NCKRI REPORT OF INVESTIGATIONS 4

EVALUATION OF CAVE AND KARST PROGRAMS AND ISSUES AT US NATIONAL PARKS

National Cave and Karst Research Institute

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NATIONAL CAVE AND KARST RESEARCH INSTITUTE
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Cover photo: Skylight entrance of Skylight Cave, El Malpais National Monument, New Mexico. National Park Service photo by Dale Pate.

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NCKRI Organization and Mission

NCKRI was created by the US Congress in 1998 in partnership with the State of New Mexico and the City of Carlsbad. Initially an institute within the National Park Service, NCKRI is now a non-profit 501(c)(3) corporation that retains its federal, state, and city partnerships. Federal and state funding for NCKRI is administered by the New Mexico Institute of Mining and Technology (aka New Mexico Tech or NMT). Funds not produced by agreements through NMT are accepted directly by NCKRI.

NCKRI's enabling legislation, the National Cave and Karst Research Institute Act of 1998, 16 USC. §4310, identifies NCKRI's mission as to:

1) further the science of speleology;
2) centralize and standardize speleological information;
3) foster interdisciplinary cooperation in cave and karst research programs;
4) promote public education;
5) promote national and international cooperation in protecting the environment for the benefit of cave and karst landforms; and
6) promote and develop environmentally sound and sustainable resource management practices.

NCKRI Report of Investigation Series

NCKRI uses this report series to publish the findings of its research projects. The reports are produced on a schedule whose frequency is determined by the timing of the investigations. This series is not limited to any topic or field of research, except that they involve caves and/or karst. To minimize environmental impact, few or no copies are printed. Electronic copies of this and previous reports are available for download at no cost from the NCKRI website at www.nckri.org.

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Lewis Land, George Veni, Dianne Joop
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Introduction

Approximately 20 to 25% of the United States is karst, a terrain that is widely recognized for diverse natural and cultural resources and exceptional vulnerability to environmental degradation (Veni and DuChene, 2001). Seven US National Park Service (NPS) units were established primarily to protect caves: Carlsbad Caverns, Jewel Cave, Mammoth Cave, Oregon Caves, Russell Cave, Timpanogos Cave, and Wind Cave. In 2001, Ek determined that 100 of the then 384 NPS units contained caves and karst. Not all contained significant cave or karst resources, but many did.

Since 2001 there has been no further NPS-wide study of caves and karst resources. The NPS is actively developing cave and karst inventory and monitoring protocols (e.g., Baker et. al., 2013; Horrocks, 2013), but no comprehensive evaluation of cave and karst programs, activities, needs, and issues exists for NPS sites containing cave and karst resources. This study was designed to meet that need by conducting a survey from which the NPS may readily identify and prioritize research, remediation, interpretation, and other programs and activities to best understand, manage, and interpret these valuable resources.

Exploration of and general attention to NPS caves is often focused on Mammoth Cave, Jewel Cave, Wind Cave, and Lechuguilla Cave (in Carlsbad Caverns National Park), which rank respectively as the first, third, sixth and seventh longest in the world (Gulden, 2013). However, cave and karst significance is not solely determined by size (Figure 1). Many parks which are not generally recognized for caves or karst contain important caves and karst resources (Veni and Pate, in press.).

Reliable understanding of caves and karst for effective management requires knowledge of their geologic settings. Karst is a landscape formed mostly by the dissolution of usually carbonate or evaporite bedrock. The longest, deepest, and largest caves in the world are formed in carbonates, usually limestone, and are products of surrounding karst drainage patterns. Exceptionally long caves also form in gypsum.

However, a crucial aspect to understanding and properly managing karst terrains is that they are often rich in natural and cultural resources, and highly vulnerable to environmental degradation, even in the absence of any caves.

This study examines “caves and karst” because not all caves and related features are karstic. *Pseudokarst* collectively describes cavernous landscapes and features formed by non-karstic processes. Pseudokarst caves formed by wind, stream, and sea and lake erosion of cliffs, fracturing of rock and soil, and out-washing of sediment from under a cap of harder material are typically small compared to karst caves. Volcanic caves, notably lava tubes formed by the draining of molten rock beneath a cooled, solidified roof, can be long and complex (see cover photo).

Figure 1. *The smoke-blackened ceiling of this small shelter cave at Carlsbad Caverns National Park, New Mexico, suggests use by Native Americans and cultural significance. NCKRI photo by George Veni.*

In their most basic conceptual form, caves are space. Their value to society stems from what occupies that space. Water, habitat, geological and cultural materials are a few of the many resources offered by caves and karst areas, which contain many of the world’s most important aquifers, rare ecosystems, and significant archeological and paleontological sites. This study identifies the general cave and karst resources of each NPS park that responded to the survey, research

conducted on those resources, actual or potential management issues for those resources, and how those resources are interpreted to educate the public.

The purpose of the study is to do the following:

- provide the NPS with an updated list of all NPS units with karstic and/or pseudokarstic caves and terrains
- develop a comprehensive database with basic cave and karst information about the parks and their related resources
- evaluate the database for general trends in cave and karst research, management, and education/ interpretation
- identify the most critical needs in cave and karst research, management, and education/interpretation and provide recommendations on a general park-wide level and for specific parks
- provide the database in a format where it can be queried and filtered by the NPS to create custom "menus" of needs by topic, region, or park

National park units that are specifically identified in the following discussion are used as both general and specific examples. Where those examples indicate inadequacies, mistakes, or flaws, they are not meant to negatively portray the parks. We understand the limits in funding, time, resources, expertise, and staffing throughout many park units, and applaud the dedicated staff of the NPS for their excellent efforts to understand, manage, and interpret all of their resources.

Methodology

The National Cave and Karst Research Institute (NCKRI) conducted this study in four phases: survey development, identification of relevant NPS units, data collection, and data analysis. Each phase is described below. NCKRI suggested that a questionnaire forwarded to all NPS units with potential for cave and karst resources would be the basis for collecting most data concerning these resources within the NPS.

Survey Development

NCKRI personnel met extensively with Dale Pate, then Acting and now fulltime NPS Cave and Karst Program Coordinator (Geologic Resources Division [GRD], Denver Office), and created a list of questions that would hopefully fulfill the purposes of this study. The questions were sent to selected park units (see next section below) and divided into four groups:

- "General" questions focused on basic information about each park unit, its purposes, caves, karst and pseudokarst areas, cave/karst related projects, and staff working on caves and karst.
- "Research" questions determined if cave or karst research had been or was currently conducted in the park and its results in the following categories: general, geology and hydrology, biology, archeology, and paleontology.
- "Management" questions related to known or potential impacts to cave and karst resources from within and outside of the parks, and were subdivided into the following categories: general, geology and hydrology/water quality, groundwater quantity, mineral resources, biology, archeology, paleontology, and recreation.
- "Education" questions were provided in two groups: karst education resources and karst interpretation resources; they were designed to collect information on what karst educational and interpretive resources were provided at each park and the degree of public participation.

The number of questions and their specific content were designed to elicit key information needed for GRD to effectively evaluate and support cave and karst programs at the park units. Subdividing the survey into four groups was aimed to reduce the workload on any particular staff member, to increase participation in the survey, and to allow specialists at each park to complete the sections of their expertise to increase accuracy in the answers. The questions were reviewed by and, following minor revision, approved by an independent NPS team for distribution. The complete sets of questions with summary replies are provided in Appendices A (general), B (research), C (management), and D (education).

Identification of Relevant NPS Units

In order to determine which parks to send the survey questions, NCKRI contacted the US Geological Survey (USGS) for geographic information system (GIS) digital files with the current version of the draft National Karst Map. While the map that was provided was not complete and had not gone through review for public release, it was far more complete, detailed, and accurate than previous maps of US karst distribution, and included areas of potential karst and potential volcanic pseudokarst. NCKRI also contacted the NPS for GIS files that contained the boundaries of all NPS sites. Because the USGS could not release its draft maps, it provided NCKRI a GIS file that showed park units intersected by mapped karst and pseudokarst areas. Using this GIS file, the intent was to determine the following factors, in the order listed:

1. the current number and names of NPS sites potentially containing caves, karst, and volcanic pseudokarst

2. the area of potential karst and volcanic pseudokarst at each NPS site
3. the percentage of each NPS site which is potentially karst or volcanic pseudokarst

However, NCKRI discovered that some park units were not included in the GIS file and there was a difference between the sizes of some of the areas in the file and an NPS report (National Park Service, 2011). Following additional research, the NPS report was considered the more authoritative reference and was used primarily to determine the sizes of the park units. Analysis of the GIS data in comparison with the NPS report suggests a roughly 5% error in the areas reported in GIS, which indicates the sizes and percentage of karst and pseudokarst areas of each park are accurate at best to within about 5%.

During NCKRI's final stages of completing this report (November 2013), the USGS provided NCKRI GIS information from the final version of the National Karst Map, which had gone through review and was awaiting publication. The information from that version is presented in the calculations of the parks' karst and pseudokarst areas, although some interpolation was occasionally required. For example, large swaths of Everglades National Park extend below sea level; but since the sea floor is carbonate rock that was once above sea level and exposed to karst-forming processes, it is included as part of the park's karst areas. With other parks, especially with deeply buried carbonate rocks or volcanic terrain, the degree of geologic mapping is not always sufficiently detailed to identify which areas may contain karst or volcanic pseudokarst, so those areas were estimated based on the best data available. Several parks were included in the survey, not because of any exposed karst or pseudokarstic rock, but because Ek (2001) determined that cave and/or karst features were present or the parks had buried karst. In a number of cases in Florida and Georgia, the buried karst was the Floridan Aquifer, which is relevant to the parks as an important drinking water supply.

Following the results from the initial GIS data, NCKRI staff reviewed with NPS personnel the list of NPS parks identified as containing caves, karst, or pseudokarst to identify additional such parks that may have been missed by the GIS exercise. Several were added, mostly sites with pseudokarst features, such as sea caves, shelter caves, and suffosion sinkholes.

Data Collection

On 18 April 2013, the letter in Appendix E was sent by email or conventional postal delivery to 196 park units identified as containing or potentially containing caves, karst, or pseudokarst. The letter described the survey and provided instructions for its completion, which was conducted online via the polling service Survey Monkey. Prior to sending the letter, GRD contacted all NPS Regional Resource Chiefs to notify them of the study and encourage participation of the parks under their supervision.

Shortly after the letters were sent, NCKRI contacted GRD and received permission to send a new letter to all of the remaining 205 parks. Similar to the 18 April letter, this letter also included the following paragraph:

> *Your park has not been included in that survey because we are not aware of any known or suspected cave and karst resources there. However, for verification and as the first nationwide survey of NPS cave and karst resources, we are sending you this letter and the enclosed self-addressed and pre-paid postcard. Please simply fill in your park's name and then check and return the postcard to indicate if you have any caves or karst resources at your park. If you do have such resources, then please read below and complete the on-line survey. If you are unsure or need clarification, please contact Dr. Lewis Land.*

Data Analysis

At the end of the survey period, the data were downloaded from Survey Monkey and placed into an Excel file, as requested by GRD. The data were unfortunately not organized by Survey Monkey in a fashion that tied the answers to the parks that provided them, and they had to be reorganized for correlation. Most of the answers provided time stamps and other information that clearly identified which parks provided which responses. A few required phone calls and emails to the parks for verification.

The Excel file was then examined for trends, commonalities, and notable replies for discussion in this report. Some general observations are made below, followed by only significant or potentially significant observations and recommendations. The menu structure of the Excel file allows the NPS to analyze the data in greater detail as needed. Given the nature of this survey, quantifying the potential error in most the results is not generally feasible. However, some discussion is provided where it is apparent that some answers are inconsistent or the respondents did not appear to understand the questions. Until roughly the past 10 to 15 years, karst science was rarely taught at US universities.

Figure 2. *Locations of the 191 NPS park units identified by this study as containing or potentially containing caves, karst, and/or pseudokarst.*

As a result, many scientists, technicians, and land resource managers are unaware or poorly informed about the unique character and fragility of karst landscapes.

