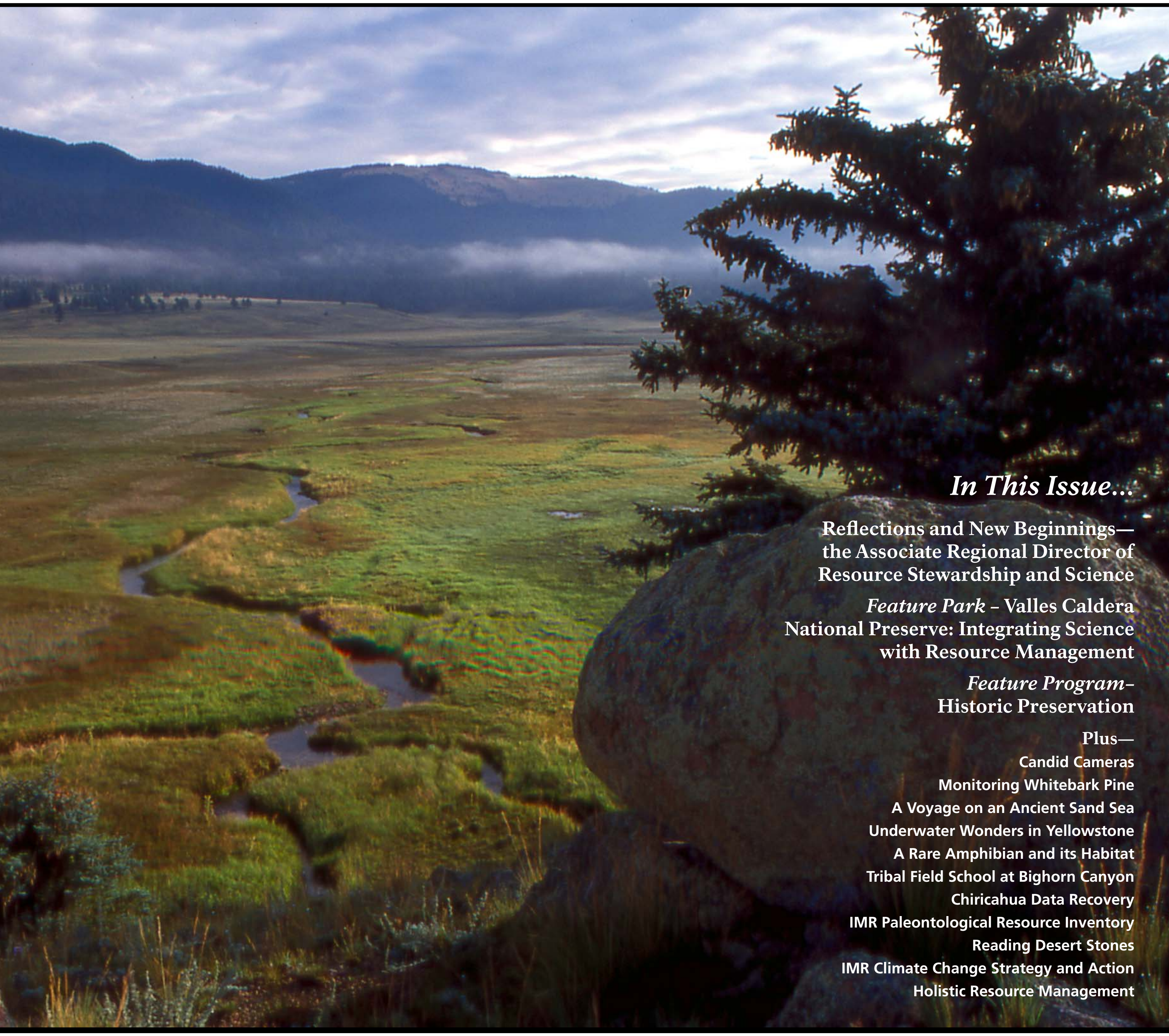
**Intermountain Region**
**Resource Stewardship and Science**

National Park Service
U.S. Department of the Interior

# CROSSROADS IN SCIENCE

***Where the Intermountain Region's Resource Stewardship and Science Programs and Centers Meet***

**Fall 2015** *Issue 3*



## *In This Issue...*

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Front Cover:
Valles Caldera National Preserve
**See the feature park article on page 1.** ***(Source: Don Usner, 2003)***

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# Associate Regional Director Reflections and New Beginnings

Three years ago, we began a new publication in the Intermountain Region Resource Stewardship and Science (RSS) Directorate. Our hope was that this publication could provide insight and knowledge as the scientific community came together to share ideas.

Together, *Crossroads in Science* has become a premier scientific publication in the National Park Service. Although our original intent was to serve parks in the Intermountain Region, this publication has been widely recognized throughout the Service. This is due to RSS employees taking a collaborative approach and working with other offices, divisions, programs, parks, DOI bureaus, and universities.

I want to thank you for all of your incredible contributions both in the field and in submitting engaging articles. *Crossroads in Science* would not be successful without the input and commitment of park and regional office employees.

As I leave the Intermountain Region to take on a new role as the superintendent of Big Cypress National Preserve, I will take with me the broad knowledge and wisdom that I've gained from the great people of this region. You have been a joy to work with and I'm grateful for the nearly five years I've spent here.

As I move on, I am confident that the tradition of excellence in Resource Stewardship and Science will continue. We have an amazing team and the right people are set in place to continue to move this Directorate forward.

This issue of *Crossroads in Science* highlights our newest addition to the National Park Service - Valles Caldera National Preserve. The article showcases the area's vast cultural and natural resources. This issue also features articles on archeology, historic preservation, and management techniques of cultural resources and explores natural resource challenges involving paleontology, wildlife, and rare aquatic frog monitoring. Finally, the inventory and monitoring program within the Intermountain Region conveys the benefits of long-term monitoring and how it can help better manage our resources.

I hope you enjoy reading this issue and are inspired by the great work that is being done to enhance resource stewardship in the National Park Service.

Tammy Whittington
Associate Regional Director
Resource Stewardship and Science

Valles Caldera National Preserve

—NATURAL RESOURCES—


Source: Don Usner

# Feature Park— Valles Caldera National Preserve

# Valles Caldera National Preserve: Integrating Science with Resource Management

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## New Mexico's "Super Volcano"

The Valles Caldera National Preserve in the Jemez Mountains of northern New Mexico is one of the newest units in the national park system. Located at the intersection of two major fault systems, the Rio Grande Rift Valley and the Jemez Lineament, the Jemez Mountains overlie a weak point in the Earth's crust that has spawned volcanoes for the last 14 million years. The preserve contains the remnant caldera of a massive eruption 1.25 million years ago (figure 1). Since that time, more than 15 major eruptions have created numerous volcanic domes

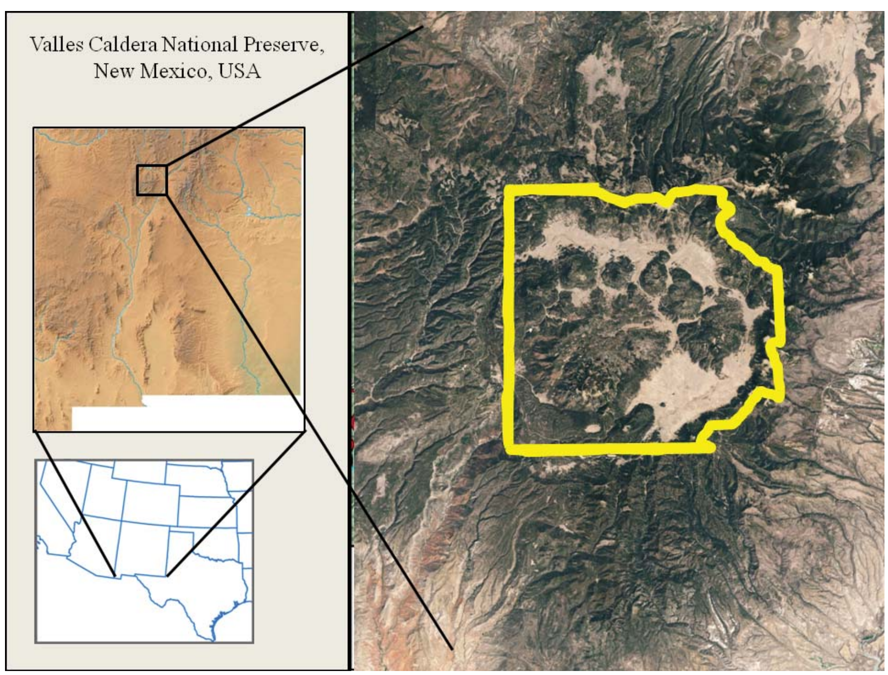

Figure 1. Landsat image of the Jemez Mountains with the Valles Caldera National Preserve *(Source: Robert Parmenter, 2015)*

within the caldera, including the major resurgent dome, Redondo Peak (elevation 11,254 ft.). The 12–15 mile diameter caldera is presently dormant (but not extinct) and still displays signs of volcanic activity, with hot springs and sulfuric acid fumaroles (Goff 2009).

