Intermountain Region
Resource Stewardship and Science

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Crossroads in Science

Where the Intermountain Region's Resource Management Programs and Centers Meet

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In This Issue...

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Front Cover:
Dark night skies over Natural Bridges National Park. *(Credit: Dr. Tyler Nordgren)*

See the Natural Resources, Soundscapes and Night Skies feature program article on page 21.

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Resource Stewardship and Science Directorate Welcomes New Regional Director

New beginnings are special occasions. I would like to extend a warm welcome on behalf of myself and the Resource Stewardship and Science (RSS) Directorate to Intermountain Region's new regional director, Sue Masica. Sue comes from Alaska, where she worked as regional director for almost six years. In a recent interview about her new appointment, Sue said, "This is an opportunity to support employees in their efforts to care for these specials places…I will listen carefully to their voices as we work together to preserve these treasures…"

Tammy Whittington, Associate Regional Director, Resource Stewardship and Science (left), with Sue Masica, Regional Director, Intermountain Region (right).

This second of edition of *Crossroads in Science* is a unique collection of voices from all over the region. The articles reveal the breadth of the RSS Directorate and how that work goes beyond the parameters of our specialized fields. Although the magazine focuses on science, this issue only exists because of RSS's collaboration with employees from other offices, divisions, programs, parks, DOI bureaus, and universities.

I would like to thank each of the authors for taking the time to write with enthusiasm and passion about your contributions to the region and the National Park Service. You have made creating this issue memorable.

And finally, to the reader, I hope, no matter what field or office you work in, that you'll not only enjoy this issue, but be inspired by these voices of the Intermountain Region.

Tammy Whittington

Tammy Whittington
Associate Regional Director
Resource Stewardship and Science

Glacier National Park

—Natural Resources—

Feature Park—Glacier National Park

Ice Patch Archeology and Paleoecology in Glacier National Park: High Country Heritage Science

By Pei-Lin Yu, Cultural Specialist for the Rocky Mountains Cooperative Ecosystems Studies Unit, pei-linyu@boisestate.edu

Contributing Authors: Craig Lee, Robert Kelly, Ira Matt, Francis Auld, Kevin Askan, John Murray, Maria Nieves Zedeno, Frank Tyro, David Rockwell, Lon Johnson, Deirdre Shaw, Mike Durglo, Sr.

Introduction: Emerging From the Ice

A fragment of basket, the tip of a digging stick, the shaft of a spearthrower: very rarely do such items preserve in the archeological record. However, these works of ingenuity and craftsmanship have been discovered in near-perfect condition in ice and snow patches preserved for hundreds, or even thousands, of years.

Antler arrow point found in ice patch in Lake Clark National Park and Preserve. *(Credit: http://frontierscientists.com/wp-content/uploads/2013/03/pointjagged.jpg)*

Ice patches are formed when enough snow accumulates in places like the lee of boulders to become thick enough to withstand summer temperatures. Unlike glaciers, ice patches don't move. Anything that falls onto an ice patch can become encased and frozen, including trees, fragments of lighter vegetation and seeds, animal dung, animals themselves, and discarded or lost items from human hunters, gatherers, and travelers. As this cycle repeats over the years, the old snow stratifies into layers of low-density ice that provide a record of the animals and people who found reasons to travel into the high country.

Higher temperatures related to global warming endanger ice patches and the delicate organic contents within. Shorter, warmer winters with winter rainfall erode ice patches

quickly. After exposure, organic items have a short window of time before irrevocable loss, even if left undisturbed by animals or humans. For example, the fletching on a lost arrow will detach within a year of exposure, sinew, which holds the point in place, will loosen shortly thereafter. According to ice patch archeologist Craig Lee, wood deteriorates in four or five years, and bone or antler within 10 years.

Ice Patch Archeology Team member Rachel Reckin discovers wood fragment at Glacier NP ice patch. *(Credit: R. L. Kelly)*

The NPS is charged with the stewardship of the material traces of our natural and cultural heritage, and is also responsible for minimizing the loss of these items. The NPS, and the Intermountain Region (IMR) specifically, have parks rich in ice patches. Recent discoveries in Rocky Mountains National Park and just outside Yellowstone National Park have produced spectacular and unique archaeological materials: a 10,000-year old atlatl foreshaft; a beautifully woven women's basket fragment; and paleobiological specimens like animal remains, feces, frozen trees, and other natural items dating to before 7,500 years BP (Before Present), all of which were literally frozen in time--in an ice patch.

Ice Patch Archeology partners include researchers and experts from the University of Wyoming, Confederated Salish and Kootenai Tribes (CSKT), University of Colorado Boulder, Blackfeet Nation, University of Arizona, Glacier National Park, and the Rocky Mountains Cooperative Ecosystem Studies Unit. From left to right: Bob Kelly, University of Wyoming; Rachel Reckin, U.S. Forest Service; Dave Schwab, CSKT of the Flathead Reservation; Craig Lee, University of Colorado Boulder; Don Sam, CSKT of the Flathead Reservation. *(Credit: Ira Matt)*

New Frontiers in Science: The Glacier National Park Ice Patch Archeology and Paleoecology Project

In the winter of 2010, Glacier National Park convened a multi-disciplinary team to respond to the National Park Service's call for climate-change related research applications with an ambitious proposal to survey and map the park's high priority ice patches and protect, and if necessary collect and curate, exposed cultural and paleo-biological items. The proposal was unique in its culturally-informed protocols for documentation, handling, and collection in full partnership with tribal experts. The project team includes members of the Confederated Salish and Kootenai Tribes of the Flathead Reservation, the Blackfeet Nation, the University of Wyoming, the University of Colorado Boulder, and the University of Arizona as well as Glacier National Park's cultural resources program and the Rocky Mountains

Cooperative Ecosystem Studies Unit (CESU). The proposal was fully funded in 2010 and implemented through the Rocky Mountains CESU: the only cultural resources project supported that year by the National Park Service's Climate Change Response Program.

Relationships and Capacity-sharing

The Glacier Ice Patch Archeology and Paleoecology Project is centered on an interdisciplinary approach: the research blends archeology, traditional knowledge, ice science, zoology, and botany into a comprehensive understanding of the science and cultural heritage of Glacier National Park's ice patches and unique sub-alpine mountainscapes. The project is a powerful combination of academic, tribal, and federal expertise. It is the only ice-patch focused research in the Service with direct tribal involvement in all phases. The team has assembled the "Protocol for Field, Lab/Analysis, and Transport Actions: Artifacts" which is distributed to field-going personnel each year. This 'living' document has been revised adaptively in response to conditions encountered in the field, based on input from the crew. In addition, the Ice Patch team has been so successful as a model for collaborative project planning and execution that Glacier National Park intends to continue working with team members under the newly-formed Glacier Cultural Resources Management Group.

What Have We Learned So Far?

In three field seasons, no human-made artifacts have yet been found in Glacier National Park ice patches. Since man-made artifacts have been found in other ice patches in IMR, the likelihood of finding similar items in Glacier is high, and the park is scoping options for routine monitoring of highest priority ice patches. In addition, several paleo-biological discoveries have enormous research potential for understanding ancient climates and ecosystems of Glacier NP, as well as transformations of these systems over time.

Ice Core Organic Layers: The Glacier Ice Patch team has pioneered, with the U.S. Ice Drilling Design and Operations Program at the University of Wisconsin-Madison, a new technique for obtaining cores from the unusually porous ice found in sub-alpine patches. In 2013 the team collected several samples from an ice patch near Siyeh Pass. Thin dark layers of organic matter composed of windblown dust, animal feces, tiny leaf fragments, and possibly volcanic ash, are indicative of warming periods when melting layers 'lagged' or collapsed on top of each other. Samples of these dark layers were melted, strained through a fine mesh,

Ice Patch core showing melting episodes and organic layers. *(Credit: R. L. Kelly)*

Bison cranium and femur found downslope of ice patch in 2012. *(Credit: R. L. Kelly)*

Wood fragment possibly indicating ancient forests during a prior warming period, in what is now the sub-alpine zone. *(Credit: R. L. Kelly)*

packaged in the field, and dated in the lab. Radiocarbon dates from samples at the base of the ice core place the age of the bare surface at about 6,500 years ago. This agrees well with current estimates of when the park's glaciers and material in the sample also indicates that the ice patch has not melted to a smaller size since its formation.

Wood: A variety of trees are represented by wood fragments found in or near Glacier's ice patches. Collected specimens include yew, western larch, Douglas fir, and pine (possibly white pine). Radiocarbon dates vary from 160 +/- 40 BP to 5,300 +/- 40 BP (both yew specimens). A cluster of dates in the 900-1,300 BP range include Douglas fir, larch, and pine species as well as yew. These finds indicate the ancient climate experienced some warming, and, as a result, the treeline moved upsloped from where it is now. More wood samples are currently under analysis.

Bone: In 2012, a high-elevation ice patch yielded many animal bones. The bones showed no signs of human modification and were likely deposited when the animals died naturally, probably upslope of their current location. Most bones were from mountain goat and bighorn sheep, but an unusual and interesting discovery was the well-preserved cranium and several limb, rib, and vertebral elements of an adult male bison. This is the first confirmed material evidence of bison in the high mountains of Glacier National Park. A sample of the bison bone dates to 967 ± 15 BP and the carbon values are suggestive of a diet primarily consisting of high country plants. This could indicate this bison was a frequent visitor to the high country. Researchers plan to evaluate the bison's genetics in more detail to see if this is a 'mountain' sub-species.

Panoramic view of a few of Glacier's ice patches. *(Credit: R. Reckin)*

Getting the Message Out

This project has fascinating themes and concepts for a variety of audiences. The Salish-Kootenai College has produced a youtube video (http://www.youtube.com/watch?v=ifmdf2RHsK8) and is constructing an interactive website. The website will feature special pages with targeted content for teachers, kids, scientists, and managers.

To date, this project has received coverage on the local NPR station, in the National Parks Conservation Association magazine, the tribal newspaper Char Koosta (Confederated Salish and Kootenai Tribes), and the University of Montana's Vision magazine. In 2012, the project was recognized nationally by the Department of the Interior with the Secretary's Partnerships in Conservation Award. Glacier National Park and the Rocky Mountains CESU will work with Intermountain Region and Washington Office cultural resources programs to disseminate culturally sensitive field and lab protocols as a transferable example to parks and other agencies.

Looking Forward

The Glacier Ice Patch Archeology and Paleoecology Project reaches beyond the traditional role of archeology. The project team hopes to engage a global community of First Nations and other indigenous peoples whose heritage is being affected by climate change, academics, public land managers, and young people in this unique and endangered form of archeological research. For now, the field work on foot has concluded and the project team is scoping a new monitoring program to continue their research before it is too late.

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—Natural Resources—

Denizens of the Night: What IMR is Doing on the Front Lines of Bat Conservation

By Mike Wrigley, IMRO Wildlife Biologist, mike_wrigley@nps.gov

Contributing authors:
Kevin Castle, NPS Wildlife Veterinarian, BRMD; David L. Hays, Natural Resources Branch Chief, El Malpais and El Moro National Monuments; Greg Holm, Wildlife Program Manager, Grand Canyon National Park; Jason Mateljak, Chief of Resource Management, Chiricahua National Monument, Coronado National Memorial, Ft. Bowie National Historic Site; Cami McKinney, Chief of Resource Management, Timpanogos Cave National Monument; Rene Ohms, Chief of Resource Management, Devil's Tower National Monument; John Treanor, Wildlife Biologist, Yellowstone National Park; Paul Whitefield, Natural Resource Specialist, Wupatki, Sunset Crater Volcano, and Walnut Canyon National Monuments

Bats: What's the Big Deal?

Bats are key indicators of the health of our national parks and ultimately the environment and its biodiversity. Most bats are insectivores and primarily consume nocturnal insects. Some bats eat up to their entire body weight *per night* in insects. Also, bats can cover long distances and play a major role in insect control, transporting nutrients across the landscape, and contribute to the greater benefit of the agricultural economy.

Lesser long-nosed bat. (*Leptonycteris curasoae*) *(Credit: USFWS)*

However, not all bats eat insects; some eat only plant products and serve as important pollinators of many flowering species. For example, the lesser long-nosed bat (*Leptonycteris curasoae*), living in the desert Southwest parks of the Intermountain Region (IMR), eat only fruit and nectar of night-blooming cacti including saguaro (*Carnegiea gigantea*), organ pipe (*Stenocereus thurberi*), and several species of agave (*Agave* sp.). These and other "vegetarian" bats have long faces and tongues allowing them to drink nectar deep inside flowers. If the bat pollinators disappeared, these majestic plants and the wildlife that rely on them would be seriously threatened. This is important because the loss of plant and animal diversity is one of the most serious long-term global problems affecting the planet.

Saguaro cactus (*Carnegiea gigantea*) blossoms. *(Credit: Ken Bosma, Wikimedia)*

Like birds, some bats play a critical role in spreading the seeds of fruit trees and other plants. Some bats carry seeds

inside them as they digest the fruit, and then excrete the seeds far away from the original tree. These seeds drop to the ground in their own ready-made fertilizer, which helps them germinate and grow. Because of this bats can even play an important part in helping the regrowth of forests primarily through seed dispersal, but pollination is likely key as well. Many plants, without the aid of modern cultivation methods, still rely on bats for their proliferation in the wild.

Echolocation

Even though all bats have eyes, most insectivorous species use echolocation (rapid pulses of ultrasonic sound from their mouth or nose that bounce off an object) to "see" with sound. They use echolocation to locate prey, avoid barriers and even to return to their roosts in the dark. Bats and some other animals like whales, dolphins, shrews, and some birds, use echolocation to navigate and find food. Bats emit sound waves that hit objects around them. The soundwave bounces off the object and returns to the bat's ears as an echo. Bats listen to these echoes to figure out an object's location, size, shape, and the direction it is moving. Using echolocation, bats can detect objects as thin as a human hair in complete darkness. Echolocation allows some bats to find insects the size of a small gnat.

Winter Months

The majority of bats are most active during warm months in the hours just after dusk and preceding dawn. Bats in the IMR migrate, hibernate, or do both. During the summer, males and females of many bat species live apart while the females raise the young. For most insectivorous bat species, when fall arrives, both sexes fly to "swarming areas" where they mate and prepare to enter a deep, prolonged hibernation.

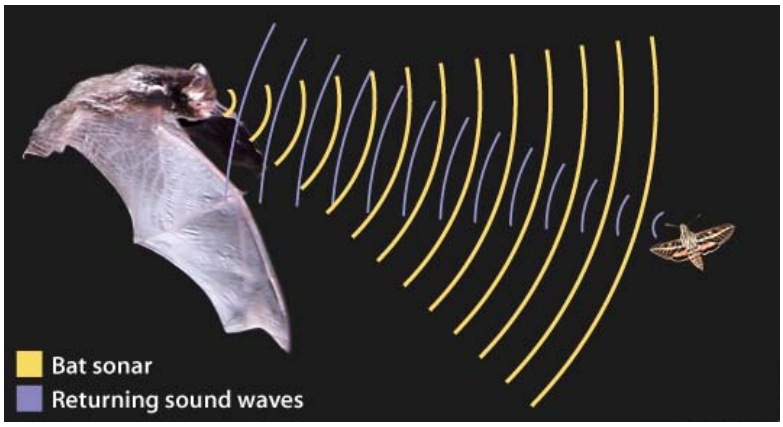


Illustration of echolation. *(Credit: ASU School of Life Sciences)*

During the winter, many species of bats hibernate in dark and moist caves or mines, playing an important role in cave ecosystems by bringing in important resources. Hibernation is an adaptation and vital for bat survival during the cold winter months when there are no insects available to eat. Many bats hibernate in caves as a community, while some species overwinter in small groups or individually. Bats hibernate within an aptly-named "hibernaculum" that has very specific, favorable habitat conditions of temperature and moisture with no human disturbance. Bats very often return to the same hibernaculum, even to very nearly the same spot within a hibernaculum. We also know that some bats will switch hibernacula during winter.

While in hibernation, bats enter into "torpor" which is a physical state when they lower their physiological activity which includes heart rate, respiration, metabolism, and body temperature. Bats must store energy, in the form of fat, prior to hibernation. One of the major concerns with the increasingly widespread disease white-nosed syndrome (WNS) is that the hibernation of afflicted bats is interrupted; often leading them to depart their winter roost early and to eventually starve to death because there is no food available.

Threats to Bats

Bats are among the most intensely feared and relentlessly persecuted animals on earth. Through ignorance, many populations of bats have been needlessly destroyed. Most people know little about bats, often believing popular myths. Bats are virtually defenseless, and large colonies make easy targets. A single act of vandalism can kill millions at a time, having a significant impact on the survival of an entire species. Despite the great benefits which bats provide to humans, they are still among the most persecuted animals on earth. Every year there are new reports in the U.S. of thousands of bats killed needlessly in caves and mines.

Bats may be mysterious and misunderstood, but the earth's only flying mammals are essential to our global environment.

The decrease in bat numbers mirrors the ever-changing landscape to which they rely upon for survival. In IMR, the availability of natural habitat for bats and other animals is declining and becoming increasingly fragmented. It is important to protect and manage existing habitats to help bats to thrive. Loss of habitat, the use of pesticides, and other management practices have all lead to a reduction in the abundance of insects which many bats rely on as their only food source.

Amid heightened concerns about climate change and the economic and environmental costs of fossil fuels, wind has become an increasingly popular source of energy. Wind-generated electricity is renewable and generally considered environmentally clean, but wind-energy facilities often take a toll on wildlife. Widespread fatalities at wind turbines can have significant impacts on bird and bat populations.

Climate change may cause severe stress for bats. The projected increase in aridity and decrease in precipitation in many regions has been shown to greatly impact the reproductive capabilities of bats (Adams 2010, Frick et. al. 2010). Changes in temperature, especially warming trends, are often associated with global climate change. The average temperature of the Earth's surface increased by less than 2 degrees F (1.1° C) in the past 100 years, but global climate change is projected to increase that average by another 2 to 11 degrees F (1.1° to 6° C) over the next century (Parry et al. 2007, Saunders et al. 2008).

Only a handful of studies have specifically examined climate change and bats, and they strongly suggest that bats will be affected as much as other organisms, including the wintering range of bats in North America to keep expanding northward (Wheeler 2012).

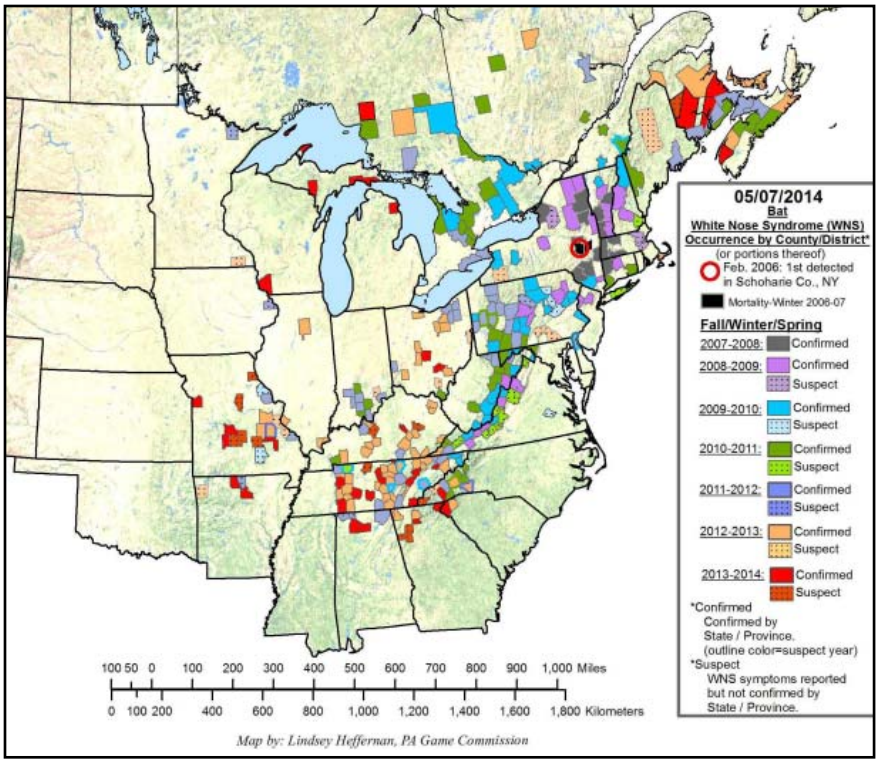
Changes in temperature may affect hibernation periods and the availability of suitable hibernacula in the future. Increased variation in climatic extremes raises the possibility of bats emerging from hibernation early or at a greater frequency. That would not only put hibernating bats at risk from depleted energy stores, but could also affect the birth and survival of pups. Resources, especially insect prey, may be limited or variable during periods of early arousal from hibernation. Changes in climate may also influence insect life cycles, which would in turn affect when feeding and habitat conditions for bats.

When a colony of bats is lost, the potential benefits of countless microorganisms and other animals perish with them. Loss of bats may seriously damage entire ecosystems upon which we depend with unpredictable and potentially disastrous consequences.

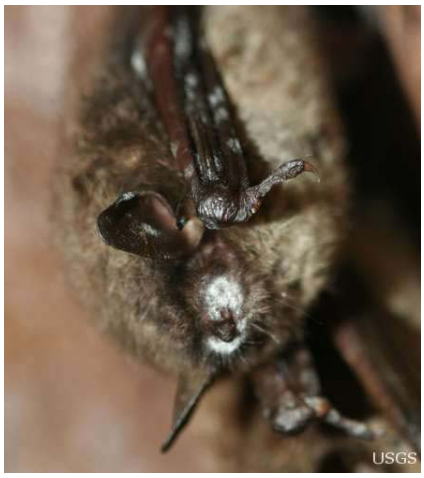
Importantly, bats can act as early-warning indicators of large-scale ecological effects resulting from regional warming and drying trends currently at play in western North America. The future of bats relies on researchers like the NPS and its many partners. By supporting conservation education and research, the NPS is working to learn more about bats and to change the public's general perception of bats as scary to one of wonder.

White-nose Syndrome

Since the winter of 2006, a deadly disease known as white-nose syndrome (WNS) has killed millions of bats in North America. WNS is a disease caused by a non-native, cold-loving fungus (*Pseudogymnoascus destructans* [*P. destructans or Pd.*] formerly called *Geomyces destructans*]), which can be found in many caves in the Northeast, Midwest, and Southeastern regions of North America. The name of this disease refers to the white fungal growth found on the muzzle of infected bats, although it is also often visible on their wings and tail membrane. WNS was first discovered in caves located in New York during the winter of 2006-2007 where it killed over half of some wintering bat populations.



Counties with documented occurrences of WNS and the year they were suspected and confirmed with the disease. (*Credit: White-nose syndrome.org*)



Hibernating little brown bat with white-nose syndrome. *(Credit: USGS)*

P. destructans is thought to be native to European caves (or elsewhere in the Old World) where local bats may have evolved with the fungus, allowing them to coexist and not be harmed; unlike North American bats. The fungus currently affects hibernating bat species in the eastern half of the United States and parts of Canada; but it continues to spread westward across the continent. Currently seven bat species have been infected, including: little brown bats (*Myotis lucifugus*), northern long-eared bats (*Myotis septentrionalis*), big brown bats (*Eptesicus fuscus*), tri-colored bats (*Perimyotis subflavus*), eastern small-footed bats (*Myotis leibii*), endangered gray bats (*Myotis grisescens*), and endangered Indiana bats (*Myotis sodalis*). Alarmingly, some species such as the little

brown bat, one of the most common species in North America, are experiencing some of the highest mortality rates from this disease: up to 90-100 percent in some populations. This issue has become a high priority to researchers and conservationists.

