CAVE MANAGERS PARTNERING WITH SCIENTISTS TO ENHANCE CAVE AND KARST MANAGEMENT

Keynote Address

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Abstract

The benefits of cave managers and scientists working together to improve cave and karst management by acquiring scientific data upon which to make sound management decisions are illustrated through three example partnerships. These partnerships, just a few of the many that exist worldwide, include (1) the study of the balance between active cave exploration and the impact on native microbial communities in Lechuguilla, Spider, and Mammoth Caves; (2) atmospheric studies of cave climate in Carlsbad Caverns to monitor cave health and to provide data for scientific modeling of cave climate; and (3) a biomonitoring of the effects of entrance modifications in Mammoth Cave.

Introduction: Benefits of Working Together

Cave managers, whether they are managing commercial show caves or caves on federal lands, can form collaborations with scientists to more effectively manage karst lands and their caves. Such collaborations are often a win-win situation for both cave managers and scientists. Working in caves with controlled access can be advantageous to scientists who can be assured that experiments are not disturbed and that conditions necessary to a particular experiment are maintained. Caves with the most unusual geological, biological, and archaeological features are often managed caves; these are also some of the most desirable sites for scientists to conduct research because they contain the best examples of particular phenomena. Of particular value to scientists is the mental databank of observations that many cave guides acquire in the long hours that they spend in the cave. Cave guides see many things that scientists may not chance upon and are often eager to share their observations with interested scientists. Additionally, scientists gain opportunities to involve students in research, data for publications and presentations, and evidence of previous results on which to build grant proposals. These advantages to scientists also come full circle, providing cave managers with information and publicity for their caves.

Managers can gain expert and high-level assistance from scientists in studying their caves. Some scientists are funded through research grants to study areas of particular interest to them and may come with, or be able to acquire, funds to conduct research of interest to cave managers. Of value to cave managers is the opportunity to involve scientists in gathering data to support or refute the value of a particular management decision before it is implemented. There are instances of well-intentioned cave conservation practices that have actually deteriorated the cave environment. Prior research on a small scale could have predicted the negative outcome and suggested alternatives. In many other instances, we just do not know whether management practices are good or bad for the cave and its inhabitants. Agreeing on research projects that are

of mutual interest is one of the challenges of these partnerships.

Many active partnerships between cave managers and scientists exist throughout the United States and other parts of the world. In the following paper I will highlight a few of the ones in which colleagues and I have been involved, and the benefits gained by both managers and scientists. These case studies are not meant to be comprehensive, but to illustrate the potential of such partnerships.

Highlighted Partnerships: Studying the Balance Between Cave Exploration and the Impact of Humans on Microbial Communities

In the mid 1990s an opportunity arose to evaluate the impact of humans on the microbial communities of Lechuguilla Cave. During this time the National Park Service was increasingly concerned about impact on the cave and I was beginning intensive studies of microbial communities based on early work by Kiym Cunningham (Northup *et al*. 1994; Cunningham *et al*. 1995). The Charles A. and Anne Morrow Lindbergh Foundation agreed to fund a project to explore the balance between conservation and human exploration, serving the aim of the National Park Service to evaluate impact and the desire of myself to further investigate the microbial communities and the impact of humans on these communities. Selected scientific details of this study are covered elsewhere in this symposium proceedings (see Lavoie and Northup 2006). This scientific study illustrates a very successful partnership between the National Park Service and scientists. The aims of the study were to evaluate (1) whether bacteria indicative of human presence (for example *E. coli* (a bacterium associated with fecal matter), *Staphylococcus aureus* (a common skin organism), and high-temperature *Bacillus*, which would be transported into the cave from desert soils by boots) were present in the cave, (2) whether these human indicator bacteria persisted when the cave was given a chance to rest from human presence, and (3) whether the management practice of confining travel to established trails and camping and urine dumping to designated sites was effective in limiting the introduction of exotic bacteria.