The current landscape is covered with high-elevation coniferous forests and meadows. The iconic features of the preserve are the large, grassy valleys (valles in Spanish) that today cover the rich soils of ancient lakebeds. The numerous volcanic domes support extensive forests, with the lower slopes dominated by ponderosa pine, the middle slopes composed of mixed-conifer species of White fir, Douglas fir, Colorado blue spruce, and Southwestern white pine, and the upper peaks cloaked in Engelmann spruce and Corkbark fir; extensive aspen stands are sprinkled throughout (Muldavin et al. 2005; figure 2). Overall, the preserve is home to more than 750 species of vascular plants, mosses, and algae, along with a rich assemblage of vertebrate and invertebrate wildlife. The preserve's caldera is also the top of the watershed for the Jemez River, a tributary to the Rio Grande. More than 76 miles of perennial streams drain the preserve's watersheds, supporting rich communities of aquatic invertebrates and trout fisheries.

Figure 2. View of the Valle Grande from Redondo Peak *(Source: Robert Parmenter, 2006)*

## Human History

While prehistoric use of the preserve by American Indians included the usual activities of hunting game and gathering native plants for food, medicine, and ceremonies, the signature resources for the indigenous peoples were the extensive volcanic deposits of obsidian for the manufacture of tools and weapons. The high quality, weapons-grade obsidian quarries on and near the preserve yielded critical materials for spear points, arrowheads, knives, and other tools. Obsidian artifacts dating back nearly 12,000 years have been found in the caldera, with prehistoric use increasing steadily throughout the Archaic period (10,000–1,500 years ago). Evidence of ancient human use is found in prehistoric quarries, reduction sites, temporary campsites, and seasonal villages. Obsidian artifacts from around the world can be analyzed for site-specific chemical constituents, which allows the original geologic source of each piece of obsidian to be identified, and many obsidian tools and other artifacts found across the United States have their origins in the Jemez Mountains (figure 3), illustrating extensive transport of these artifacts and providing a testament to the high value placed on Jemez Mountains obsidian.

In the 12th century, Pueblo tribes began immigrating to the Rio Grande Valley from the Colorado Plateau, and

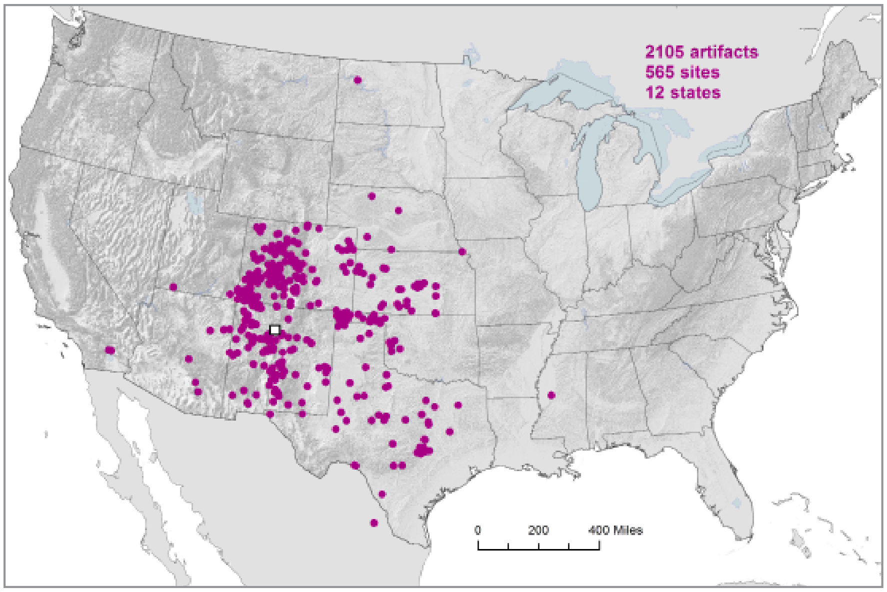


Figure 3. Locations of Jemez Mountains obsidian artifacts; white square indicates Valles Caldera National Preserve, New Mexico *(Source: Anastasia Steffen, 2007)*

several successfully established extensive networks of villages and farm fields in the Jemez Mountains (Anschuetz and Merlan 2007). A small corner of the preserve, below 8,400 feet today, contains the remains of the uppermost-elevation field houses and agricultural sites, delineating the altitudinal maximum for farming limited by the short growing season. The Jemez Mountains also are important for spiritual, cultural, and ceremonial reasons. The preserve continues to host American Indian religious and ceremonial sites and contains numerous areas considered sacred by several tribes.

Hispanic and Anglo use of the preserve during the 19th and 20th centuries was predominantly sheep and cattle ranching and timber harvest (Martin 2003). These activities had profound impacts on the landscape, with high stocking rates of livestock influencing stream channels, grassland productivity, forest structure, and fuel loads (figure 4). Fire regimes were dramatically altered by the livestock's removal of grasses (fine fuels) on the forest floor, preventing the spread of low-intensity ground fires (Allen 2002). Young sapling trees, previously killed by frequent ground fires, quickly filled in the forest and increased both fuel loads and ladder fuels. Forest clear-cutting in the latter 20th century created dense, second-growth pine and fir forests, exacerbating the landscape

Figure 4. Top: Sheep herd crossing Jaramillo Creek in Valle Grande, circa 1935 *(Source: T. Harmon Parkhurst; Museum of New Mexico image #51457)*; Bottom: Same location, present day *(Source: Steve Tharnstrom and John Hogan; USGS Jemez Mountains Field Station image #JMFS 306)*

fuel patterns and amounts (Balmat and Kupfer 2004). In recent years, large-scale uncharacteristic wildfires, such as the 2011 Las Conchas fire and the 2013 Thompson Ridge fire, have burned more than 60% of the preserve to varying severities.

Today, most human activities on the preserve are recreational—hiking, mountain biking, equestrian, snowshoeing, cross-country skiing, hunting, fishing, and night-sky events. The preserve is also a popular venue for filming TV shows and movies. In 2014, the preserve hosted nearly 120,000 visitors, and annual visitation has consistently increased since 2003.

## Landscape Restoration

As a result of the existing ecosystem conditions at the time of federal acquisition, a major effort was initiated to restore the landscape to a more resilient condition and reinstate natural fire regimes. The preserve formed a partnership with the Santa Fe National Forest, The Nature Conservancy, the Pueblo of Jemez, Bandelier National Monument, and more than 30 other agencies and organizations to develop and implement a landscape restoration strategy. Projects undertaken by the collaborative included forest thinning and prescribed burning,