The results of the survey are contained in two Excel spreadsheets that accompany this report. Karst survey results.xlsx contains the survey responses from parks which replied. Some responses that are too extensive are linked to separate worksheets with the information. All parks that were identified by this study as containing or potentially containing caves, karst, or pseudokarst are listed in Karst and pseudokarst park areas.xlsx, which lists the sizes of the parks, and the sizes and percentages of karst and pseudokarst within each.

Survey Results

Of the 205 park units that were contacted by post card, two completed at least part of the survey. In total, 56 park units responded to all or part of the karst resources survey, giving a response rate of 28.3% of the 198 park units that received a solicitation to participate, including the two post card responses.

After reviewing GIS karst and pseudokarst data, survey responses, and other sources, the following park units

that responded to portions of this project's survey were determined to contain no known or potential caves, karst, or pseudokarst:

- Fire Island National Seashore
- Homestead National Monument
- Jean Lafitte National Historic Park
- Wolf Trap National Park for the Performing Arts

Their survey responses are included in Karst survey results.xlsx but they are not listed in Karst and pseudokarst park areas.xlsx. Additionally, the following parks were among the 196 initially contacted for this study as potentially having caves, karst, or pseudokarst. That was later determined not to be the case, though they did not reply to the survey, so they are also not included in either Excel file:

- Assateague Island National Seashore
- Rock Creek National Park
- Saratoga National Historical Park
- Upper Delaware Scenic Recreational River

This study finally determined that 191 NPS park units contain or potentially contain caves, karst, or pseudokarst; the parks' geographic details are provided in Karst and pseudokarst park areas.xlsx and summarized in Appendix F; their distribution is illustrated in Figure 2.

Most of the park units with significant cave or karst resources responded to the survey, although there were some notable absences. We received no response from Craters of the Moon, Oregon Caves, or Timpanogos Cave National Monuments, or from Great Smoky Mountains, Guadalupe Mountains, Kings Canyon, and Sequoia National Parks. By contrast, we did receive responses from several small and probably understaffed park units, including Capulin Volcano National Monument, Hopewell Furnaces National Historic Site, and National Park of American Samoa. Valley Forge National Historic Park, along with several of the Civil War battlefield parks, provided surprisingly detailed responses.

The general information section of the survey received 50 responses, more than any of the other sections. The management section received 45 responses, research received 40, and education/interpretation received 32. Three park units provided two or more responses to the management section of the survey, probably due to more than one staff member unknowingly responding; where their specific answers differ, all responses are provided in the spreadsheet of data.

General

Fifty park units responded to the General Information survey (see Appendix A for summary replies to this part of the survey). Of these, 26 park units stated that their primary purpose or outstanding resources were geological features within the park. Eleven parks listed biological features as their outstanding resource, 15 listed cultural or aesthetic features, and one park (Lake Roosevelt National Recreation Area) listed recreation as its primary purpose. This question permitted multiple answers; biological resources were frequently listed as second in importance after geological ones.

Of the 50 parks that responded to the General Information survey, 23 reported known solutional caves within the park unit; 22 parks reported notable non-cavernous karst features, including four park units that did not report caves. Sixteen parks reported either cavernous or non-cavernous pseudokarst features within their park unit. Twelve parks reported the presence of pseudokarst caves, which were in most cases lava tubes; however, Denali National Park in Alaska reported that probably thousands of ice caves are present within its boundaries (Figure 3). Several parks included rock shelters in their listing of non-cavernous pseudokarst. Twelve park units reported the presence of paleokarst features. Overall, 35 of the respondents to the general information survey (70%) reported the presence of either cavernous or non-cavernous karst or pseudokarst within their boundaries.

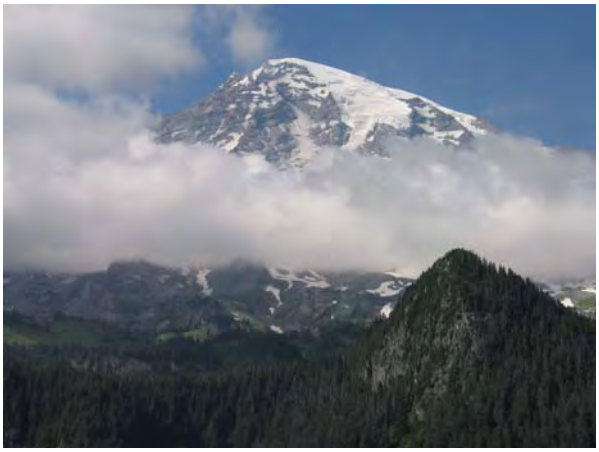

Figure 3. *The glaciers of Mount Rainer, Mount Rainer National Park, Washington, formerly held the Paradise Ice Caves, once the most extensive ice caves in the United States. Although glaciers still exist on the mountain, the caves have melted away due to global climate change. NCKRI photo by George Veni.*

Eleven of the parks surveyed reported operating show caves (Figure 4), in most cases only one or two, although Lava Beds National Monument reported 22 show caves, far more than any other respondent. Seven parks also reported operating wild tour caves.

Figure 4. *The major management challenge for show caves, such as Crystal Cave, Sequoia National Park, California, is finding the balance between presenting caves in attractive, safe, and interesting ways, while maintaining the integrity of the natural environment. NCKRI photo by George Veni.*

Fourteen parks have caves open for recreational use, with Lava Beds again the leader, with over 700 of their reported 780 pseudokarst caves available for recreational purposes. However, Dale Pate (personal communication, 2013) has noted that only one cave at Lava Beds meets the traditional definition of a show cave. The other 21 have some trail development, but for what is generally considered recreational caving. He also pointed out that while several parks have not officially closed access to all of their caves, that does not mean they are all open for recreation, but further explains that the Superintendent's Compendium for Lava Beds National Monument indicates that unless a cave is posted as "closed" it is open to potential recreational use at that park unit.

Eighteen parks, or 32% of the respondents, reported some type of active research project within the park unit. Most of these projects focus on exploration, survey or inventory. Twenty-six of the respondents reported having at least one staff member dedicated to cave and karst-related management issues at least part time, with Mammoth Cave reporting by far the most—120 full-time employees, either park staff or contractors and partners. On the other hand, 25 parks reported having no staff dedicated to cave and karst resources.

General Observation 1

Seventy percent of respondents to the general information section of the survey report the presence of solutional caves, non-cavernous karstic features, or pseudokarst within their park unit. Yet 50% of the respondents also report having no staff dedicated to management of cave or karst resources, either full or part-time. Meanwhile, some parks with cave management staff report an insufficient number of employees to adequately meet the park's needs. For example, Carlsbad Caverns National Park reported losing 50% of their cave resource management staff in the past few years, and it is unclear if those vacant positions will be filled.

General Recommendation 1

Staffing for the management of cave and karst resources is lacking or insufficient in many park units. While it is clear with current funding levels that all parks with caves and karst resources cannot have staff dedicated to their management, the data collected from this study should be used by the NPS to prioritize which parks have the greatest need for staff dedicated to cave and karst management. Prioritization should not be based solely on the number or size of caves or the percentage of karst and pseudokarst, but also on the most urgent management needs.

General Observation 2

A significant number of the responding parks indicate that they simply do not know the answers to some of the survey questions. In several cases, questions about the number of cave and karst resources within a park unit received responses such as "unknown," "none currently identified," or there was no reply. We suspect that in some cases a response of "zero" actually means that the respondent did not have the information available to provide an accurate answer. Examples of this basic lack of information include the following:

- Hawaii Volcanoes National Park, which reported "unknown but numerous" non-cavernous karst and pseudokarst features.
- Death Valley National Park, which reported the presence of 76 solutional caves within the park. Having provided that precise number, the respondent went on to state that the number of caves open for recreational use is simply unknown.
- Cape Krusenstern National Monument, which reported that "caves in the park need inventory; none have been currently identified, but karst terrain is present."
- White Sands National Monument, a park unit whose gypsum sand dunes are unique, world-class geological phenomena, reported that its outstanding

resource is biological. White Sands also reported the presence of three solutional caves within the Monument. However, a follow-up phone conversation suggests that the respondent may have been referring to small sinkholes, not caves.
- In response to a question on paleontological resources at the end of the survey, National Park of American Samoa replied, "We really know next to nothing about our caves, including not being sure any true caves exist under the thick tropical vegetation."

This lack of knowledge of their karst resources often appears to be due to a park unit's lack of staff or funding.

General Recommendation 2

Related to the previous recommendation, additional staffing remains a critical need for park units. While more employees are needed to manage these resources, park staff in general need to be aware of their existence. For parks with staff knowledgeable about caves and karst, those employees should train or at least inform other staff about those resources on at least an annual basis. Many parks also occur relatively close to groups of organized cavers, who should be contacted to determine what assistance they may be able to voluntarily provide to find and inventory park caves and karst resources, consistent with their abilities and knowledge and with consideration of any sensitive park resources.

General Observation 3

It appears from some of the ambiguous responses described above that the survey was not always sent to the most appropriate staff member. This pattern is repeated in the education, management, and research sections of the survey. Additionally, four surveys were not completed with Survey Monkey. As this report was being written, NCKRI hosted a conference where staff from four parks that had not completed the on-line survey were present. They completed the survey on paper during the conference with the reference materials and knowledge they had readily available and reported never hearing that this survey was sent to their parks.

General Recommendation 3

The NPS should directly contact at least some of the non-responding parks to determine why the survey was not completed. Potential responses could include insufficient time/staffing, the survey was never received, and/or the topic was considered a low priority or not relevant to the park. Such responses could help the NPS gauge additional needs related to park staff understanding the importance of caves and karst, and improve participation and effectiveness of future NPS surveys.

General Recommendation 4

Four other likely reasons exist for some of the ambiguous responses mentioned in General Observation 3:

- insufficient understanding of the terminology of the survey
- insufficient explanation of the terminology in the survey
- insufficient NPS policy or documentation on the status of caves
- lack of knowledge or implementation of current NPS policies

If the NPS follows up this study with more specific surveys, a glossary or parenthetical explanation of potentially unfamiliar terms should be included, such as "show cave." The apparent differing view of caves open for recreational purposes also suggests that parks with caves of potential recreational interest should develop formal policies that define which caves are open to recreation and under what conditions.

Research

The research portion of the karst resources survey received 40 responses (see Appendix B for summary replies to this part of the survey). Of those 40 parks, 33 reported caves of some sort within their park unit. One park (Effigy Mounds National Monument) reported no true caves, only rock shelters.

Sixteen parks reported that they have a scientist on their resource management staff who works at least part-time on karst research. Most of those parks have just one or two working scientists on their staff, although Mammoth Cave reported nine staff scientists, with expertise in biology, geology, meteorology, history, and cultural resources. Of those 16 parks with working scientists, nine reported that biology was their primary area of expertise, six had a geological background, and one was an archaeologist.

Twenty-one respondents reported they had surveyed the caves within their park units. However, the responses varied because, "How many caves have been surveyed?" was intended to refer to surveys of the physical geometries of the caves, but was not always interpreted as such. For example, Golden Gate National Recreation Area reported that 500 possible sea caves had been identified from aerial photos. Of the 21 respondents, 17 stated that cave inventories had been conducted in at least some of their caves, the majority for geological, biological and/or cultural resources.

Twenty-three respondents reported that geologic mapping had occurred within the park unit at some scale, ranging from 1:1000 up to 1:250,000.

Twenty-two parks, or 55% of respondents to the research section, reported the presence of solutional caves within their boundaries, the vast majority formed in carbonate bedrock. Volcanic caves were a distant second, with six parks reporting lava tubes, bubbles, rifts, etc. Four parks reported the presence of sea caves, five reported tectonic caves, and eight reported talus caves. Two respondents reported the presence of glacial caves within their park units, and two stated that they had no true caves, only rock shelters or bluff shelters formed by differential weathering (Figure 5). Eleven respondents reported the presence of karst springs, although only six parks had delineated the drainage basins of some or all of those springs. Wind Cave and Carlsbad Caverns were the only parks to report any research on paleokarst features within their parks.