The scientists provided (1) the funding through their grant writing, (2) the experimental design and research supplies, (3) their time to carry out experiments in the cave, (4) the analysis of results and the statistical analysis of the data, and (5) a final report with recommendations. The Cave Resources office personnel provided (1) research permits, (2) their expertise in site selection with the cave, (3) visitation statistics for various areas of the cave, (4) implementation of the experiments in the physically most demanding areas of the cave, (5) closure of the three branches of the cave at different times in order to evaluate the effect of giving the cave a break from humans on the microbial populations, and (6) field support in terms of carrying scientific equipment and helping with experiments. Further studies were carried out by the National Park Service to monitor the presence of *E. coli* and fecal coliforms in drinking sources within Lechuguilla Cave. During the various stages of the study a dynamic relationship existed between the Cave Resources Office at Carlsbad Caverns National Park and the scientists involved in the study, with each supplying expertise.

These studies in the mid-1990s led to an interesting finding that one site in particular in the Western Borehole did not show die-off of *E. coli* bacteria and later findings by Boston and colleagues found that another Western Branch area, Red Lake, was contaminated with *E. coli.* This finding spawned a Masters project by Andrea Hunter that led to recommendations considering the kind of tubing that should be used in cave pools to acquire drinking water (Hunter *et al*. 2004). Both cave managers and scientists had not previously realized that plasticizers from tubing can leak into cave pools, changing the balance of power among microbial communities and leading to unhealthy growth in cave pools. A very worthwhile conservation procedure had undesirable effects and showed the need for prior testing outside of the cave environment. The study by Hunter *et al*. (2004) also spawned a lively debate in the *Journal of Cave and Karst Studies*. Such debate is an important part of advancing our management of caves and establishing best practices for conducting scientific research in caves.

Highlighted Partnerships: Studying Cave Climate in Carlsbad Caverns

With the goals of (1) understanding natural air

and heat flow and (2) ameliorating human-caused changes in cave natural resources, Penny Boston; her graduate student, Setsuko Shindo; and Paul Burger, the Hydrologist at Carlsbad Caverns National Park, teamed up to conduct climate studies in Carlsbad Cavern. As part of his duties as a cave manager and a National Park Service scientist, Paul was already studying and monitoring temperature and humidity in various locations throughout Carlsbad Cavern. He was able to provide Penny and Setsuko with several years of climate data, advice about good locations for additional data acquisition, and his observations of airflow patterns. With these data and their own new observations, they were able to construct a mathematical model (Shindo *et al*. unpublished data) that disclosed several new aspects of climate in caves that can now be tested against reality. Paul reviewed their model and results and provided further input to the study. Penny Boston and Paul Burger co-authored a presentation of these results for the National Speleological Society annual meeting in 2005 (Boston *et al*. 2005).

This partnership illustrates a high-level collaboration in which all parties have a strong scientific background. As with the previous partnership this one illustrates a dynamic collaboration with each partner providing different skills and knowledge, with the sum being greater than the parts. Also, it was extremely fortuitous that the Cave Resources Office and Paul, in particular, had chosen to establish a study program that had already accumulated several years worth of climate data that served as the foundation for this study. Having a strong cave monitoring program in place is ideal because:

- Baseline data help managers monitor the health of the cave and help to interpret the possible outcome of changes in the cave and its resources.
- Data and observations are available to help in making new management decisions.
- A database such as this temperature, humidity and airflow dataset can attract the interest of scientists who can take the data in additional directions, generating models, building in new data and observations, and seeing new patterns in old data.
- New observations obtained and conclusions made can be used to enhance visitor interpretation programs and exhibits, giving new meaning to the "Why should we care about this cave" question. Visitors appreciate new information and interpretation.
- Many scientists really enjoy working with cave managers conducting monitoring studies because they gain different, in-depth views of the cave and the cave resources (Figure 1 and 2).