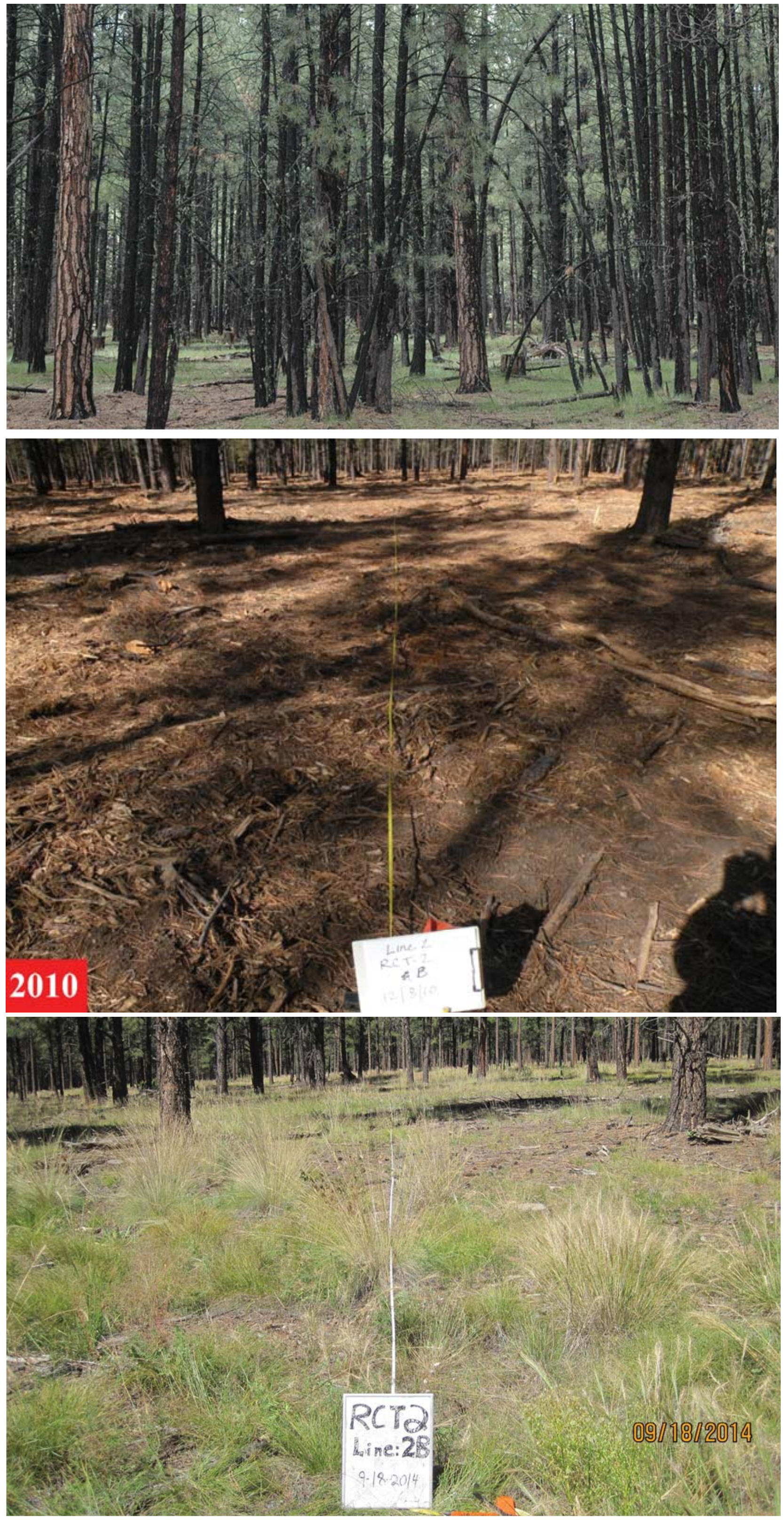


Figure 5A. Repeat photos of dense Ponderosa pine stand before thinning (top, spring 2010), after thinning (middle, fall 2010) and two years after burning (bottom, 2014). *(Sources: top to bottom- Robert Parmenter, Rebecca Oertel, Martina Suazo)* management of natural fires, riparian restoration, species reintroductions, and road closures (figure 5A). Upon completion in 2019, the preserve's ecosystems will be on the long-term successional trajectory to once again become a mosaic of old-growth forests, lower-density second-growth forests, and montane meadows and grasslands with natural fire-return intervals (figure 5B).

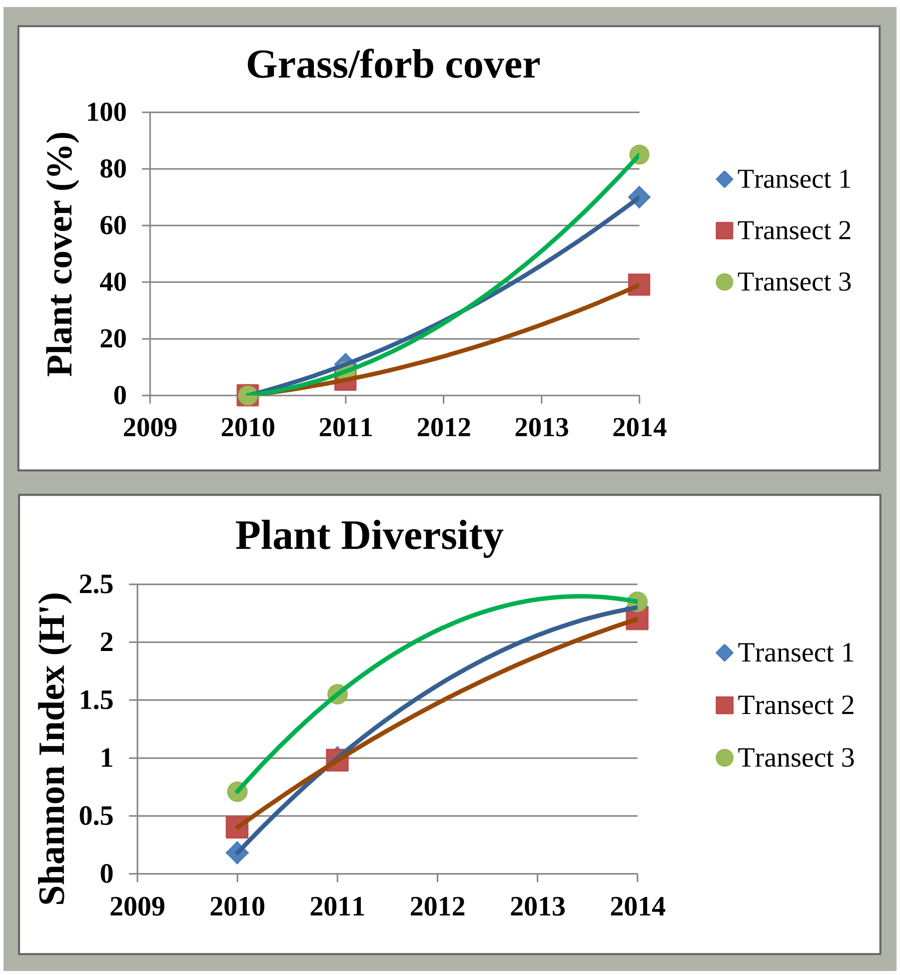


Figure 5B. Monitoring data from sites in Figure 5A show increase in grass/forb cover and diversity after thinning and burning. *(Source: Martina Suazo, 2015)*

## Science-Informed Management

With the wide range of public activities, the preserve has tasked the Scientific Services Division to acquire the necessary information to ensure that science-based adaptive management is realized in management decisions (figure 6). Early efforts were devoted to inventories of natural and cultural resources, and an extensive geographic information system (GIS) was developed; data layers include a high-resolution (2m-pixel) vegetation map, a new level-2 soils map (from the Natural Resources Conservation Service and the Forest Service), a new geology map, and data layers for topography, roads, streams, archaeological sites, and historic features. To date, nearly 20,000 acres have been inventoried for cultural resources—with documentation of 680 prehistoric and historic sites, and GIS data points for 65,800 artifacts.

A major component of the preserve inventories was compiling species lists and distributions of the fauna and flora. Intensive field sampling campaigns, often coupled with ongoing monitoring programs, have led to the near-completion of species lists for vascular plants, mosses, algae, fungi and lichens, mammals, birds, reptiles, amphibians and fish, and many taxa of aquatic and terrestrial invertebrates (thanks to the efforts of scientists from the Systematic Entomology Laboratory / Smithsonian Institution). Many archived voucher specimens have been placed in the national collection at the Smithsonian Institution, the University of Wyoming's herbarium, and the University of New Mexico's Museum of Southwestern Biology.