Transmission of the fungus associated with WNS is believed to occur in two possible ways: through bat-to-bat contact and by humans visiting caves and mines and transporting the fungus to a new location. Bat-to-bat contact occurs during pre- and post-hibernation movements, while in hibernacula, and in maternal colonies. Conditions in hibernacula make it an ideal place for the spread of the fungus as temperature and humidity are optimal and high densities of bats are gathered in one location.

The fungus can persist in cave sediment after bat colonies leave their hibernacula in the spring, and can survive to infect next winter's arrivals. Some estimates show a 93 percent decline of little brown bats in 23 caves at the epicenter of WNS (New York Department of Environmental Conservation). The disease is spreading rapidly and has the potential to infect at least half of the bat species found in North America. To date, WNS has not been detected in IMR parks; however, the threat of this deadly disease spreading here is real.

The fungus can also very likely be transferred from cave to cave by equipment that is not properly disinfected. It is hypothesized that this method may have been what brought *P. destructans* to the United States; however such a "smoking gun" has not been determined. *P. destructans* is spread by spores, which are released when the bats try to rub the fungus off of their noses and wings. The spores spread to bats by direct contact with infected bats or via contact with contaminated substrates (cave walls, ceilings, etc.).

The NPS Office of Public Health has issued the following statement on WNS: The human health risk from WNS is unknown but appears to be low. No human illnesses to date have been associated with contact or exposure to WNS-infected bats or caves. In addition, *P. destructans* only grows at temperatures well below human body temperature so infection is very unlikely.

Bat Research and White-nose Syndrome

Today, researchers are concerned that WNS will appear in the many caves and bat hibernation areas found in the Intermountain Regional parks. Just like park scientists who put radio collars on wolves or elk, bat biologists' radio-tag bats using exceptionally small transmitters that are specially designed to be carried by bats. Once a bat is tagged, NPS researchers are able to follow it while it forages and returns to its roost. Researchers can eavesdrop on bat echolocation calls by using "bat detectors" which pick-up their high-frequency sounds and let the scientist know if bats are just flying through an area or if they are catching and eating insects. However, acoustic monitoring alone does not provide data on sex, age, or reproductive condition of specific bat species, and can under-represent the occurrence of species whose echolocation calls are of low energy and difficult to detect. Additional data on individuals and populations are collected by using mist netting, harp trapping, and other capture methods, and by observing colonies and individuals at their roosts. While each method has its advantages and disadvantages, the combination of acoustic monitoring, observation, and capture provides a more complete view of bat ecology than any one method can obtain.

While this deadly disease is the focus of much research and attention, researchers still do not have all of the answers or a cure; indeed, as with most wildlife diseases a cure

Each evening in summer Mexican free-tailed bats exit Carlsbad Cavern in search of a smorgasbord of insects for dinner. *(Credit: Nick Hristov)*

may be illusive. Research has shown that WNS-infected bats awaken from their winter torpor as often as every 3-4 days as opposed to the normal every 10-20 days or longer. The fungus also damages the connective tissues, muscles and skin of the bats while and disrupts their physiological functions such as water and electrolyte balances. While in their winter torpor, the immune systems of the bats are suppressed, corresponding with the need to conserve energy and nutrients. Infected bats awaken dehydrated and hungry and go looking for food and water, but they find none since it is still winter, and unfortunately, many of them starve to death. Because most species of bats only produce one pup per year, the bat population is unable to recover very quickly.

The bat conservation community is deeply concerned and involved with fighting the spread of WNS. Researchers and land managers including the NPS are working to find a way to mitigate this fatal disease. Federal, state, and local organizations are focusing their efforts on conservation, containment, and education. IMR parks are diligently taking proactive steps to minimize the spread of WNS by employing a variety of measures aimed to keep WNS from infecting more bats.

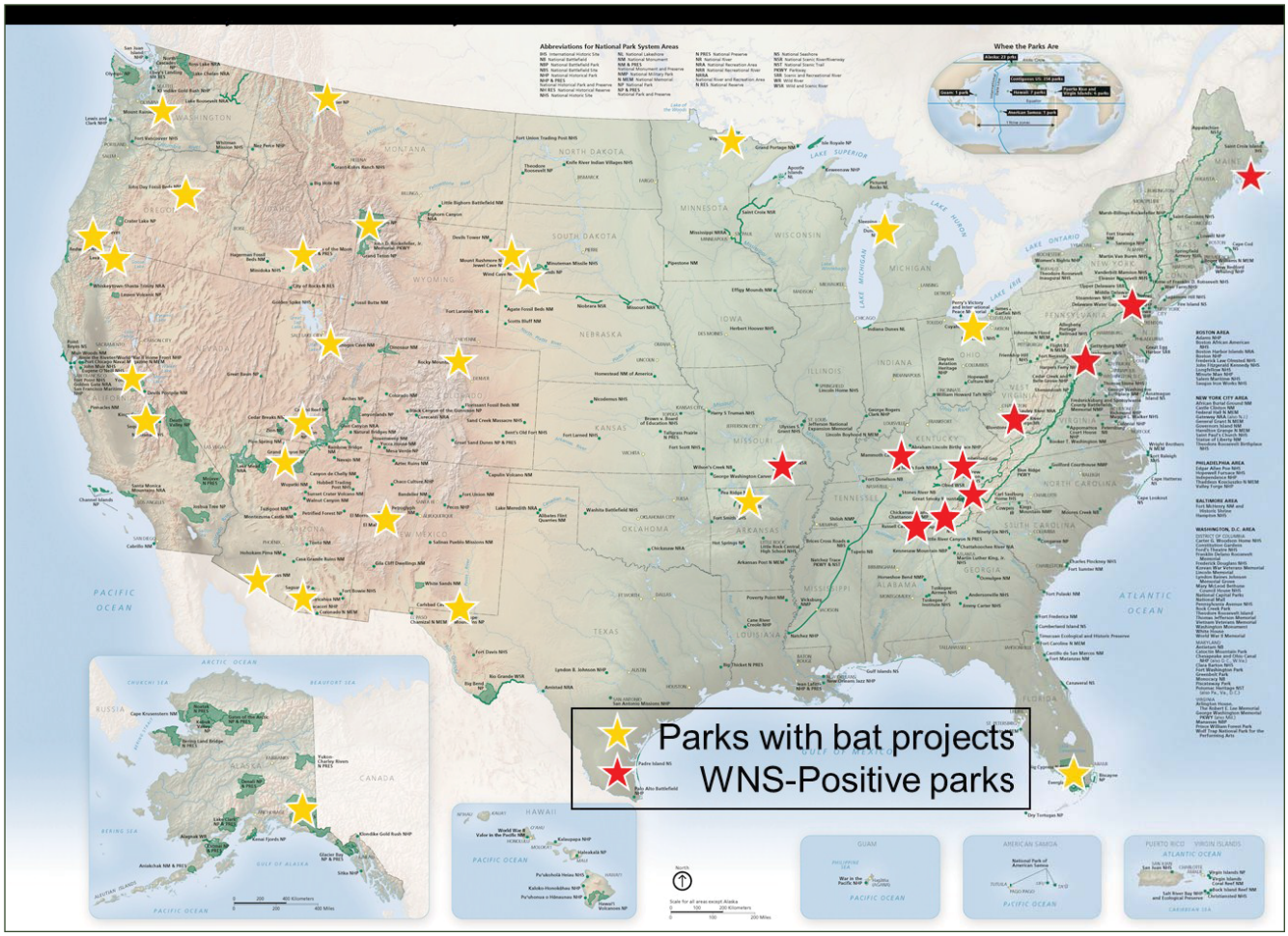
WNS and the National Park Service

NPS manages over 84 million acres in 401 units. Nearly one in four NPS units have caves, and one in three contains mines that can provide habitat for bats and other organisms. Nation-wide about 40 species of bats occurs in NPS units, including seven species that are federally listed as threatened or endangered, and numerous other species that are state listed. *P. destructans*, the causative agent of WNS has been found in or immediately adjacent to ten NPS units.

NPS units welcome over 270 million visitors per year and in many national parks in IMR, such as Carlsbad Caverns and others, caves are the primary attraction to visitors; in many more, caves are secondary attractions.

What are IMR Parks Doing About WNS?

- Parks with cave resources are updating their Cave Management Plans and using other means to minimize the risk of *P. destructans* spreading to their bat populations. These actions include providing extensive WNS education materials; screening visitors and gear; disinfection; and, when necessary, closing cave resources.
- Access to all NPS caves is restricted to those who hold appropriate permits or tour tickets. Show caves such as those located in Carlsbad Caverns National Park, El Malpais National Monument, Timpanogos Cave National Monument, and others remain open with precautions in place.
- The NPS Abandoned Mineral Land Program requires all inspectors,



NPS units with documented WNS and parks conducting bat research and conservation projects.

surveyors, and contractors to use new gear or to disinfect existing gear prior to working in NPS mines.

- NPS wildlife veterinarians are providing service-wide coordination on WNS surveillance and management, and partnering with other federal and state agencies in national coordination efforts.

Bat Conservation Projects and Activities in IMR Parks

Parks across the Intermountain Region are actively addressing pressing bat conservation issues by conducting state-of-the-art research to better understand bats, their habitats, and threats facing them. Below are highlights from a few of IMR's exciting studies.

Southeast Arizona Group

The Southeast Arizona Group, (Chiricahua National Monument, Coronado National Memorial, and Fort Bowie National Historic Site) is engaged in several projects related to monitoring of bat populations and restoration of bat habitats. They recently completed an intensive four-year study of federally endangered lesser long-nosed bats (*Leptonycteris yerbabuenae*) roosting in the State of Texas Mine. The study

Video camera locations used during bat surveys at the State of Texas Mine at Coronado National Memorial. Ellipses highlight video camera locations used to record bats as they exit and enter the mine. *(Credit: NPS)*

State of Texas gate to prevent human access while allowing bat passage in and out of mine at Coronado National Memorial. *(Credit: NPS)*

focused on evaluating the impacts of a "bat gate" that was placed at the entrance of the mine to prevent disturbances from illegal smuggling activities to a large communal bat roost. Researchers were concerned the design and construction materials may impede the movement of bats in and out of this important roost site.

This study was implemented according to criteria established by U.S. Fish and Wildlife Service, and used up to six strategically placed video cameras to record bats entering and exiting the mine. In addition, roost microclimates were monitored using data loggers. Researchers studied the bat gate's design to determine if unacceptable mortality rates of bats entering and exiting the closed mine were occurring. Results indicate this design is compatible with bat passage and bat populations fluctuate dramatically between years at this and other sites in the area.

Palmer's agave–an important food source for lesser long-nosed bats. *(Credit: NPS)*

Coronado also has a large-scale restoration project focused on propagating and transplanting Palmer's agave (*Agave palmeri*), a principle food source for lesser long-nosed bats. This project involves hosting large volunteer events and working with local schools and youth programs.

Chiricahua and Fort Bowie have also been engaged in long-term monitoring of bat species for a number of years. The study completed its 15th summer survey and fourth winter survey of bat species.

Researchers take measurements (left) of a Townsend's big-eared bat and swab a bat for fungus (right) at El Malpais National Monument. *(Credit: David Hays)*

With new threats such as WNS, the survey's focus and methods are shifting to create protocols, such as acoustic monitoring, for studying the species with minimal contact.

Devils Tower National Monument

During the summer of 2014, Devils Tower National Monument biologists initiated a new acoustic bat monitoring project. As with other similar studies at IMR parks, biologists used specialized equipment such as Wildlife Acoustics SM3© detectors to digitally record bat vocalizations. Monitoring data collected will be used to determine which areas of the monument are used by bats. Using specialized software, recorded calls are used to identify species using their unique patterns and frequencies. Management will use this information to guide the implementation and timing of future practices that could affect bat habitat; particularly decisions concerning forest management (e.g., mountain pine beetle mitigation, prescribed fire, etc.).

El Malpais National Monument

El Malpais National Monument, in northwest New Mexico, is prime habitat for cave-roosting bats, with 180 known major lava tube caves and numerous other cave-like features spread over the monument's diverse 114,000-acre volcanic landscape. At least a half-dozen resident species hibernate in the monument's caves during the winter.

The abundance of caves and cave-roosting bats in the monument, along with the threat of WNS, has prompted a multi-pronged approach to both cave and bat management and research at the monument. In December 2010, the monument halted all public access to caves as a preventative measure and to give staff time to develop a WNS response strategy. This also set in motion several research projects to establish baseline data about cave microenvironments, bat populations and colony locations, and a system for identifying caves that were appropriate for recreational visitation.

To investigate the ambient environmental conditions within the monument's lava

tubes, researchers Debbie Buecher and Dr. Diana Northup of the University of New Mexico deployed dozens of Hobo-brand "iButton" temperature and humidity dataloggers to multiple sites within twelve lava tube caves. As expected, they found that individual caves can harbor many very different microhabitats, including some that provided appropriate cool, moist conditions known to facilitate the growth of *P. destructans*. This is key information to assessing the risk that WNS may gain a foothold in specific caves with appropriate environments.

Soil sampling at El Malpais National Monument. *(Credit: Kenneth Ingham)*

To further investigate ambient conditions, researchers sampled soil and detritus within the lava tube caves at multiple locations for genetic analysis. Slow-growing, cold-temperature laboratory cultures from these samples provided invaluable genetic information that led to the identification of several close, possibly unnamed fungal relatives of *P. destructans*. Identifying these other endemic fungus strains may help researchers understand what makes *P. destructans* pathogenic. Scientists swabbed and cultured microbes from live bats roosting in caves and mist-netted at the surface. Preliminary results show a wide variety in the microbial fauna found on individual bats, as well as the microbes associated with different capture sites.

USGS bat biologist Dr. Ernest Valdez deployed a network of more than twenty solar-powered digital acoustic monitoring stations over a large area of the park's lava flows. These acoustic sensors will allow Dr. Valdez to development an occupancy model to show "hot spots" of hibernacula use, greatly helping monument staff prioritize areas for hibernacula surveys and bat population monitoring efforts.

During the summer of 2014, increased funding for WNS research and planning allowed the monument to continue and expand these existing research projects, while also funding needed technology and infrastructure improvements. These included gating one major hibernacula cave and installing a solar-powered, cellular-data-connected live Internet web camera to monitor a major bat colony. Monitoring was also expanded to a summer maternity colony. Two Student Conservation Association interns will be hired to perform winter bat hibernacula surveys in other unsurveyed cave sites. These and other research projects are ongoing to ensure that monument staff has the latest and most comprehensive scientific understanding of their fragile and vulnerable cave and bat resources.

Grand Canyon National Park

Biologists at Grand Canyon National Park are conducting on-going research to determine the spatial and temporal bat habitat use patterns in the park. Researchers use acoustic equipment placed at selected locations to record bat use during three seasons: warm (March, April, October, and

November), cold (December, January, and February) and hot (May, June, July, August, and September). By spreading the sampling across seasons, they can compare bat diversity and use throughout the year. Acoustic data is analyzed and compared with data from other monitoring stations to create a proportion of each bat species and the number of occupied days within each week. Biologists also capture bats during these same seasons. Where possible, they set nets across and adjacent to available water sources where bats tend to concentrate their activities. Nets are set one-half hour before sunset, capturing bats for four hours. Captured bats are identified to species, measured, weighed, and released.

Solar powered acoustic monitoring station in Grand Canyon National Park. *(Credit: Greg Holm)*

A bat night interpretive program at Timpanogos Cave National Monument where park visitors are seeing how biologists use bat detecting equipment for identifying and monitoring bats. *(Credit: Cami McKinney)*

Timpanogos Cave National Monument

Biologists at Timpanogos Cave National Monument are expanding their research to identify unknown roost sites in high cave ceilings, abandoned mines, and hydroelectric pipe tunnels using bat roost data-loggers. Park biologists are also netting bats every two weeks throughout the summer to document species use and activities in the American Fork Canyon. To improve visitor education regarding bats and WNS, an interpretive ranger conducts visitor and student programs about bats, focusing on their value to the environment, how to protect their habitat, and stopping the spread of WNS westward to IMR parks.

Flagstaff Area National Monuments

Because of regional geologic processes, a network of unique subterranean "earthcrack" fissures is located at Wupatki National Monument. Thirty-six earth crack openings are documented, and six are large enough for human exploration. Air currents move within an interconnected fissure system and are driven by atmospheric pressure fluctuations at unique "blowhole" openings. The blowholes are also affiliated with the unique archeological sites for which the monument was established to protect. During the 1970's, a survey and biological inventory of the largest earthcracks resulted in the discovery of two endemic *pseudoscorpion*

species (Muchmore 1981). These features are also used by bats, including the Townsend's big-eared bat (*Corynorhinus townsendii*), listed as a wildlife species of conservation concern (Bain 1986).

In 2014, researchers began conducting earthcrack surveys where little existing biological surveys or monitoring has been completed in the last 35 years. Biologists seek to gather information on bat use and other general information to better manage visitor access, identify any rare bats, assess the risk of WNS contamination, and better understand the earthcrack microclimate and potential changes related to global climate warming. Specifically, park staff and researchers will develop detailed maps of subsurface and earthcrack entrances, systematically inventory arthropod and bat fauna, acquire baseline microclimate data, and analyze sediment for presence of *P. destructans*.

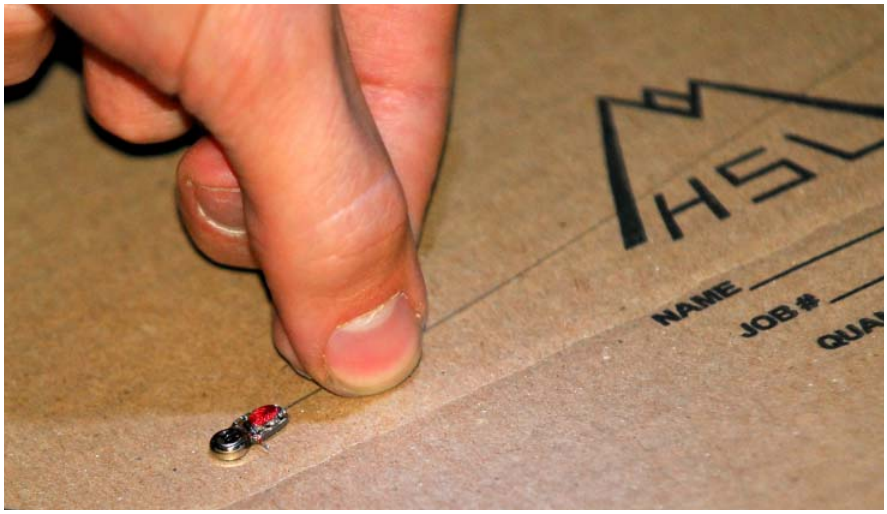
Because the monument's unique earthcrack fissure system is responsive to surface weather and essentially "breaths" surface air, these microenvironments may be altered by global climate warming. Microclimate data are desired to better understand earthcrack temperature zonation, potential surface air-mix zones, and to establish a baseline for monitoring potential climate-warming effects. Soil fungal spore assay data and microclimate data will be used to assess the risk of WNS spreading to the monument's earthcracks, and for advance planning to prevent or deter WNS infection in bat populations. These results will be used by the monument to better manage these unique caves and their resources in the future.

Yellowstone National Park

Yellowstone National Park is assessing its bat population and the potential impacts of WNS. The park is taking proactive measures by initiating a monitoring effort for the long-term management of bats. Biologists are describing the status, distribution, and roost locations of bat species in the park through mist-netting, radio-telemetry, and acoustic monitoring. Acoustic data provide important information on the distribution of bat species over a large spatial area, such as Yellowstone, and by combining mist-net survey data with acoustic sampling data, researchers are able to create a comprehensive assessment of bat species diversity, and habitat requirements.

From 2010 to 2013, bats fitted with radio-transmitters helped identify buildings in the park that serve as maternity roosts (sites where bats raise their young) for little brown bats (*Myotis lucifugus*). This species has experienced substantial declines in the eastern North America as a result of WNS. Because female bats show high fidelity to maternity roosts

Little brown myotis (*Myotis lucifugus*) roosting in a building attic in Yellowstone National Park. *(Credit: John Treanor)*



Temperature-sensitive radio transmitter used to track and monitor bats in Yellowstone National Park. *(Credit: John Treanor)*

across many years, there is a need to understand the consequences of excluding bats from buildings in the park.

Thermal conditions inside roosts affect the ability of adult females to successfully rear young. Researchers use temperature-sensitive radio transmitters to provide information on the thermal conditions of roosts used during pregnancy and lactation. These data describe the torpor patterns by species and reproductive condition, and help explain why bats select certain buildings for reproduction. Buildings that serve as maternity roosts and provide conditions that facilitate reproductive success may be essential for population recovery following declines caused by WNS.

Acoustic monitoring at the park provides baseline indices of bat activity by species, which researchers use to identify changes in species occurrence over time. Acoustic sampling in both summer and winter has been used to identify 11 species of bats in the park.

Together, data collected from each of these studies will help detect impacts to bats related to WNS and will improve the ability of bat populations to recover, should they experience the dramatic declines similar to those observed in the eastern United States and Canada.

Other bat research and conservation efforts in IMR Parks

- **Bryce Canyon and Zion National Parks**: Conducts bat monitoring using acoustic equipment and mist netting to assess bat species composition and changes over time and site characteristics.
- **Curecanti National Recreation Area:** Conducts species inventories for baseline data; site-specific surveillance to assess arrival, departure, and over-wintering bats; site-specific monitoring to determine baseline and unusual winter activity.
- **Glacier National Park:** Collects baseline data on species diversity, occupancy, arrival and departure, bat health, bat hibernacula, and migration corridor activity.
- **Organ Pipe Cactus National Monument:** Monitors known maternity roost sites for endangered lesser long-nosed bats, investigates activity patterns, and survey other potential roost sites. Monitors bats using mist net sampling at water sources to create an index of species presence and abundance.
- **Pipe Spring National Monument:** Determines seasonal use, temporal, and spatial distribution of sensitive bat species throughout the year including during migration pulses. Collects acoustic data, and traps, identifies, and releases bats to monitor populations.
- **Saguaro National Park:** Monitors two closed and gated mines and will develop and implement remote monitoring system for known roost of endangered lesser long-nosed bats in the future.

For more information please visit the following sites:

http://www1.nrintra.nps.gov/BRMD/WNS/index.cfm

http://nature.nps.gov/biology/wns/index.cfm

https://www.whitenosesyndrome.org/

http://www.nwhc.usgs.gov/disease_information/white-nose_syndrome/

http://www.batcon.org/index.php/what-we-do/white-nose-syndrome.html

NPS ShareNRSS SharePoint site:
http://inpniscvsp05:39904/brmd/wildlife/wns/Shared%20Documents/Forms/AllItems.aspx

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Bat facts

Did You Know?