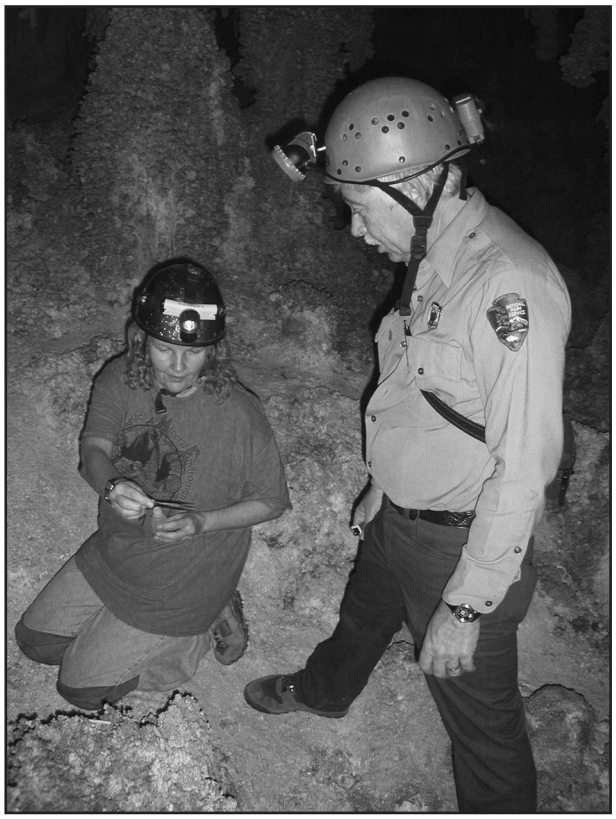

Figure 1: Dale Pate (National Park Service) and Diana Northup work together culturing microorganisms in Left Hand Tunnel, Carlsbad Cavern, Carlsbad Caverns National Park, NM, USA. Photo by Kenneth Ingham.

Highlighted Partnerships: Mammoth Cave Entrance Biomonitoring

My third example partnership illustrates the value of the collaboration between Mammoth Cave Park scientists and academic scientists with a long history of study in Mammoth Cave. As the longest cave in the world, Mammoth has many entrances. Most of the entrances have been modified or are artificial, and have existed for decades. These entrances have caused the influx of cold, dry air in

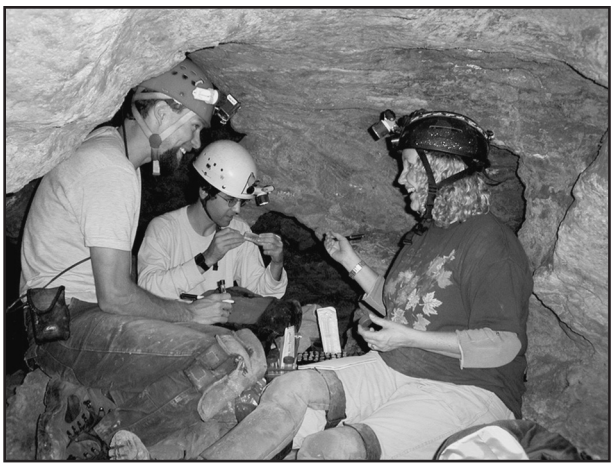

Figure 2: Stan Allison (National Park Service), Marc Toso, and Diana Northup work together on a research project in Spider Cave, Carlsbad Caverns National Park, NM, USA. Photo by Kenneth Ingham.

the winter, resulting in significant drying effects on formations, walls, and biota. The effects of the entrance modifications became a concern to the National Park Service who invited Tom Poulson; Kathy Lavoie; and Tom's graduate student, Kurt Helf, to conduct a study of the impact of a proposed restoration plan on the biota of Mammoth Cave.

In a major restoration effort conducted by the National Park Service, entrances to Mammoth Cave were retrofitted to restore more natural climatic conditions that are favorable to native invertebrates and microorganisms. Some entrances were fitted with airlock doors, others with baffles. Poulson, Lavoie, and Helf (Poulson *et al.* 1996a,b) determined baseline numbers, types, and distribution of organisms near entrances before and after retrofitting. While the main focus of the study was on the keystone species, *Hadenoecus subterraneus* (a species of cave cricket), results were extended to most organisms found near entrances. Poulson *et al.* discovered a problem with many of the doors immediately after installation. Although the entrances are artificial, a large community had developed over the decades, and lack of access was having a major negative impact. With discussion, the National Park Service responded quickly and modified their gate plans to include different size and differently located critter holes suitable to allow entry and egress for crickets, salamanders, and the few bats. This was immediately successful in most entrances, which became much warmer and wetter, also potentially contributing to greater success for actinomycete bacteria and other microbes.