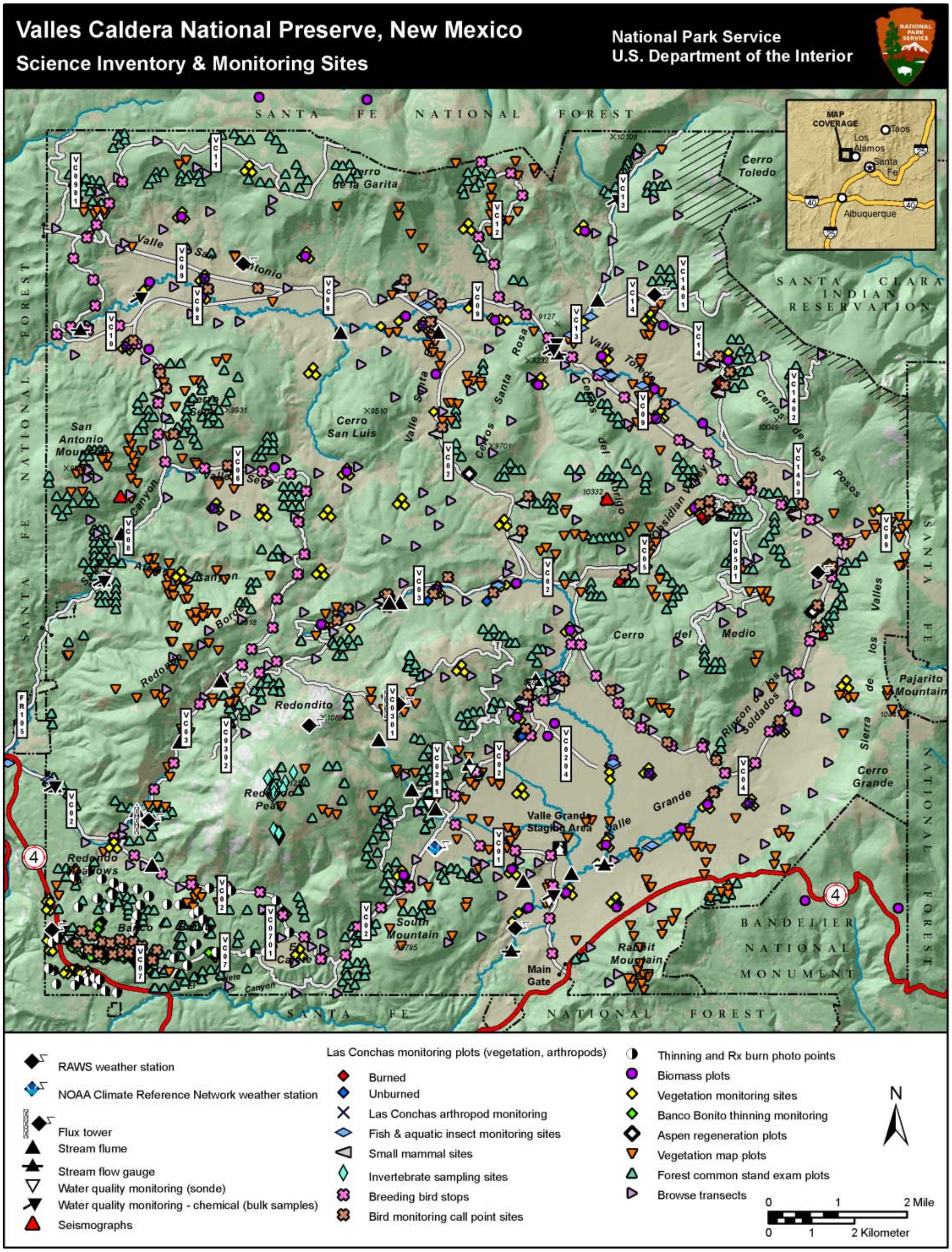


Figure 6. Map of Science Inventory and Monitoring Sites on the Valles Caldera National Preserve
*(Source: John Swigart, 2015)*

Inventories of remaining taxa continue, with the goal of completing an all taxa biological inventory mirroring that of the Great Smoky Mountains National Park. Given the documented climate change in the preserve, coupled with anticipated increased regional temperatures and declining precipitation in coming decades, the preserve's present-day inventory will provide a detailed benchmark to which future generations of scientists can compare changes in biodiversity over centuries to come.

Monitoring programs were established in response to a number of issues. With ongoing climate change, the preserve set up a network of weather stations, including the preserve offices in the town of Jemez Springs. Data from the Jemez Springs station, coupled with comparable data since 1914, show that annual temperatures have risen 1.8° F over the past 101 years, and that the most rapid increases are occurring in the months of March, June, July, and August; this finding is important for anticipating future snowmelt periods and fire seasons (figure 7).

At the time of acquisition, nearly all the streams on the preserve were impaired for high temperatures and turbidity, a result of prior land-use activities. Preserve streams

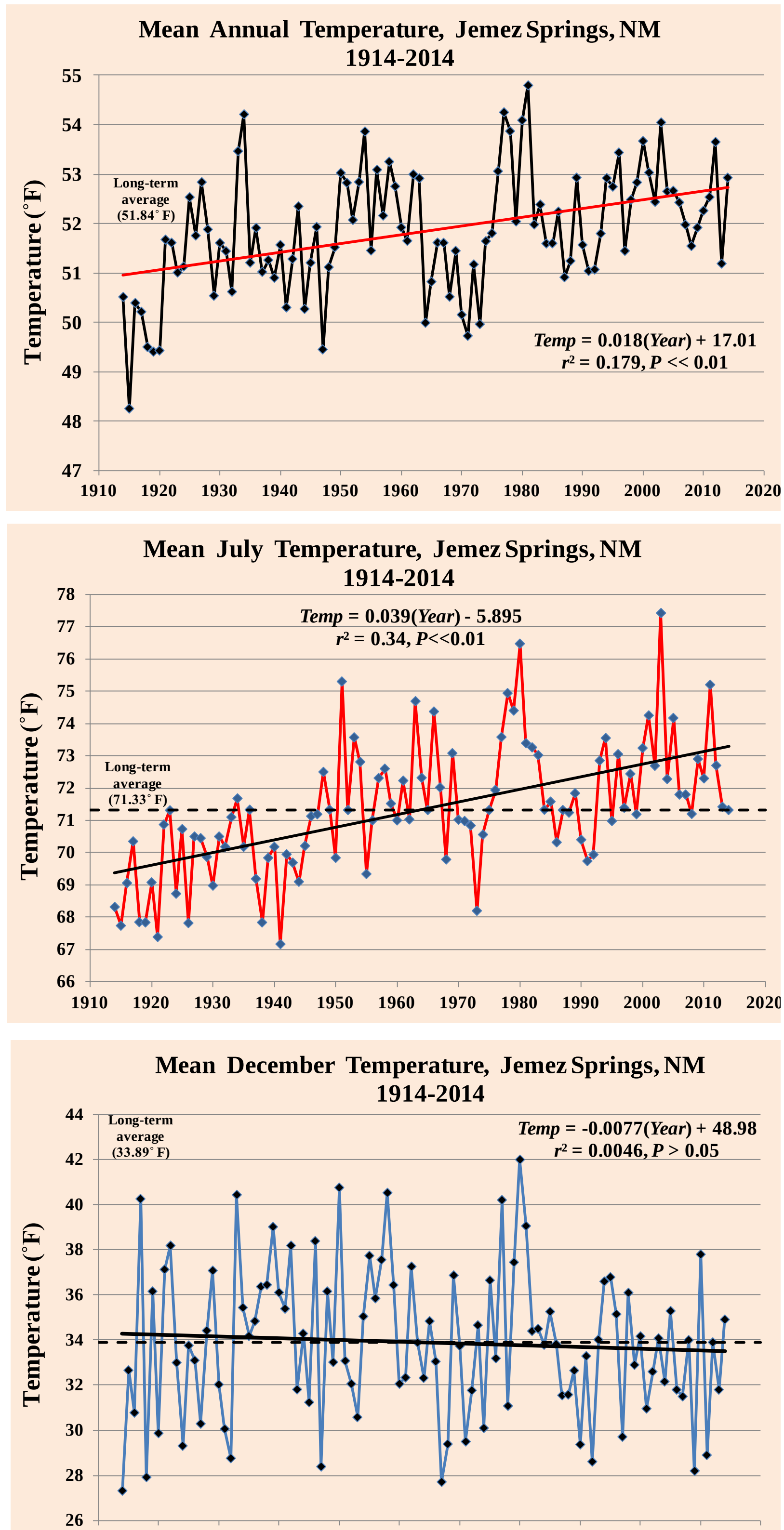


Figure 7. Temperature increases in Jemez Springs, New Mexico, 1914–2014; note that temperatures are increasing in midsummer (July), but not in midwinter (December) *(Source: Robert Parmenter, 2015)*

have been monitored for water quality using automated instruments (sondes) for temperature, dissolved oxygen, pH, conductivity, and turbidity. These data inform management on the success of watershed restoration treatments (e.g., planting willows to shade stream channels and lower temperatures), as well as document impacts of wildfires upstream. Stream discharge is monitored on all 1st-, 2nd-, and 3rd-order streams on the preserve using flumes and stream gauges; these data will prove critical for determining if forest thinning increases net water yield during spring snowmelt, an important goal of watershed restoration (Parmenter 2009).