- Bats are found throughout North America in all 50 states and elsewhere world-wide.
- There are over 1,100 species of bats which account for almost a quarter of the world's mammal species.
- More than one-half of American bat species are in severe decline or already considered endangered. World-wide over one-fifth of all bat species are considered threatened.
- Bats are the only mammals that can fly.
- Most bats are insect-eating machines. A single little brown bat can catch and eat up to 1,200 mosquito-sized insects in one hour.

Bats contribute to our rich biodiversity and well-being, through pollination, seed dispersal, insect control and other eco-services in rainforests, woodlands, wetlands, grasslands, deserts, and cities.

- Some bats can scoop up insects in their tail or wing membranes and then place them in their mouth.
- There are fruit-eating bats, nectar-eating bats, carnivorous bats (that prey on small mammals, birds, lizards and frogs), fish-eating bats, and blood-eating bats.
- Bats usually emit 20 calls per second when in flight. When pursuing prey, they can emit over 200 calls per second.
- Normally, bats hang head down; females giving birth reverse their position, so their heads are up.
- Most species of female bats give birth to only one young each year and this slow reproduction rate makes them exceptionally vulnerable to extinction.
- As temperatures decrease in the fall and the number of insects diminish, many bats migrate to their hibernacula in caves or mines for the winter. During hibernation a bat will reduce its body temperature, slow its heart rate to only one beat every four or five seconds, and rely on its stored fat reserves to survive until springtime.
- Loss of bats increases demand for chemical pesticides, can jeopardize whole ecosystems of other animal and plant species, and can harm human economies.
- Bat droppings in caves support whole ecosystems of unique organisms, including bacteria useful in detoxifying waters, improving detergents, and producing gasohol and antibiotics.

—Natural Resources—

Feature Program— Soundscapes and Night Skies

Starry, Starry Nights on the Colorado Plateau

By Nate Ament, Colorado Plateau Dark Sky Cooperative Coordinator, nathan_ament@nps.gov and Theresa Ely, Soundscapes and Night Skies Coordinator, IMR Natural Resources Division, theresa_ely@nps.gov

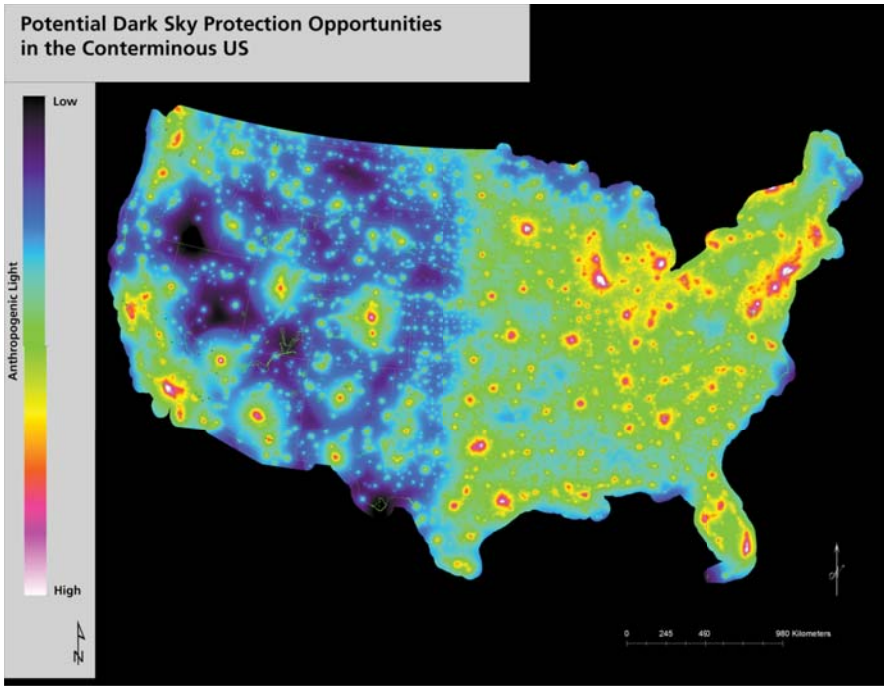
As the 100-year anniversary of the National Park Service in 2016 fast approaches, a Call to Action initiative, known as Starry, Starry Night, is focused here in the Intermountain Region. This initiative is gaining momentum with the support of employees from the Intermountain Region (IMR) Natural Resources Division, the Washington Office (WASO) Night Skies Team, and the Pacific West Region (PWR) Natural Resources Division as they collaborate with an exciting community and park-based engagement known as the Colorado Plateau Dark Skies Cooperative (Cooperative).

The volunteer-based Cooperative is promoting the preservation, enjoyment, and tourism potential of stargazing and astronomy in the region by providing community support for night sky events and projects that reduce light pollution, educating diverse audiences through hosting and participating in conferences, assisting with night sky park designation applications, distributing information to teachers for the classroom, and providing technical support to IMR parks.

The Colorado Plateau Dark Sky Cooperative logo.
(Credit: Dr. Tyler Nordgren)

The Cooperative focuses on the topographic heart of the high desert, forest, and canyon country where the Four Corners states meet. The 130,000 square mile Colorado Plateau, contains substantial parts of Utah, Colorado, Arizona, and New Mexico. The area's combination of high elevation, excellent air quality, low population density, and frequent cloud-free weather afford world-class viewing and enjoyment of naturally dark, star-filled skies.

As the public loses the experience of a dark night sky in their backyards, they are increasingly seeking it in areas like the Colorado Plateau. The unfettered view of the Milky Way, meteors, galaxies, and the impression of looking beyond our planet is being lost to outdoor lighting from distant cities and nearby towns. City lights produce sky glow that can be seen up to 200 miles away, while nearby glare sources can cause even greater impact. Natural darkness is rapidly being lost throughout the United States, but there are opportunities where a little effort can make a big difference. The Colorado Plateau is one such place.



Anthropogenic Light Ratio model that predicts light pollution levels for the continental U.S. *(Credit: NPS Night Skies Team)*

Community Support

Since 2011, WASO, IMR, PWR, and the Cooperative have fostered education and conservation partnerships with communities across the region. These partnerships include local governments, businesses, and organizations that work together to promote awareness of the impacts of light pollution and organize efforts to reduce it.

For example, the city of Springdale, Utah, working with the Cooperative, is presenting a series of six night sky events throughout 2014 in partnership with Zion National Park, local community members and business, and the St. George Astronomy Group. These free public events include educational talks, telescope programs, lunar viewing, and night sky photography instruction. The talks will also feature Springdale's progressive outdoor lighting ordinances and practices.

On the other side of the state, the town of Monticello will host a similar series of programs. Hosted by the Four Corners School of Outdoor Education and the Cooperative, these free events give participants of all ages an opportunity to enjoy astronomy programs under the naturally dark skies of southeast Utah.

Also in Utah, the town of Torrey is a proud sponsor of the annual Heritage Starfest, a two-day astronomy event which brings together the town, Capitol Reef National Park, the Entrada Institute, Wayne County, and visitors from all over the world. This year will be the 5th Heritage Starfest celebrating the dark night skies of the Colorado Plateau.

Bryce Canyon National Park has been dedicated to providing ranger-led astronomy programs to the public for 45 years. This year rangers will present 142 talks to bring the stars to visitors from around the globe. In addition, each year the park teams up with the Salt Lake Astronomical Society, other volunteers, and local businesses to host its annual Astronomy Festival: an astronomy event like no other. Astrotourism is a significant boost to local economies around Bryce. In 2012, the park estimated 50,000 astronomy-related visits, with an economic impact of $2 million to the local economies.

Flagstaff, Arizona, the world's first International Dark Sky City, leads the way in lighting practices and technologies on the Colorado Plateau. Local dark skies groups (http://www.flagstaffdarkskies.org/) and the Lowell Observatory located in Flagstaff (www.lowell.edu) are key partners with the Cooperative that engage the community and area parks to protect dark night skies.

The Milky Way soars over the 2013 Bryce Canyon Astronomy Festival, where visitors can peer into dark skies through over 50 telescopes. *(Credit: Geoff Goins)*

Dark Skies and Emerging Technology Summit

On August 18-20, 2014, the Lowell Observatory, the City of Flagstaff, The Keystone Center, and the Cooperative hosted "Blinded By The Light: A Summit and Call To Action To Protect Our Night Skies." This conference sought to find plausible solutions to the growing threat of light pollution from the popular white and poorly-filtered LED outdoor lighting widely used in this region. The Summit attracted a broad set of participants including: local planners, traffic engineers, policy makers, scientists, the outdoor lighting and advertising industries, National Park Service staff, public and tribal land managers, commercial real estate developers, members from the oil and gas and mining industries, and community leaders and activists. The

Casa Rinconada at Chaco Culture National Historical Park *(Credit: Dr. Tyler Nordgren)*

summit included extensive education and discussion on the significance of good lighting choices to the region, the nation, and the world, and provided a set of practical tools to protect dark night skies in our parks and communities. For more information, please visit www.keystone.org/darkskiesconference.

International Dark Sky Parks on the Colorado Plateau

In 2007, Natural Bridges National Monument in southeast Utah was the first park in the world to be designated by the International Dark Sky Association (IDA) as an International Dark Sky Park.

International Dark Sky Parks are parks or other public lands possessing exceptional starry skies and natural nocturnal habitat where light pollution is mitigated and natural darkness is valued as an important educational, cultural, scenic, and natural resource.

More recently in 2013-2014, Chaco Culture National Historical Park and Grand Canyon-Parashant National Monument were each awarded the designation of International Dark Sky Park and both celebrated these events with collaborators and visitors, showcasing the amazing nightscapes of the parks. The Cooperative continues

Chaco Culture International Dark Sky Park, is the fourth NPS park awarded this honor (2013). *(Credit: Dr. Tyler Nordgren)*

to support IMR parks by assisting them in developing their applications to gain this recognition. Parks given the award receive widespread international attention, and often increased visitation due to their conservation efforts and dark skies.

Education

The Cooperative believes that night sky awareness and education is crucial to the preservation of natural darkness. There are many opportunities to invite people out under the stars, and the Cooperative supports the efforts of these and other partners to spread the night skies message:

- In 2013, in partnership with the NPS Night Skies Team, the Cooperative hosted a four-day workshop in Moab, Utah, for astronomy and night sky program presenters. Twenty-six interpreters and educators from across the western United States learned how to effectively guide participants through the cosmos above our heads.
- The Cooperative provides outreach and educational materials to regional guides and outfitters to teach their customers about the stars. This year, with help from Dr. Tyler Nordgren (University of Redlands), the Cooperative provided training and materials to the Grand Canyon River Guides at their annual meeting, creating the potential to reach as many as 17,000 commercial river passengers per year.
- At the 2013 Biennial Conference of Science and Management on the Colorado Plateau, the Cooperative hosted the first Night Skies Symposium and spread the word about new research and efforts in dark skies conservation.
- The Cooperative fosters partnerships between parks and local astronomy groups such as the Black Canyon Astronomical Society, the St. George Astronomy Group, and the Salt Lake Astronomical Society. These partnerships increase the IMR parks' abilities to host night sky programs and events.

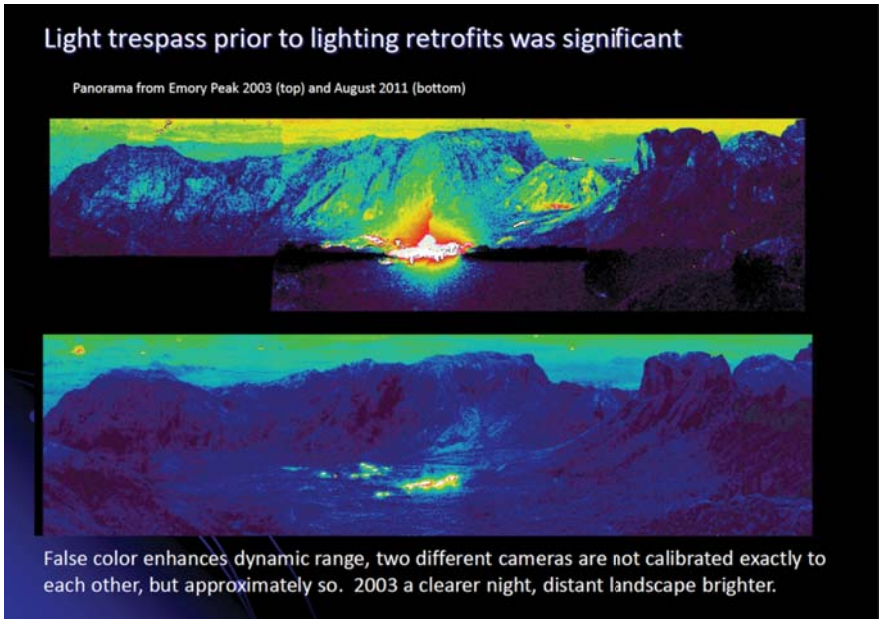
- The Cooperative teams up with schools and educational organizations including the University of Utah Astronomy program, Four Corners School of Outdoor Education, and Global Explorers to promote astronomy classes, activities, and curricula that can be used by teachers in classrooms from elementary schools to college levels.

For a full schedule of night sky educational events on the Colorado Plateau, please visit www.nightskyparks.org.

River by day, Milky Way by night, dark skies sail overhead of a commercial river trip on the San Juan River in Utah. *(Credit: Dr. Tyler Nordgren)*

Encouraging Common Sense Ways to Think About Outdoor Lighting

Essential to addressing the environmental and economic impacts of unnecessary outdoor lighting are several general lighting principles. In designing, selecting, and operating outdoor lighting, these six universal guidelines can achieve the goal of night sky protection in parks, businesses, and communities. These mitigations are intended to be reviewed sequentially, and used in concert with one another. They are, in order:



Change in observed glare and uplighting due to night-sky-friendly lighting retrofit, Chisos Basin, Big Bend National Park. *(Credit: NPS Night Skies Team)*

1. Light only **WHERE** you need it;
2. Light only **WHEN** you need it;
3. **SHIELD** lights and direct them downward;
4. Use the **MINIMUM AMOUNT** of light necessary;
5. Select lamps with **WARMER COLORS**; and,
6. Select the most **ENERGY EFFICIENT** lamps and fixtures.

Training to Support Fully Sustainable Outdoor Lighting in IMR Parks

From 2014 to 2017, the Cooperative, the NPS Night Skies Team, Grand Canyon National Park (GRCA), and the IDA (through a cooperative agreement) will embark on a multi-year effort to elevate the capacity of parks to effectively evaluate outdoor lighting, attend training events, and install fully shielded, lower wattage sustainable lighting. This work will address the degree of unsustainable outdoor lighting in parks, and introduce the solutions developed through short-term projects at GRCA and other locations.

Overall, this project will train and empower parks to evaluate their outdoor lighting and successfully plan for installing lighting that is effective but still preserves the night sky. Ultimately, parks and their surrounding areas will enjoy darker skies and unfettered views of the cosmos.

Shielded lighting, reduced bulb wattage, and warm colored bulbs at Chisos Basin in Big Bend NP allow for reduced glare, substantial reduction in energy use and associated cost savings, and the ability to see the dramatic landscape and night skies. *(Credit: NPS Night Skies Team)*

Skyglow from energy development in the Permian Basin near McDonald Observatory in west Texas. *(Credit: Bill Wren)*

Guidance for Energy Development Lighting

Energy development in rural and remote lands has the potential to impact the nighttime scene, even at large distances. Direct glare and sky glow from these facilities may degrade the natural lightscape, lessen the view for stargazers, affect those seeking a wilderness experience, and impact nocturnal wildlife.

In 2013, the NPS and the Cooperative had the opportunity to collaborate with the BLM Field Office in Moab by advising them on Best Management Practices (BMPs) for their new Master Leasing Plan relating to oil and gas development. These BMPs have identified several opportunities where modest changes to equipment and practices can substantially improve the nighttime resource. For example, the BMPs including interim best lighting practices are an intended first step in mitigating environmental impact from artificial lighting. The BMPs will also serve as a model and foundation for future leasing and oil and gas development plans on public and private lands.

Direct Support to IMR

In addition to supporting communities and other agencies, the Cooperative directly assists IMR parks by:

- Supporting expanded night sky interpretive programs and events in the parks
- Assisting with applications for the International Dark Sky Park designation
- Advising parks when determining night sky impacts of energy development
- Assisting parks with planning large events on public lands in order to mitigate any impacts to natural darkness
- Aiding in the development and testing of lighting inventory protocols
- Assisting in selecting fully shielded and sustainable lighting for new park projects and lighting retrofits
- Assisting parks when seeking funding for enhancing night sky interpretive and lighting projects.

Telescopes stand ready to guide participants through the stars at an NPS-sponsored astronomy event. *(Credit: Debbie Biddle)*

Acknowledgements

The Cooperative's progress toward preserving the night skies of the Colorado Plateau would not be possible without support from the NPS Night Skies Team, Bill Dickinson (Superintendent, Lake Mead National Recreation Area) and Judy Rocchio (Dark Night Skies, Pacific West Region). Bill Wren's (Special Assistant to the Superintendent, McDonald Observatory) work with the oil and gas industry near McDonald Observatory has helped us make significant headway in empowering energy development to curb excessive lighting. The National Parks Conservation Association (NPCA) continues to promote night skies conservation and education across the Southwest United States and beyond. And finally, the Cooperative would like to thank the many individuals, communities, businesses, agencies, and organizations of the Colorado Plateau who are the ultimate key to success in preserving night skies.

For Further Information Please Visit:

Colorado Plateau Dark Sky Cooperative on Facebook

NPS Night Skies Program: www.nature.nps.gov/night/

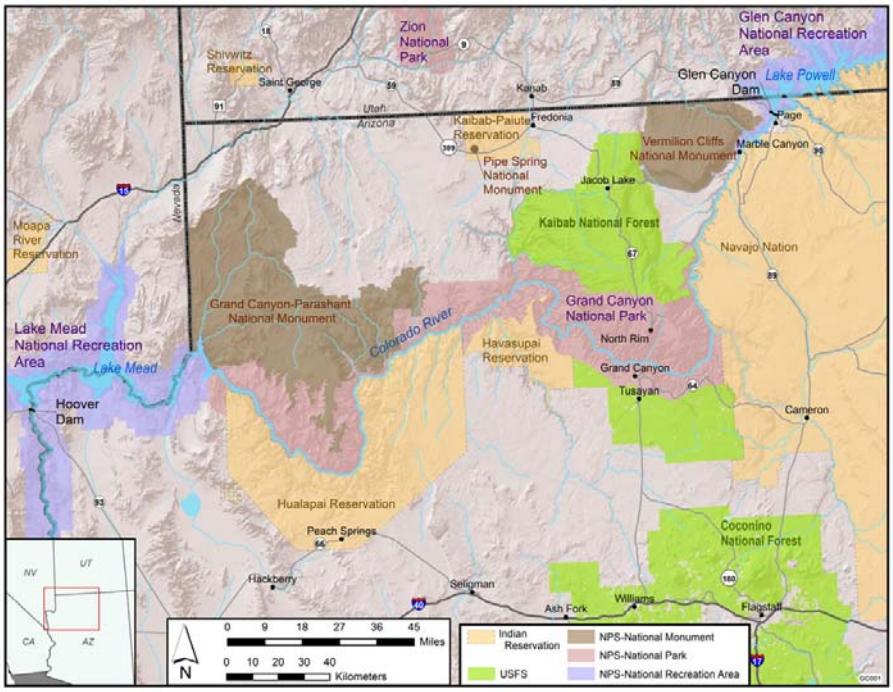
International Dark Sky Association: www.darksky.org/

Exploring Uncharted Waters: Glen Canyon Dam EIS

By Rob Billerbeck, Colorado River Coordinator, rob_billerbeck@nps.gov and Jenny Hauer, Colorado River Biological Science Technician, jennifer_hauer@nps.gov

In 2011, the National Park Service (NPS) began working with the Bureau of Reclamation (BOR) on an Environmental Impact Statement (EIS) for the operation of Glen Canyon Dam on the Colorado River. The dam operations affect a 15-mile stretch of Glen Canyon National Recreation Area and 277 miles of Grand Canyon National Park, and to some extent, a portion of Lake Mead National Recreation Area. This process has been unique and interesting for the NPS in the following ways:

1. The NPS is a co-lead agency with the BOR in a non-delegated Department of Interior process.
2. The DOI established an Adaptive Management Working Group which includes diverse stakeholders and tribes affected by dam activities. NPS and BOR have been working closely with these stakeholders every step of the way.
3. The NPS and BOR have used a Structured Design Analysis process and computer simulation models for many aspects of this process. This process is new to the NPS but other government agencies and the military have used it successfully in the past.



LTEMP EIS project area map. *(Credit: Argonne National Laboratory)*

Completed in 1963, Glen Canyon Dam has a long history and a high level of scrutiny that past planning processes have been subjected to. This time there has been a strong desire from the beginning to conduct this process with the best available science, strong engagement with stakeholders, and transparent decision-making. This article will explain how the NPS and BOR have approached this process to try to achieve these goals while providing information that will be valuable to others who may undergo a similar process in the future.

Many people are familiar with the rich history of debate and the high interest across the Western United States regarding the Glen Canyon Dam. Authorized by Congress

2013 Glen Canyon Dam high flow event. *(Credit: BOR)*

in 1956, the Glen Canyon Dam on the Colorado River was completed in 1963. The dam provides water storage, flood control, hydroelectric power, and recreation; but dam operations also have fundamentally altered the river ecosystem, Grand Canyon National Park, and Glen Canyon National Recreation Area. Concerns related to impacts on downstream riparian ecosystems, recreation, and endangered fish were the primary drivers for the passage of the 1992 Grand Canyon Protection Act (GCPA) and a subsequent 1995 EIS and 1996 Record of Decision (ROD) that resulted in significant changes to the operation of Glen Canyon Dam. The GCPA provides a unique legal foundation to dam management as this law requires that the dam be operated to protect, mitigate and improve downstream resources in Glen Canyon National Recreation Area and the Grand Canyon National Park while still complying with all relevant water delivery laws, compacts, and treaties. Although there have been many smaller planning processes, primarily in the form of Environmental Assessments, this current planning effort is the first major comprehensive look at the effects of dam operations since 1996.

In July of 2011, the Secretary of Interior began the Long-Term Experimental and Management Plan (LTEMP) for Glen Canyon Dam with a Notice of Intent. This is a non-delegated process which means the Secretary of Interior will make the final decision by signing the ROD after finalization of the EIS.

The Secretary decided to have NPS and BOR work together as co-leads in preparing the LTEMP. BOR has the primary responsibility for operating Glen Canyon Dam, and the NPS has the primary responsibility for visitors and conservation of the resources in Grand Canyon National Park, Glen Canyon National Recreation Area, and Lake Mead National Recreation Area. This is unique because it may be the first time that the NPS has been a co-lead rather than a cooperating agency on a planning process related to a dam. Having co-lead agencies with different missions heading a complex process is not always easy, but it creates a situation where there is a great deal of conversation between the leads about many more aspects of the process. The NPS experience has been that the dialog ultimately increases the thought behind each and every step and improves the quality of information shared with cooperating agencies, stakeholders and the public.