Cricket guano is an important food source and habitat for communities of invertebrates and microbes, which are very sensitive to external weather conditions. Influx of cold, dry air causes seasonal changes in organisms that colonize guano deposits (Poulson *et al*. 1995). The moral of the tale is that restoration efforts like entrance retrofitting can have profound and complex effects on cave biota. Such efforts must be thoroughly thought through and studied before and after to monitor possible changes, either beneficial or deleterious. Such studies ideally are carried out by collaborations of scientists and cave managers who know the ecosystems and organisms involved. During the study, close coordination is required between managers and scientists in order to make changes in management plans and study procedures to obtain the best results. This case study also illustrates the value of close and continuous coordination.

Contributions by Scientists

The previous case studies that highlighted various partnerships between cave managers and scientists emphasized partnerships that provide data for assisting in making management decisions and monitoring organisms and abiotic aspects of caves to provide baseline data, as well as data for best management practices. Scientists can and will provide many other useful things to cave managers.

For me, one of the most fun aspects of collaboration has been the provision of photos illustrating "science in action" and phenomena, such as the biota and geological formations unique to particular caves. My husband, Kenneth Ingham, accompanies us on our research trips and photographs the scientific endeavors [that is "science in action" and the subjects of the scientific study (critters, mineral formations, and the like.)]. These photos have been used by the National Park Service on calendars, for advertising "science in the parks," by media writing about various caves, for exhibits (interior and exterior), for talks given as part of National Parks Week, and for informal science education. Potentially, scientists could put together slide shows or electronic presentations that can be used in cave guide training. For one study in a national monu-

ment, we provided a set of slides that illustrated the biota, science in action (Figure 3), cave formations, and general habitat shots as part of our contract.

Figure 3: Mike Spilde takes air samples from a cave in New Mexico, USA. Photo by Val Hildreth Werker.

Consider asking scientists who have conducted research in your caves to come speak to visitors or to guides during training sessions. Scientists are sometimes accused of talking Latin, or of talking a foreign language. They vary in their ability to speak to the general public in an entertaining and easily understood manner, without talking down to their audience. Check out your scientist of choice by asking them to tell you about their work. If you do not understand something, stop them and ask them to explain it a different way. This interaction will allow you to assess how they will do with a more general audience. Scientists are smart people—they can be trained to speak English.

Many cave managers ask scientists to submit reports concerning studies conducted in their caves. These are usually written for other scientists and contain a wealth of detail about methods, results, and conclusions. These reports are a good thing. However, not all of it is digestible by all cave managers. Consider asking them to write a separate, shorter write-up that could be used for interpretation to visitors. Some scientists are very interested in informal science education and with a little prompting can be persuaded to write up materials that can be turned into brochures, booklets, exhibits, websites, and the like for the cave visiting public. If you have an educator on staff, get the scientists and the educator together to design and produce interpretive material.

Caves have become sexy topics for the media. Several shows about caves have been done by CNN, National Geographic, NOVA, the Discovery Channel, the BBC, and so on. in the last few years (Figure 4). Many of these shows enlist the aid of a scientist and cave guides to talk about the caves and research being conducted in them. These are the "talent." When I did my first interview for one of these, I was horrified to be quoted in print as saying that "marauding red-brown crickets were taking over the lunchroom in Carlsbad Cavern." I considered never doing another interview. However, I have since come to realize that with thought and preparation, media experiences can be fun for all involved and can provide caves in general and in particular with some excellent publicity that highlights why we should protect and conserve caves. A very key element is to decide ahead of time what message you want to get across and to be able to answer the one question they always ask: "Why should we care about your cave and your work?" In addition, scientists can work in a conservation message into their presentation. Many of the media do not strictly control what is filmed and will readily accept suggestions about what and where to film. They are usually good people who want to do a good job. Turn this into an opportunity to get footage you can use with visitors and to showcase your caves and research being conducted in them.