By congressional statute, the preserve conducts a livestock grazing program for regional ranchers. Based on forage production models and a designated light-grazing regime, the preserve supports approximately 750 cow-calf pairs for 4 months/year. Livestock are kept in upland pastures, fenced away from riparian zones. Vegetation monitoring provides forage production and utilization measures, along with plant cover and diversity within and outside of livestock exclosures to ensure compliance with National Environmental Policy Act requirements. Livestock owners are charged market rates


Figure 8. Forest-floor herbaceous vegetation recovery in a mixed-conifer stand following the 2011 Las Conchas Fire. Top left: Immediately post-fire, July 2011. Top right: 2012. Lower left: 2013. Lower right: 2014 *(Source: Rebecca Oertel and Martina Suazo)*

for pasturage, and as a result, the preserve actually makes a small profit from the program.

Vegetation monitoring also provides estimation of fuel loads for prescribed fires, as well as tracking changes in plant communities following forest restoration and fires (figure 8). During fieldwork, preserve botanists document populations of invasive/nonnative plant species for subsequent removal; they also record locations of sensitive and rare plants for incorporation into future management planning for public access and use.

Wildlife population monitoring data are used in all aspects of preserve management. Information on the preserve's elk herd is critical to monitoring herd condition, demographics, habitat use, migration corridors, and disease so that the preserve can maintain a sustainable population for recreationists and hunters. Preserve biologists and collaborating scientists also monitor other large mammals, including mule deer, black bear, mountain lions, and coyotes, using GPS radio collars for movements and habitat use, scat analyses for diets, teeth collections for age determinations, and blood samples for diseases (figure 9). Small mammal studies (rodents, shrews, and bats) have been conducted for post-fire successional patterns, along with long-term monitoring of breeding birds. Fisheries across the preserve have been monitored each spring and fall since 2003, allowing evaluation of recreational fishing programs, as well as impacts of post-fire flooding. Biologists also track the distributions of protected species, such as the endemic Jemez Mountains salamander, and have reintroduced other species that were extirpated decades ago, including the northern leopard frog, the Rio Grande chub, and the Rio Grande sucker.

Figure 9. New Mexico State University graduate student Sarah Kindschuh administers a "wake-up" injection to anesthetized black bear with iridium GPS collar *(Source: Mark Peyton, 2012)*

In addition to vertebrate wildlife, preserve entomologists and collaborating biologists have monitored a wide variety of pest and beneficial insects, spiders, and other invertebrates. Ongoing monitoring projects include post-fire successional patterns of aquatic and terrestrial invertebrates following both wildfires and prescribed fires, in areas with and without ungulate grazing (elk and livestock). These results are continuously contributing to management understanding of the rates of successional changes following restoration of fire regimes on the preserve.

## Science Education and Interpretation

Virtually all of the data from the inventory and monitoring programs, and from outside research, are used in interpretive and educational materials for the public and school groups visiting the preserve. Visitors learn the latest information on the geology, biology, archaeology, hydrology, fire history, and climate of the Jemez Mountains from the preserve's interpretive staff. Preserve education specialists (including volunteer teachers) conduct hands-on field exercises with school classes, measuring vegetation, wildlife, and stream water quality in untreated control sites and areas being restored. Multiple years of education programs' data are being compiled into classroom activities involving not only natural resource ecology, but also mathematics and data analyses.

## Future Science

The science program contributes to the baseline knowledge of the preserve's natural and cultural resources, provides information for management planning and decision-making on all programs and activities, informs restoration efforts during the planning, implementation and post-action evaluation monitoring phases, and transfers synthesized results to public education and interpretive programs. Visiting scientists to the preserve contribute additional knowledge via their research studies; in 2014, the preserve hosted 53 permitted research projects with outside funding of more than $5.2 million. This amount exceeded the preserve's FY 2014 appropriated budget and recreational revenues combined. The preserve provides an important outdoor laboratory and classroom; with increasing visitation, climate change, and the expanding programs for public access and use, the science program will continue to provide salient information to fulfill the goal of science-based adaptive management.

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—Natural Resources—

# Candid Cameras – Using Wildlife Cameras to Monitor Mammal Communities in Southwestern National Parks and Wildlife Refuges

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Worldwide, mammals are considered one of the most threatened taxonomic groups, with some estimates that roughly one-fourth of all species—some 1,130 total—are in danger of extinction (Baillie and Groombridge 1996). Many consider national parks in the United States as essential refugia for mammals, especially for unique and charismatic species such as American bison, grizzly bears, and bighorn sheep. However, there is evidence that mammals have declined and become locally extirpated in many parks, particularly low-profile species in smaller parks.

The Sky Island region of the southwestern United States, known for its very high biodiversity, is one area where mammals have declined. Saguaro National Park, with approximately 70 native mammals documented (Powell et al. 2006, 2007), has lost several high profile species since it was established in 1933. The last record of a Mexican gray wolf is an individual shot by a gun just outside the park boundary by the park's caretaker, Don Egermayer, while he was off-duty in 1947. Bighorn sheep were illegally hunted in the park during the 1940s and had completely disappeared by the 1950s. The last confirmed jaguar was shot by a hunter in 1932, and the last grizzly bear was trapped in the early 1920s (Swann 2011). Park staff routinely reported North American porcupines in the first four decades of the park, but none have been observed since the 1990s and may also be extirpated. Similarly, Chiricahua National Monument and Fort Bowie National Historic Site have 67 and 58 native mammal species listed (Powell et al. 2005, 2008), respectively, with several species not documented in the last 10 years (common porcupines and raccoons) or considered extirpated from the parks (wolves, jaguars, and grizzly bears [Hoffmeister 1986]).

Determining the status of mammals in national parks is difficult to achieve. Twenty years ago, Newmark (1995) estimated that mammal species survivorship in the western United States national parks had declined since each park's establishment, and that extirpation greatly exceeded colonization. Newmark's paper was controversial among National Park Service (NPS) biologists because it was based on visitor and staff sightings, which are often inaccurate. However, it was difficult to confirm or deny the results because museum specimens, the classical way of confirming species presence, are difficult to obtain in parks where collecting by shooting and trapping was discouraged.

Fortunately, camera traps (also called wildlife cameras; figure 1) have become an effective, inexpensive, and widely available method for documenting the distribution and relative abundance of mammals. Camera traps can sense infrared heat of a passing animal, capture the event

Figure 1. Setting a camera trap at Manning Camp during the 2011 BioBlitz at Saguaro National Park *(Source: NPS, 2015)*

Figure 2. Gray fox photographed by camera trap at Chiricahua National Monument, January 2015 *(Source: NPS, 2015)*

in a digital photograph, and take photos with no human interaction. This is far more accurate than recording observations, and much less intrusive and invasive than traditional methods for studying mammals. Camera traps are used in many parks to study a host of wildlife management issues, including use of water developments, identifying animals digging into archeological sites, studies of habitat use and nest predation, interactions between wildlife and humans, and learning about rare and endangered species. They often produce high quality photos (figure 2) that can be used to interpret elusive wildlife to park visitors.

In the southern Arizona national parks, we've used camera traps to focus on mammal communities by documenting the presence and distribution of all species of medium and large mammals present in our parks. Many of these species, such as white-nosed coatis (figure 3) and collared peccaries, are only found in a few national parks. Others, such as ocelots and jaguars, are extremely rare in the United States. One of our greatest fears is losing species without even knowing it is occurring; preserving them in the face of increasing human threats is important for protecting natural wilderness values and to achieve the NPS Organic Act goal to conserve "wild life" unimpaired for the enjoyment of future generations.

Figure 3. White-nosed coati photographed by camera trap at Chiricahua National Monument, December 2015 *(Source: NPS, 2015)*

## From Field to Photos: Four Camera Trap Surveys in Southern Arizona

In 2011–2012, as part of a major BioBlitz sponsored by the NPS, the National Geographic Society, Friends of Saguaro National Park, and many other partners, Saguaro National Park conducted an inventory of medium and large mammals. To achieve an unbiased sample of mammals, we used a randomized design and unbaited camera traps (figure 4). Our goal was to develop a comprehensive knowledge of the distribution and presence of mammals, as well as to compare our results with a similar randomized inventory in the early 2000s. We set more than 50 camera traps in both the east (Rincon Mountain) and west (Tucson Mountain) districts of the park.