In order to best evaluate the extensive issues related to the dam as well as an unusually large amount of scientific studies , it is worth noting that there are still scientific uncertainties, primarily regarding sediment and fish, that remain to be addressed. One of the major concerns has been that the dam prevents more than 90 percent of the

sediment from flowing down the Colorado below the dam (GCDAMP 2013). That sediment is, of course, what provided the red color that gave the Colorado River its name (in Spanish, colorado means ruddy), but now the water below the dam runs mostly clear. Side tributaries such as the Paria River and the Little Colorado River are now the major sources of sediment input below the dam and dam operations affect whether that sediment is deposited or eroded. Since the sandbars and open sand beaches were the defining features and habitat at the bottom of the Grand Canyon prior to the dam, trying to manage the dam for more deposition than erosion has been a major concern for the NPS. Additionally, the endangered Humpback Chub is a major consideration in dam management and a concern for NPS and many other stakeholders. Cultural resources (including tribal concerns), changing vegetation along the river corridor, a rainbow trout fishery, river rafting recreation, and the hydropower produced by the dam are also major considerations related to dam operations. Many complex interactions among these resources exist in the physical as well as political realms.

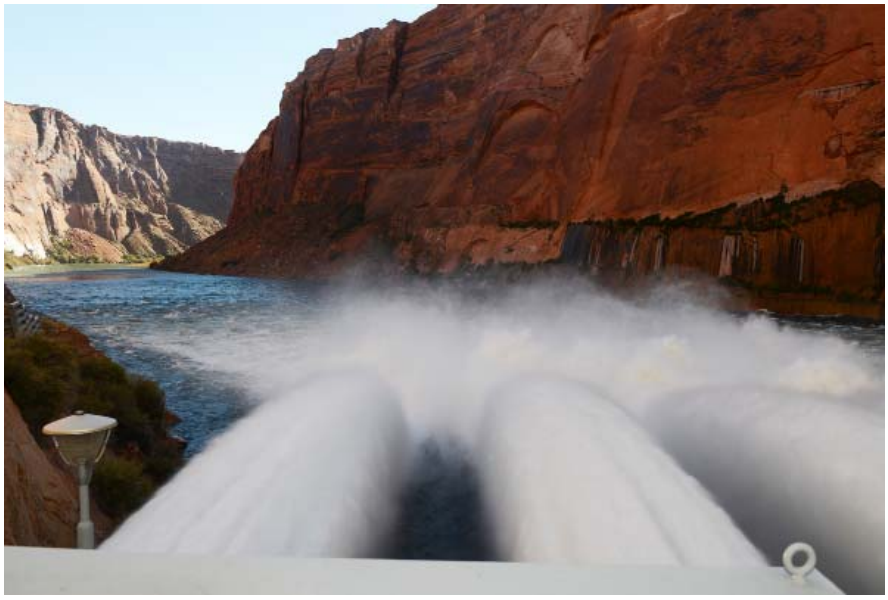
The Endangered Humpback Chub (Gila cypha). *(Credit: George Andrejko, Arizona Game and Fish Department)*

Boaters running Lava Falls Rapid in Grand Canyon National Park. *(Credit: NPS)*

Aside from working as co-lead agencies, another unique aspect of this project is the existence of a federal advisory group related to the dam that is part of the Glen Canyon Dam Adaptive Management Program (GCDAMP). The GCDAMP was established by the Department in the 1996 Record of Decision on the Operation of Glen Canyon

Aerial photo of Glen Canyon Dam. *(Credit: BOR)*

Dam, in order to comply with monitoring and consultation requirements of the GCPA. The GCDAMP includes a Federal advisory committee known as the Glen Canyon Dam Adaptive Management Working Group (AMWG; BOR 2008), a technical working group, a scientific monitoring and research center (U.S. Geological Survey's Grand Canyon Monitoring and Research Center (GCMRC) which is a group of scientists dedicated to studying the impacts of the dam), and independent scientific review panels. The AMWG makes recommendations to the Secretary concerning Glen Canyon Dam operations and other management actions. The AMWG is made up of stakeholders from the seven Colorado Basin states, power industry entities, federal agencies including the BOR, NPS, U.S. Fish and Wildlife Service (USFWS) and Bureau of Indian Affairs, several tribes, and environmental and recreational groups. This group meets several times a year and has lively debates related to the dam and the budget for GCMRC that conducts most of the scientific research related to the dam. Since this project was announced, the Secretary and the Assistant Secretary for Water and Science have called for a close working relationship between federal agencies, the AMWG and stakeholders in



2013 Glen Canyon Dam high flow event. *(Credit: BOR)*

this EIS process. Many of the stakeholders are cooperating agencies and have been very involved with monthly meetings throughout the process.

The NPS and BOR have also created a number of opportunities for the AMWG and stakeholders to collaborate in the process by providing input on action alternatives, objectives and performance metrics, and viewing early modeling results. The co-leads are also taking additional steps to ensure that tribes are able to provide meaningful and valuable input to the EIS draft related to tribal perspectives on a number of issues. Providing additional steps for input beyond those required by the National Environmental Policy Act (NEPA) is not quick or simple, but the hope is that this additional coordination, with this diverse group of stakeholders, has increased understanding and knowledge about the process that will produce a better LTEMP as a result.

The AMWG was established to help provide an adaptive approach to the dam management in coordination with the USGS scientific group, GCMRC, but adaptation in this complex and challenging situation has proven difficult. Adaptive management is intended to facilitate decision making that assists with resolving uncertainties that impede effective management (William and Brown 2012). Adaptive management can be useful in cases where natural resources are responsive to management, but there is also uncertainty about the impacts of management

2013 Glen Canyon Dam high flow event. *(Credit: BOR)*

A commercial raft trip on the Colorado River passes Cardenas Creek in Grand Canyon National Park. *(Credit: NPS)*

interventions. This approach has been employed since the 1995 EIS. In recent years, two Environmental Assessments analyzed new fish management tools and the regular and frequent use of high flow experiments for sediment conservation. Those processes introduced the use of an approach called Structured Decision Analysis (SDA) to the Glen Canyon Dam dialog (Runge et al. 2011).

Given the complex resource interactions, the scientific uncertainties, and the diverse interests of various stakeholders involved, the Department of Interior decided to use SDA to enhance aspects of the LTEMP EIS analysis. SDA draws from the well-established field of decision analysis to provide quantitative tools to support decision makers in the framing, analysis, and communication of their decisions. SDA is somewhat new to NPS and BOR for NEPA projects; however, it has been applied by other agencies, particularly the military and the USFWS. Adaptive management is a special form of SDA, with special emphasis on iterative decisions that take uncertainty and the potential for learning into account (USFWS 2008; Williams et al. 2009; Williams and Brown 2012).

SDA identifies and evaluates alternatives by engaging stakeholders, experts, and decision makers in a decision-oriented analysis and dialogue. Typically decision-making begins with a problem that has already been specifically identified. SDA differs in that it invites group members at the start to identify the problem to be solved (Wilson and Arvai, 2011). Many of the problematic issues in the participatory decision-making process are due to a lack of an approach that helps diverse stakeholders

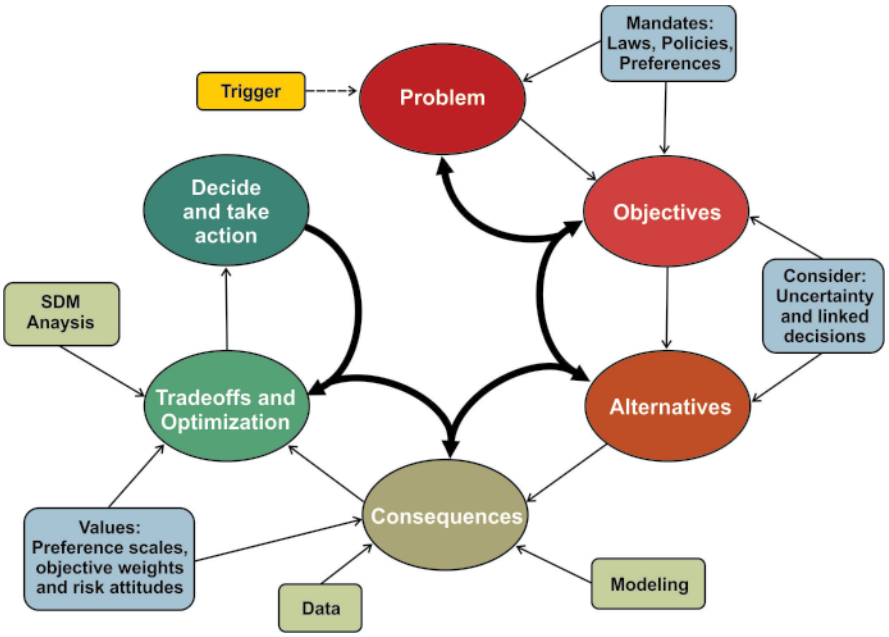
understand the problem, express and clarify their values and concerns, and carefully weigh the pros and cons of different actions or options. Wilson and Arvai (2011) state that efforts that fail to address diverse concerns often leave participants believing that the process is not responsive to their interests, and that the opinions of technical experts dominate those of the participating community and stakeholders.

To alleviate those problematic issues in this LTEMP process, the project team worked closely with Michael Runge (USGS), an expert in SDA. Dr. Runge invited stakeholders to help identify issues, objectives, and possible performance measures to approach those objectives using a variety of methods. This involves extensive work with modeling and technical experts for quantitative approaches and many meetings with stakeholders, and particularly with tribes, to try to match potential modeling or quantitative approaches to their values, concerns and objectives. After more than a year of effort, models which provided a strong set of quantitative measures for sediment, fish, cultural resources, vegetation, recreation, hydropower, and tribal interests became available. The SDA process also provided a logical framework to capture major scientific uncertainties from scientists and experts and to identify hypotheses for the response of important resources to dam operations. There was an extensive modeling effort conducted that will form a major part of the impacts analysis of this project. The use of SDA in this process has required more time and effort, but it has been value-added to the LTEMP EIS process. It has a provided an objective, impartial way to use the best available science and provide comprehensive modeling results, though those results are subject to many limitations and assumptions.

View of River Mile 81 taken after the high-flow experiment on April 6, 2008. *(Credit: Roderic Parnell, Northern Arizona University)*

Most recently Dr. Runge has led the co-lead agencies and the stakeholders through a process to develop weights for the objectives that reflect the values, policies, and missions of the individual stakeholders. Through a process called multi-criteria decision analysis, these weights are combined with the analytical results from modeling to rank the alternatives in relation to different scientific uncertainties. Decision analysis tools have been used to calculate the value of information for resolving scientific uncertainties. This process is rich with information and is providing guidance on the experimental design for this process.

This unique planning process is still on-going and the NPS and BOR plan to produce a public draft EIS this fall. The NPS is happy to share information with others within NPS on any of the unique aspects of this process.



Schematic representing steps included in a Structured Decision Analysis Process. Adapted from an original diagram by Jean Fitts Cochrane. *(Credit: USFWS, 2008)*

Grand Canyon Protection Act of 1992 (Reclamation Projects Authorization and Adjustment Act of 1992, Title XVIII – Grand Canyon Protection, §§ 1801–1809, Pub. L. No. 102-575, 106 Stat. 4600, 4669).

The Secretary shall operate Glen Canyon Dam in accordance with the additional criteria and operating plans specified in section 1804 and exercise other authorities under existing law in such a manner as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established, including, but not limited to natural and cultural resources and visitor use (GCPA § 1802[a]).

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—NPS Submerged Resources—

Revisiting the *Charles H. Spencer*

By Susanna Pershern, A/V Production Specialist, susanna_pershern@nps.gov

It is early spring of 2014 in Glen Canyon National Recreation Area (GLCA), and Jim Bradford, IMR Regional Archeologist and collateral NPS diver for the Submerged Resources Center (SRC), stands tall in his drysuit, taking notes on waterproof paper clipped to a slate propped against the remains of the partially submerged paddlewheel steamboat, *Charles H. Spencer*. In 1986, nearly 26 years earlier, Bradford was part of the SRC team that undertook initial field work to document this vessel, one of the last steamboats to be part of the search for gold in the banks of the Colorado River and an important vestige of the placer gold era along the Colorado River corridor. Bradford spent ten days mapping the area, and now he and a new dive team have returned to the site because there is concern that the *Charles H. Spencer* is in jeopardy.

IMR Archeologist Jim Bradford, noting changes to the wreck on a slate with waterproof paper in March of 2014. *(Credit: Susanna Pershern)*

Toni Carrell and Jim Bradford documenting the Lee's Ferry Mining District in 1986. *(Credit: NPS)*

At the dawn of the twentieth century, when the distant portions of a new country remained largely unknown to many, the Colorado River and the surrounding Grand Canyon constituted a formidable obstacle to westward migration.

The barrier was only breached in a few points and the owner and operator of Lee's Ferry, John D. Lee, predictably attracted the attention of a diverse array of individuals. Some were passing through and some were more intent on what the land might offer at that spot.

One such individual, the charismatic mining entrepreneur, Charles Spencer, saw the lower bedding planes of the exposed Chinle shale and immediately thought of gold. In order to mine for gold in this location, Spencer needed a way to transport supplies and coal from a seam at Warm Creek to Lee's Ferry; he chose to use a paddlewheel steamboat that was ideally designed to operate in shallow water. The vessel that was to bear his name was ordered, pre-built, and then disassembled for shipping in San Francisco. From San Francisco it traveled by train to Marysvale, Utah, then it was hauled by oxcart to the mouth of Warm Creek. Here, it was assembled for its inaugural voyage on the Colorado River in the spring of 1912. What Spencer did not know, nor could he have known, was that while the Chinle formation did contain gold, it also contained the rare earth element rhenium that rendered gold extraction commercially untenable. By the end of the summer, Spencer's dream had crumbled, and his crew docked the steamboat, never to sail again. The steamboat remained in situ, succumbing to the elements sometime after 1915. Today it sits, at the bottom of the Grand Canyon, a unique part of a larger historical mosaic found along the red canyon floor.

The *Charles H. Spencer* in 1921. *(Credit: BOR)*

In 1963, the floor of the Colorado River began to change with the completion of the massive Glen Canyon Dam. Managed by the Bureau of Reclamation (BOR), the dam was built to provide hydroelectricity to the west, regulate the erratic flows of the upper Colorado River, and to store water in case of times of drought. Damming the mighty Colorado led to major physical and ecological changes in the lower river by preventing the natural flow and deposit of sediment downstream, thus causing natural sandbars and habitat to disappear, and river banks to crumble. Beginning in 1996, the BOR, working with partner agencies, began to change the way they released water from the dam. By conducting periodic high flow events (HFE), the goal was to simulate the natural flooding of the upper river and to restore habitat throughout the Grand Canyon by redistributing the sediment that travels downstream from below the dam. Over the years, the number of the HFEs increased and in 2012, concern arose over how the redistributed sediment would affect the *Charles H. Spencer* and its surroundings. The vessel sits on the riverbed just 15 miles south of the dam, near the mouth of the Paria River where large amounts of sand are deposited in the confluence. In light of this, the BOR agreed to budget for initial site documentation and to the creation of a comprehensive long-term monitoring protocol, including the establishment of park-based capacity for ongoing monitoring.

Jessica Keller and Dave Conlin survey the remains of the *Charles H. Spencer* from the surface. *(Credit: Susanna Pershern)*

In March of 2014, after two years of planning, the SRC arrived onsite with a truck full of supplies: dive gear, copper and aluminum rods, steel pipe and end caps, and an eight foot section of 2" pipe, and decades of experience mapping underwater archeological sites. They met with the GLCA Dive Officer, Pat Horning, who had already hauled down to Lee's Ferry 20 steel SCUBA cylinders from park headquarters in Page, Arizona. They also met Lee's Ferry LE Ranger Peggy Kolar, who handed over the keys to GLCA Vessel #2, a squirrely jetboat built specifically for maneuvering in rivers with shallow sandbars. With everything in place, the next morning they set out to see what had changed in the last 26 years.

Still visible both above and below the surface, the boiler is a prominent feature of the wreck. *(Credit: Susanna Pershern)*

Downstream from Jim Bradford is a team of SRC divers suiting up into drysuits to prepare for their first dive. Among their ranks is Dave Conlin, SRC Chief; Jessica Keller, SRC Archeologist; Susanna Pershern, SRC photographer; and Jim Koza, SRC volunteer and retired diver from the Lake Mead Dive team. Koza is eager for the dive to begin. Like Bradford, Koza partcipated in the 1986 mapping project and has not seen the wreck for a quarter of a century. Everyone else on the team is excited to learn what has changed in the eyes of veteran divers.

Bradford, Keller, Pershern enter the water for the initial assessment. At 46 degrees, the water is shockingly cold despite the thermal protection of drysuits and 7mm hoods, even though they are only, at most, fifteen feet below the surface. However, the "ice-cream headache" abates as the water in their hoods warms up. The divers adjust their buoyancy to hover above the sediment, which is easily disturbed with the slightest fin-kick, and get to work. Keller and Bradford carry the original plan view map copied on waterproof paper and fastened to slates

with duct tape. They note changes to the structure of the site on the original map that Bradford helped create almost thirty years ago. At the same time, Pershern photographs the entire structure to make a photomosaic that will supplement the updated map the archeologists will create to show the changes to the wreck since 1986. Meanwhile, Conlin and Koza make their dive to survey the riverbed sediment to determine how best to precede with the sediment monitoring protocols they have in mind. After thirty minutes in the cold water, the team has a good idea of the work required in the next few days of diving. They surface, remove their gear, and warm up in the cozy Arizona sun.

The initial reconnaissance dive revealed that the wreck was well protected by the sediment, and Bradford's measurements indicated that there were no major disturbances to the site. With his underwater mapping expertise, he and Keller efficiently document the wreck, despite the short dive times limited by the cold water. On their second dive, Conlin and Koza dive to set scour chains in two transects upstream and downstream of the site. The scour chains are set by threading the chain through a five foot piece of pipe, and pounding the pipe vertically into the riverbed. The divers then remove the pipe

Jim Koza and Dave Conlin install one of six scour chains that will measure sediment accretion and erosion on the site. *(Credit: Susanna Pershern)*

but keep a three-foot portion of the chain in the hole, which fills in and holds the chain in place. The remainder of the chain is exposed and lays flat on the surface of the sediment. After setting the scour chains, the divers attach a cattle tag to the chain to mark where the chain enters the sediment. If, in the future, sediment is depleted from around the site, more links of chain will show above the sediment, and vice versa if sediment is added. If the sediment levels remain the same, so will the number of visible links. This gives the SRC an easy and accurate method to calculate how much sediment is affected by the HFEs.

The SRC divers complete 35 short dives for a total of 16 hours underwater without incident or accident. The team installs six scour chains and two stainless steel datums that track sediment accretion and erosion. These methods are inexpensive to install and require minimal time in the future for monitoring. In addition, two sediment samples are collected from independent sites on the wreck that will be analyzed for grain size distribution and specific gravity. The entire project is documented both underwater and topside with images and video—similar to the 1986 project, without the need to make a daily trip into to Page, Arizona to get the film developed.

Using modern technology, this visit to the *Charles H. Spencer* resulted in the collection of hundreds of GPS points for monitoring datums, sediment samples, wreck structure and local topographic information that were collected using a total station. A total station is an electronic surveying instrument that can measure distances and slopes from the instrument to a point without needing a reflector. In coordination

Submerged Cultural Resource Unit team members conducting the initial assessment of the *Charles H. Spencer* in 1986. *(Credit: NPS)*

Jim Koza observing how to survey with a plane table in 1986. *(Credit: NPS)*

Jim Koza and Jim Bradford, original members of the 1986 team, working together again on the *Charles H. Spencer*. *(Credit: Susanna Pershern)*

GLCA Staff Thann Baker, Archeologist, Ted Neff, Compliance Archeologist and GLCA intern Jordan Judon take GPS points on the wreck with a total station unit in 2014. *(Credit: Susanna Pershern)*

with GLCA staff, Archeologist Thann Baker, Ted Neff and Jordan Junod, the information accumulated in a single afternoon with the total station is staggering in comparison to the rudimentary angles and distances that archeologists recorded in 1986 with a plane table. The total station data will be exported into multiple GIS layers that will be an important tool for long-term. Moreover, the GLCA archeological team is now familiar with the new monitoring stations on the steamboat and has a method to determine if there are changes to the site.

Jim Koza and Jim Bradford pose for a picture in front the Spencer's boiler. The project is over, and the team cleans the boat and gear, packs the truck, and returns Denver. Diving on a historic paddlewheel steamer in the spectacular Lee's Ferry Mining district is unforgettable, yet getting to be a part of history, in which two Park Service employees work together on the same site, a quarter of a century apart, is a career highlight for the younger members of the SRC. This is the human element that exists alongside the science-based research in the parks, and when they come together in such a project, history is both made and preserved. The *Charles H. Spencer* will continue to be an important reminder of the hard-working miners who lived a century before, and through the hard work of dedicated park service employees, this history and science will be shared with the general public unimpaired for future generations.