Figure 4: Penny Boston and Diana Northup conduct research in Cueva de Villa Luz, Tabasco, Mexico. Photo by Kenneth Ingham.

If cave managers and scientists work together it is possible to work effectively with the media to produce material that will not embarrass anyone. Do not fall for the need to make everything dramatic. It is possible to be entertaining without saying things like "We've discovered the origin of life in this cave."

Contributions by Managers

Nobody knows a particular cave like the people who manage and interpret the cave. I make it a point to talk with the cave guides and managers whenever I can. Besides being enjoyable, these encounters often give me interesting observations about the cave and its inhabitants. For example, one of the rangers at Carlsbad Caverns who has been there for at least two decades keeps close tabs on the happenings of the camel crickets that inhabit much of the cave. Every time I encounter him I will learn about anything new that he has seen. These observations have given me ideas for research projects. Cave managers and guides can provide information about best sites for research studies. For caves on federal lands, cave managers also provide research permits allowing scientists to conduct their studies.

Absolutely invaluable to scientists is access to research facilities on site, provided by cave managers. Research facilities can take many forms, but key facilities include a place to sleep, eat, clean up, and process data and samples. Being close to the cave allows scientists to give free reign to their innate workaholic nature and provides cave managers with that much more information. Some research studies need space to set up experiments on the surface that are time-sensitive and need to be set up immediately. Security for such experiments is also important. In-cave experiments may need assistance from cave managers in terms of continuing measurements in the absence of the scientist who does have to go back and teach and see to other commitments. Scientists can train guides or other personnel in taking field measurements. We have found that this kind of partnership leads to cave managers learning about the science of their cave and increases their observations of interesting and important phenomena in their caves (Figure 5).

Field assistance can be quite helpful to scientists. One cave manager has joked that Ph.D. stands for

Figure 5: Stan Allison (National Park Service) records observations in Spider Cave, Carlsbad Caverns National Park, NM, USA. Photo by Kenneth Ingham.

"Please Help the Doctor." On a more serious note, I would like to point that that tagging along on science trips allows managers to learn some science and some research techniques. My experience has been that during these trips a lot of good ideas and observations get discussed, promoting good companionship and good working relationships (Figure 6). It is useful for managers and scientists to discuss, on site, what size and kind of sample is needed.

The aid of several cave managers has been invaluable. In Lechuguilla Cave, where travel times can be long, rangers have often helped out with retrieving samples from remote areas in a timely manner. Some science experiments require a lot of heavy, bulky equipment and assistance from persons who know the cave well can eliminate damage to the cave. I do not mean to imply that scientists need baby sitting, but rather that some collaborative trips can serve many purposes and can strengthen working relationships.

You may think that all scientists know everything about what other scientists are doing, but this is not always true. Therefore, a very important role for cave managers to play is in networking scientists. Networking of scientists by cave managers can take the form of informal linkages (telling one scientist about the work of another) or the sharing of reports turned into the cave managers. Some scientists are sensitive about being scooped and advance permission is a good idea, or general policy that results will be released to others after one year. An excellent way of networking scientists is done through the *Science*