In the Southeast Arizona Group (SEAZ) parks of Coronado National Memorial, Fort Bowie National Historic Site, and Chiricahua National Monument, camera traps have been used for nearly two decades to document the presence of rare mammals, interactions with border crossers, and use of water developments (Swann et al. 2010; Powell et al. 2005, 2008). As part of an effort to test a

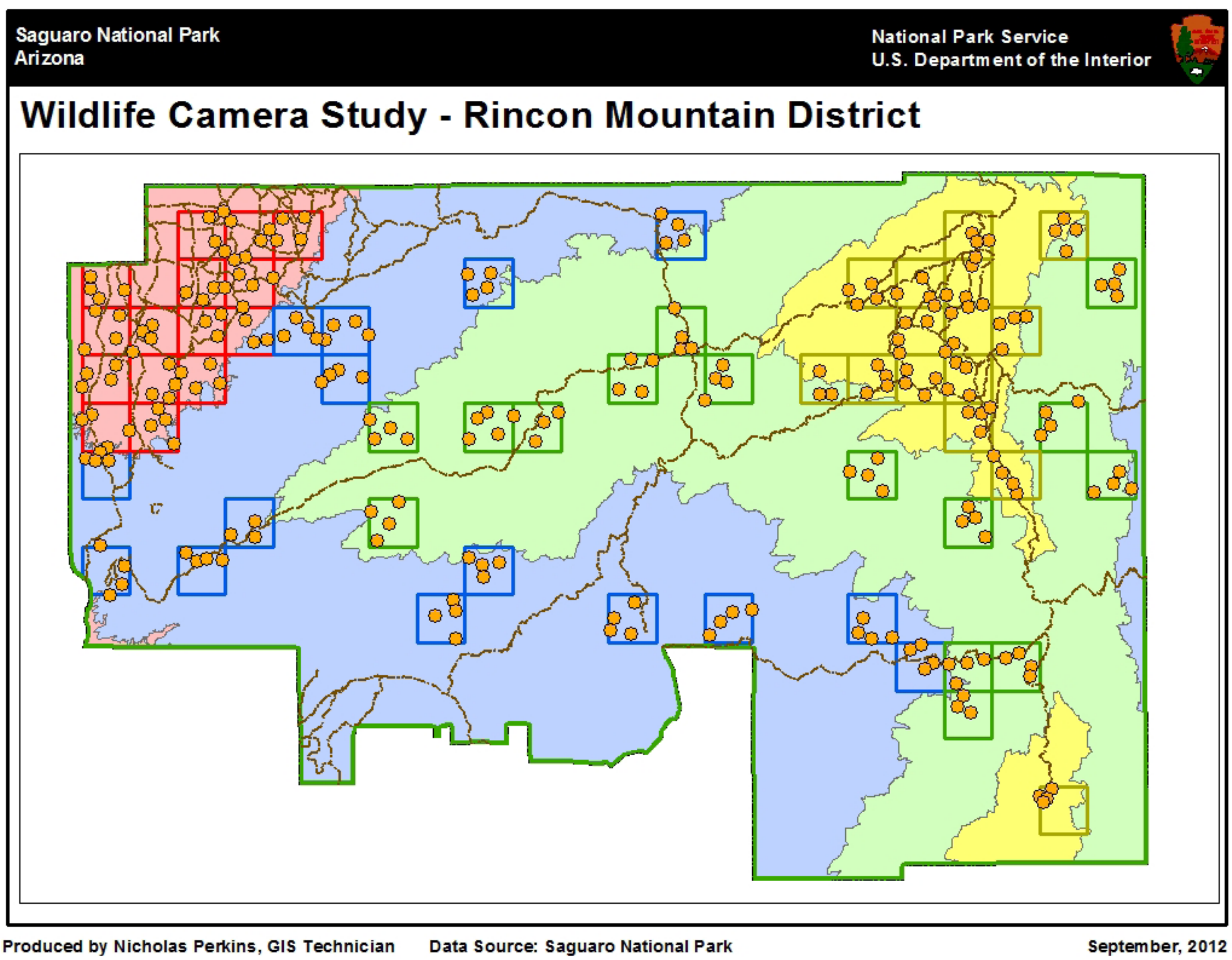


Figure 4. Map of Rincon Mountain District, Saguaro National Park, showing randomized locations of camera traps during mammal survey, 2011–2012. *(Source: Nicholas Perkins, 2012)*

regional camera trap monitoring protocol, in 2013–2014 we set out unbaited camera traps in three randomized designs at Fort Bowie and Chiricahua. At Fort Bowie, we set out 40 cameras for six weeks, and compared results from both randomly generated locations and “biotech’s choice” locations. At Chiricahua, we set out 45 cameras for eight weeks in a stratified random design (figure 5).

## From Photos to Data: Processing, Storage, and Analysis

Each sampling effort generates thousands of photographs, which are sorted and identified by species for analysis. To complete this task, we employed two methods utilizing readily available software. For the sampling from Saguaro, we used Photo Mechanic—this software adds metadata to the photographs themselves using preset dropdown menus. Adding metadata allows for simpler data management, quality control for species identification, and ensures that information travels with the photograph. Information is easily extracted into data formats recognizable by common software used for analyzing and summarizing data.

With the Chiricahua survey, we utilized a software suite developed by Sanderson (Sanderson and Harris 2013).

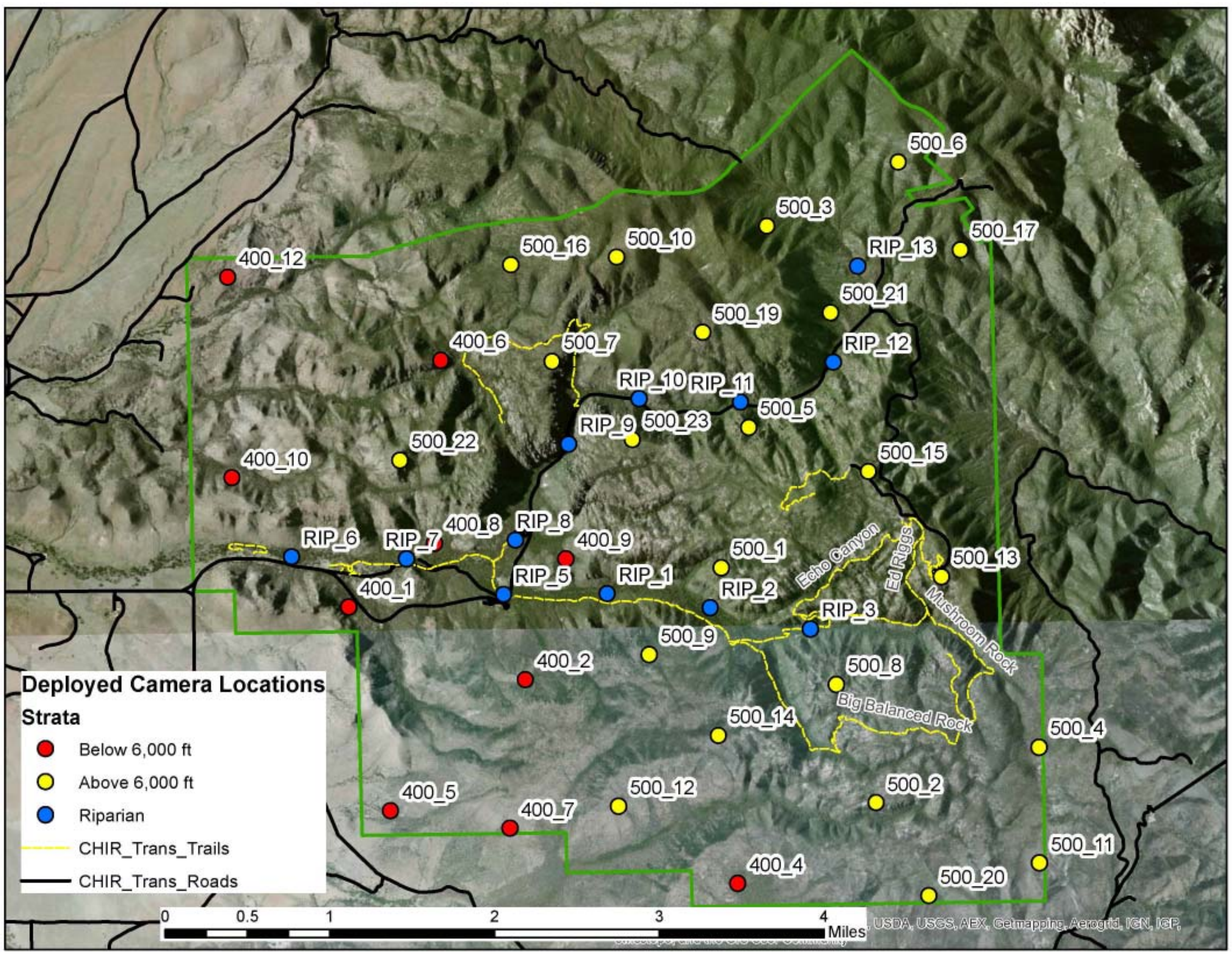


Figure 5. Map showing randomized locations of camera traps at Chiricahua National Monument during mammal survey, 2014–2015. *(Source: Amanda Selnick, 2015)*

This software rapidly processes and analyzes wildlife photos through iterative steps: batch renaming photos by date, identifying species present in photos, and placing photos accordingly in digital folders pre-named and organized by species and number of animals. The software uses the folder tree for performing a series of basic data analyses. However, unlike Photo Mechanic, it lacks the metadata editing features and enhanced ability for tagging photos for interpretive use. To analyze the Fort Bowie survey, we used both Photo Mechanic and the Sanderson method for comparison purposes.