Figure 5. *The small sandstone shelter caves of Michigan's Pictured Rocks National Lakeshore provide important evidence of modern and past lake levels in Lake Superior as well as refuges for aquatic wildlife. NCKRI photo by George Veni.*

Thirteen parks reported that biological inventories had been conducted in at least some of their caves; four reported that microbiological inventories had been conducted. Eight parks reported biological inventories of their karst springs. Sixteen park units stated that their caves had bats living in them, with species numbers ranging from one to twelve. Mammoth Cave and Grand Canyon-Parashant National Monument were the only park units that had established ecosystem dynamics for the caves within their parks. However, the reports of 155 and 210 troglobites from two parks suggests the respondents did not understand the difference between troglobites and other less-adapted cave species, even though the term was defined in the question, because such troglobite abundance would be highly unusual.

Sixteen park units reported that archeological inventories had been conducted in at least some of their caves; archeological data had been used to study paleocultures in the region in 10 of those parks. Nine park units reported that paleontological inventories had been conducted in at least some of their caves; caves in six of those parks had been subject to paleoclimate investigations. Data from those investigations had been used to reconstruct the paleoenvironment in five of those parks.

Research Observation 1

More than 82% of respondents to the research survey report caves of some sort within their park unit. However, 60% of the parks that responded have no scientists on their staff dedicated even part of their time to karst research. However, each sub-section of the research survey concluded with an open-ended question, "Please describe any geological/biological/archeological/paleontological topic unique or significant to the park unit not mentioned above." In most cases these questions received no reply, but a few parks provided remarkably detailed and intriguing narrative responses. In some cases these responses came from relatively small park units with little or no scientific staff. Wupatki National Monument, for example, reported on studies of how the earth cracks within the Monument "breathe" through various blowhole sites that are sacred to affiliated modern Native American tribes. Palynology of aeolian dust from one of the earth cracks is being analyzed to document long-term vegetation changes near the cave entrance. Valley Forge National Historic Park described an important discovery of Pleistocene fossils in one of their caves during the late nineteenth century. Those fossils are now curated at the Academy of Natural Sciences in Philadelphia.

Research Recommendation 1

As noted in General Recommendation 1, the data collected from this study should be used by the NPS to prioritize which parks have the greatest need for cave and karst research. Prioritization should not be based solely on the number or size of caves or the percentage of karst and pseudokarst, but also on research topics that may identify or answer the most urgent management needs. See Research Recommendation 2.

Research Observation 2

Several of the park units report research conducted by outside investigators, including prestigious organizations such as the Smithsonian Institution, which

performed paleontological surveys at Big South Fork National River in the 1990s.

Research Recommendation 2

Given the limited or non-existent science staff in many of the park units, collaboration with outside investigators and institutions is critical to maintaining scientific research within the NPS. Universities, research institutes, caving organizations, and public research programs (e.g., Earth Watch) could provide excellent sources of volunteer research and pro bono analyses. Collaboration with local, state, as well as other federal agencies, could lead to cost-sharing programs for research, especially where long-term monitoring is needed and may have results that extend beyond and/or into the park boundaries. For research that may have management implications and requires rapid analysis and results, the park should consider contracting with an organization that is knowledgeable in caves and karst and the specific type of research needed.

Research Observation 3

As previously mentioned in the discussion of general survey results, some cryptic, contradictory, and unlikely replies suggest that the research survey may not always have been sent to the most appropriate person on the park staff, and/or the terminology and concepts, even where defined in one case, in the survey were not familiar to or understood by some of the respondents (see General Recommendations 2 through 4).

Management

Fifty-six parks returned the surveys (see Appendix C for summary replies), 45 completed or partially completed the management questions, several of which answered few questions. Eight of the 11 parks that did not reply (Cape Krusenstern National Monument, Fire Island National Seashore, Homestead National Monument, Manassas National Battlefield Park, Missouri National Recreational River, Natural Bridges National Monument, Point Reyes National Seashore, Wolftrap National Park for the Performing Arts) had few or no known caves, karst, or pseudokarst, or were focused on other issues; the exceptions were Russell Cave National Monument, Virgin Islands National Park, and White Sands National Monument. Following is a summary of the important observations in the answers and resulting recommendations.

Management Observation 1

Some of the park staff are either unaware of karst in their parks and/or may not fully understand karst. For example, Katmai National Park commented, "We have no known karst resources, so have trouble answering most of these questions," even though our use of USGS karst data to identify park units with karst or pseudokarst has identified that 50% of the park is karst and 2% pseudokarst. Effigy Mounds National Monument noted, "There is no traditional karst in the park. Some limestone atop the bluffs—but no real karst." In contrast, karst geologists observe that it is exceedingly rare for limestone to be exposed without any notable degree of karstification.

Management Recommendation 1

NPS staff who work at parks whose areas contain a significant percentage of karst and pseudokarst should receive training on the nature of karst and pseudokarst, the types likely to be observed in their parks, the types of management problems that are likely to occur in their parks, and at least general research tools and remediation methods to address those problems. An exact percentage of karst or pseudokarst is not suggested for identifying what is a "significant percentage" because other factors should be considered, such the significance of the cave, karst, pseudokarst resources to the park and nationally. The training should be repeated every few years, with interim continuing education provided by remote training (e.g., webinars) and attendance by park personnel at relevant conferences and meetings.

Management Observation 2

National Park of American Samoa and Stones River National Battlefield commented that because their caves are not advertised to the public and are difficult to find, that there is little need to protect them from trespassing or monitor them for impact. Stones River also commented, "Our cave…entrance is too small to access"; it is not clear if they think the cave is too small for anyone to enter, in which case they cannot know that it is a cave, or if they think the small size of entrance will keep the public from entering. Remote locations and difficult entrances do reduce the potential for traffic into a cave but they cannot assure it (Figure 6). Further, the impacts on a cave cannot be determined if the cave is not visited. Many caves assumed "safe" for these reasons have been found damaged by unexpected visitors.

Management Recommendation 2

A schedule should be developed for regularly inspecting all caves in a park with a priority listing for those most likely impacted by unexpected visitation. Factors such as importance of the caves' resources and the difficulty in finding and entering each cave should be considered in planning the frequency of the inspections.

Figure 6. *A steep climb and the nearly-hidden, narrow, and rubble-blocked entrance of Church Cave did not prevent its discovery in Kings Canyon National Park, California. NCKRI photo by George Veni.*

Protocols for the inspection should be developed. Volunteer cavers may often be available to conduct the inspections on behalf of park staff at little or no cost.

Management Observation 3

Cave and karst management plans are mostly developed at parks with major caves. However, "karst" is often overlooked by parks assessing their need for a plan. For example, Everglades National Park is 100% karst, but has no cave or karst management plan even though its main feature, water, is closely tied to a karst aquifer (a draft General Management is being prepared for Everglades, but was not available for review during this study to see if karst is considered).

Management Recommendation 3

All parks with a significant percentage of karst or pseudokarst, or significant cave, karst, or pseudokarst resources, should establish management plans for those resources. If the park does not have the staff or expertise to develop such plans, it should contract with an organization with that expertise and experience for outside assistance. This also applies to several of the following management recommendations involving specialized technical issues such as drainage basin delineation, water quality and quantity determinations, defining critical habitat, etc.

Management Observation 4

Seven of the responding parks drain potential contaminants from outside of the parks and have not delineated those surface drainage basins:

- Antietam National Battlefield
- Buffalo National River
- Carlsbad Caverns National Park
- Cumberland Gap National Historical Park
- Effigy Mounds National Monument
- Pea Ridge National Military Park
- Wilson's Creek National Battlefield

Ten of the responding parks drain potential groundwater contaminants from outside of the parks and have not delineated those groundwater drainage basins:

- Amistad National Recreational Area
- Antietam National Battlefield
- Buffalo National River
- Carlsbad Caverns National Park
- Catoctin Mountain Park
- Cumberland Gap National Historical Park
- Effigy Mounds National Monument
- National Park of American Samoa
- Pea Ridge National Military Park
- Wilson's Creek National Battlefield

Nine of the responding parks drain potential contaminants from inside of the parks and have not delineated those groundwater drainage basins:

- Antietam National Battlefield
- Buffalo National River
- Carlsbad Caverns National Park
- Catoctin Mountain Park
- Coronado National Monument
- Cumberland Gap National Historical Park
- Everglades National Park
- Grand Canyon National Park
- Wilson's Creek National Battlefield

Management Recommendation 4

The relevant surface and groundwater drainage basins of the parks in Management Observation 4 need to be delineated to evaluate their potential for contamination and to facilitate remediation if necessary.

Management Observation 5

Some parks have sewage treatment, gasoline, and hazardous materials facilities located on karst.

Management Recommendation 5

Parks that are completely or have a high percentage of karst should seek off-park and preferably off-karst

locations for those facilities. Parks that have notable non-karst areas should evaluate relocating those facilities to their non-karst areas or off the parks (Figure 7).

Figure 7. *Hazardous materials storage facilities should be located outside of karst areas whenever possible, which in some cases may involve locations outside of the park units, such as this non-karst location where a leaking gasoline storage tank is being replaced. NCKRI photo by George Veni.*

Management Observation 6

The following parks indicate having water quantity issues but do not monitor groundwater volume, recharge volume, or gather information on water use and aquifer response:

- Amistad National Recreation Area
- Apostle Island National Lakeshore
- Carlsbad Caverns National Park
- Catoctin Mountain Park
- Grand Canyon National Park
- Hawaii Volcanoes National Park
- Lava Beds National Monument
- Mammoth Cave National Park

Management Recommendation 6

Parks that have at least indications of potential water quantity problems at a minimum should:

- measure the volume of karst groundwater used at the park;
- identify and quantify non-park groundwater uses that might affect groundwater within the park;
- quantify the volume of recharge into the aquifer both within the park and regionally; and
- monitor karst aquifer water levels.

Management Observation 7

Most of the parks responding to the survey reported at least one type of past and/or current extractive industry potentially impacting the park from within or outside of its boundaries. The variety of extractive industries and other geologically-related management issues for the parks is highly diverse.

Management Recommendation 7

No specific recommendations can be made within the scope of this report on extractive and other geologically-related management issues. However, all parks that report potential problems of this type need to develop karst management plans that can effectively address their specific issues.

Management Observation 8

Bering Land Bridge National Park, Glacier National Park, Noatak National Park, and Valley Forge National Historical Park answered “no” to all biology questions but noted they actually did not have any information on this subject. Kenai Fjords National Park did not answer these questions also for lack of information, but plans to inventory its sea caves in 2015. The negative responses from some of the other parks may also indicate similar absences of information rather than absences of potential biological concerns.

Management Recommendation 8

Many karst areas and caves have proven to contain rare and endemic ecosystems, even from small and seemingly insignificant caves and aquifers. Biological surveys of all caves and karst and volcanic pseudokarst aquifers should be conducted to establish if any rare, endemic, threatened, or endangered species are present.

Management Observation 9

The following eight parks report having threatened and/or endangered species but state that the critical habitats have not been defined for their species:

- Big South Fork National River and Recreational Area
- Buffalo National River
- Cumberland Gap National Historical Park
- Grand Canyon National Park
- Grand Canyon-Parashant National Monument
- National Park of American Samoa

- Ozark National Scenic River
- Wind Cave National Park

Management Recommendation 9
The US Fish and Wildlife Service (USFWS) should be asked to establish critical habitat for the threatened and endangered species found within the eight parks noted in Management Observation 9.

Management Observation 10
Seven parks reported having rare and/or endemic species and are not monitoring them:
- Amistad National Recreation Area
- Antietam National Battlefield
- Big South Fork National River and Recreation Area
- Grand Canyon National Park
- Lava Beds National Monument
- National Park of American Samoa
- Wind Cave National Park.