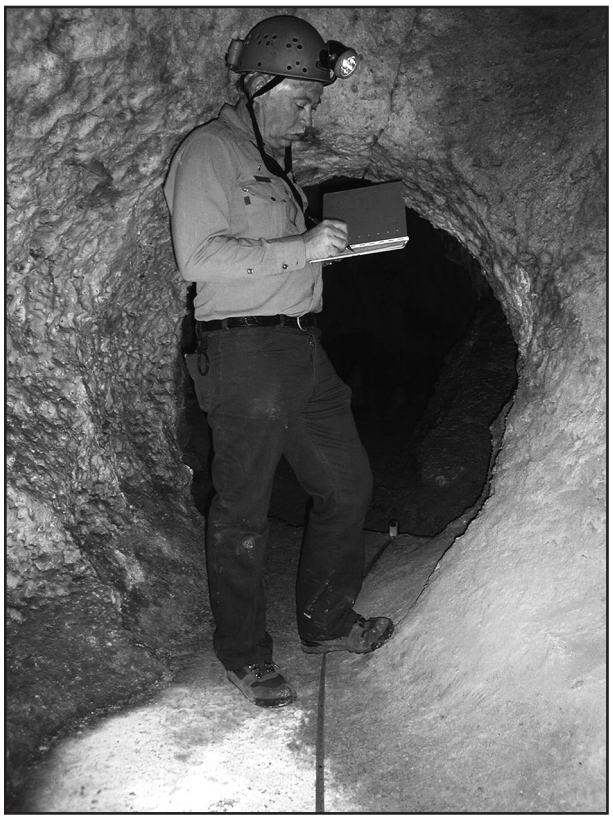

Figure 6: Dale Pate (National Park Service) documents observations in Left Hand Tunnel, Carlsbad Caverns, Carlsbad Caverns National Park, NM, USA. Photo by Kenneth Ingham.

in the Park symposia held at Mammoth Cave National Park. Scientists conducting research at Mammoth Cave meet at regular intervals and present their findings at the symposia. Just the act of getting the scientist together helps facilitate networking. Smaller caves might hold a regional conference, drawing scientists together who work in caves in a particular region. The National Cave and Karst Research Institute also will play an increasingly important role in networking scientists.

Money is critical to doing good science. Some agencies, such as the National Park Service, provide small or medium-sized grants for doing research. An example is the USGS-NPS grant competition which funds a U.S. Geological Survey scientist to do research in a national park. Some small grants may be available through individual works to do research on a specific topic needed by the particular cave. I have done contract work to compile biological surveys of caves. Even if there are no funds available to support scientists, cave managers can write glowing support letters to accompany grants to agencies such as the National Science Foundation or private granting foundations. Strong support letters impress grant reviewers and the support letters add an important positive element to a scientist's grant proposal.

Last, but not least, is the idea of hiring staff with scientific backgrounds. Such staff can conduct baseline studies to help interpret changes in cave resources and conditions. They can work with visiting scientists on research projects and can provide valuable information for interpretive programs.

Challenges:

The previous sections have emphasized the positive contributions that both sides bring to these partnerships. Like any relationship, a good outcome does not just happen by throwing together one scientist, one manager, a pinch of money and resources, plus one cave. Working together effectively requires expert, regular coordination on the part of both scientists and managers. Managers must clearly communicate what they are expecting to receive if they have initiated the request for the research study. Any restrictions and rules that need to be followed must be clearly communicated. Scientists need to ask about these things if they have not been spelled out. A very helpful thing is to provide trip reports after each scientific expedition and yearly reports that detail experiments conducted and findings. If managers have deadlines for reports, these need to be clearly communicated. If equipment is purchased as part of a study funded by the cave management, it needs to be clear who will retain the equipment. Copyrights for pictures taken in the cave of the science or the cave resources need to be established. Hopefully these examples illustrate the point that the more that is spelled out, discussed, and agreed upon, the less misunderstanding there will be. If misunderstandings arise, deal with them quickly. Good partnerships do not just happen—they require work on the part of both parties.

Additional Opportunities: Informal Science Education

The National Science Foundation increasingly has emphasized the need for an outreach and edu-

cation component in all grant proposals. This emphasis on outreach and education provides a great opportunity to expand the nature of cave manager/scientist partnerships by including informal and formal science education components in funded grants that study caves. For example, as part of an EPSCOR grant that I helped with, Tamara Montoya and I developed a **Cave Journey** (www.caveslime.org/cavejourney or www.vce.inram.org) (Figure 7), an Internet resource for grades 5–12, tied to New Mexico Science Benchmarks and Standards. The website includes a glossary of terms, species accounts, a photo gallery that can be used by students in presentations, content about geological and life sciences of caves, and activities written by two New Mexico teachers, Patsy Jones and Ray Bowers. The content of this website was drawn from research projects that I have done over the years at Carlsbad Caverns National Park. In the fall of 2004 we held a teacher workshop in Carlsbad to introduce New Mexico teachers to the activities and content of the Web site. The workshop included a tour of the cave led by Paul Burger, the Cave Resources Office Hydrologist at Carlsbad Caverns National Park. The cave tour was a huge hit with the teachers who most liked the tour of the cave. We will be expanding this website to include a "virtual tour" of Carlsbad Caverns that highlights the biology and geology of the cave with the aid of the Cave Resources office at Carlsbad Caverns National Park. The Cave Journey and teacher workshop are just examples of the multitude of opportunities for including an informal science education component to scientist/cave manager partnerships.