By using a different software by Google called Picasa, we can post-process the photos for easy searching, viewing, and mapping the photo's location. We can search by individual species, such as "mountain lion," and Picasa will return all of the mountain lion photos located anywhere in the folder structure, then display on a map where each of the photos were taken. These two methods are not exclusive, and migration between the methods can be done simply to utilize the advantages of each. Furthermore, the systems are being designed to facilitate data sharing in the future. For instance, the new Spanish templates for Photo Mechanic enables data to be entered in Spanish but is capable of returning results for searches in English for certain fields, such as species identification and vice versa. Therefore, searching for "mountain lion" will return the same results as searching for "puma."

## Mammal Communities in Southern Arizona Parks

Photos from camera traps have provided a wealth of wildlife photos and revealed an impressive variety of mammals in our parks. Camera traps from all four surveys generated 21,266 photographs that contained photos of medium and large mammals during a period of 21,090 survey nights. Camera survey nights are equivalent to 506,160 survey hours, which would take a team of 10 biological technicians approximately 25 years to replicate (assuming 8-hour work days and 260-day work years). We estimated that, even in very complex terrain, the number of hours that biological technicians spent setting cameras and analyzing photo data was 1%–2% of the total time the cameras were gathering data.

**Camera survey nights are equivalent to 506,160 survey hours, which would take a team of 10 biological technicians approximately 25 years to replicate...**

At Saguaro, with randomly placed cameras set for a total of nearly 15,000 camera nights across 353 locations, during 2011–2012 we collected just over 5,000 photos of medium and large mammals that could be identified to species (Swann and Perkins 2012). In total, we detected 24 native species (as well as nonnative dogs, cows, and horses) at random locations, and two others at nonrandom sites, and estimated species richness (the number of species in the park), to be 25 (+/- 1.79). We detected large numbers of coatis and mountain lions, as well as one species (Mexican opossum) that had only been documented once previously.

At Saguaro, we compared results between the two districts and compared results from each district with similar surveys conducted in the early 2000s. Although we photographed 26 native species in the park's Rincon Mountain District, we only documented 15 in the more western Tucson Mountain District. The Rincon Mountains are larger and have a much greater elevational range, so more mammal species might be expected there. However, we failed to photograph four species that had been previously photographed in the Tucson

Mountains and, in general, obtained far fewer records of carnivores. The missing species included: raccoon, Western spotted skunk, striped skunk, and Eastern hog-nosed skunk (figure 6); and species with very few photos included: American badger, ringtail, mountain lion, kit fox, and hooded skunk.

Figure 6. Eastern hog-nosed skunk (one of four species of skunks in Saguaro National Park) photographed in the Tucson Mountains in 2009 during a University of Arizona research project *(Source: University of Arizona, 2009)*

At Fort Bowie, cameras were deployed for 42 days or 1680 total survey nights, yielding more than 12,000 wildlife photos (7,202 "biotech choice" and 4,984 random). We documented 16 species within this 1,000-acre park, but failed to detect four species that had been previously documented; possibly due to seasonal timing or inadequate sampling effort. Comparing methods, we photographed eight more species with the biotech's choice than at completely random sites (15 versus 7), but one species (white-nosed coati) was documented only at a random site. Gray fox photos comprised 45% of total photos, while the spotted skunk, cliff chipmunk, and hooded skunk only appeared on camera 1–2 times.

At Chiricahua, 45 cameras were deployed for 78 days (3,510 total survey nights) and captured 3,956 photos identifiable to species. We photographed a total of 22 medium and large mammal species, which included most of the species that could be detected with wildlife cameras. We failed to detect two habitat specialists, American badger and raccoon, but did detect mule deer for the first time. Species photographed ranged in size from American black bears to small rock squirrels. Photos composed mainly of unknown cottontails, gray foxes, and white-tailed deer, with mule deer and collared peccary captured only once each.

## Species Changes in Southern Arizona Parks

Our results reveal that the species richness and composition of the mammal community in the two larger park units, Chiricahua National Monument and Saguaro National Park's Rincon Mountain District, are very similar to previous inventories in the early 2000s. In Saguaro's Rincon Mountain District, we detected all of the species that had been recorded in recent decades except for the American porcupine, which was also not detected at Chiricahua or Fort Bowie. We photographed 22 of the 24 large mammal species previously documented at Chiricahua and documented a species (mule deer) that has likely long been present but never documented. We are still uncertain of the status of several species at Fort Bowie and plan on doing additional work in the next several years to determine whether they still occur at this small historic site.

However, in Saguaro's Tucson Mountain District, the fact that we did not find species that had been documented only a decade before was concerning to us. Small carnivores such as skunks often experience large fluctuations in population size due to rabies and other diseases, but we worry that these processes may be interacting with the increased loss of connectivity of the Tucson Mountains as it becomes surrounded with housing, highways, canals, and other developments. In response, since the inventory ended in 2012 we have continued searching for these species, including setting camera traps in locations where the three missing skunks had been detected in the past.

## Developing a Regional Monitoring Partnership

Seeing the value of using camera traps to monitor changes in the mammal community on a landscape scale, we have been working closely with the NPS Sonoran Desert Inventory and Monitoring program, the US Fish and Wildlife Service monitoring program, and nonprofit groups such as the Sky Island Alliance to increase our knowledge of mammals in the desert Southwest and help set regional monitoring priorities. We have developed a draft camera trap protocol for parks and refuges inspired, in part, by international efforts such as the Tropical Ecology Assessment and Monitoring network (TEAM) and the Wildlife Picture Index (WPI). Both partnerships have well-developed protocols and methods for data management and analysis (Ahumada et al. 2011; O'Brien et al. 2010). The camera trap survey at Chiricahua National Monument was a first test of this collaborative effort and was successful at detecting most of the species believed to be present. Over the next year, we hope to continue to test the protocol in other refuges, parks, and protected areas and involve other agencies and organizations.

Figure 7. Setting a camera trap at Ajos-Bavispe National Forest Reserve in Sonora, Mexico (sister park for Southeast Arizona Group parks), during International Parks Visit and Tracking Workshop with Sky Island Alliance in August 2014 *(Source: NPS, Don Swann, 2014)*

One organization that has been instrumental in this effort is the Sky Island Alliance, a nongovernmental organization dedicated to a bi-national conservation and protecting the native species and habitat in southwestern United States and northwestern Mexico. Biologists from the alliance are helping develop a regional partnership with Mexican national parks and other protected areas. We've shared visits among parks, including Saguaro's sister parks Parque Nacional Constitución de 1857 and Parque Nacional Sierra de San Pedro Mártir in Baja California, and SEAZ's sister park Ajos-Bavispe National Forest Reserve in Sonora (figure 7). In February 2015, we hosted a camera trapping workshop as part of a visit to southern Arizona by biologists from eight Mexican national parks, where we discussed the common problem of managing the huge amounts of photo data that can lead to backlogs and lost data. Many parks in Mexico are also using camera traps, and in general, we can all do a better job in organizing, sharing, and using data from camera traps to develop a greater understanding of the status of different species on a local and regional scale. In the long run, we believe this is essential for helping to evaluate different threats and provide opportunities for making wildlife conservation efforts more efficient and effective, not only in our parks, but throughout the region.

## Using Wildlife Cameras in Education and Interpretation

During Saguaro's BioBlitz, which was held on October 21–22, 2011, we worked closely with youth groups from high schools who learned to set camera traps, and students from middle schools were led on a wildlife tracking and camera program in the field (and acquired amazing photos; see figure 8). In addition, the park now has a wildlife educational program called the Lost Carnivore program, where middle and high school students set out camera traps and learn about wildlife tracking, then download photographs from camera traps set by previous students. More than 200 students participated in 2014–2015. One middle school student, Ava Galbraith, developed an independent project by setting up cameras where the lost carnivores had been previously detected. Although we still have not photographed the three missing skunk species, the science fair student photographed a raccoon (the first record since 2005) and won a series of awards at the regional science fair.

