“A playful, stunning documentary... as epically gorgeous as it is fantastically artful.”
– EdhatReview, Santa Barbara International Film Festival.

“Your story brought a charming, creative and delightfully humanizing dimension to spiders which audiences enjoyed immensely.”
– Session Chair, Smithsonian National Museum of Natural History (DC).

“I don't think it could ever be said that the work of Attenborough will at any point be irrelevant –but, like all art, there is always room for adaptation and imagination. SIXTEEN LEGS arguably does just that.”
– Wild Melbourne Review, Melbourne test screening of the rough cut.
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