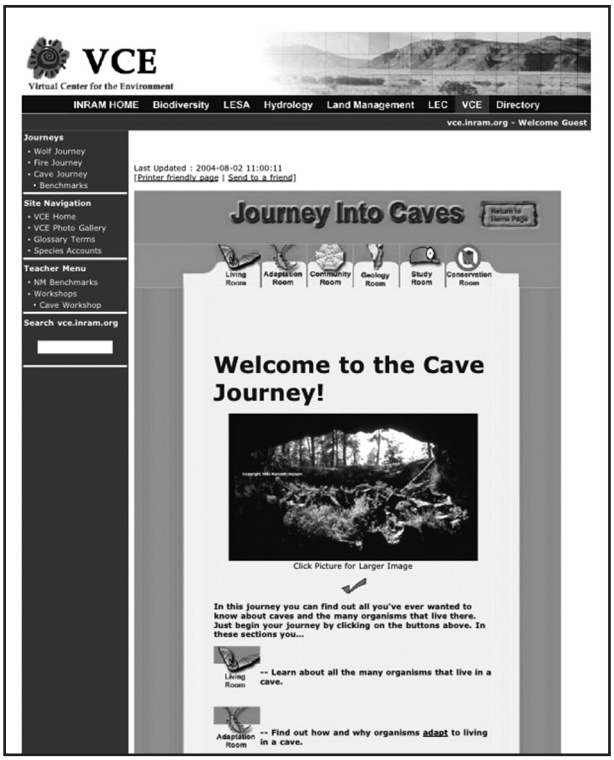

Figure 7: Screen capture of Cave Journey website.

Additional Opportunities: Karst Information Portal Initiative

As discussed elsewhere in this NCKMS Proceedings (see Hose *et al.* 2006), the National Cave and Karst Research Institute, the University of New Mexico, and the University of South Florida have formed a partnership to create a Karst Information Portal. The goal of the Karst Information Portal is to make information about karst and caves available to scientists and others interested in caves worldwide. Much valuable cave and karst literature exists as grey literature, unpublished or informally published literature, which is hard to obtain. A prime example of this is the report literature generated by scientists for agencies managing caves on federal lands. These reports contain valuable information and a wealth of detail about caves and their resources. Report literature is rarely indexed, sometimes lost, and is extremely hard to actually acquire. One of the objectives of the Karst Information Portal is to index and where possible or not already done, digitize scientific reports on research done in caves on federal lands. One project proposed for the Portal is to create a database of scanning electron micrographs (Figure 8), thin section images, and other visual records of scientific research done in caves. We propose to create a keyword index of these images that allows browsers of the index to search by morphology in order to seek examples similar to those already known to the searcher. Such a database would enhance data mining and allow for new connections to be made about phenomena occurring in more than one cave. Another objective the Karst Information Portal is to increase communication among cave and karst scientists. An additional part of this could be to promote the relationship between scientists and cave managers.