Seven parks reported having threatened and/or endangered species and not monitoring them:
- Antietam National Battlefield
- Big South Fork National River and Recreation Area
- Grand Canyon National Park
- Lava Beds National Monument
- National Park of American Samoa
- Wind Cave National Park
- Wupatki National Monument.

Three parks reported having rare and/or endemic species and exotic species are not monitoring for exotics:
- Antietam National Battlefield
- Buffalo National River
- Wupatki National Monument

Two parks reported having threatened and/or endangered species and exotic species are not monitoring the exotics:
- Antietam National Battlefield
- Buffalo National River

Management Recommendation 10
The parks in Management Observation 10 that are not monitoring their rare and/or endemic species should establish a monitoring plan to determine if those populations are stable or at risk; this includes monitoring the exotic species that might predate upon, compete with, or unfavorably alter the habitat. The parks that are not monitoring their threatened and/or endangered species should coordinate with the USFWS on monitoring as appropriate to the species' recovery plans (if such have been written for each species) or other consultation, including monitoring for potentially deleterious exotic species.

Management Observation 11
Several parks provided contradictory information on their biological status. Capitol Reef National Park, Carlsbad Caverns National Park, Catoctin Mountain Park, Death Valley National Park, Great Basin National Park, and Yosemite National Park answered that they had critical habitat defined, even though they also replied that they do not have threatened or endangered species for which critical habitat is designated. Capitol Reef National Park, Catoctin Mountain Park, Effigy Mounds National Monument, and Hopewell Furnace National Historic Site, stated they do not have endemic, rare, threatened, or endangered species, yet also answered that they are monitoring for them. Grand Canyon-Parashant National Monument, Hawaii Volcanoes National Park, and Natchez Trace Parkway also state they do not have exotic species but also answer that they are monitoring their impacts.

Management Recommendation 11
The parks in Management Observation 11 should be contacted to clear up their status relative to cave and karst fauna and the database associated with this survey should be updated.

Management Observation 12
Evaluation of the answers to the archeology and paleontology questions in this survey was limited by sensitivity of the subjects and not asking questions like, how many sites are known and, what types of monitoring and gates are in place. Also, at least two parks (Bering Straits National Park and National Park of American Samoa) noted that they answered "no" to the survey questions only because they have not inventoried their caves for these materials. Lastly, several of the parks in combination identified a diverse list of potential adverse impacts.

Management Recommendation 12
Information on archeology and paleontology of caves in the national parks should be gathered separately through more secure means in order to obtain more detailed and meaningful results.

Management Observation 13
Grand Canyon National Park has not determined the carrying capacity of its caves but believes it is being exceeded. Death Valley National Park answered that its carrying capacity was not exceeded but in a comment says a cave has been closed due to recreational impacts. The answers of six other parks with recreational usage of caves that are reported to not exceed the caves' carrying capacities are invalid because they also report they have not established carrying capacities. Similarly,

nine parks have recreational usage of their springs and none believe they are exceeding the carrying capacity, but none have established the springs' carrying capacity.

Management Recommendation 13

Carrying capacities should be established for any cave or spring that is open to recreational caving or other usage and then managed to that limit, followed by monitoring to confirm the carrying capacity is not exceeded.

Management Observation 14

It is not clear from the design of the survey if all caves with recreational access have safety and rescue plans. Buffalo National River has safety and rescue plans for certain caves, but not a general plan for other caves in the park. Death Valley National Park, Grand Canyon National Park, Natchez Trace Parkway, Ozark National Scenic River, and Wupatki National Monument have recreational use of caves but possess neither general nor cave-specific safety and rescue plans. Natchez Parkway adds a note that its one open cave for recreation is "very shallow" suggesting minimal risk.

Management Recommendation 14

A general safety and rescue plan should be established for each park with recreational caving. Afterward, plans that are specific to certain caves should be written as needed. No cave, no matter how small, should be excluded from consideration and should be addressed at least in general in the general safety and rescue plan.

Education

Educating the general public about the environment is increasingly important with today's global society and its environmental issues. Increasing scientific knowledge allows individuals to engage in the greater conversation about climate or environmental issues. Sustainability of stewardship programs depends on an educated populace, because people will not value and protect things that they do not understand. Two documents were utilized as guides to analyze the education/interpretation portion of this survey as a basis for recommendations: the Federal Cave Resources Protection Act of 1988 (FCRPA) and National Park Service Director Jonathan Jarvis's strategic plan, *A Call to Action: Preparing for a Second Century of Stewardship and Engagement,* implemented on August 25, 2011.

The survey data collected for cave and karst education and interpretive programming gives an overview of NPS programs, audience potential, as well as identifying an area of need. Of the 56 NPS units that returned surveys, 32 units' survey responses were completed for the education and interpretive section, with a 16% margin of error (see Appendix D for summary replies to this part of the survey). Twenty-nine surveys were completed electronically and two were completed manually. Two parks, or roughly 6% of the survey information, were cross referenced for validity by telephone interviews with park education and interpretive staff. In general, the telephone interviews clarified and offered greater detail to the surveys. Since NPS educational and interpretive programming is framed around the natural resources and mission of the unit (Figure 8), it was important to cross-reference other parts of the survey for clarity on the current status of cave and karst educational and interpretive programs. Following is a summary of the important observations and resulting recommendations.

Education Observation 1

- 94% of the 32 responding units have a total of 4258 known cave or other non-cavernous karst features; this total differs from the accompanying Excel file where the survey says Grand Canyon National Park has 2,500 caves and karst features but Dale Pate (personal communication, 2013) corrected this to 511 when he reviewed the draft version of this report.
- 72% of the 32 units collectively provide educational programming for 153,050 visitors.
  - ◊ 7.5% is cave/karst related or focused.
- 75% of the 32 units collectively provide interpretive programming for more than 16,200,000 visitors annually.
  - ◊ 3.2% is cave/karst related or focused.
- 22% of the 32 units offer interpretive staff cave/karst related training.
- 37.5% of the 32 units have collectively 797 caves open for public use through guided tours or recreational use. Of these park units:
  - ◊ 100% provide education and interpretive programs.
    - > 75% of educational programming is cave related or focused.
    - > 83% of interpretive programming is cave related or focused.
  - ◊ 92% have cave resource staff.
  - ◊ 42% offer cave interpretive training.

Education Recommendation 1

NPS educational and interpretive programming is a viable communication avenue for cave and karst resource management to utilize for public outreach and should continue to be supported and enhanced where possible. This recommendation is supported by the purposes of the FCRPA, which is to foster increased

Figure 8. *This exhibit at Mammoth Cave National Park, Kentucky, effectively conveys the concept of a karst window at Cedar Sink and how it is an integral part of an important groundwater drainage systems that extends far off the park. NCKRI photo by George Veni.*

cooperation and exchange of information between governmental authorities and those who utilize caves located on federal lands for scientific, educational, or recreational purposes (16 USC sec 2), as well as a management action that calls for fostering communication, cooperation, and exchange of information between land managers, those who utilize caves, and the public (16 USC sec 4).

Education Observation 2

The data from this survey indicate 72 to 75% of the responding park units provide interpretive programming; this number went up to 100% through telephone interviews and by examining park websites. Of those park units, 92% have cave resource staff while only 42% offer interpretive training on cave and karst resources. This low number may be at least partly attributed to communication between departments. For example, the initial response from Lava Beds National Monument indicated resource specific training was not offered, while during the follow-up interview the interviewee indicated such training is offered but conducted by interpretive staff. Similarly at Carlsbad Caverns National Park, the survey completed stated there were no paleokarst features in the park while a telephone interview with an interpretive supervisor, who was not the person that completed the survey, stated such features are present and included in some interpretive programs. While this could be a function of different staff interpreting the term "paleokarst" differently, as discussed previously in this report for other terms, increased or improved communication within the park could reduce or eliminate such confusion.

Education Recommendation 2

Parks with at least notable cave, karst, and/or pseudokarst resources (not limited to parks featuring caves) should develop or support an education/ interpretation division position or shared position as a

science liaison to communicate cave and karst related resource, research, and management issues to the interpretive staff, develop cave and karst interpretive training, and assist the resource staff with public outreach. This recommendation is also supported by FCRPA's second management action, to foster communication between land managers, those who utilize caves, and the public (16 USC sec 4). This recommendation is also supported by *A Call to Action*, which encourages all NPS employees and partners to commit to actions that will advance the mission of the NPS toward a shared vision for 2016. Director Jarvis envisions the second century of the NPS to connect people to the parks by helping communities protect what is special to them, to advance the NPS' educational mission by strengthening the NPS as an educational force based on scientific scholarship, and to advancing the NPS Education Mission to strengthen the NPS as an education institution and parks as places of learning that develop American values, civic engagement, and citizen stewardship (Jarvis, 2011).

Concluding Recommendations

Many specific recommendations in the previous sections of this report can be broadly summarized by stating that most park units are underfunded and in some cases severely understaffed. As discussed above, in a number of cases the survey may not have been completed by the most appropriate person, such as a staff scientist, resource manager, education coordinator, or interpretive ranger, resulting in incomplete, inaccurate, or ambiguous responses. More than half of the park units that responded to this survey have no staff dedicated to management or research of cave or karst resources; thus we suspect that in many cases there may simply have been no appropriate staff person available. In such cases the survey may have been completed by an overcommitted superintendent or office staff member with little time or resources to find the correct or complete responses to survey questions. Unfortunately funding and staffing decisions are ultimately dependent on legislative action at the national level.

A lack of basic knowledge or understanding of the cave and karst resources within a park unit is a striking and recurring feature of all sections of this survey. This lack of information may reflect insufficient training for park staff, which again may result from limited staff and funding. This lack of knowledge may also result from poor communication among different departments within park units, a communications phenomenon referred to as "stovepiping." Development of a liaison position to facilitate communication among the research, management, and education divisions could significantly improve knowledge of karst resources within park units.

The NPS should consider additional and more focused surveys to enhance and follow on the results of this study. However, such studies should review this report to avoid limitations, definition issues, and other issues that may have also contributed to some of the ambiguous, contradictory, and absent replies to this survey.

Several parks indicated that they were collaborating with external investigators, contractors, or volunteers to conduct research, education, or resource management within the parks. In many cases, solid science and education is being done because of these collaborative efforts. Such external support and collaboration may be critical to maintaining cave and karst management, research and education programs in the near future and should be supported whenever possible (Figure 9).

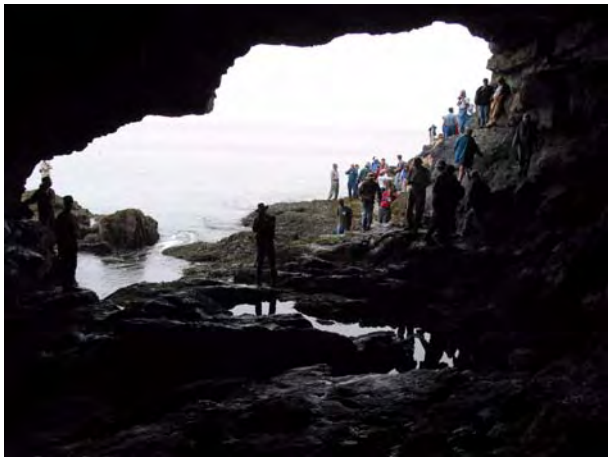

Figure 9. *A field trip of biologists and geologists visit Anemone Cave, Acadia National Park, Maine, to both learn and share knowledge of the park's natural resources. NCKRI photo by George Veni.*

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Diverse textures, colors, and environments are clues to the many mysteries hidden in the beckoning darkness of caves. While many of the world's greatest caves are on NPS lands, most knowledge about them, their management, and values to humanity has yet to be discovered. NPS photo by Dale Pate of the entrance to Braided Cave, El Malpais National Monument, New Mexico.