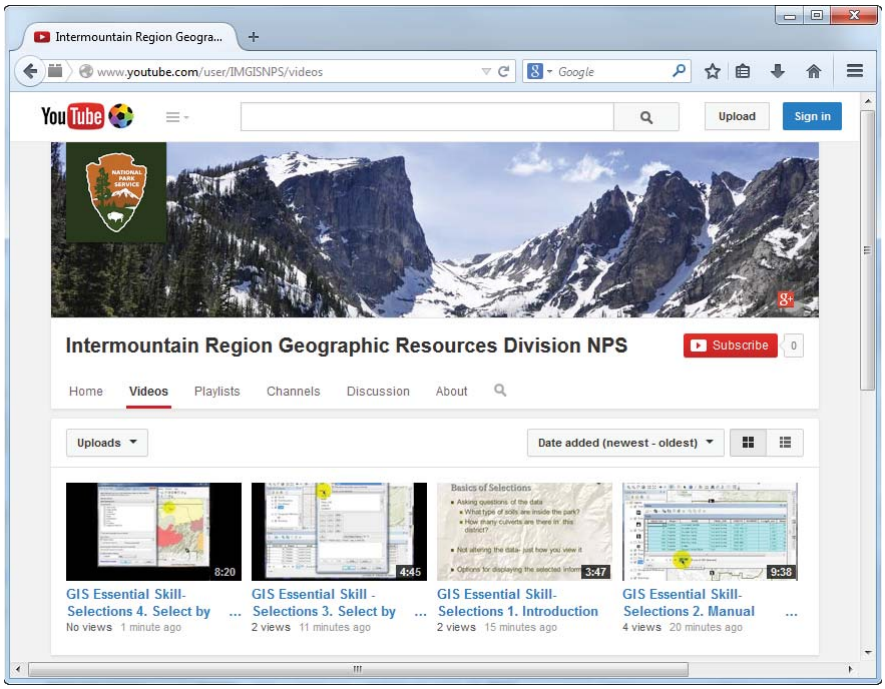
New Training and Resource Material from the Geographic Resources Division

By Victoria Smith-Campbell, GIS Specialist, IMR Geographic Resources Division, victoria_smith-campbell@nps.gov

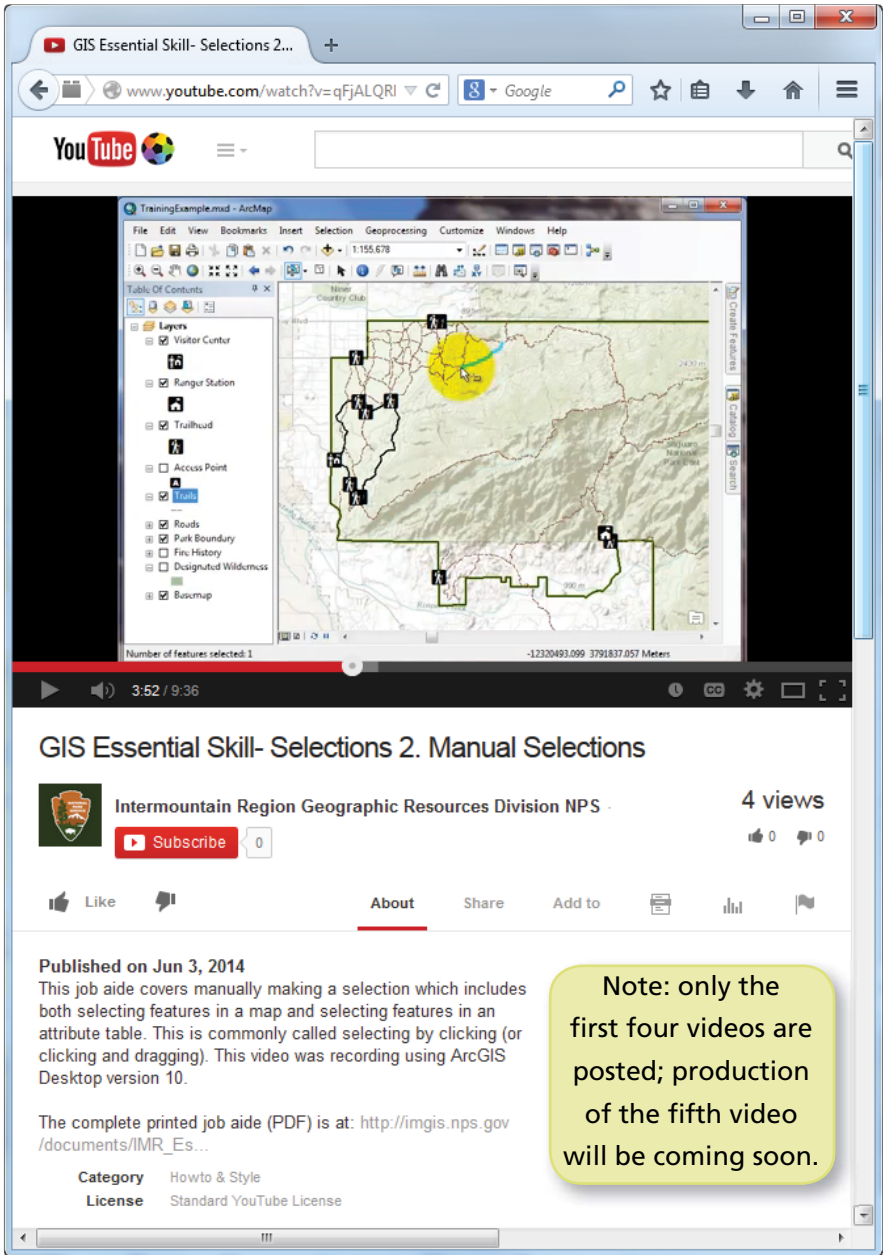
The Geographic Resources Division which specializes in geographic information systems (IMR GIS) is creating geospatial training resources to allow National Park Service staff to remotely access instructional information "on demand." IMR GIS has focused on developing documents that provide step-by-step instructions for common actions taken in GIS software. This material is intended for the general user (biologists, geologists, archeologists, interpretive staff, and geographers) as well as experienced GIS users. Because the NPS has a diverse workforce with many varying schedules, IMR GIS felt that this remote learning strategy benefit the most number of users. The training resources can be found on a website, a YouTube channel, and in the Park Atlas web viewer.

Resources on the IMR GIS website (http://imrgis.nps.gov/) are found under the GIS Resources tab, and there are specific materials for the Intermountain Region users. In the IMR Resources option under this tab, the two major sections are Trainings and Templates. The Trainings section includes a category of detailed and longer "How To…" documents that IMR GIS will continue to expand. Topics currently covered in this section include: Selections, Projections, Editing Overview, Georeferencing, Metadata, Introduction to ArcPad, and Trimble GPS.

In addition to the IMR GIS website, there is a new Intermountain Region Geographic Resources Division NPS YouTube channel (http://www.youtube.com/IMGISNPS) that also contains training. Under the "Playlist" tab, the first in the GIS Essential Skills series, Selections, is broken out into five short video segments. Each video series reviews and visually expands on the "How To" document enabling the



View of IMR GIS YouTube Channel video selection.



View of video playing from YouTube.

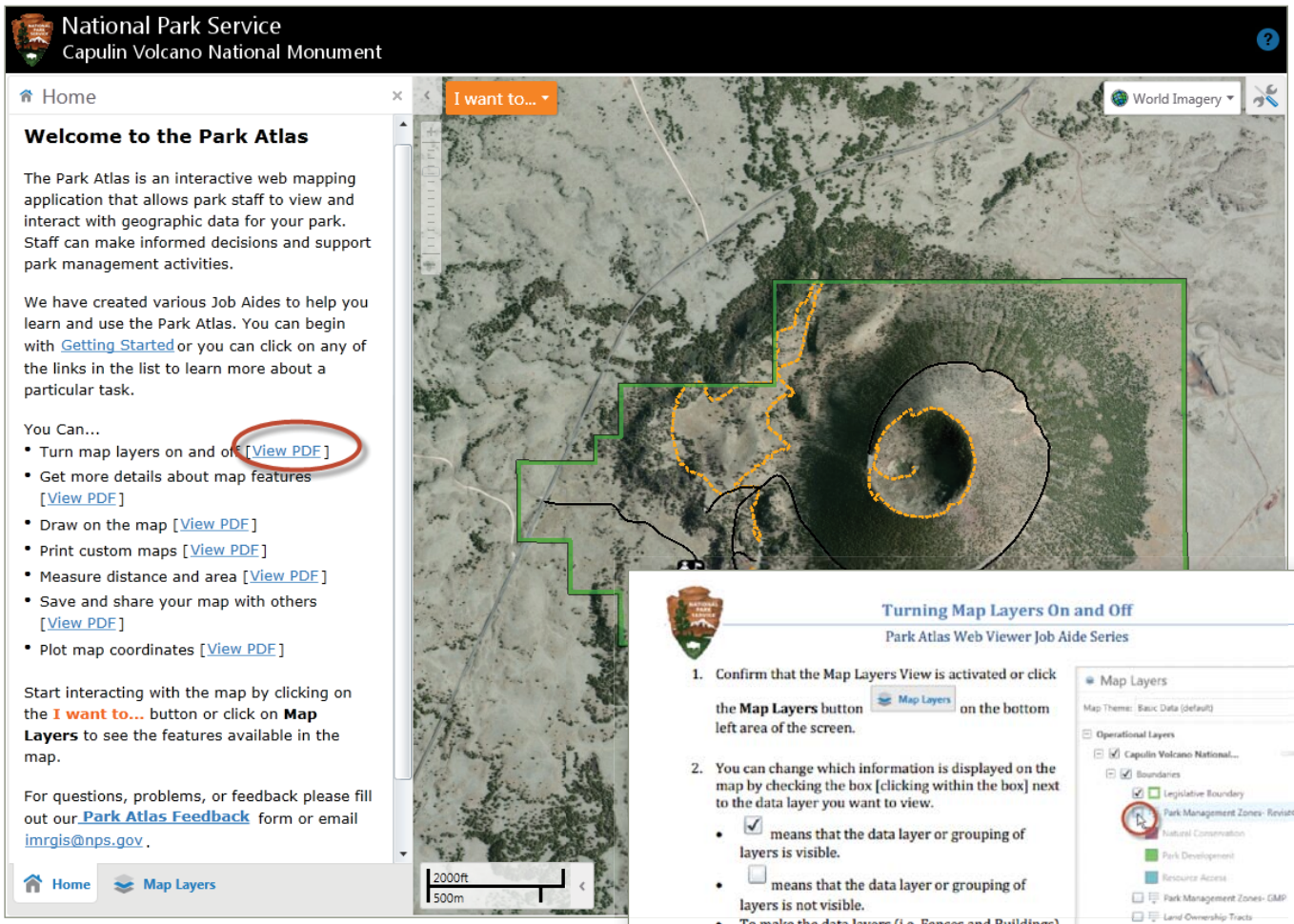
user to watch the steps being demonstrated. The user can choose to watch the entire Playlist or a single section with a specific skill. This resource also includes closed captioning. IMR GIS plans to develop additional videos, over time, to support the region's needs.

In addition to creating new locations to find information, the IMR GIS is working to embed learning resources in existing locations. For example, the current Park Atlas web viewers for the Intermountain Region now have handy "job aides" which are shortcuts and instructions to help the user accomplish a specific task. The park atlases are internally accessible through the Park Atlas Gallery (http://insideparkatlas.nps.gov/Gallery/). After a user launches a Intermountain Region Park Atlas web viewer, the Home view appears on the left of the screen and displays a list of job aides including:

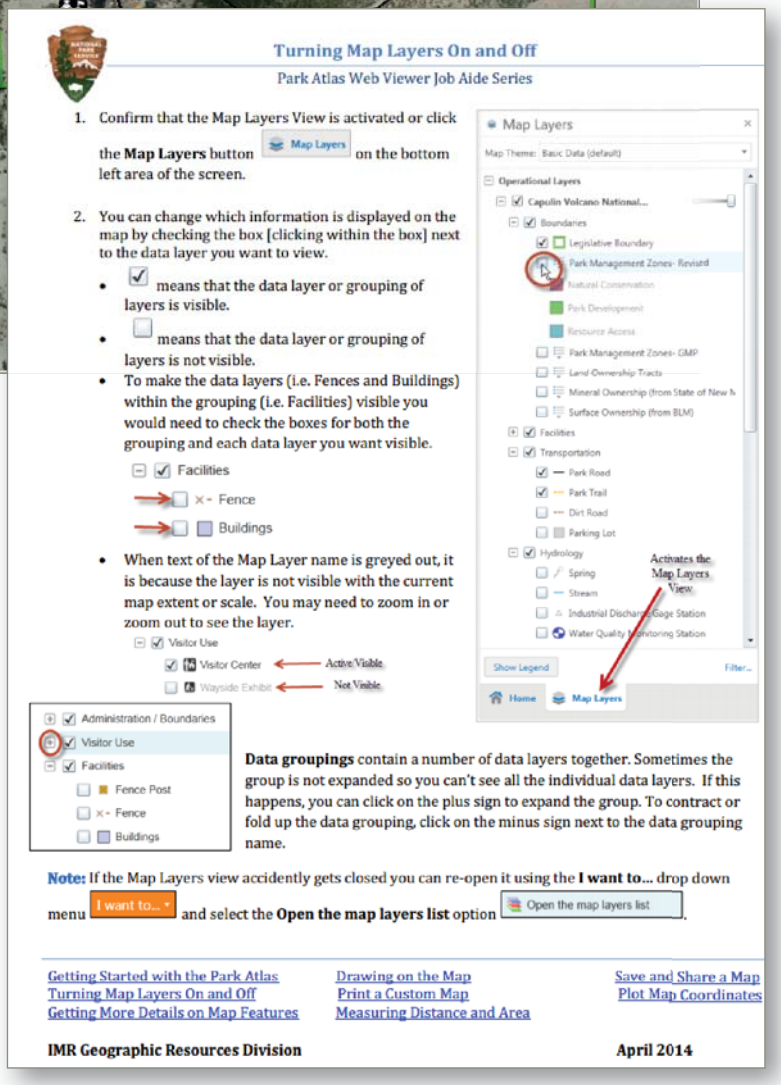
- Turn map layers on and off.
- Get more details about map features.
- Draw on the map.
- Print custom maps.
- Measure distance and area.
- Save and share your map with others.
- Plot map coordinates.

All of these job aides are directly linked on the Home view to teach new or refresh skills. The job aides are one to two page reference documents that are quick and simple to follow.

The IMR GIS team is excited to provide skill-building information using new platforms that are easily accessible for staff—no matter where they are or what time they are working. In addition, a number of these resources are also available to share with NPS partners. In sharing these best practices, we open opportunities to learn new and different ways to get the job done.



Park Atlas Home screen with links to job aids.



Example Park Atlas job aid.

For Further Information About These Training Opportunities Contact:

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—Natural Resources—

The Uninvited Guest

By Dr. Nicki Frey, Utah State University Extension, nicki.frey@usu.edu, and Sarah Haas, Wildlife Biologist, Bryce Canyon National Park, sarah_haas@nps.gov

Introduction

For its size, Bryce Canyon National Park (BRCA) really packs a punch. In addition to beautiful, dramatic scenery, BRCA has a historic lodge and cabins for rent that date back to the early 1920's, built using local materials and local labor. Like many national parks, BRCA has a "high" season from May through October with fewer visitors during the winter.

Aside from hosting visitors, BRCA is home to an assortment of wildlife including small mammals such as the golden-mantled ground squirrel (*Spermophilus lateralis*), Uinta chipmunk (*Tamias quadrivittatus*), the elusive ringtail (*Bassariscus astutus*), bushy-tailed woodrats (*Neotoma cinerea*), and deer mice (*Peromyscus spp.*). During the summer, the more social of these animals (ground squirrels and chipmunks) can be seen scampering around the buildings and the visitors. It is not surprising that some of these animals are comfortable spending the winter inside the crawl spaces and attics of the historic lodge and cabins, as well as other small structures when they are unoccupied.

However, in 2011, visitors began reporting noises in the attics of the cabins during the summer season. BRCA wildlife biologist Sarah Hass and her colleagues were determined to solve the problem of the uninvited guests. Sarah contacted me, at Utah State University Extension, because I had experience researching ringtail intrusions in historic structures at Zion National Park. While damage to the cabins from winter habitation was a problem, we were more concerned with the much larger issue of human health and safety. *Hanta* virus and other wildlife diseases are present in this region of the United States. Specifically, *Hanta* virus is spread when spores on mouse feces (predominantly *Peromyscus*) become airborne. Although we were not

Aerial view of the historic lodge and cabins within Bryce Canyon National Park, and inset of the location of Bryce Canyon National Park in Utah. *(Credit: Google Earth)*

concerned that summer guests would encounter mice feces in the main living space of their cabins, we did feel there was a rick of exposure if a guest decided to access the attic. Additionally, this was also a hazard to maintenance workers who sometimes access the attics or crawl spaces.

Together, we formulated a strategy to create an adaptive resource management plan. Our objectives were to determine what animal species were using the historic lodge and cabins, the frequency of use, and how the wildlife was getting in. Then, we aimed to develop a way to remove the small guests from the buildings, prevent them from entering again, and to develop a method to monitor the structures.

How Does One Detect Small Nocturnal Animals Living in Attics?

Our research focused on alleviating the specific problem of unwanted occupation at the historic lodge and cabins. We surveyed the lodge and 23 historic cabins, which were either single rooms or divided into two or four rooms, for animal activity. We needed to use survey methods that would record animal activity when we were not in the attics or crawl spaces, so that we could get an accurate assessment of what species were there, and at what times of the day. Luckily, there were a few tools we knew would be successful.

Survey for Wildlife

We used two basic methods to determine which species were using the lodge and cabins. We knew from concurrent research at Zion National Park that documenting small mammals inside buildings could be challenging, and that the use of both track plates and trail cameras would be needed. Track plates are a common method of recording animal footprints, by luring the animal to walk across a sticky surface. However, track plates only display data if an animal actually steps on the surface, so we decided to use cameras to capture activity in the vicinity of the track plate and to obtain the most complete record of wildlife use possible.

In July 2013, we began our surveys of the attic spaces of the historic cabins and the lodge to catalog a human health risk assessment. We surveyed five to eight cabins at a time, including the lodge. For each survey, the set of locations was monitored for two weeks, and then we moved the materials to the next set of locations.

Track Plate Surveys

Initially, we based the track plate survey design on the methods used during my study of ringtail distribution at Zion National Park. Each track plate unit consisted of a track plate and lure placed inside a corrugated plastic tunnel. The track plates were 1 ft. x 3 ft., also made of corrugated plastic. To create a track plate, we wrapped contact paper (sticky side up) around the middle one-foot of the three-foot corrugated plastic. This left one section at each end of the track plate exposed. On these portions of the sheet, we brushed a slurry of artist charcoal powder and isopropyl alcohol (1:8 ratio). Once the alcohol evaporated, it left a very light film of charcoal powder on the (non-sticky) ends of the corrugated plastic sheet. Next, we removed the contact paper protective cover, and slid the sheet into a corrugated plastic tunnel which was a 1 ft. x 1 ft. x 3 ft. box.

To entice a small mammal visitor, we attached a lure, approximately half way into the tunnel, so the animal would have to walk across the charcoal powder while investigating the lure. The lures consisted of small plastic vials that contained a cotton swab dipped into scent. During the spring, we used a musk-based lure, which often is more successful attracting animals that are reproductively active. If an animal was also territorial, a new musk scent in its territory would cause it to investigate the smell. We chose

a musk-based lure of a raccoon, which is not a predator to most small mammals, to ensure we did not scare away any small species. In the summer, we use oil scented with wild orange, to mimic the smell of a novel, sweet food. Access to food is not an issue in the summer for most small mammals at BRCA, thus we needed a new smell that might entice an animal to investigate.

Photo of the inside of a track plate tunnel box with camera mounted to the box (left) and track plate without the tunnel box, with camera mounted on a post nearby (right). (*Credit: Nicki Frey, Utah State University Extension)*

We placed track plate tunnels in the crawl spaces or attics of each cabin. While the attics of the two- and four-room structures were our main target, to be consistent we also surveyed the single-room cabins, which had only a crawl space and no attic. By the second round of surveys, we removed the tunnel in some of the smaller spaces because the camera flash reflected off the tunnel and over-exposed the pictures. Instead, we used a track plate with no cover and attached the lure to a rock, so that it was sitting upright, and placed the rock in the middle of the track plate.

Camera Surveys

We partnered each track plate with a trail camera to take a picture of each activity event during the surveys. Initially, we mounted the small trail cameras to the edge of a track plate tunnel to take pictures of animals that investigated inside the tunnels. Once we realized there was too much reflection from the flash, we turned the cameras to face out. In some events, this also posed a problem when the track plate was set close to a wall. In these situations, we mounted the camera to a pipe or other structure a few feet away from the tunnel with the camera facing the track plate. Because this arrangement resulted in the least reflection of the camera flash and the best photographs, this design became our established method for the rest of the surveys.

Trail cameras work by motion activation. To begin, we set the camera to the least sensitive motion setting to get a focused picture of animals close to the camera. When an animal disturbed the laser emitted from the camera, the camera shutter would activate. We set the camera to take a burst of three pictures each time the shutter activated. The camera would then turn off for 10 seconds and reset for the next activation. The pause in activation enabled us to detect small mammals that visited the track plates while minimizing the amount of redundant photos of the same animal. Every two weeks, we retrieved the cameras, removed the SD cards and uploaded all pictures to a laptop computer. The SD card was then erased, placed back in the trail camera, and deployed to the next location.

Attic Risk Assessment

One outcome of our wildlife visitation surveys was the realization that the problem was both bigger and older than we thought. As a result of our track and camera data, we began an additional surveys and assessments of each cabin in the

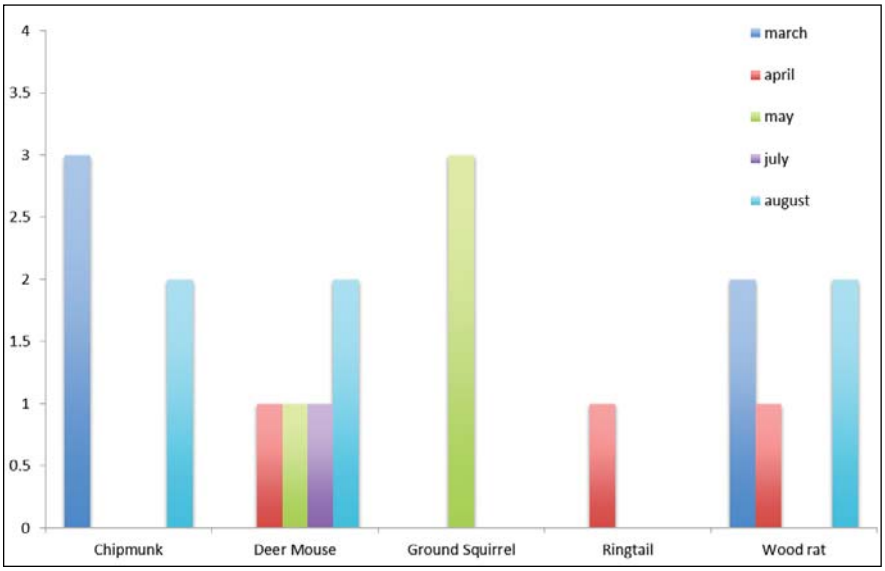
summer to determine the level of wildlife activity present in the attics, which might present a health risk to park staff and visitor. For example, evidence of wildlife tracks in an attic is not much affect on human health, but several nests or woodrat middens in an attic could present a health risk. In the attics, there was a partition built to create a level of security such that a guest in one room could not enter the attic and cross into another room. While the partition was an obstruction to humans, wildlife could move throughout the attic with ease. For our track and camera surveys we treated each cabin structure as one sample, but for this assessment, we investigated each entry into the attic so that we could obtain a visual estimate on either side of the partition. To accomplish this, a single structure was assessed in at least two different locations. This method provided us with more detailed information as to which area of the cabin may have the entry location, based on the location of nesting material, fecal pellets, or other signs. However, we did not identify every wildlife entry location at this time.

During the surveys we took photos of the attic while standing at each access point. Ideally, we took one photo toward each cardinal direction, however because of the privacy partitions placed in the attics and access point locations, this was not always possible. For example, one access location was six inches from a wall. In this case we took pictures of the base of the wall, but an outward facing picture would have been illogical.