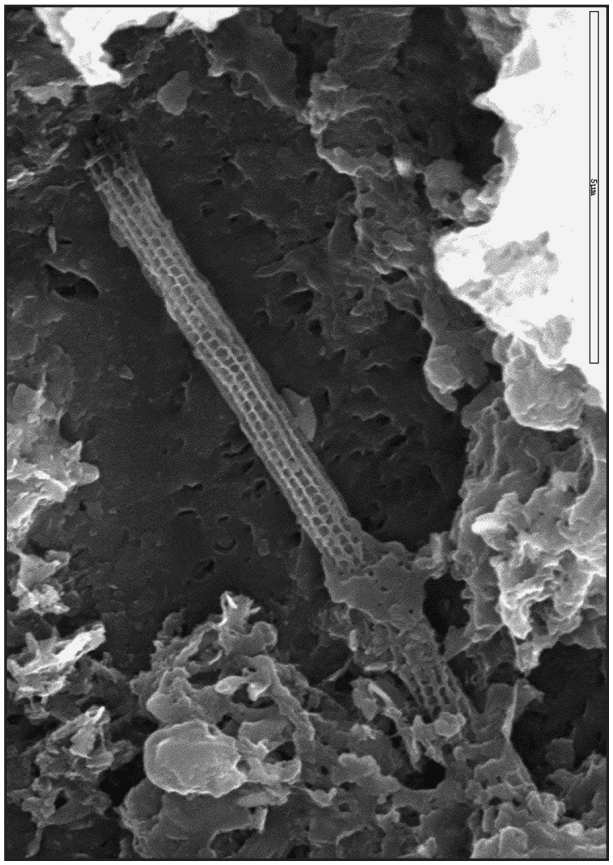

Figure 8: Scanning electron micrograph of a reticulated filament from a carbonate formation. Photomicrograph by Mike Spilde and Leslie Melim.

Management Issues That Can Benefit from Partnerships

There are many opportunities for conducting scientific research in caves that benefit both scientists and managers and that would allow us to make better management decisions. Some of these include:

- Introduced materials: When wood, plastics, and other materials are introduced into caves, they have an effect on the biota of the cave. In many instances, we do not really know the full effect of these introduced materials.
- Removal of materials: Whether or not to remove materials of human origin from caves (for example, wood) and if yes, how fast, are important questions. Total removal over a short period of time may cause a population crash among invertebrates living on the materials introduced years before.
- Human impact: Is it best to confine human traffic to established trails? What effect does lint have on formation? How much organic carbon enrichment does it take before the balance of power between native and exotic microbes is tipped? The impact of humans on native microbial communities is really a new science for caves and requires a great deal of study to determine the effects we are having on caves.
- Best site location: Do "highways of invertebrate and vertebrate traffic" exist that we should avoid in the placement of trails?
- Restoration methods: Many of the restoration methods and materials currently in use are extremely detrimental to invertebrate and microbial life in caves. However, little science exists to determine what "Best Practices" should be used. Val Hildreth-Werker and Jim Werker are currently producing a book of restoration best practices that addresses many of these issues.
- Inventories: Biological, archaeological, and geological inventories remain an important part of the partnership between scientists and managers. Data from these inventories needs to be accessible and in a format that is easily used by others.
- Microbe monitoring: Little thought has been given to microbial communities in caves, and in the environment in general, until the last decade. We have made important advances in discovering "Who's home," but much remains to be learned about how microorganisms affect the functioning of the cave and how human visitors affect microbial communities. We need to establish baselines concerning microbial populations and their functioning in order to know when problems arise.
- Impact of gates, airlocks, doors, etc. can have deleterious effects on cave biota. Their design for a given cave should be carefully planned and evaluated. Bat-friendly gates, in particular are critically important.

Summary

Strong partnerships between scientists and managers can be an important tool in increasing visitor appreciation and enjoyment of caves. Cave managers get expert help and information from

scientists, who in turn get access to ideal natural laboratories in which to work. The information generated by scientists enriches the database of information about caves and how they function and can be turned into a wealth of interpretive material. We have a lot to gain by working together and most importantly, caves and visitors both benefit when cave managers and scientists work together.

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Acknowledgements

I wish to express my thanks to Kathy Lavoie and Dale Pate for critically reading the manuscript, which is much improved due to their efforts. Many thanks to Penny Boston and Kathy Lavoie for discussions about the presentation's content and to Mike Warner for inviting me to give the Keynote address.

Biography:

Diana has studied biospeleology since 1984, investigating the ecology of invertebrate communities and microbes that make their homes in caves. She currently studies cave microbial communities and their interactions with minerals with colleagues in the Subsurface Life in Mineral Environments (SLIME) team. She is Professor Emerita in the Science and Engineering Library and a Visiting Associate Professor in Biology at the University of New Mexico).