Appendix A:

Cave and Karst Survey Questions and Summary Results: General

1. Park unit name
   Replies
   56 parks replied at least partly to the survey.
2. Park unit code:
   Replies
   51 of 56 parks provided their code (NCKRI provided the missing five codes to the survey).
3. Primary purpose(s) or outstanding resources:
   - □ geological
   - □ biological
   - □ cultural
   - □ educational
   - □ aesthetic
   - □ recreational
   - □ other (please specify)

   Replies
   - 24 geological
   - 30 biological
   - 36 cultural
   - 11 educational
   - 14 aesthetic
   - 21 recreational
   - 4 other:
     - 1 cave, out of five responding parks with "cave" or "cavern" in their name
     - 1 historical event
     - 1 marine
     - 1 performing arts
   - 3 no reply

2. State:
   Replies
   56 of 56 parks provided their states
3. Estimated size of the area of karst inventoried for karst features:
   Replies
   - 20 parks with inventoried karst areas, ranging from 0.4 to 4,047 km^2 per park
   - 21 parks with no inventoried karst areas
   - 4 not applicable (NA)
   - 2 unknown
   - 8 no reply
4. Number of karstic caves (please give specific number or closest approximation):
   Replies
   - 24 parks with estimated or known numbers of karstic caves, ranging from 1 to 2,500 per park
   - 19 parks with no known karstic caves
   - 3 NA
   - 3 unknown
   - 7 no reply
5. Number of notable non-cavernous karst features (e.g., sinkholes):
   Replies
   - 22 parks with estimated or known numbers of non-cavernous features, ranging from 1 to 1,000 per park
   - 20 parks with no known non-cavernous karst features

3 NA
4 unknown
7 no reply

6. Estimated size of the area of pseudokarst inventoried for pseudokarst features. (Pseudokarst refers to terrain with landforms that resemble karst but are not formed by dissolution of soluble rock.):
   Replies
   22 parks with estimated inventoried pseudokarst areas, ranging from 0.12 to 80,000 km^2 per park
   20 parks with no inventoried pseudokarst areas
   3 NA
   4 unknown
   7 no reply
7. Number of pseudokarst caves (e.g., sea caves, tectonic caves, lava tubes, etc.):
   Replies
   12 parks with estimated or known numbers of pseudokarstic caves, ranging from 1 to "thousands" per park
   29 parks with no known pseudokarstic caves
   1 NA
   5 unknown
   9 no reply
8. Number of notable noncavernous pseudokarst features (e.g., shelters, earth fissures, lava pits):
   Replies
   13 parks with estimated or known numbers of non-cavernous features, ranging from 1 to 432 per park
   26 parks with no known non-cavernous karst features
   2 NA
   5 unknown
   10 no reply
9. Are any paleokarst features known? (Paleokarst refers to ancient karst features unrelated to current geological processes.)
   □ yes
   □ no
   Replies
   11 yes
   37 no
   8 no reply
10. Number of currently active show caves:
    Replies
    11 parks with show caves, ranging from 1 to 22 per park
    37 parks without show caves
    1 NA
    7 no reply
11. Number of guided wild tour caves:
    Replies
    7 parks with guided wild cave tours, ranging from 1 to 3 tours per park
    43 parks with no guided wild cave tours
    1 NA
    5 no reply
12. Number of caves open to recreational use:
    Replies
    13 parks with caves open to recreational use, 1 to 700 per park
    31 parks with no caves open to recreational use
    1 NA
    2 unknown
    9 no reply

13. Do you have active cave research projects?
    - □ yes
    - □ no

    Replies

    18 yes
    35 no
    3 no reply
14. If so, what are the main purposes of the projects?
    - □ exploration
    - □ survey
    - □ inventory
    - □ science
    - □ management
    - □ interpretation
    - □ NA (not applicable)
    - □ other (please specify)

    Replies

    6 exploration
    15 survey
    16 inventory
    11 science
    9 management
    3 interpretation
    10 NA
    0 other
    26 no reply
15. How many park staff members (permanent, term, seasonal, or contractors/partners) spend at least part of their time working on cave and karst resource related management issues?

    Replies

    26 parks with staff working on caves/karst, ranging from 1 to 120 per park
    25 parks with no staff working on caves/karst
    1 NA
    4 no reply

Appendix B:

Cave and Karst Survey Questions and Summary Results: Research

General Section

1. How many scientists are on the resource management staff who spend at least part of their time conducting research on caves and karst within the park?

   Replies

   24 0
   7 1
   6 2
   1 9
   1 unclear
   17 no reply

2. If any, what is their area of expertise (e.g., biology, geology, etc.)?

   Replies

   4 archeology, cultural resources, history
   11 biology/ecology, marine biology
   1 cave management
   11 geology, hydrology, paleontology
   1 meteorology
   2 none
   5 NA
   32 no reply

3. How many caves have been surveyed?

   Replies

   17 0
   4 1
   4 2–10
   7 11–100
   3 101–300
   2 >300
   1 NA
   19 no reply

4. How many caves have been inventoried?

   Replies

   17 0
   5 1
   4 2–10
   9 11–100
   0 101–300
   2 >300
   1 NA
   18 no reply

5. What do the cave inventories include?

   □ geology
   □ biology
   □ paleontology
   □ cultural resources
   □ other (please specify)

Replies
16 geology
15 biology
10 paleontology
15 cultural resources
6 other:
2 hydrology
1 location
1 mineralogy
1 photo monitoring
1 vandalism
30 no reply

6. Do you have a cave inventory form or procedure?
□ yes
□ no
Replies
11 yes
29 no
16 no reply

7. If space permits, please copy and paste your inventory form or procedure into the box below. Otherwise, please send a digital version to lland@nckri.org, or mail hardcopy to
Dr. Lewis Land
National Cave and Karst Research Institute
400-1 Cascades Ave.
Carlsbad, NM 88220-6215
Replies
5 forms or procedures
1 none
2 NA
48 no reply

Geology and Hydrology Section

8. At what scale has geologic mapping been completed in the park unit?
Replies
1 1:1,000
1 1:12,000
1 1:15,000
8 1:24,000
2 1:100,000
1 1:125,000
3 1:250,000
1 various
3 large/course
1 none
1 NA
4 unknown
29 no reply

9. How many karst springs are known in the park unit?
Replies
21 0
6 1–40
2 41–60
0 61–380
2 >380

4 unknown
19 no reply

10. How many of the springs' groundwater drainage basins have been delineated?

Replies

22 0
3 2
1 5
1 <12
1 31
2 NA
2 unknown
24 no reply

11. What are the rock types that contain karst and pseudokarst caves and related features?

□ limestone or dolomite
□ gypsum
□ volcanic rock
□ talus
□ glacial ice
□ other (please specify)

Replies

21 limestone or dolomite
4 gypsum
5 volcanic rock
2 talus
1 glacial ice
6 other:
  2 sandstone
  1 various
  1 none
  2 unknown
26 no reply

12. Has there been any research of paleokarst features in the park?

□ yes
□ no

Replies

2 yes
33 no
21 no reply

13. What types of caves occur in the park?

□ solutional caves, formed by groundwater circulating through soluble rock (e.g., limestone or gypsum)
□ volcanic caves, formed as lava tubes, bubbles, rifts, fissures, pits, etc.
□ sea caves, formed by coastal erosion
□ tectonic caves, formed by some type of ground movement, such as a landslide in jointed rock
□ talus caves, formed in rock debris at the base of a cliff or along a mountainside
□ glacier caves, formed in a glacial ice mass
□ other (please specify)

Replies

24 solutional caves, formed by groundwater circulating through soluble rock (e.g., limestone or gypsum)
5 volcanic caves, formed as lava tubes, bubbles, rifts, fissures, pits, etc.
4 sea caves, formed by coastal erosion
6 tectonic caves, formed by some type of ground movement, such as a landslide in jointed rock
6 talus caves, formed in rock debris at the base of a cliff or along a mountainside
2 glacier caves, formed in a glacial ice mass

2 other:
2 shelter caves
22 no reply

14. Please describe any geological research topic unique or significant to the park unit not mentioned above.
Replies
1 cave meteorology/climatology
1 cultural resources
1 epikarst
2 geomicrobiology
1 hydrology
1 microtopography
1 paleontology
1 rockfall
1 sea caves
1 speleothems as earthquake indicators
1 stromatolites
1 survey of caves is funded to start in 2015
1 none
1 NA
33 no reply

Biology Section

15. How many caves have been biologically inventoried?
Replies
24 0
7 1–10
6 11–40
19 no reply

16. How many karst springs have been biologically inventoried?
Replies
25 0
3 1
1 2
1 4
1 5
2 10
2 NA
21 no reply

17. How many caves have been microbiologically inventoried?
Replies
33 0
1 1
2 2
1 7
19 no reply

18. How many caves have bats?
Replies
16 0
10 1–10
2 11–50
1 140
1 >250
1 >350
1 NA

4 unknown
20 no reply

19. How many species of cave bats are known?
Replies
13 0
7 1–3
11 6–12
1 NA
4 unknown
20 no reply

20. How many different species of troglobites (cave-dwelling creatures that spend their entire lives underground) are known?
Replies
18 0
6 1–10
3 13–16
1 40
1 155
1 210
1 NA
5 unknown
20 no reply

21. How many different species of stygobites (aquatic troglobites who spend their entire life cycles in caves or karst systems) are known from cave streams?
Replies
23 0
2 1
2 5
1 7
1 15
1 NA
6 unknown
20 no reply

22. How many different species of stygobites are known from karst springs?
Replies
25 0
1 1
1 2
1 15
3 NA
4 unknown
21 no reply

23. How many different species of stygobites are known from springs in lava fields?
Replies
28 0
3 NA
1 unknown
24 no reply

24. Have the ecosystem dynamics been established for caves within the park unit?
□ yes
□ no

Replies
2 yes
34 no
20 no reply

25. Please describe any biological research topic unique or significant to the park unit not mentioned above.
Replies
1 microbiological inventory
1 needs inventory
2 sampling of aquifer fauna
1 sampling of spring fauna
1 study of carbon dioxide, methane, and environmental DNA to track rare species
1 study of cave fish in solution holes
1 study the effects of lampenflora
1 White-nose Syndrome
1 NA
49 no reply

Archeology Section

26. How many caves have been archeologically inventoried?
Replies
17 0
10 1–10
3 17–35
3 60–80
1 NA
1 unknown
21 no reply

27. How many caves contain historical cultural materials?
Replies
18 0
4 1
2 2
1 4
1 6
1 50
1 100
1 NA
4 unknown
23 no reply

28. How many caves contain prehistoric cultural materials?
Replies
17 0
8 1–15
1 46
1 71
1 500
1 NA
4 unknown
23 no reply

29. Have data from the caves been used to study the paleocultures of the park unit?
□ yes
□ no

Replies
10 yes
21 no
25 no reply

30. Please describe any archeological research topic unique or significant to the park unit not mentioned above.
Replies
1 develop archeological protocols
1 DNA analysis of organic materials
1 document agricultural materials
1 document cave ceremonial practices
1 investigation of air flow in sacred earth cracks
1 excavation
1 shelter caves used for habitat and burial
1 stabilization of cultural materials
1 NA
50 no reply

Paleontology Section

31. How many caves have been paleontologically inventoried?
Replies
25 0
6 1–4
2 10
1 16
2 unknown
20 no reply

32. How many caves contain recent paleontological materials?
Replies
21 0
2 1–2
1 12
1 30
2 42–45
1 360
1 NA
4 unknown
23 no reply

33. How many caves contain Pleistocene or older paleontological materials (not including fossils in bedrock)?
Replies
20 0
3 1
1 2
1 4
1 10
1 12
1 NA
5 unknown
23 no reply

34. How many of the caves have been subject to paleoclimate investigations?
Replies
28 0
4 1
1 2
1 10

1 unknown
21 no reply

35. Have data from the caves been used to study the paleoenvironment of the park unit?
□ yes
□ no

Replies
6 yes
27 no
23 no reply

36. Please describe any paleontological research topic unique or significant to the park unit not mentioned above.

Replies
1 excavations prior to inundation by a dam
1 palynology study of earth cracks to evaluate changes in vegetation
1 relocation effort of lost paleontology cave

Appendix C:

Cave and Karst Survey Questions and Summary Results: Management

General Section

1. Are any caves within the park unit monitored for trespassing or other impacts?
   - □ yes
   - □ no

   Replies
   - 20 yes
   - 24 no including Wind Cave National Park
   - 12 no reply
2. If so, for what types of impacts?
   - □ recreational
   - □ archeological
   - □ paleontological
   - □ biological
   - □ geological
   - □ general vandalism
   - □ White-nose Syndrome
   - □ NA (not applicable)
   - □ other (please specify)

   Replies
   - 14 recreational
   - 11 archeological
   - 6 paleontological
   - 8 biological
   - 9 geological
   - 18 general vandalism
   - 12 White-nose Syndrome
   - 12 NA
   - 1 other:
     - 1 tours
   - 24 no reply
3. If so, by what means are the caves monitored?
   - □ regular visitation
   - □ cameras
   - □ alarms
   - □ NA
   - □ other (please specify)

   Replies
   - 17 regular visitation
   - 7 cameras
   - 2 alarms
   - 16 NA
   - 5 other:
     - 2 irregular visitation
     - 1 only monitoring archeological sites in rock shelters
     - 1 infrared counters
     - 1 cave registers
   - 20 no reply

4. Are the impacts mapped?
   □ yes
   □ no
   Replies
   10 yes
   29 no
   17 no reply
5. Are there management plans specific to the park unit's cave and karst resources?
   □ yes
   □ no
   Replies
   15 yes
   30 no
   11 no reply
6. Are park visitors provided with any formal or informal information on methods to decrease the chances of contaminating cave or karst resources?
   □ yes
   □ no
   Replies
   14 yes, mostly on White-nose Syndrome
   29 no
   13 no reply

Geology and Hydrology/Water Quality Section

7. Have the surface water drainage basins flowing from outside the park unit onto karst within the park been delineated?
   □ yes
   □ no
   Replies
   10 yes, mostly where hydrology is important, although Buffalo River replied “no”
   31 no
   15 no reply
8. Do urban, industrial, sewage, landfill, or other potential sources of surface water contamination occur in those non-park areas?
   □ yes
   □ no
   Replies
   16 yes
   26 no
   14 no reply
9. Have the groundwater drainage basins flowing from outside the park unit into karst aquifers in the park been delineated?
   □ yes
   □ no
   Replies
   9 yes
   34 no
   13 no reply
10. Do urban, industrial, sewage, landfill, or other potential sources of karst groundwater contamination occur in those non-park areas?
    □ yes
    □ no

Replies
17 yes
23 no
16 no reply

11. Are the groundwater drainage basins for karst springs within the park unit delineated?
    □ yes
    □ no
    Replies
    12 yes
    32 no
    12 no reply
12. Do sewage facilities, buildings, roads, and other potential sources of karst groundwater contamination occur in those park areas?
    □ yes
    □ no
    Replies
    16 yes
    26 no
    14 no reply
13. Do facilities exist to treat parking lot runoff in or upstream of karst areas?
    □ yes
    □ no
    Replies
    7 yes
    35 no
    14 no reply
14. Are sewage treatment facilities located on karst?
    □ yes
    □ no
    Replies
    11 yes
    31 no
    42 no reply
15. Are gasoline stations or other facilities that store hazardous materials located on karst?
    □ yes
    □ no
    Replies
    14 yes
    27 no
    15 no reply
16. How many caves and sinkholes are unrestored old trash dumps?
    Replies
    Five parks contain such dumps, with generally one or two caves each. Some parks are not certain if such dumps occur or not; Mammoth Cave National Park notes there are no cave dumps in the park but several nearby outside of the park.
17. Is groundwater quality monitored at the park?
    □ yes
    □ no
    Replies
    28 yes
    16 no
    12 no reply
18. If so, where?
    □ wells

□ springs
□ streams
□ cave streams
□ other (please spsecify)

Replies

24 wells
16 springs
16 streams
7 cave streams
2 other:
1 cave pool
1 marsh

19. Are any water quality issues currently known with respect to the park's karst groundwater?
□ yes
□ no

Replies

11 yes
32 no
13 no reply

Groundwater Quantity Section

Please indicate unit of measurement.

20. What is the volume of park use of groundwater?
3 parks using karst groundwater in quantified volumes: 1 mgd, 2 mgd, and "690 million gallons"
20 parks using karst groundwateer but in unknown and unquantified volumes
11 parks not using karst groundwater
22 no reply
21. Is there non-park use of karst groundwater outside of the park which is or might significantly affect karst groundwater resources within the park unit?
□ yes
□ no

Replies

9 yes
19 no
14 unknown
14 no reply

22. What is the volume of karst groundwater recharge?

Replies

3 known quantified volumes
8 "0" recharge, all non-karstic or pseudokarstic except for Everglades National Park
16 unknown
29 no reply

23. Is groundwater quantity monitored at the park?
□ yes
□ no

Replies

15 yes
26 no
15 no reply

24. If so, please indicate the types of sites monitored and the number of monitoring stations per site type.
□ wells
□ springs
□ streams
□ cave streams

□ other (please specify)

Replies

8 wells
7 springs
8 streams
2 cave streams
2 other:
  1 cave pool
  1 "other"

25. Are any water quantity issues currently known with respect to the park's karst groundwater?

□ yes
□ no

Replies

11 yes
30 no
15 no reply

Mineral Resources Section

26. What current or past extractive mineral industries operate within the park unit's karst areas, or in areas where they may impact karst (e.g., oil and gas drilling, surface or underground mining, other)?

Replies

Some of the following were not provided for this question but question #28. Some parks replied with more than one industry.

13 none known
7 stone/gravel quarries
6 oil and gas
13 minerals

27. Please indicate the distance from the park of extractive industries located outside the park's boundaries.

Replies

20 within 10 miles (most within two miles)
4 >10 miles

28. Please describe any geological management topic unique or significant to the park unit not mentioned above.

Replies

Agricultural runoff
Cave microclimate
Climate change
Dam leakage
Hypogene caves
Nuclear testing and storage
Permafrost
Rockfall in cave
Subsidence
Surface water and groundwater control structures
Volcanic hazards
Some replies duplicated previous information or did not relate to the question.

Biology Section

29. Are rare or endemic species known in the park unit's caves, karst springs, and/or lava field springs?

□ yes
□ no

Replies

21 yes
19 no
16 no reply

30. Are threatened and/or endangered species known in the park unit's caves, karst springs, and/or lava field springs?
    - □ yes
    - □ no

    Replies

    12 yes
    28 no; Grand Canyon answered "no" but indicated the use of caves by an endangered species in reply to question #35. This is accounted for in the above count.
    16 no reply
31. Has critical habitat been defined for the threatened and/or endangered species?
    - □ yes
    - □ no

    Replies

    10 yes
    11 no
    18 NA
    17 no reply
32. Is the ecological status of rare, endemic, or threatened/endangered species monitored?
    - □ yes
    - □ no

    Replies

    17 yes
    7 no
    15 NA
    17 no reply
33. Are exotic species or other adverse impacts known at the park unit's caves, karst springs, and/or lava field springs?
    - □ yes
    - □ no

    Replies

    11 yes
    27 no
    1 NA
    17 no reply
34. Are those adverse impacts monitored?
    - □ yes
    - □ no

    Replies

    10 yes
    27 no
    1 NA
    18 no reply
35. Please describe any biological management topic unique or significant to the park unit not mentioned above.

    Replies

    Flooding from dammed lake
    Green techniques used to rebuild turf
    Invasive species management not related to karst species
    Possible candidate species at Death Valley National Parl following further study
    Species extirpation
    Threatened and endangered species in Everglades National Parl that are not related to the karst
    White-nose Syndrome

Archeology Section

36. Does access to any caves require coordination with cultural groups?
    - □ yes
    - □ no

    Replies
    6 yes
    34 no
    16 no reply
37. Are adverse impacts to cultural materials known at caves within the park unit?
    - □ yes
    - □ no

    Replies
    7 yes
    32 no
    17 no reply
38. Are there any trespass issues with caves containing cultural materials?
    - □ yes
    - □ no

    Replies
    10 yes
    30 no
    16 no reply
39. Please describe any archeological management topic unique or significant to the park unit not mentioned above.

    Replies
    Cultural sites known but not in caves or karst features
    Deterioration of historic structures in caves
    Insufficient staff and funding to work on cultural resources
    Many caves already looted
    Need for protection/management of exposed cultural materials
    Some materials known but inadequately inventoried
    Threats by water levels in dammed lake

Paleontology Section

40. Are adverse impacts to paleontological materials known at caves within the park unit?
    - □ yes
    - □ no

    Replies
    3 yes
    38 no
    15 no reply
41. Are there any trespass issues with caves containing paleontological materials?
    - □ yes
    - □ no

    Replies
    5 yes
    35 no
    16 no reply
42. Please describe any paleontological management topic unique or significant to the park unit not mentioned above.

    Replies
    Burning of ground sloth den
    Cave gated to protect paleontological site
    Inadvertent damage by cave visitation
    Insufficient funding to support monitoring of cave resources

Monitoring needed for bedrock fossils

Quarrying exposed sinkhole with Pleistocene materials at Valley Forge National Historical Park, later filled with asbestos waste and lost; should be relocated, cleaned up, and then studied.

Recreation Section

43. Is there any recreational use of caves within the park unit?
    - □ yes
    - □ no

    Replies

    11 yes
    29 no
    16 no reply
44. Have carrying capacity limits been defined for those caves?
    - □ yes
    - □ no

    Replies

    3 yes
    35 no or NA
    38 no reply
45. Are the carrying capacity limits for these caves being exceeded or nearly exceeded?
    - □ yes
    - □ no

    Replies

    1 yes, Grand Canyon National Park
    36 no
    19 no reply
46. Is there any recreational use of karst and/or lava field springs within the park unit?
    - □ yes
    - □ no

    Replies

    9 yes
    29 no
    18 no reply
47. Have carrying capacity limits been defined for those karst and/or lava field springs?
    - □ yes
    - □ no

    Replies

    0 yes
    38 no
    18 no reply
48. Are the carrying capacity limits for these springs being exceeded or nearly exceeded?
    - □ yes
    - □ no

    Replies

    0 yes
    36 no
    20 no reply
49. Is there a general safety and rescue plan for caves within the park unit?
    - □ yes
    - □ no

    Replies

    8 yes
    29 no
    19 no reply

50. Is there a safety and rescue plan for specific caves?
    - □ yes
    - □ no

    Replies

    9 yes
    29 no
    18 no reply
51. Please describe any recreational management topic unique or significant to the park unit not mentioned above.

    Replies

    American Samoa has few visitors and believes no one could find their caves. Glacier NP also cites low visitation and difficult location, but concludes it results in low visitation.

    Amistad is developing a cave management plan before allowing access. Grand Canyon emphasizes it needs one.

    Capulin has insufficient staff and funding to handle recreational cave use.

    Cave trail conditions.

    Stones River NB allows visitors to walk through historic stone labyrinth.

    Wupatki NM has a deep vertical entrance close to popular trails. They do not think it is causing problems, but recognize they should be monitored to be certain.

Appendix D:

Cave and Karst Survey Questions and Summary Results: Education/Interpretation

Karst Education Resources Section

1. Does the park unit have an education specialist?
   - □ yes
   - □ no

   Replies
   - 24 yes
   - 9 no
   - 24 no reply
2. Is your education program associated with an NPS education center?
   - □ yes
   - □ no

   Replies
   - 7 yes
   - 23 no
   - 26 no reply
3. If so, please describe the type of education center.

   Replies
   - 1 Civil War
   - 1 Crown of the Continent Research Learning Center
   - 1 in development
   - 1 Howland Hill Outdoor School and Wolf Creek Education Center
   - 1 Learning Center of the Southwest
   - 1 Mammoth Cave Science and Learning Center
   - 1 Murie Science and Learning Center
   - 1 NA
   - 48 no reply
4. Is your education program associated with a non-NPS education center?
   - □ yes
   - □ no

   Replies
   - 4 yes
   - 26 no
   - 26 no reply
5. If so, please describe the type of education center.