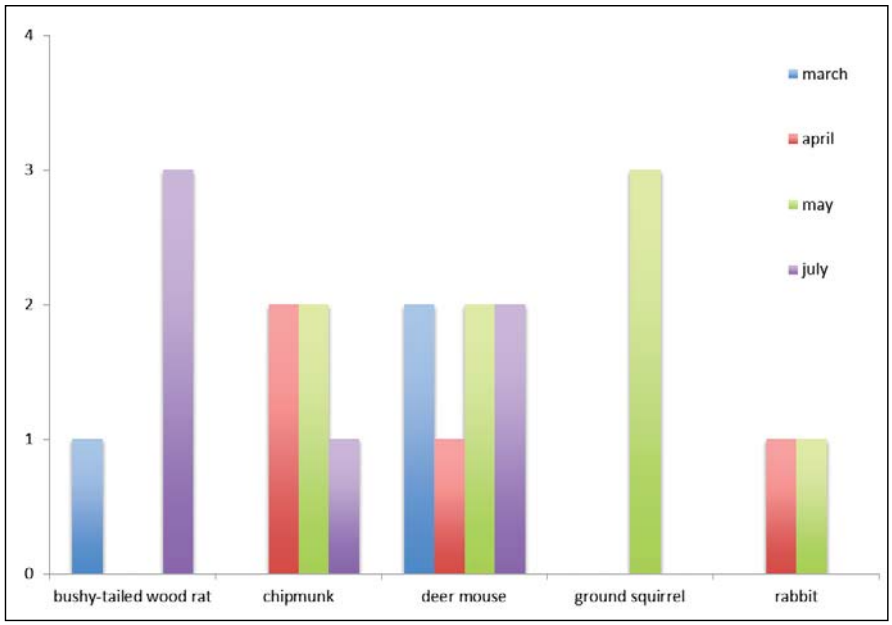
Results of the Survey for Wildlife

Originally, our goal was to determine which structures were being used by small mammals, and if possible, how frequently were they being used. We conducted two full rounds of track plate and camera surveys. Additionally, active areas were surveyed more often, as reports of disturbances occurred.

Of the 24 unique areas surveyed, we detected small mammals via the track plates in 12 of the structures. These included chipmunks (*Neotamias spp.*), deer mice (*Peromysus spp.*) and golden-mantled ground squirrels (*Callospermophilus lateralis*). Because an animal could visit the track plate more than once during the two-week period, we counted all tracks of the same species as one detection, rather than counting each set of tracks per species. Of the 45 separate cameras in the 24 unique areas, there were numerous (+25) pictures of small mammals; the most unusual was a cottontail rabbit. Setting the camera to pause for 10 seconds after a picture did reduce the number of photos we received per animal visit, but some animals stayed in the vicinity of the camera and track plate for up to five minutes. It was easy to follow the animal through the series of photos, so we only recorded the event as one animal visit. However, it



Number of times tracks were recorded from different small mammal species, March – August 2013. *(Credit: Nicki Frey, Utah State University Extension)*



Number of events recorded by camera per species, March – July 2013.
(Credit: Nicki Frey, Utah State University Extension)

was difficult to distinguish how many separate individuals these pictures contained overall. For example, if a chipmunk was seen each day for three days, there was no way to determine if this was one chipmunk seen three times or three separate chipmunks. Therefore, we recorded our pictures as "events" rather than "number of animals" per the two-week period for each camera set. Most of the pictures were obtained in the crawl spaces underneath the single-room cabins, with ten separate events recorded in the attics. Of course, these separate instances still may be recording the same individual animal more than once.

Another focus of this study was to determine if the lodge and cabins were inhabited specifically by ringtails, which are easy to remove and manage for future activity. Because of their size, ringtail activity in a cabin attic is very noticeable to guests, and would have resulted in complaints from visitors. On our track plates set April 1 - 15, 2013, we obtained a single track from a ringtail. This was not surprising because we encountered a large amount of woodrat scat and other signs of activity in that cabin when we set the track plate. Further inspection of the cabin revealed ringtail and woodrat tracks in the dust, ringtail mud prints on the walls, and a woodrat scat pile over one inch deep. This was the only cabin with such an intensive record of small mammal activity.

Results of the Attic Risk Assessment

During July 2013, we began our surveys of the attic spaces of the historic lodge and cabins to catalog a human health risk assessment. All cabins open to visitors were surveyed at least once, with our focus on those

The rim of the attic crawl space entry, indicating extensive and longterm woodrat and ringtail activity in the attic of an historic cabin, April 2013.
(Credit: Nicki Frey, Utah State University Extension)

particular cabins with animals detected within. We surveyed 21 access points, including the lodge; three attic spaces were not surveyed because there was no access. In other cabins, the entire attic was available to any small mammal and we grouped our access point assessments by structure, regardless of how many rooms were below. We classified the attic on a scale of 1-5 for small mammal activity and evidence of habitation (1 being clean of activity and 5 indicating an infestation requiring immediate attention). Of these, 14 (67 percent) had evidence of small mammal activity; however, only two of these were rated a level 3 or more.

Discussion

It wasn't surprising that there was evidence of mouse and chipmunk activity within the historic lodge and cabins of Bryce Canyon National Park. Anybody who has visited or worked at a National Park knows that these animals have learned to exploit the human-sourced food available around cabins, gift shops, general stores, and lodges. Animals as small as mice and chipmunks can often live in close proximity to humans, in attics and basements, without ever being discovered. But, when the animals are larger, such as wood rats or ringtails, or their inside habitation becomes more frequent, humans tend to notice. When one is trying to sleep below an uninsulated attic space, a one-pound animal can make A LOT of noise.

While one might expect deer mice to explore cabins periodically, we generally do not want them to live inside the same spaces inhabited by our visitors and staff. Their nests and feces are breeding grounds for bacteria and viruses that can be contracted by humans, and therefore, cannot be tolerated inside National Park structures. Additionally, we were not expecting several cabins to be visited by wood rats, and had mixed feelings about the ringtail living in one of the cabins. Ringtails are elusive, nocturnal, highly charismatic animals about the size of a small house cat. They have

Photos of attic assessment. The attics were rated on a scale of 1 (left) to 5 (right) for evidence of wildlife activity.
(Credit: Nicki Frey, Utah State University Extension)

gorgeous striped tails that are about the same length as their bodies. Ringtails are usually associated with chaparral habitat, and riparian areas in canyons. The area of the lodge is not located in either of these types of habitat. We were excited to document ringtails, and are interested in keeping the animals in the park...but not inside the cabins.

Given that small mammals can move through a cabin unnoticed much of the time, we were surprised that we could find evidence of wildlife living in 67 percent of the attic structures we surveyed. This indicated that the issue was more serious than we first considered. Either the animals were spending more time in the attics than we anticipated, there were more animals than we expected, or both. Due to the extent of the animal sign, as well as the need to immediately fix those cabins that received a rating of more than 3, the park staff initiated an exclusion plan in late August 2013. Additionally, the cabin that had the woodrat nest and ringtail activity was closed to visitors, out of concern for human safety. The exclusion plan involved a three-step process: First, all the cabins would be surveyed for potential access points in the walls, roofs, chimneys, etc. Next, the cabins would be cleaned and all evidence of inhabitation removed. At this time, the staff would ensure the animals were no longer in the space. Finally, the access points would be closed and filled, excluding animals from future use without trapping them inside the building.

The ringtail became a cause of concern when we decided to begin the exclusion process because we wanted this exclusion to benefit the humans without harm to the wildlife. In August, a ringtail could be living in the cabin rearing babies. If this was the case, the exclusion activities could disrupt her and cause her to abandon her young. Therefore, prior to any exclusion efforts, we placed wire traps in the attic in an attempt to remove the ringtail and relocate it safely. By setting live traps, we could potentially capture a ringtail and her young strategically, as opposed to accidentally coming across the nest, and risking human safety as well as that of the juveniles. We did not capture any animals in the trap, nor did we hear or see any evidence of activity; therefore we began exclusion measures on the cabins. The park hired a professional team to thoroughly clean each attic space and then contracted a company to block and repair any hole that was located on the inside and outside of the attic.

Crawlspaces under the single room cabins presented a difficult situation. Because of the nature of their construction (simple wooden slats surrounding the cabin floor)it was impossible to exclude from wildlife without damaging the historic building. Instead, we requested the hospitality staff to alert us if they observe any small mammal signinside the cabins, such as the start of a nest or mouse feces. If any of these signs are found, we would conduct an exclusion of the interior of the cabin to prevent animals coming inside the room from the crawl space.

National parks present an interesting interface between humans and wildlife. The parks have a goal to support healthy wildlife populations. Human visitors enjoy seeing wildlife, from the chipmunk to the moose. Because of the colocation of the historic cabins with the natural environment, we cannot be surprised when a small mammal decides to investigate. To ensure human health safety, we must continually work to prevent these wild residents from inhabiting the same spaces our visitors and staff use. The efforts to maintain human health and safety in the historic lodge and cabins at BRCA includes educating all staff and visitors on how to notice a small mammal habitation, and how to discourage animals from staying inside the buildings. These methods include: how to recognize the scat of different

animals, the best way dispose of food items (even waste paper baskets are not safe!), keeping outside doors closed, and many other simple steps. Also, we will continue to educate the staff and the public abouth the importance of not feeding wildlife. We were discouraged by the amount of human-sourced food that we found in the attics and crawl spaces of the historic structures; items that could only have been put there by a well-meaning person.

Cups found in the attic of an historic cabin, where evidence of wildlife habitation was also found, April 2013. *(Credit: Nicki Frey, Utah State University Extension)*

Next Steps

In the summer of 2014 we continued our study of the lodge and cabins. Naturally, our first order of business was to revisit the attics to determine if the exclusion efforts from the previous summer were successful. The plan for the future is that if wildlife tracks are detected, we will alert the BRCA biologists to begin new exclusion activities on that space. Detection of feces or nests will result in a consultation with the hospitality company and closure of the cabin until the exclusion has concluded. We are also continuing to expand another pilot study we began in 2013, that documented how often human and wildlife interacted, and in what way. We hope that by measuring these different types of interactions at Bryce Canyon National Park, we can target the best educational strategy that keeps wildlife outside: a solution that is healthy for all of the species at the park.

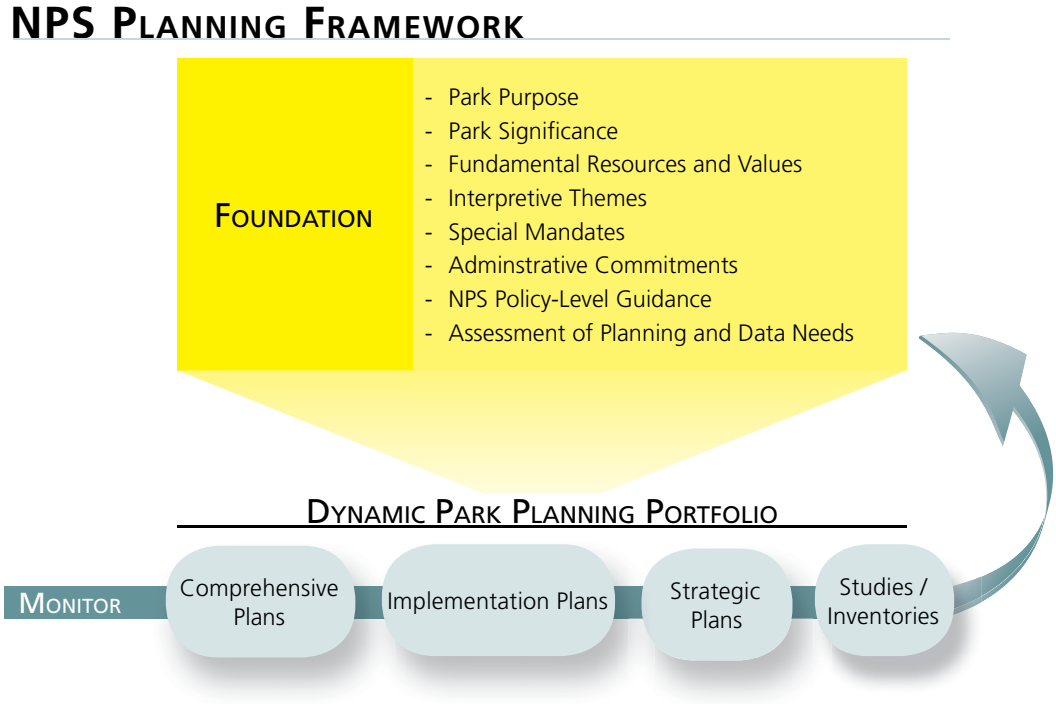
— Planning —

Planning for the Future

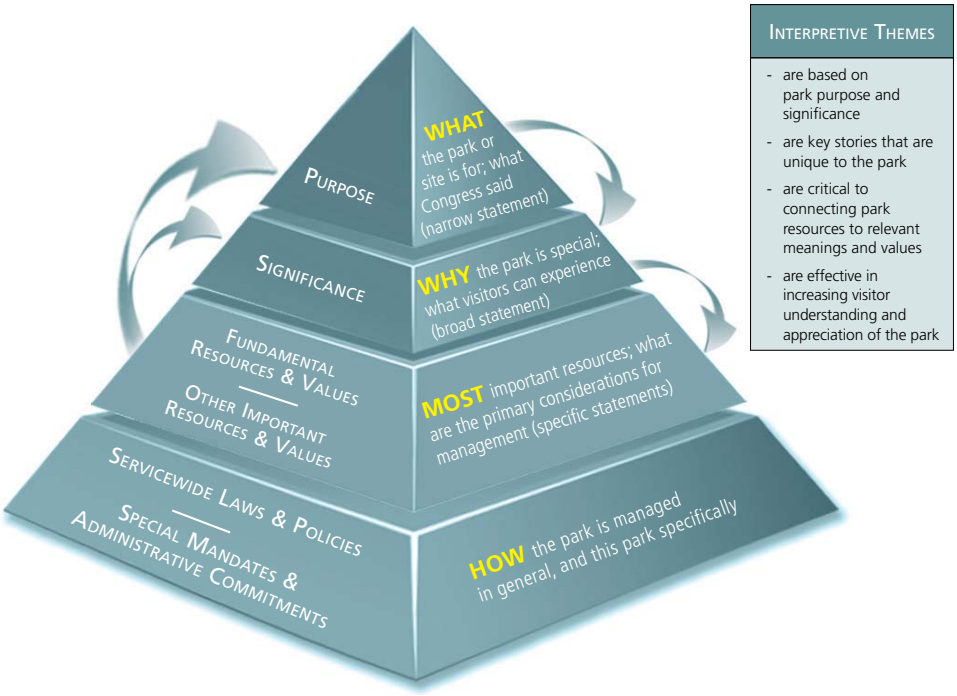
By Sami Powers, IMRO Planning, sami_powers@nps.gov and
Art Hutchinson, IMRO Chief of Planning, art_hutchinson@nps.gov

On November 10, 1978, the 95th Congress passed Public Law 95-625, the National Parks and Recreation Act of 197, also known as The Redwoods Act. The comprehensive Act increased park budgets, authorized new acquisitions, expanded park boundaries, changed some park names, designated new wilderness, established new trails, and authorized multiple studies. Buried in the law, Section 604(3)b stated, *"General management plans for the preservation and use of* ***each unit*** *of the National Park System, including areas within the national capital area, shall be prepared and revised in a timely manner by the Director of the National Park Service."* While this critical component of the Act seemed necessary and appropriate, in practice it became contentious, time consuming, and expensive. This provision determined the course of planning in the NPS since it was initiated in 1978, but for some time now, the NPS has been struggling with the issue of completing General Management Plans (GMPs) efficiently and effectively with increasingly limited resources.

Now, with the approaching National Park Service Centennial, the NPS is planning for the future by adopting new and innovative management practices, forging collaborations with other land managers and communities, and pursuing excellence in science and scholarship, all while ensuring that park planning, policy, and decision-making will allow the NPS to preserve America's special places for centuries to come. As part of this *Call to Action*, divisions throughout the service evaluated how they conducted business and determined where changes needed to be made. The Park Planning and Special Studies Division worked with the nationwide Planning Leadership Group to develop a



Building Blocks of a Foundation Document



new NPS planning framework that would address pressing park needs more effectively by streamlining the planning process.

To implement the new planning framework, planning teams are working with park managers to answer key questions that provide the foundation for a park's existence from which park staff and planning experts will be able to extract important management decisions and planning needs for the future. The effort will be recorded in a Foundation Document which describes the core mission of the park unit by identifying the purpose, significance, fundamental and other important resources and values, and interpretive themes in order to identify key issues and prioritize future planning and data needs. Ultimately, the Foundation Document will serve as a core element of each park's new planning portfolio, a concept that will be used for park planning into the future. The Foundation Document will serve as the underlying guidance for management and planning decisions in National Park units by identifying a shared understanding of what is most important about a park and using that understanding to integrate and coordinate planning and decision making on multiple levels. The planning branch has been tasked with completing a Foundation Document for all 401 park units by August of 2016.

The development and adoption of a Foundation Document will provide the opportunity for integration and coordination of planning and decision-making on many management levels from a collective concept of the most important aspects of a park. The Document will help focus efforts to protect the most important resources and values while still considering items that are important, but not critical to the park's purpose (other important resources and values). The development of the Document ensures that that all programs and actions contribute to achieving the park's mandates, while maintaining consistency in planning and decision-making. The Foundation Document will identify current conditions and threats facing key resources and values and serve as the basis for developing future plans. Finally, the process will enable park staff, working closely with regional and WASO staff, to identify and prioritize necessary plans and studies.

The Intermountain Region (IMR) Planning Division has worked closely with other regional planning offices, the Planning Leadership Group (PLG), and the Denver Service Center (DSC) to streamline the process used for creating Foundation Documents. Each step in the process from project commencement to publication is critical to the production of

a high quality and useful document. There are three major phases in the Foundation process including background and preparation work prior to a workshop, the on-site Foundation workshop, and creation of the Document after the workshop.

Workshop Preparation

The process begins with Library Services of the DSC researching, compiling, and assembling available materials to provide a solid background on the history and management of each park. Also, the staff from Natural Resources Stewardship and Science (NRSS) submit any pertinent information that might play an important role in the exploration of the Foundation of a park. In addition to the background information collected through Library Services and NRSS, IMR Planning has initiated a process of sending a notification to all division chiefs in the region so that any information or issues that might pertain to a particular park can be identified and articulated to Planning staff in advance. Finally, a worksheet is sent to park superintendents and staff to identify specific information and issues that exist at a park level. The information collected from these varied sources is all used in the creation of a workshop participants guide which serves as an outline and agenda for addressing all the major issues that are discussed at the workshop.

Regional office and park staff, along with stakeholders, participating in Foundation workshops at Little Bighorn Battlefield National Monument. *(Credit: Tatiana Marquez)*

Regional office and DSC staff tour Bandelier National Monument in preparation for Foundation workshops. *(Credit: Michele D'Arcy)*

On-site Workshop

Whenever possible, the workshop takes place at the park with the planning team facilitating in person. The planning team always consists of least one member of the IMR planning division in order to create and maintain a long-term relationship between the park and the Regional Office for future planning efforts. Sometimes the planning team is also comprised of other NPS staff including subject matter experts and, at times, DSC staff. For example, a staff member from the Office of Indian Affairs and American Culture traveled with the planning team to the Foundation workshop at Little Bighorn Battlefield National Monument because of her intimate knowledge of the affiliated tribes and other anthropological issues. When the Foundation is managed out of the DSC, the IMR planning team member serves as a liaison between the park and the region for both the Foundation and future planning efforts. Otherwise, the team producing the Foundation Document will be made up entirely of IMR planning division staff members.

Once on site, the planning team takes time to tour the park with staff to gain a greater understanding of the management issues. After exploring the park, the planning team runs a three-day workshop with park staff identified by the superintendent. Often, the superintendent choses the park's leadership staff to attend the workshop, but other times additional park staff members attend because of their specialized knowledge. In some cases, depending on specific issues and relationships, stakeholders are also asked to attend the workshop.

The Foundation Document

The final Foundation Document will consist of two main components; the core components and the dynamic components. The core components are the static and unchanging aspects of a park. In the Foundation Document, these begin with a brief description of the park such as location, size, key attributes, and a consideration of the park in its regional context. In the next section the park purpose is drafted based upon analysis of the enabling legislation or executive order and the legislative history. In assessing the park purpose, the Foundation Document is more than simply a restatement of legislation, but rather an exploration of the shared assumptions of legislative meaning for managers.

Guess that Park from the Significance Statement

Fill in the blanks...

1. _____ showcases one of the largest and most colorful concentrations of erosional geologic features in the world, including hoodoos, fins, windows, fluted cliffs, bridges, arches, and grottoes. This unusual landscape within the Claron Formation is created by a unique combination of natural processes, location, rock properties, and climate.

2. _____ is a geologic showcase of brilliantly colored strata highlighted by sheer Navajo sandstone cliffs that are among the highest in the world and expose ancient remnants of the largest known sand dune system. Geologic processes continue today as the free-flowing Virgin River rapidly cuts into the margin of the Colorado Plateau, incising a multitude of deep, narrow canyons. An abundance of canyon springs, fed by groundwater, create hanging gardens and grottos that support endemic varieties of flora and fauna. These exceptional features and processes contribute to the outstanding scenery and scientific value of the park.

3. Between 1833 and 1849, _____ was the most important staging point for the U.S. commercial and military expansion into what is now the American Southwest, and played a vital role in developing political and cultural ties between the U.S., Mexico, and the Southern Plains tribes, culminating in the military acquisition of the adjacent Mexican territory.

4. _____ contains a high concentration of the best-preserved freestanding towers and related structures in the American Southwest. Located in several canyon head settlements, these remains are excellent representations of ancestral Pueblo communities existing on the Great Sage Plain during the late Pueblo III period.

5. The dramatic elevation range within the park boundary, which spans from 7,600 feet to 14,259 feet and straddles the Continental Divide, allows for diverse terrestrial and aquatic ecosystems, varied plant and animal communities and a variety of ecological processes. _____ is designated as a United Nations Educational, Scientific, and Cultural (UNESCO) international biosphere reserve and globally important bird area, with portions of the park's montane, subalpine, and alpine ecosystems managed as research natural areas for scientific and educational purposes.

Answers on page 56.

Another core component is the significance of the park as explored through significance statements which express why the resources and values of a park are important enough to be a part of the National Park System. Established by workshop participants based upon the agreed purpose of a park, significance statements explore the park purpose within a local, regional, national, and global context. This section of the Foundation Document contains the most current scientific or scholarly inquiry to the park, which may have changed since establishment.

It is these resources and values that merit primary consideration during planning and management processes...

The next topic in the core section explores the fundamental resources and values (FRVs) of a park. The primary purpose of the National Park Service and therefore the foremost responsibility of park managers is to ensure the conservation and public enjoyment of the resources and values preserved. The resources that are fundamental to achieving the park's purpose and maintaining its significance are the FRVs. It is these resources and values that merit primary consideration during planning and management processes because they reflect what is truly important about the park and are critical for maintaining the park's purpose and significance. The FRVs help to focus planning and management in a park unit. In addition to exploring the most fundamental resources and values, Foundation Documents take the time, when necessary to evaluate other important resources and values which may be unrelated to purpose or significance, but are still important to consider in planning and management processes.

Interpretive themes are the major stories or concepts through which the park's national significance is conveyed to the visitor. These themes should be understood by all after a park visit.

After identifying the purpose and significance of a park, the interpretive themes are addressed. Interpretive themes are the major stories or concepts through which the park's national significance is conveyed to the visitor. These themes should be understood by all after a park visit. The themes are derived from the park purpose, significance, resources and values, and ultimately connect park resources to larger ideas, meanings, concepts, and contexts of which they are a part. The themes provide the mechanism for increasing visitor understanding and appreciation of the significance of park resources to a higher level.

The dynamic components of the Foundation Document are those aspects of park management that change through time. Special mandates may be expressed in enabling legislation, separate legislation following the establishment of the park, or through a judicial process and are requirements specific to a park that must be fulfilled. These mandates may expand on a park purpose or introduce elements unrelated to the purpose of the park. Administrative commitments are agreements that have been reached between the park and other or external entities. These can be formal agreements reached through documented processes or may be informal agreements, but both special mandates and administrative commitments are generally made with other federal agencies, state and local governments, utility companies, partnering organizations, or other entities.

After the core and dynamic components are thoroughly discussed, the final section of the Foundation Document is an assessment of planning and data needs. This section presents

planning issues, projects that will address those issues, and associated information required to meet planning needs. Also included in this section is an assessment of the fundamental and other resources and values, their current state or condition, and existing or potential threats or opportunities related them.

This final section of the Foundation Document also identifies key issues that need to be addressed through future planning and data efforts. Finally, the list of planning and data needs are prioritized through consideration of the FRVs and key issues, providing the park and regional liaison with high, medium, and low priority projects. These prioritizations provide a roadmap for funding requests, partnering, and other future management actions.

Answers to "Guess that Park by Significance Statement"

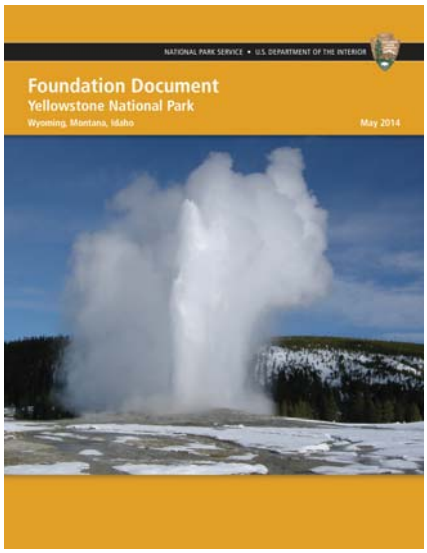
1. Bryce Canyon NP

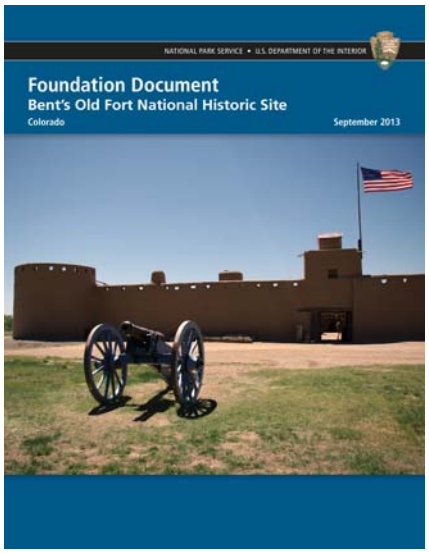
2. Zion NP

3. Bent's Old Fort NHS

4. Hovenweep NM

5. Rocky Mountain NP

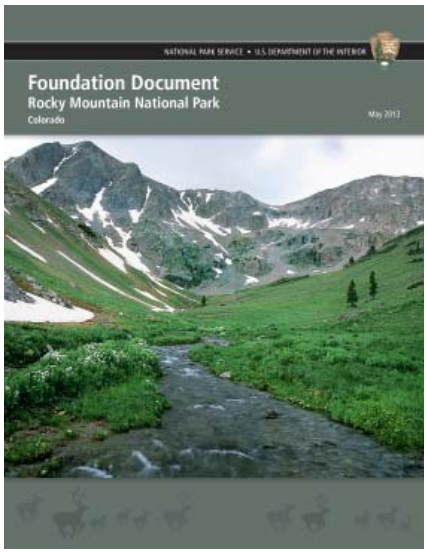


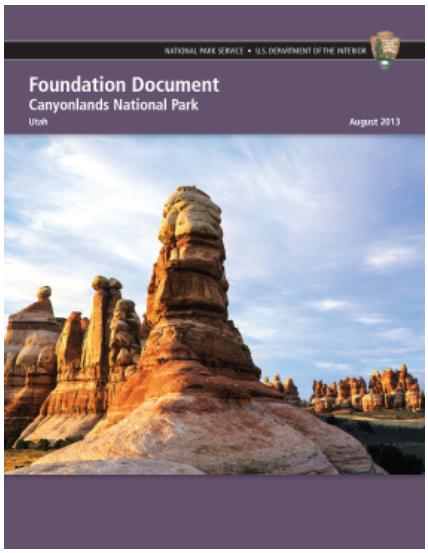


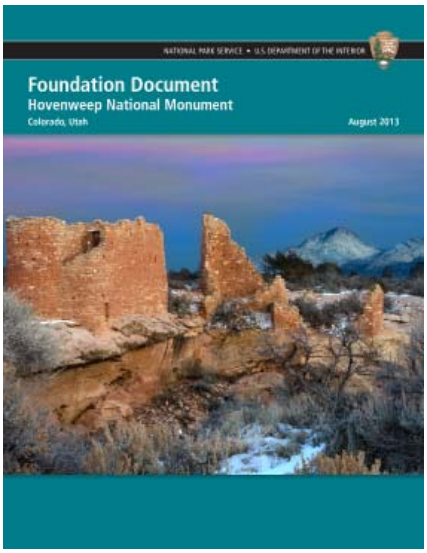
Final Products

The final product is a comprehensive document that contains the core components typically reflected in Chapter 1 of the GMP and the dynamic components with important information about a park that can easily and quickly change over time. The Foundation Document goes through several phases of review, first on a micro scale with the core team who attended the workshop and worked on the development of the Document. Following that it goes out for broader review by regional and WASO Foundation program managers. Finally, the superintendent of the park and the Regional Director both review and sign the finalized version. In addition to the larger document, which serves as a comprehensive internal document, all Foundation Documents also have an overview pamphlet. The pamphlet summarizes the main points of the Foundation Document and provides a more user-friendly document that can be easily distributed to the public.

Another important and extremely useful product from the Foundation effort is the park atlas. The atlas consists of both an electronic and paper compilation of geospatial data ranging from natural and cultural resources, visitor use patterns, facilities, and other data pertinent to the park unit. The data is compiled using geographic information systems (GIS) and the atlas comes with a desktop application that facilitates assessment of the geospatial data with little to







no familiarity with GIS so a broad spectrum of park staff can utilize it. The final result is a tool to showcase and analyze park resources and develop future planning projects and data needs.

With the new vision for planning in the National Park Service, the Foundation Document serves as the centerpiece of the new planning framework. The question becomes, how can this effort be translated into positive actions to benefit our parks? In the past, planning depended on the completion of lengthy and high cost GMPs. Now, with a new framework for planning with Foundation Documents at the center of the portfolio for park planning, funds are no longer centered on GMPs, and can be opened up for a wide variety of park planning needs identified through the Foundation process. Through the Foundation efforts, parks identify high priority needs that are shared with Regional and WASO leadership, who understand and approve of the needs, making the request for limited funding that much stronger.

The question now arises—what is next for planning? There is no question that parks have long needed the ability and funding to tackle smaller planning projects. The funding for such smaller plans will now be available from the WASO Planning budget. This will allow for regional planners to help parks accomplish these plans and also look for other sources of supplemental or leveraged funding. We anticipate that the need for planning will only grow. Perhaps this is the best time to plan: plan for a time when project funding is more available and we can have "shovel ready" plans in place for the second century of park needs.

—Cultural Resources—

Pictures into the Past: Restoring the Kolb Studio

By Ben Isaacson, Preservationist, Western Center for Historic Preservation, ben_isaacson@nps.gov

Standing at the edge of the Grand Canyon, leaning over the abyss, my insides tighten with fear and awe. As I capture a photo at the perfect moment, where the clouds create a pattern of light and shadow that dance across the omnipresent red rock canyon, I realize how lucky I am. For some people this is a once in a lifetime vacation, but for me, this is my job. Whether I am bumping along a two-track road in 4-wheel drive, snowmobiling in the dead of winter, or hiking and canoeing to a remote location, the goal is always the same: I am here to preserve and document structures because I work for the National Park Service Western Center for Historic Preservation (WCHP).

Kolb Studio on the south rim of the Grand Canyon. *(Credit: NPS)*

Established in 2005 as part of the Vanishing Treasures Network, the WCHP is a hands-on training and resource center based in Grand Teton National Park and is dedicated to the preservation of traditionally built architecture in the western national parks. The center is located within 600 miles of 2,500 significant historic structures on National Park Service and other federal lands. Many of these structures, which are able to tell a story richer than any history book, are in need of rehabilitation or stabilization and the WCHP works to document and preserve as many of these buildings as possible. Although I have traveled all over the

mountain west, stabilizing and preserving structures from further decay, no project has been more dramatically located than the Kolb Studio in Grand Canyon National Park.

In 1904, brothers Emory and Ellsworth Kolb began a commercial photography business on the south rim of the Grand Canyon. After experiencing a year of mild success, they built what was to become their home and photographic studio at the head of the popular Bright Angel Toll Road (now Trail). From this location, the Kolb brothers became some of the first entrepreneurs to document tourism in the national parks. The process of creating and selling a photograph to a visitor was an arduous one. First, Ellsworth would position himself (often precariously) to take shots of the mule riders as they descended the trail. Because the studio had no running water, Emery would then run four and a half miles down the trail with the photographic plates—often passing the riders—to Indian Gardens where they had a small darkroom studio next to a natural spring. After he finished developing the prints, he would rush back to the rim and sell the images to the visitors as they returned from their daylong mule ride.

During the years of 1911-1912, Emery and Ellsworth filmed themselves rowing and rolling from the Green River in Wyoming to the Colorado River and all the way through the Grand Canyon; an 11,000 mile trip in all. This movie was the first motion picture documenting river running down the Colorado River and became a national success. After touring the country with the movie, the Kolbs returned to the Grand Canyon and added an auditorium on to the east end of the studio where the movie showed every day from 1915 to 1976 with live narration by Emery until 1932. This film holds the record as the longest continually running movie in U.S. history. Although Ellsworth left the business a few years after returning from the river trip, Emery remained the owner and operator of the business until his death in 1976. The Kolb brothers, known for their energy and daredevil antics, are responsible for taking over 3 million pictures of visitors and helping shape the nation's view of western national parks.

One of the most iconic pictures of the Kolb brothers is of a log bridged over a deep chasm with one brother dangling from a rope looped around the log, presumably to get the "perfect shot." I often recall this photo while standing on the scaffolding surrounding the exterior of the building—a

The Kolb Brothers at work in 1915. (*Credit: E.L. Kolb*)

building which is 80 feet high and perched at the edge of one of the deepest canyons in the world. Normally, scaffolding is anchored at the base to flat, solid ground; but the edge of the Grand Canyon is not flat. Because of this, we constructed platforms to create a level starting point and then erected the scaffolding against the side of the building. In many places, the scaffold is over ten feet tall and it was necessary to secure it to the building to prevent it from falling away from the structure. Our efforts created one of the most scenic, and inspiring job sites I have ever experienced. After long hours of replacing siding or painting, I can turn around and drink in the same view the Kolb Brothers loved.

Paul Jensen and Chris Frank assemble scaffolding. *(Credit: NPS)*

Platforms were constructed to create a level starting point for scaffolding which was secured to the side of the building. *(Credit: NPS)*

Hank McCurdy stands on scaffolding that levels the 3 tiers of scaffolding above it. *(Credit: NPS)*

The WCHP documents all of our work in photographs and words, which will allow this icon of history to share its story for years to come. As we work on the Kolb Studio, the WCHP repairs decayed half-log and cedar siding, three rotting porches, two sagging awnings, and more than 80 windows and doors, all while disturbing as little of the remaining historic structure as possible. The process involves carefully removing a decayed area and replacing it with similar wood or epoxy. Also, we focus on documenting all the windows, including ones that do not need repair. However, after examining the glazing and caulking, we discover that some of the windows have, in fact, been repaired over the last 80 years but nothing was recorded. As part of the process, each window is numbered and photographed during several stages of the rehabilitation.

Office with a view. (*Credit: NPS*)

Working on the scaffolding, I am, at times, at the same level as visitors on the Bright Angel trail. Many stop to ask mundane questions such as, "Where are the bathrooms?" but other hikers show interest in the building and the work, often inquiring, "Is this the original studio?" or "Are you using the same materials?" Questions such as these lead to discussions about the work and usually end with supportive comments and the visitor leaving with a greater insight of the Grand Canyon's historic characters and the

Park visitors stop to learn about the studio as work is underway. *(Credit: NPS)*

Ben Isaacson (author) works atop scaffolding to repair an upper window of the Kolb Studio. *(Credit: NPS)*

WCHP's unique work within the NPS.

At the end of March 2014, the WCHP completes the onsite portion of the Kolb Studio and we return to our headquarters at Grand Teton National Park. Back at the office, we are currently working on a window assessment and completion report that details all the future work required for this special structure. Once the project is complete, the WCHP will have transformed a building that is over 100 years old and readied it for 100 more years of history and storytelling.

Living and working in national parks for the last ten years has inspired me to document my adventures in writing, photos and videos; and this project has only increased my desire to do so. Surrounded by the stories and photos of these two pioneering brothers, I gained a deeper connection to the area through the history of the people who recognized the magic and grandeur of this place. Now, it is my turn to pass the magic on.

Geology: The "Real" Story Behind the Scenery

Completing All 76 IMR Digital Geologic Map Datasets

By: Tim Connors, Acting IMR Physical Resources Manager (January – April 2014) / Geological Resources Division Geologist, tim_connors@nps.gov and Michael Bozek, Regional Program Manager, IMR Inventory and Monitoring Division, michael_bozek@nps.gov

Introduction

Since 1998, the service-wide Inventory and Monitoring (I&M) program has been working to complete 270 required digital geologic map datasets for park units nationwide, 76 of which are for IMR areas. In spring of 2014, the Geological Resources Division (GRD) completed the final digital geologic IMR park map and posted it to the NPS Data Store on the Integrated Resource Management Application (IRMA). This represents a huge accomplishment for IMR that highlights cooperation between the Inventory and Monitoring Program, the GRD, the Geologic Resources Inventory (GRI) program, and the Intermountain Region. These datasets supply much-needed geoscience information on bedrock and surficial geology; paleontology; geologic hazards; locations of seeps, springs and caves; and volcanic and geothermal features. They are crucial for many NPS activities including overall resource stewardship and management, the Park Atlas projects, Foundation documents, Natural Resource Condition Assessments, and State of the Parks reports. They also serve to remind users that there is truth to the saying "geology: the 'real' story behind the scenery."

Background

The importance of geology to National Park Service areas goes beyond the iconic scenery. Geology transcends the stunning beauty of our parks and provides vital functional information on the paleontological and archeological context of time periods; the processes that formed the landscape; soil genesis and watershed condition; and hazardous conditions to visitors, park structures, and cultural resources. These widespread uses of geologic information underscore the value the geologic inventories have in parks throughout the Intermountain Region.

The Inventory and Monitoring program, established through the Natural Resource Challenge, is tasked with providing guidance, technical assistance, and funding for parks to complete a set of 12 basic natural resource inventories.

These inventories are designed to provide park management staff with a base-level of information with which to help manage the natural resources within their particular park and geology is one of them. Now, with the maturation of the I&M program, many inventories are well underway, and the IMR geology map inventories and their respective products are among the first to be completed.

NPS-75 (Natural Resources Inventory and Monitoring Guideline) defined "natural resource inventorying" as "*the process of acquiring information on park resources, including the presence, distribution, and condition of plants, animals, soils, water, air, geological features, biotic communities, natural processes, and human-induced changes in park resources*." It also specified the objective to "*inventory mapped information on vegetation,*

soils, geology, and other natural resources."

"*Chemical and geophysical inventory and monitoring focuses on those geological, hydrological, and meteorological processes and variables that comprise the physical habitat component of park ecosystems. Physical-chemical inventory and monitoring should identify important geomorphic, hydrologic, and atmospheric processes responsible for the character of park natural resources and monitor those processes most vulnerable or likely to change measurably or to cause fundamental changes to occur among park resources and park ecosystems*."

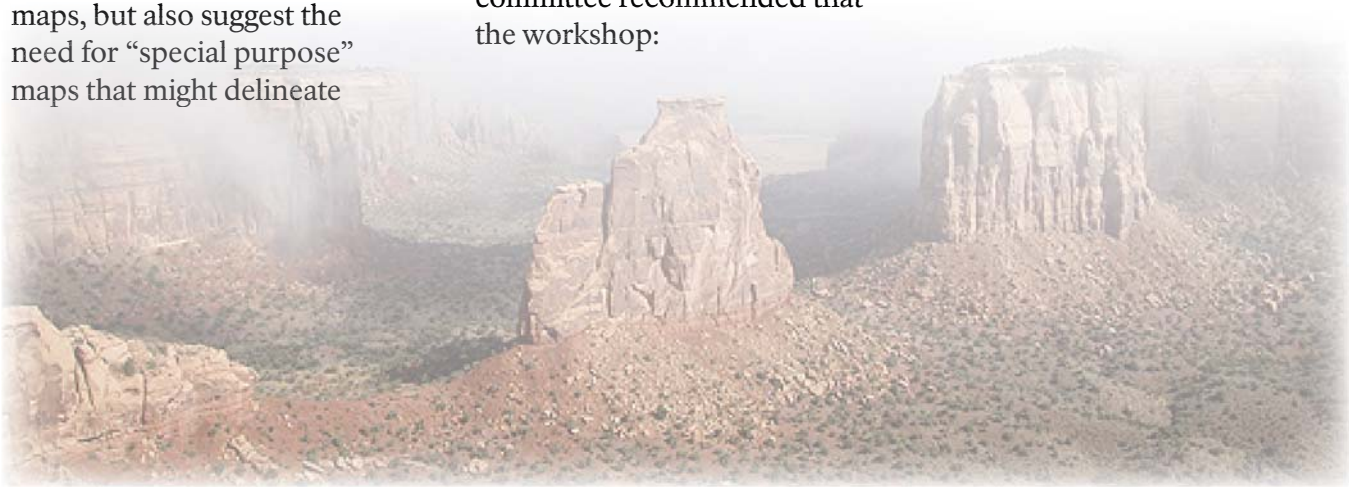
Moreover, NPS-75 states that a "*recommended minimal set of natural resources information which should be available in all natural resource parks*" as "*digital geology maps (bedrock and surficial)*." The guidelines indicate the desire for both bedrock and surficial geologic maps, but also suggest the need for "special purpose" maps that might delineate geologic hazards such as floodplains, volcanic potential, paleontological potential, mineral composition, and swelling bedrock units.

To this end, 76 parks in the NPS Intermountain Region were deemed "natural resource parks" and were targeted for geologic inventories and the development of digital geologic maps.

Process

In November 1997, the NPS Geologic Resources Division hosted a "Baseline Geologic Data Workshop" at the request of the NPS Inventory and Monitoring Program Advisory Committee to provide an outline for the geologic inventories. Participants included NPS superintendents, park and regional natural resource managers, Inventory and Monitoring Program staff, U.S. Geological Survey (USGS) geologists, and heads of state geological surveys. The advisory committee recommended that the workshop:

1. Assess the Level I geology inventory needs of parks in relation to the current I&M program; focus on both bedrock and surficial geologic mapping.
2. Determine how to evaluate the quality and applicability of existing baseline geologic information.
3. Consider the need to interpret geologic information for parks, to clarify its management applications.
4. Review the geologic information gathered by the I&M program thus far, and evaluate it in terms of park needs.
5. Recommend the most effective next steps in map acquisition and digitization, bibliographic work, and initiation of new efforts, including partnership opportunities with the USGS, state geological surveys, and others.



Workshop Participants

NPS Field Areas:
Phil Brease (geologist, DENA)
Marsha Davis (geologist, CCSO)
George Dickison (GIS group, ASO)
Suzette Kimball (acting superintendent, CAHA
Bob Krumenaker (resources management, ARO)
Laird Naylor (archeologist, ZION)
David Pugh (superintendent, WHIS)
Judy Rocchio (geologist, PWRO)
Danny Rosenkrans (geologist, WRST)
Vince Santucci (paleontologist, FOBU)
Kim Sikoryak (chief interpreter, IMRO)

NPS Deputy Associate Director Natural Resources: Abby Miller (2nd day)

NPS Geologic Resources Div.: Bob Higgins, Lindsay McClelland, Dave Shaver and other staff for portions of discussion (Cloues, Heise, Keller-Lynn, Steensen, and Wood).

NPS Natural Resources Information Div.: Joe Gregson, (Rich Gregory and Gary Williams, 2nd day)

U.S. Geological Survey

Jack Epstein (geologic mapping - Eastern region)

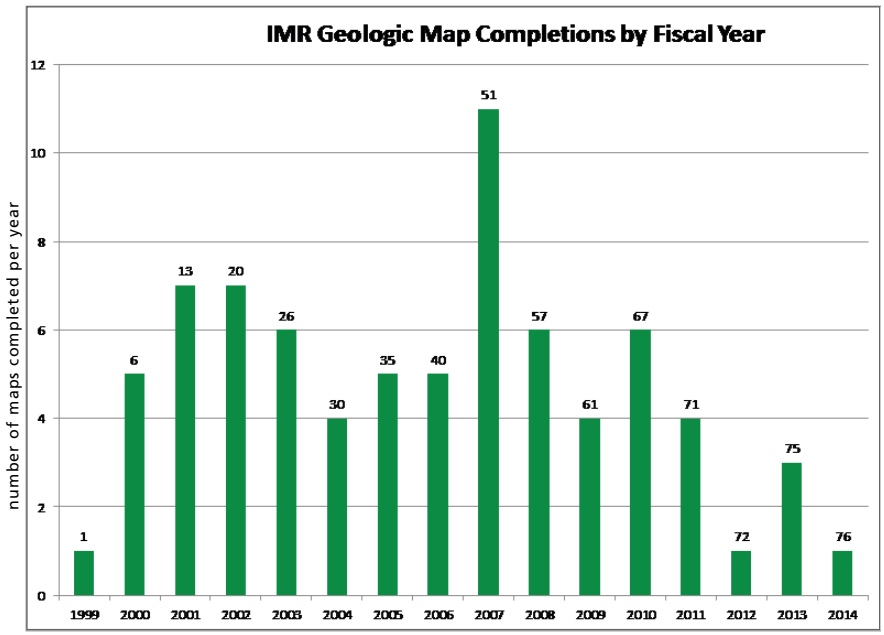
Rich Harrison (park project coordinator - Eastern)

Peter Lyttle (National CoopGeology Mapping Program)

Bonnie Murchey (geologic mapping - Western region)

Association of American State Geologists: Lee Allison (Utah), Vicki Cowart (Colorado)

Baseline Geologic Data Workshop participants, November 19-20, 1997.



Geologic map completions in IMR by fiscal year. The number at top of the bar represents the running total of completed maps.

Initially, NPS sites in Colorado were specifically chosen to pilot a partnership among the NPS, USGS, and state geological surveys for assessing existing geologic information; this project was initiated in FY98. Due to the success of the pilot, the project was expanded in FY99 to include Utah NPS properties. All of the Colorado and Utah NPS areas are included within the NPS Intermountain Region and because of the plethora of geologic features and processes, these parks proved to be an excellent starting point for collection of NPS Geologic Resource Inventory information service-wide. These digital maps are unique in that the information they contain has been collected using consistent and systematic methods, making them comprehensive. In 1999, the first digital geologic map was completed for Bent's Old Fort National Historic Site in and in 2014 the last digital geologic map was completed for Tonto National Monument.