   Replies
   - 1 unnamed community environmental education center
   - 1 Glacier Institute and Crown of the Continent Consortium
   - 1 SHUMLA and local public schools
   - 1 American Samoa Department of Education
   - 2 NA
   - 50 no reply
6. How many education programs does the park unit offer?
   - □ 0
   - □ 1–10
   - □ 11–20
   - □ 21–30
   - □ >30
   - □ NA (not applicable)
   - □ U (unknown)

Replies

0 0
9 1–10
5 11–20
1 21–30
12 >30
2 NA
2 unknown
25 no reply

7. How many of those education programs mention caves?
   - □ 0
   - □ 1–10
   - □ 11–20
   - □ 21–30
   - □ >30
   - □ NA
   - □ U

Replies

12 0
9 1–10
1 11–20
1 21–30
2 >30
4 NA
1 U
26 no reply

8. How many of those education programs mention karst?
   - □ 0
   - □ 1–10
   - □ 11–20
   - □ 21–30
   - □ >30
   - □ NA (not applicable)
   - □ U (unknown)

Replies

15 0
9 1–10
0 11–20
0 21–30
1 >30
4 NA
1 U
26 no reply

9. How many of those education programs are specifically focused on caves?
   - □ 0
   - □ 1–10
   - □ 11–20
   - □ 21–30
   - □ >30
   - □ NA (not applicable)
   - □ U (unknown)

Replies

19 0
5 1–10

0 11–20
1 21–30
1 >30
4 NA
0 U
26 no reply

10. How many of those education programs are specifically focused on karst?
    - □ 0
    - □ 1–10
    - □ 11–20
    - □ 21–30
    - □ >30
    - □ NA (not applicable)
    - □ U (unknown)

    Replies

    18 0
    5 1–10
    1 11–20
    1 21–30
    0 >30
    5 NA
    1 U
    25 no reply
11. Please list which topics are addressed by the education programs on caves.

    Replies

    1 bats, White-nose Syndrome, migration/hibernation patterns, importance of hibernation
    1 biological resources and cave ethics
    1 cultural and natural history
    1 endangered species in cave
    1 hydrology/connection with the surface
    2 lava tube geology
    1 “Stories in Rocks” program includes karst and sinkholes.
    1 To protect caves at park, they are deliberately not mentioned to the public.
    4 none
    3 NA
    40 no reply
12. Please list which topics are addressed by the education programs on karst.

    Replies

    1 hydrology/connection with the surface
    1 water quality and riparian protection
    1 hydrology, water conservation, importance of karst to desert water supply
    1 cave origin and biological and cultural use
    1 geology, management, and karst areas around the world
    1 geology
    5 none
    3 NA
    42 no reply
13. What is the average annual number of students who attend total park education programs?
    - □ 0
    - □ 1–10
    - □ 11–20
    - □ 21–50
    - □ 51–100
    - □ 101–200

□ 201–500
□ 501–1000
□ 1001–10,000
□ >10,000
□ NA
□ U

Replies

0 0
0 1–10
0 11–20
2 21–50
0 51–100
1 101–200
0 201–500
3 501–1000
15 1001–10,000
2 >10,000
2 NA
7 U
24 no reply

14. What is the average annual number of students who attend cave education programs?

□ 0
□ 1–10
□ 11–20
□ 21–50
□ 51–100
□ 101–200
□ 201–500
□ 501–1000
□ 1001–10,000
□ >10,000
□ NA
□ U

Replies

13 0
0 1–10
0 11–20
0 21–50
1 51–100
0 101–200
2 201–500
2 501–1000
2 1001–10,000
1 >10,000
7 NA
4 U
24 no reply

15. What is the average annual number of students who attend karst education programs?

□ 0
□ 1–10
□ 11–20
□ 21–50
□ 51–100
□ 101–200

□ 201–500
□ 501–1000
□ 1001–10,000
□ >10,000
□ NA
□ U

Replies

13 0
0 1–10
0 11–20
0 21–50
0 51–100
1 101–200
1 201–500
3 501–1000
1 1001–10,000
0 >10,000
6 NA
7 U
24 no reply

16. What year did education programs begin on caves in your park?

Replies

1 1975
1 1980
1 1986
1 1988
2 1998
1 2004
1 2006
1 2007
1 2011
13 NA
33 no reply

17. What year did education programs begin on karst in your park?

1 1980
1 1986
1 1988
1 1998
1 2002
1 2004
1 2006
1 2008
1 2011
14 NA
1 U
32 no reply

18. Please describe any education topic unique or significant to the park unit not mentioned above.

Replies

1 cave simulation exhibit
1 cultural resources, geology, biological and land use management
1 exploration history
1 GIS project with local high school
1 use of mines by bats
1 Samoan culture

1 too many to list, but none on caves/karst because caves/karst not yet identified in park
1 underground waterways, impacts of caves/karst on native people and vice versa
2 none
2 NA
44 no reply

Karst Interpretive Resources Section

19. What is the park unit's primary interpretive focus?

Replies

21 archeological and cultural resources, cultural history
1 bats
20 biology, ecology, marine/terrestrial resources, natural history, wildlife
4 caves
10 geology, glaciology, volcanism
1 karst
3 land management and stewardship
1 outreach
1 recreation
25 no reply

20. Does the park unit offer training on caves and karst for its interpretive staff?

□ yes
□ no

Replies

8 yes
23 no
1 NA
24 no reply

21. How many of the park's interpretive programs mention caves?

□ 0
□ 1–10
□ 11–20
□ 21–30
□ >30
□ NA
□ U

Replies

13 0
9 1–10
0 11–20
1 21–30
3 >30
5 NA
1 U
24 no reply

22. How many of the park's interpretive programs mention karst?

□ 0
□ 1–10
□ 11–20
□ 21–30
□ >30
□ NA
□ U

Replies

15 0

7 1–10
0 11–20
1 21–30
2 >30
5 NA
2 U
24 no reply

23. How many of those programs are specifically focused on caves?
    - □ 0
    - □ 1–10
    - □ 11–20
    - □ 21–30
    - □ >30
    - □ NA
    - □ U

    Replies

    18 0
    7 1–10
    0 11–20
    0 21–30
    2 >30
    4 NA
    2 U
    23 no reply

24. How many of those programs are specifically focused on karst?
    - □ 0
    - □ 1–10
    - □ 11–20
    - □ 21–30
    - □ >30
    - □ NA
    - □ U

    Replies

    20 0
    5 1–10
    0 11–20
    0 21–30
    1 >30
    5 NA
    0 U
    25 no reply

25. What methods are used to interpret caves?
    - □ signage
    - □ tours
    - □ lectures
    - □ website
    - □ printed materials
    - □ audiovisual materials
    - □ social media (e.g., Facebook)
    - □ other (please specify)

    Replies

    9 signage
    7 tours
    4 lectures

7 website
10 printed materials
7 audiovisual materials
6 social media (e.g., Facebook)
12 other:
2 artificial cave
3 displays, exhibits, models/replicas
2 none
5 NA
38 no reply

26. What methods are used to interpret karst?
□ signage
□ tours
□ lectures
□ website
□ printed materials
□ audiovisual materials
□ social media (e.g., Facebook)
□ other (please specify)

Replies
4 signage
5 tours
4 lectures
4 website
6 printed materials
5 audiovisual materials
4 social media (e.g., Facebook)
10 other:
1 exhibits
1 indirect mention from historical program
4 none
4 NA
37 no reply

27. Do any of the park's interpretive programs discuss paleokarst in the park?
□ yes
□ no

Replies
3 yes
27 no
1 U
25 no reply

28. What is the average annual number of people who attend interpretive programs offered by the park unit?
□ 0
□ 1–100
□ 101–1000
□ 1001–10,000
□ 10,001–100,000
□ >100,000
□ NA
□ U

Replies
1 0
0 1–100
1 101–1000

6 1001–10,000
11 10,001–100,000
6 >100,000
2 NA
4 U
25 no reply

29. What is the average annual number of people who attend interpretive programs focused on caves?
□ 0
□ 1–100
□ 101–1000
□ 1001–10,000
□ 10,001–100,000
□ >100,000
□ NA
□ U

Replies
13 0
1 1–100
3 101–1000
2 1001–10,000
1 10,001–100,000
2 >100,000
6 NA
3 U
25 no reply

30. What is the average annual number of people who attend interpretive programs focused on karst?
□ 0
□ 1–100
□ 101–1000
□ 1001–10,000
□ 10,001–100,000
□ >100,000
□ NA
□ U

Replies
15 0
0 1–100
2 101–1000
2 1001–10,000
1 10,001–100,000
1 >100,000
6 NA
3 U
26 no reply

31. If the park unit has interpretive programs that mention caves, please list which topics are addressed.

Replies
4 bats, White-nose Syndrome
6 cave biology, habitat, importance
8 cave exploration, safety, conservation, ethics, caving trips
6 cave resources, minerals, paleontology, importance to humans
3 cave types, origins
1 chemistry
2 conservation
7 cultural resources, pre-history, history, nitre mining

4 geology
2 water
5 NA
38 no reply

32. If the park unit has interpretive programs that mention karst, please list which topics are addressed.
Replies
1 biology
2 geology
3 history
6 hydrology
6 karst origin, distribution, types
3 management
9 NA
38 no reply

33. What year did interpretive programs begin on caves in your park?
Replies
1 1903
1 1923
1 1941
1 decades ago
1 1975
1 1990s
1 1998
1 2011
10 NA
36 no reply

34. What year did interpretive programs begin on karst in your park?
Replies
1 decades ago
1 1960s or 1970s (but before 1979)
1 1986
1 1998
1 2002
1 2008
1 2011
10 NA
1 U
38 no reply

35. Please describe any interpretation topic unique or significant to the park unit not mentioned above.
Replies
2 bats, regional ecology
4 cultural resources and history
2 hydrology
2 none (one program just ended with recent budget cuts)
5 NA
45 no reply

Appendix E:

Cave and Karst Survey Questions: Instructions/Cover Letter

April 18, 2013

Dear Park Manager,

The National Cave and Karst Research Institute, under contract with the National Park Service, is conducting a survey to assess the status and extent of knowledge of cave and karst resources within National Park Service units. This survey is being sent to all park units identified as having at least the potential for cave and karst resources, based on the location of the park unit on limestone, gypsum, or volcanic bedrock, or documented or anecdotal evidence of caves and/or karst within that park unit.

This survey and subsequent report will help the Geologic Resources Division/NPS understand more fully the extent of cave and karst resources within NPS units, identify critical resource issues and missing data-gaps, learn more about educational and interpretive opportunities parks provide, and determine long-term support needs for parks and regions with cave and karst resources. We have thus divided the survey into four categories: general information, research, management, and education and interpretation.

We are using the online service Survey Monkey to collect this information. You may access the individual questionnaires through the following links:

- General information: https://www.surveymonkey.com/s/KVSVY8X
- Management: https://www.surveymonkey.com/s/KV2KVG8
- Education and interpretation: https://www.surveymonkey.com/s/FZNHWZL
- Research: https://www.surveymonkey.com/s/KVNT2B5

Note that some of the surveys appear on-screen on more than one page, and subsequent pages can be accessed by clicking the "next" icon at the bottom of the page. In some cases, your response to the survey may be that there are no known cave or karst resources within your park unit, which in itself is useful information. Please double-check your answers before clicking "done," after which you will not be able to revise your survey.

We encourage you to assign the most appropriate person or persons on your staff to answer the different sections of the survey. If your answers require a more detailed response that will not fit in the text boxes provided, you may send that information to Dr. Lewis Land at lland@nckri.org, or contact him at 575-887-5508.

For questions or other information needs on the NPS Cave and Karst Program, contact Dale Pate by phone at 303-969-2635 or by email at: dale_pate@nps.gov.

Thank you very much for participating in this survey. Please complete it by June 24, 2013. We will send receipts acknowledging receipt of your survey after that date. We look forward to your response.