Products

The GRD team worked closely with the Colorado State University Earth Science Department and a variety of other partners to produce 76 IMR (and 239 service-wide) maps with park-specific geologic reports and digital geologic data that staff can easily access. This mutually

beneficial relationship has been in existence since the program's inception in 1998.

GRD staff hosted park-specific scoping meetings to initiate the process, bringing together local geologic experts and NPS staff to inventory and review available geologic data and discuss geologic resource management issues. After each meeting, the GRD team prepared a summary document that identified a plan to provide digital geologic map data for the park.

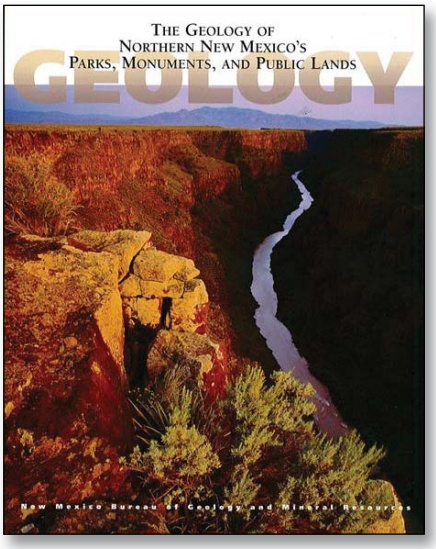
Park-specific geologic reports identify geologic resources in a traditional sense, those that are important to park management, and also issues of concern for park managers. These include identifying geologic formations, properties of geologic units, explaining local geologic processes, and identifying paleontological resources and geologic hazards.

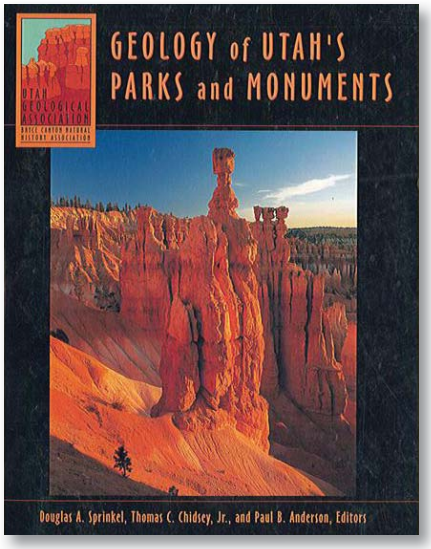
GRD staff created digital geologic maps to attempt to reproduce all aspects of traditional "paper maps," including notes, map legends, and geologic cross sections (three-dimensional views of the relationship of the geology to the surficial topographic expression) while making them more accessible. Bedrock-, surficial-, and special-purpose geology maps such as coastal or geologic hazard maps may have been employed to create the digital data that can best meet park needs as identified during the scoping sessions. These digital data allow geologic information to be easily viewed or analyzed in conjunction with a wide range of other resource management information available in park geographic information systems.

Outcomes

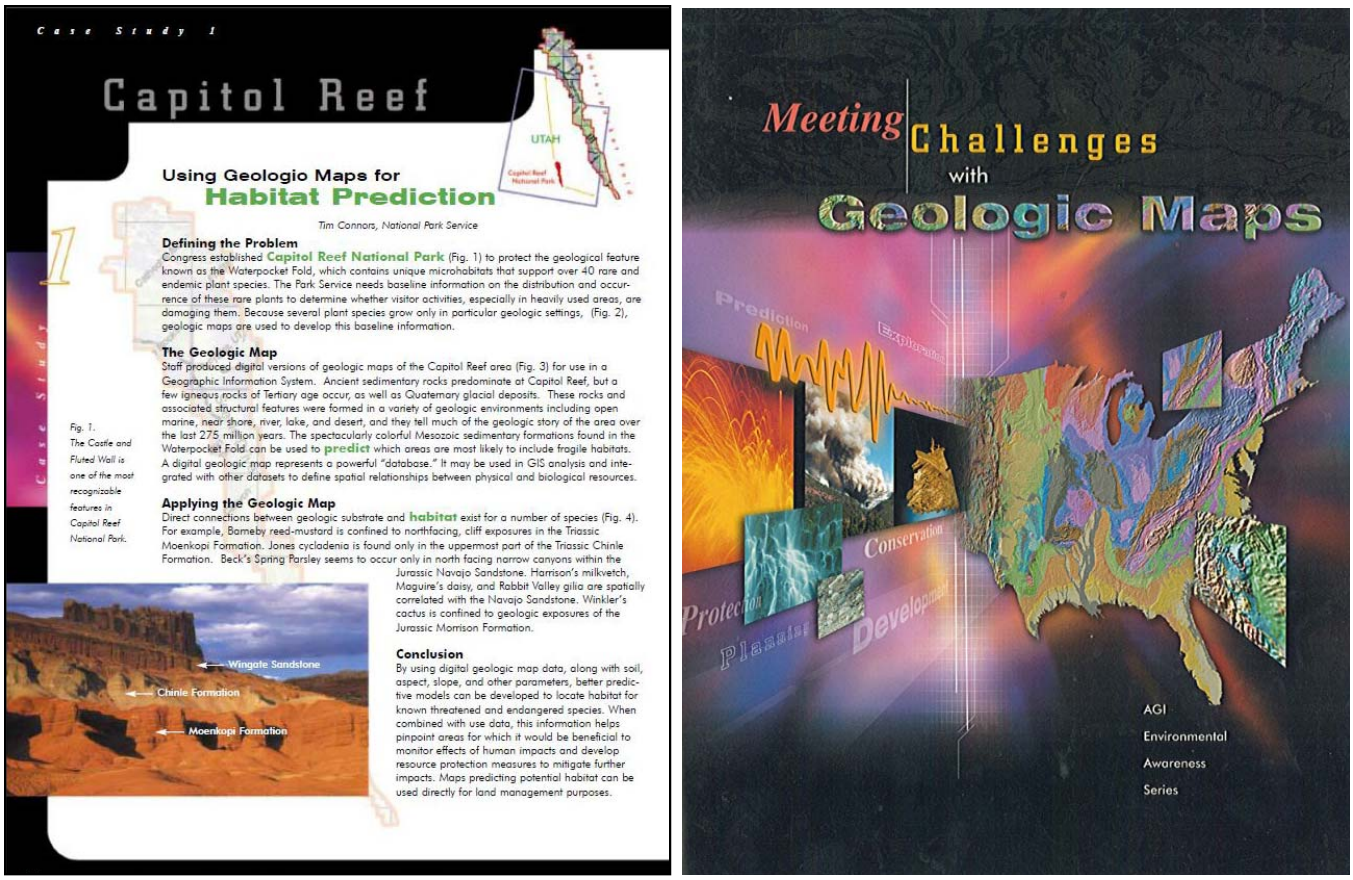
In 1999, GRD partnered with the Utah Geological Association to develop the "*Geology of Utah's Parks and Monuments*" as a year 2000 Millennium Field Conference Guidebook. This publication has become the "go-to" guide on the Geology of Utah's NPS areas. It includes detailed descriptions of each park's geologic history, stratigraphy, a geologic map, numerous images and illustrations, and a section on unique geologic features and processes present in each park. It also includes a companion volume "*Geologic Road, Trail, and Lake Guides to Utah's Parks and Monuments*" with PDF files. Several NPS staff contributed to these products. Arches National Park, Bryce Canyon National Park, Canyonlands National Park, Capitol Reef National Park, Cedar Breaks National Monument, Dinosaur National Monument, Glen Canyon National Recreation Area, Natural Bridges National Monument, Rainbow Bridge National Monument, Timpanogos Cave National Monument and Zion National Park are all covered in this volume.

This initial publication spawned similar products for NPS areas in New Mexico in "*The*





Derivative Publications on NPS Geology in partnership with the Geologic Resources Inventory.



Case Study 1

Capitol Reef

UTAH

Using Geologic Maps for
Habitat Prediction

Tim Connors, National Park Service

Defining the Problem

Congress established **Capitol Reef National Park** (Fig. 1) to protect the geological feature known as the Waterpocket Fold, which contains unique microhabitats that support over 40 rare and endemic plant species. The Park Service needs baseline information on the distribution and occurrence of these rare plants to determine whether visitor activities, especially in heavily used areas, are damaging them. Because several plant species grow only in particular geologic settings, (Fig. 2), geologic maps are used to develop this baseline information.

The Geologic Map

Staff produced digital versions of geologic maps of the Capitol Reef area (Fig. 3) for use in a Geographic Information System. Ancient sedimentary rocks predominate at Capitol Reef, but a few igneous rocks of Tertiary age occur, as well as Quaternary glacial deposits. These rocks and associated structural features were formed in a variety of geologic environments including open marine, near shore, river, lake, and desert, and they tell much of the geologic story of the area over the last 275 million years. The spectacularly colorful Mesozoic sedimentary formations found in the Waterpocket Fold can be used to **predict** which areas are most likely to include fragile habitats. A digital geologic map represents a powerful "database." It may be used in GIS analysis and integrated with other datasets to define spatial relationships between physical and biological resources.

Fig. 1. The Castle and Fluted Wall is one of the most recognizable features in Capitol Reef National Park.

Applying the Geologic Map

Direct connections between geologic substrate and **habitat** exist for a number of species (Fig. 4). For example, Barneby reed-mustard is confined to northfacing, cliff exposures in the Triassic Moenkopi Formation. Jones cycladenia is found only in the uppermost part of the Triassic Chinle Formation. Beck's Spring Parsley seems to occur only in north facing narrow canyons within the Jurassic Navajo Sandstone. Harrison's milkvetch, Maguire's daisy, and Rabbit Valley gilia are spatially correlated with the Navajo Sandstone. Winkler's cactus is confined to geologic exposures of the Jurassic Morrison Formation.

Wingate Sandstone
Chinle Formation
Moenkopi Formation

Conclusion

By using digital geologic map data, along with soil, aspect, slope, and other parameters, better predictive models can be developed to locate habitat for known threatened and endangered species. When combined with use data, this information helps pinpoint areas for which it would be beneficial to monitor effects of human impacts and develop resource protection measures to mitigate further impacts. Maps predicting potential habitat can be used directly for land management purposes.

Meeting Challenges with Geologic Maps

Prediction
Exploration
Conservation
Protection
Planning
Development

AGI
Environmental
Awareness
Series

Using Geologic Maps for Habitat Prediction at Capitol Reef National Park.
(Credit: American Geological Institute Environmental Awareness Series, "Meeting Challenges with Geologic Maps")

Geology of Northern New Mexico's Parks, Monuments, and Public Lands" by the New Mexico Bureau of Geology and Mineral Resources (2010). Aztec Ruins National Monument, Bandelier National Monument, Capulin Volcano National Monument, Chaco Culture National Historical Park, El Malpais National Monument, El Morro National Monument, Fort Union National Monument, Pecos National Historical Park, and Petroglyph National Monument are all covered nicely in this publication.

Another useful outcome occurred at Capitol Reef National Park (CARE). After discussions with the Chief of Natural Resources, the park initiated new geologic mapping projects for high visitor use areas. This was mainly based on a desire to have larger-scale information on geologic strata in the hopes of being able to tie geologic materials to threatened and endangered species. Ties between geologic materials and species distribution have been suggested at CARE for Winkler cactus, Beck's spring parsley, Maguire's daisy, Rabbit Valley gilia, Harrison's milkvetch, Jones cyclidia and Barneby Reed mustard. Management can now use this information to plan trail routes that will help preserve the sensitive plants but still provide recreation and enjoyment for visitors.

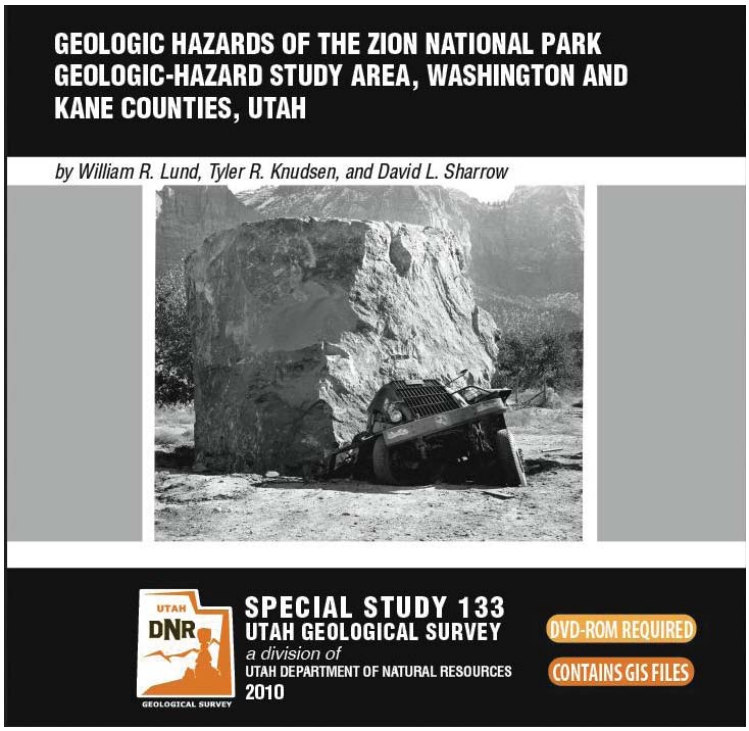
During the process of GRI scoping and evaluation of existing geologic map coverage, new geologic mapping projects have originated with USGS, individual state geologic

Geologic Map of Colorado National Monument and Adjacent Areas, Mesa County, Colorado, USGS SIM-2740, 2001.

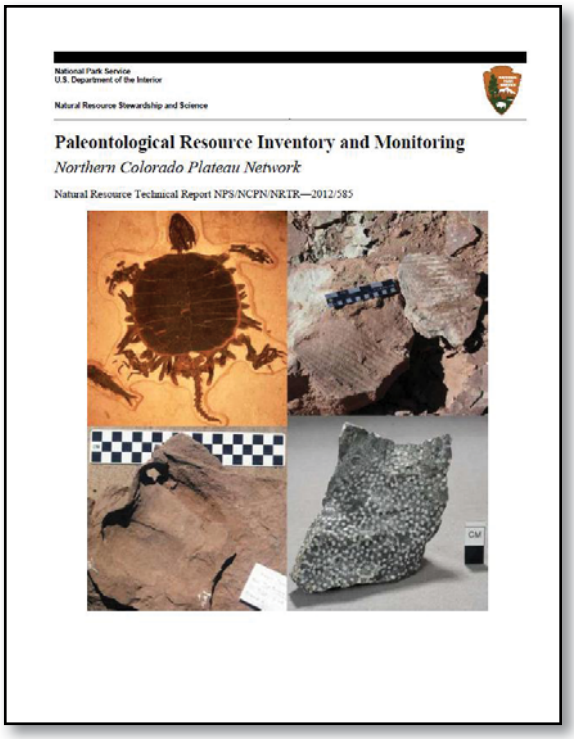
surveys, or academics for many IMR parks.

Many people view geology as scenery and rocks in a very stable setting. However, substantial focus of the inventories was dedicated to identifying geologic hazards that have real-time impacts on property and personal safety. And one only has to look at the recent flooding events in Rocky Mountain National Park (ROMO) and its economic impact to surrounding areas to understand the significance of these surveys and why geology matters on an everyday basis in our parks. As ROMO rebuilds, it now has more information to use when reconstructing the damaged roads, bridges, trails.

At Zion National Park (ZION), the digital geologic map was used by the Utah Geological Survey to conduct Special Study 133 and produce the publication, "*Geologic Hazards of the Zion National Park Geologic-Hazard Study Area, Washington and Kane Counties, Utah*." Specific hazards identified in this publication include flooding, rock fall, landslides, surface fault rupture, liquefaction, collapsible soil, expansive soil and rock, gypsiferous soil and rock, and piping and erosion. For both ROMO and ZION the lesson may be that geology is not as stable as it appears, and it can change in a single event. Having this information on the maps is invaluable for planning



Zion National Park Special Study 133.



Northern Colorado Plateau Network Paleontological Resource Inventory and Monitoring Technical Report.

ahead and for recovering from catastrophic events.

Most recently, the Digital Geologic Map for Grand Canyon National Park has been selected to be showcased during Earth Science Week 2014 for National Geologic Map Day (Friday, October 17, 2014). For more information see http://www.earthsciweek.org/geologicmap/.

These digital geologic maps have also had a very important role in deriving maps depicting paleontological resource potential for the NPS Network-based Paleontological Resource Summaries. Reports currently exist for the following Networks: Chihuahuan, Greater Yellowstone, Gulf Coast, Northern Colorado Plateau, Northern Great Plains, Rocky Mountain, Sonoran Desert, Southern Colorado Plateau, and Southern Plains. These maps can be used to predict where dinosaur or other significant fossils may be found by identifying the underlying formations in an area.

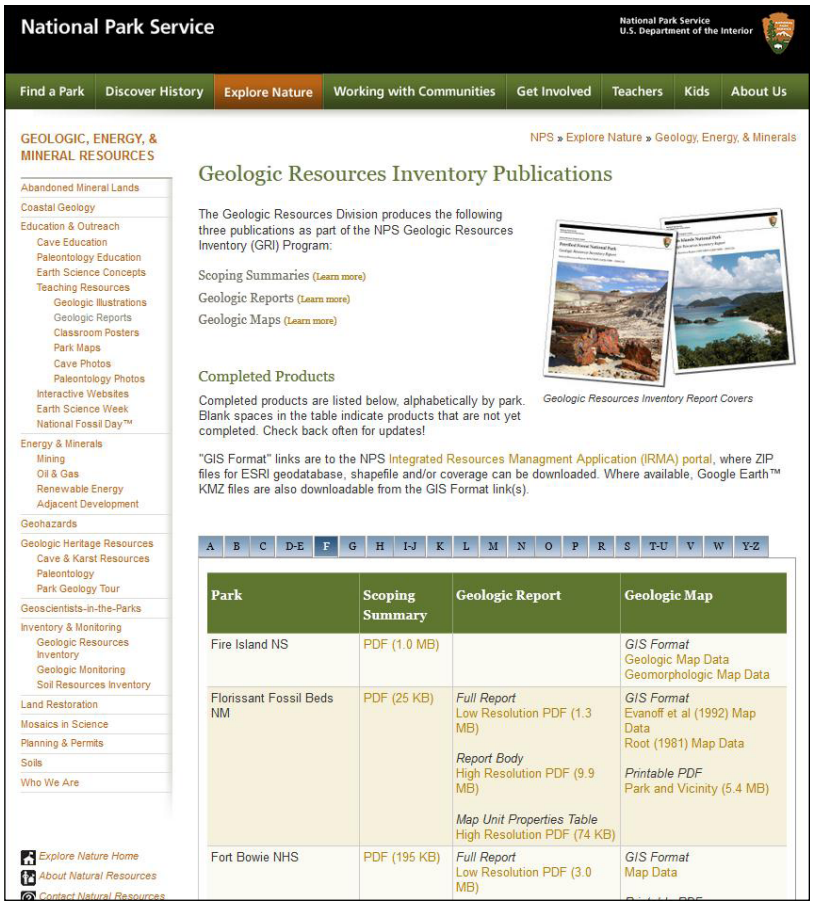
All of these examples showcase the importance of geology to NPS resource management, as well as visitor use and safety, illustrating that geology is indeed much more than scenery. These important datasets are of great use to many NPS initiatives related to planning and resource protection including Foundation Documents, Park Atlases, State of the Parks reports, and Natural Resource Condition Assessments. They also have great value for interpretation, facility management, and many NPS centennial initiatives.

Geologic Resources Inventory Products

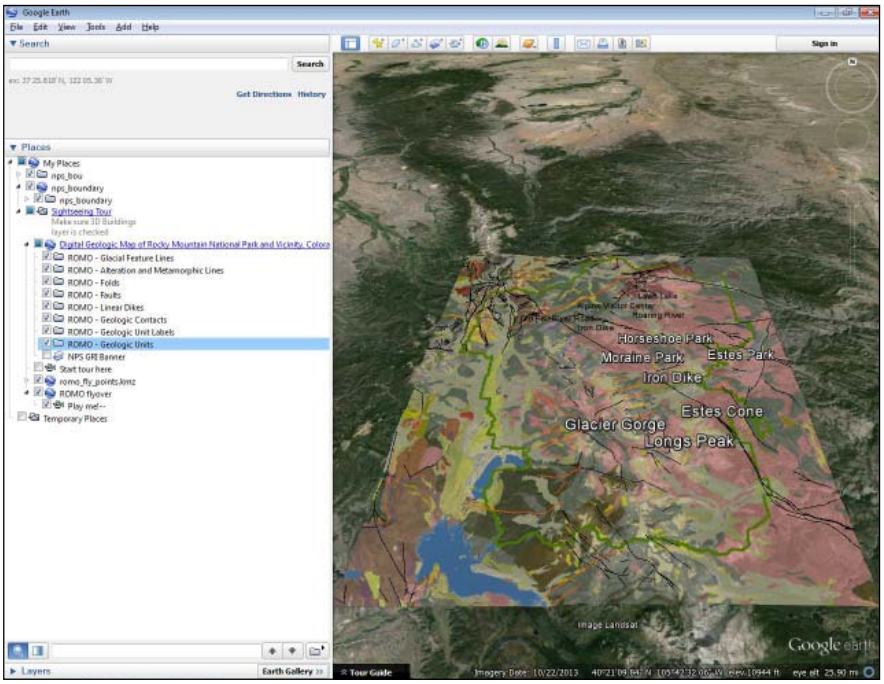
The Geologic Resources Inventory Publications page (http://www.nature.nps.gov/geology/inventory/gre_publications.cfm) serves as a one-stop hub to download GRI products. It links to compiled GIS datasets that are housed on the IRMA Portal at https://irma.nps.gov/App/Portal/Home.

The completed digital geologic maps are served as ESRI formatted files (shapefiles, geodatabases, and legacy "coverages") and more recent completions also contain geologic overlays that can be easily brought into Google Earth to visualize the geology.

More detail about the 12 inventories covered by Inventory and Monitoring can be found at: http://science.nature.nps.gov/im/inventory/.



GRI Publications page.



ROMO Geology draped over Google Earth.

Acknowledgements

The work of the Geologic Resources Inventory program could not be successful without the tireless efforts of many dedicated NPS staff in the Geologic Resources Division as well as the numerous Colorado State University Research Associates, faculty and student interns that have worked on the GRI since its inception in 1998. Many thanks also go to the numerous participants in scoping sessions (park, regional, and network staff, as well as USGS, state geological surveys, private researchers and academics) who have contributed to the appreciation of NPS Geologic Resources.

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Glacier National Park

We hope you enjoyed this second issue of *Crossroads in Science* and we look forward to publishing the next issue in the Fall of 2015.

If you would like to submit an article or have any questions, comments, or concerns, please contact the Editorial Director Nida Shaheen, nida_shaheen@nps.gov.

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