George Veni, Ph.D.
Executive Director

Appendix F:

List of Park Units Known to Contain or Potentially Contain Caves, Karst, and/or Pseudokarst (see Karst and Pseudokarst Park Areas.xlsx for complete information)

Park (Parks shaded in olive replied to survey.)	**States and territories**	**Percent karst**	**Percent pseudokarst**
Abraham Lincoln Birthplace National Historic Site	Kentucky	36	0
Acadia National Park	Maine	0	0
Ala Kahakai National Historic Trail	Hawaii	NA	NA
Alibates Flint Quarries National Monument	Texas	100	0
Allegheny Portage Railroad National Historic Site	Pennsylvania	3	0
Amistad National Recreation Area	Texas	100	0
Aniakchak National Monument and Preserve	Alaska	0	4
Antietam National Battlefield	Maryland	100	0
Apostle Islands National Lakeshore	Wisconsin	0	0
Arches National Park	Utah	46	0
Badlands National Park	South Dakota	0	79
Bandelier National Monument	New Mexico	0	0
Bering Land Bridge National Preserve	Alaska	7	57
Big Bend National Park	Texas	23	0
Big Cypress National Preserve	Florida	100	0
Big South Fork National River and Recreation Area	Tennessee	4	0
Bighorn Canyon National Recreation Area	Montana	50	0
Biscayne National Park	Florida	100	0
Blue Ridge Parkway	North Carolina	5	0
Bluestone National Scenic River	West Virginia	0	0
Brown vs. Board of Education National Historic Site	Kansas	0	0
Bryce Canyon National Park	Utah	0.4	0
Buck Island Reef National Monument	Virgin Islands	100.0	0
Buffalo National River	Arkansas	83.09	0
California National Historic Trail	multiple	NA	NA
Canaveral National Seashore	Florida	10.2	0
Canyon de Chelly National Monument	Arizona	33.2	0

Park (Parks shaded in olive replied to survey.)	**States and territories**	**Percent karst**	**Percent pseudokarst**
Canyonlands National Park	Utah	27.1	0
Cape Krusenstern National Monument	Alaska	6	36
Capitol Reef National Park	Utah	63	0
Capulin Volcano National Monument	New Mexico	0	100
Carlsbad Caverns National Park	New Mexico	87	0
Castillo De San Marcos National Monument	Florida	0	0
Catoctin Mountain Park	Maryland	0	0
Cedar Breaks National Monument	Utah	0	0
Cedar Creek and Belle Grove National Historical Park	Virginia	41.9	0
Channel Islands National Park	California	0.2	0
Chesapeake and Ohio Canal National Historical Park	Maryland	22.5	0
Chickamauga & Chattanooga National Military Park	Georgia	76.6	0
Chickasaw National Recreation Area	Oklahoma	9	0
Chiricahua National Monument	Arizona	0	0
Colonial National Historical Park	Virginia	8.0	0
Congaree National Park	South Carolina	5	0
Coronado National Memorial	Arizona	0	0
Crater Lake National Park	Oregon	0	42
Craters of the Moon National Monument	Idaho	0	99
Cumberland Gap National Historical Park	Kentucky	25	0
Cumberland Island National Seashore	Georgia	0	0
Cuyahoga Valley National Park	Ohio	0	0
Dayton Aviation Heritage National Historical Park	Ohio	100.0	0
De Soto National Memorial	Florida	100.0	0
Death Valley National Park	California	18	0.08
Delaware Water Gap National Recreation Area	Pennsylvania	24.9	0
Denali National Park	Alaska	3	27
Devils Tower National Monument	Wyoming	75.2	0
Dinosaur National Monument	Colorado	39.2	0
Dry Tortugas National Park	Florida	100.0	0

Park (Parks shaded in olive replied to survey.)	**States and territories**	**Percent karst**	**Percent pseudokarst**
Effigy Mounds National Monument	Iowa	41	0
El Malpais National Monument	New Mexico	4	93
Everglades National Park	Florida	100	0
First State National Monument	Delaware	0	0
Fort Caroline National Memorial	Florida	95	0
Fort Circle Park National Recreation Trail	District of Columbia	NA	NA
Fort Donelson National Battlefield	Tennessee	91	0
Fort Dupont Park	District of Columbia	NA	NA
Fort Frederica National Monument	Georgia	0	0
Fort Matanzas National Monument	Florida	28	0
Fort Pulaski National Monument	Georgia	0	0
Fort Stanton Park	District of Columbia	NA	NA
Fort Sumter National Monument	South Carolina	0	0
Fossil Butte National Monument	Wyoming	0.66	0
Fredericksburg and Spotsylvania National Military Park	Virginia	8.26	0
Gates of the Arctic National Park and Preserve	Alaska	9.92	0.17
George Washington Carver National Monument	Missouri	100.00	0
Gila Cliff Dwellings National Monument	New Mexico	0	0
Glacier Bay National Park and Preserve	Alaska	4.13	0
Glacier National Park	Montana	18	0
Glen Canyon National Recreation Area	Utah	23.11	0
Golden Gate National Recreation Area	California	0	0
Golden Spike National Historic Site	Utah	40.65	0
Grand Canyon National Park	Arizona	97	3
Grand Canyon-Parashant National Monument	Utah	NA	NA
Grand Teton National Park	Wyoming	8.34	0
Great Basin National Park	Nevada	36	0
Great Smoky Mountains National Park	Tennessee	2.39	0

Park (Parks shaded in olive replied to survey.)	**States and territories**	**Percent karst**	**Percent pseudokarst**
Guadalupe Mountains National Park	Texas	68.57	0
Haleakala National Park	Hawaii	0	81.79
Hampton National Historic Site	Maryland	95.65	0
Harpers Ferry National Historical Park	West Virginia	31.58	0
Hawaii Volcanoes National Park	Hawaii	0	99.10
Herbert Hoover National Historic Site	Iowa	100.00	0
Hopewell Culture National Historical Park	Ohio	19.64	0
Hot Springs National Park	Arkansas	0	0
Illinois and Michigan Canal National Heritage Corridor	Illinois	NA	NA
Indiana Dunes National Lakeshore	Indiana	28.32	0
Jefferson National Expansion Memorial	Illinois	NA	NA
Jewel Cave National Monument	South Dakota	100	0
Joshua Tree National Park	California	0	0.51
Kalaupapa National Historical Park	Hawaii	0	70.61
Kaloko-Honokohau National Historical Park	Hawaii	0	59.60
Katmai National Park and Preserve	Alaska	0.3	2.15
Kenai Fjords National Park	Alaska	0	0
Kings Canyon National Park	California	0.58	0.25
Kobuk Valley National Park	Alaska	5.90	29.12
Lake Clark National Park and Preserve	Alaska	0.03	0.33
Lake Mead National Recreation Area	Nevada	20.75	0.22
Lake Meredith National Recreation Area	Texas	100	0
Lake Roosevelt National Recreation Area	Washington	0.2	0
Lassen Volcanic National Park	California	0	66.51
Lava Beds National Monument	California	0	99.18
Little River Canyon National Preserve	Alabama	0.73	0
Lyndon B. Johnson National Historical Park	Texas	97.57	0
Mammoth Cave National Park	Kentucky	84.0	0
Marsh-Billings-Rockefeller National Historical Park	Vermont	84.53	0
Mesa Verde National Park	Colorado	0	0

Park (Parks shaded in olive replied to survey.)	**States and territories**	**Percent karst**	**Percent pseudokarst**
Mississippi National River and Recreation Area	Minnesota	50.09	0
Missouri National Recreation River	South Dakota	57.1	0
Mojave National Preserve	California	3.45	2.66
Monocacy National Battlefield	Maryland	92.3	0
Montezuma Castle National Monument	Arizona	0	0
Mormon Pioneer National Historic Trail	multiple	NA	NA
Mount Rainier National Park	Washington	0	28.94
Natchez Trace Parkway	Mississippi	19.7	0
National Capitol Parks	District of Columbia	4.47	0
National Park of American Samoa	American Samoa	NA	NA
Natural Bridges National Monument	Utah	0.2	0
Navajo National Monument	Arizona	0	0
New River Gorge National River	West Virginia	0	0
Niagara Falls National Heritage Area	New York	NA	NA
Nicodemus National Historic Site	Kansas	0	100.00
Niobrara National Scenic River	Nebraska	61.08	0
Noatak National Preserve	Alaska	10.2	8.41
Obed Wild and Scenic River	Tennessee	0	0
Olympic National Park	Washington	0	0
Oregon Caves National Monument	Oregon	100.00	0
Oregon National Historic Trail	multiple	NA	NA
Ozark National Scenic Riverways	Missouri	99.0	0
Pea Ridge National Military Park	Arkansas	73.5	0
Pecos National Historical Park	New Mexico	98.55	0
Petersburg National Battlefield Park	Virginia	9.92	0
Petroglyph National Monument	New Mexico	0	56.72
Pictured Rocks National Lakeshore	Michigan	49.94	0
Pinnacles National Monument	California	0	0
Piscataway Park	Maryland	5.26	0
Point Reyes National Seashore	California	0	0

Park (Parks shaded in olive replied to survey.)	**States and territories**	**Percent karst**	**Percent pseudokarst**
Pony Express National Historic Trail	multiple	NA	NA
Pu‘uhonua o Honaunau National Historic Park	Hawaii	0	100.00
Redwood National Park	California	0	0
Richmond National Battlefield Park	Virginia	5.07	0
Rio Grande Wild and Scenic River	Texas	NA	NA
Rocky Mountain National Park	Colorado	0	0
Ross Lake National Recreation Area	Washington	0	0
Russell Cave National Monument	Alabama	63	0
Saguaro National Park	Arizona	1.24	0
Saint Croix National Scenic Riverway	Wisconsin	8.34	0
Salinas National Monument	New Mexico	92.71	0
Salt River Bay Historic Park & Ecological Preserve	Virgin Islands	0	0
San Antonio Missions National Historic Park	Texas	1.80	0
San Juan Island National Historic Site	Washington	0	0
San Juan National Historic Site	Puerto Rico	92.13	0
Sand Creek Massacre National Historic Site	Colorado	41.04	28.08
Sequoia National Park	California	4.73	0
Shenandoah National Park	Virginia	1.42	0
Sleeping Bear Dunes National Lakeshore	Michigan	84	0
Stones River National Battlefield	Tennessee	100	0
Sunset Crater Volcano National Monument	Arizona	0	100.00
Tallgrass Prairie National Preserve	Kansas	97	0
Tennessee Civil War National Heritage Area	Tennessee	NA	NA
Theodore Roosevelt Inaugural National Historic Site	New York	100	0
Theodore Roosevelt National Park	North Dakota	0	69.98
Thomas Stone National Historic Site	Maryland	3	0
Timpanogos Cave National Monument	Utah	83	0
Timucuan Ecological and Historic Preserve	Florida	3	0
Tonto National Monument	Arizona	57	0
Tuzigoot National Monument	Arizona	0	0
Valley Forge National Historical Park	Pennsylvania	28	0

Park (Parks shaded in olive replied to survey.)	**States and territories**	**Percent karst**	**Percent pseudokarst**
Virgin Islands National Park	Virgin Islands	3	0
Walnut Canyon National Monument	Arizona	100	0
War in the Pacific National Historical Park	Guam	NA	NA
Washita Battlefield National Historic Site	Oklahoma	15	0
White Sands National Monument	New Mexico	0	0
Wilson's Creek National Battlefield	Missouri	100	0
Wind Cave National Park	South Dakota	46	14.74
Women's Rights National Historical Park	New York	100	0
World War II Valor in the Pacific National Monument	Hawaii	0.07	0
Wrangell-St. Elias National Park and Preserve	Alaska	2.20	8.04
Wupatki National Monument	Arizona	82	17.75
Yellowstone National Park	Wyoming	3.63	1.72
Yosemite National Park	California	0.07	0
Yukon-Charley Rivers National Preserve	Alaska	6.02	0
Zion National Park	Utah	16.06	8.46

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