Figure 8. Mountain lion captured by camera trap by high school students from Arizona College Prep Academy during the Saguaro National Park BioBlitz, October 2011 *(Source: NPS, 2011)*

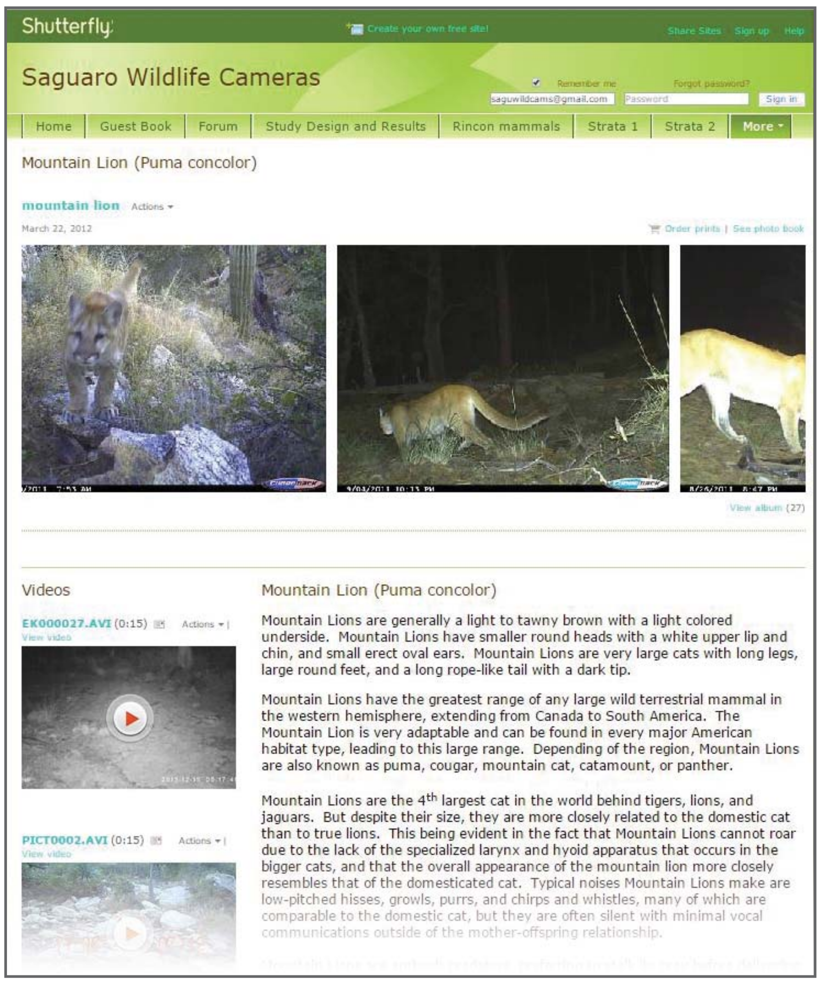


Figure 9. Screen shot from Friends of Saguaro National Park Shutterfly Site for camera trap photos taken at Saguaro National Park *(Source: https://saguwildcams.shutterfly.com/, 2015)*

In all of the parks, we've worked with interpretive staff and friends groups to upload and share wildlife photos with the public through visitor center exhibits, the park's Facebook pages, iNaturalist, the Friends of Saguaro National Park's Shutterfly wildlife page (figure 9), and other platforms. Some of the videos and photos from these camera traps are stunning and have great value in giving visitors an appreciation for seeing unusual mammals in their natural habitat that they may never be able to see otherwise. One of Saguaro's mountain lion videos has generated hundreds of thousands of views on Facebook. With added context and interpretation, these photos provide great opportunities for building support for long-term conservation and stewardship for wildlife in our parks.

## For Additional Information Please Visit:

Saguaro's Facebook page: https://www.facebook.com/saguaronationalpark?fref=ts

Mountain Lion Video: https://www.facebook.com/saguaronationalpark/videos/vb.425305310356/10155028170435357/?type=1&theater

Friends of Saguaro National Park Shutterfly Wildlife Page: https://saguwildcams.shutterfly.com/

Sky Island Alliance: http://www.skyislandalliance.org/

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—Inventory and Monitoring—

# What Can a Long-Term Monitoring Program Tell Us as a Forest Changes before Us?

## The Story of Monitoring Whitebark Pine (*Pinus albicaulis*) in the Greater Yellowstone Ecosystem

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*Michael Bozek, Intermountain Region Program Manager, Inventory and Monitoring Division, Michael_bozek@nps.gov;*
*Erin Shanahan, Field Ecologist, Greater Yellowstone Network, erin_shanahan@nps.gov*

Figure 1. Mature whirebark pine tree, *(Pinus albicaulis)*, in the Greater Yellowstone Ecosystem *(Source: NPS, Erin Shanahan, 2014)*

## Abstract

A story of large-scale change is unfolding before our eyes, and the Greater Yellowstone Inventory and Monitoring Network is poised to describe and evaluate what happened to whitebark pine stands in the Greater Yellowstone Ecosystem (GYE). Whitebark pine trees occur across approximately 10% of the 20+ million acre GYE, of which Yellowstone and Grand Teton National Parks lie in its center. As of 2013, the Greater Yellowstone Network estimated that around 27% of whitebark pine trees taller than 1.4 meters have died throughout the GYE during the recent mountain pine beetle (*Dendroctonus ponderosae*) epidemic. A majority of the whitebark pine mortality occurred in the largest, and most majestic, cone-producing trees. As a result of losing the largest trees in the stands, estimates are that up to 80% of the whitebark pine overstory vegetative cover has been lost (based on overflight and remote sensing studies). So what does it mean when a significant amount of a reproducing population is lost from an ecosystem and the remaining live trees are threatened by disease, pests, fire, and climate change? While scientists and managers discuss what may happen, the Greater Yellowstone Network is helping to tell this story with data collected through the whitebark pine long-term monitoring program.

Whitebark pine trees (*Pinus albicaulis*) are an iconic symbol of subalpine zone in western North America that often take on a gnarled or krummholz appearance in the most exposed areas. These five-needle pines are identified as a keystone species that support high elevation ecosystem functions such as retention of snowpack into late spring, which helps to maintain soil moisture for plants into the summer, and provide a food source for bears (*Ursus* spp.), Clark's nutcrackers (*Nucifraga columbiana*), and red squirrels

Figure 2. Clark's Nutcracker (*Nucifraga columbiana*) *(Source: Dave Menke, US FWS, n.d.)*

Figure 3. Red squirrel (*Tamiasciurus hudsonicus*) *(Source: Donna Dewhurst, US FWS, n.d.)*

(*Tamiasciurus hudsonicus*). Unfortunately, across its range (from the Sierra Nevada Mountains, east to the Rocky Mountains, and north into Canada), whitebark pine tree populations have declined from infestations by the nonnative pathogen white pine blister rust (*Cronartium ribicola*), the recent native mountain pine beetle (*Dendroctonus ponderosae*) epidemic, and years of wildland fire suppression (GYCCWPSC 2011). As a result of its decline, the US Fish and Wildlife Service (USFWS) listed the whitebark pine as "warranted but precluded" under the Endangered Species Act (USFWS 2011). This means that the whitebark pine merits being listed, but at the time of review, it was not listed due to actions focused on more imperiled species.

The Greater Yellowstone Network's (GRYN) long-term whitebark pine monitoring program is helping to tell a story of large- and small-scale changes occurring across the landscape of the Greater Yellowstone Ecosystem (GYE). Whitebark pine trees occur across approximately 10% of the more than 20 million acre ecosystem. Recognizing the importance of this tree species within the GYE, and potential threats to its long-term presence on the landscape, it was selected as a vital sign for long-term monitoring by the GRYN (Jean et al. 2005), and a peer-reviewed protocol was established to guide the monitoring (GYWBPMWG 2011). This ground-based monitoring program is unique in that it is an interagency effort occurring across National Park Service, US Forest Service, and Bureau of Land Management lands. Monitoring was initiated in 2004 and occurred at a perfect time to capture the impact of the mountain pine beetle epidemic. This will allow us to subsequently follow what happens as other environmental factors, such as blister rust, wildland fire, and climate change, continue to change the landscape.

Figure 4. White pine blister rust (*aecia, Cronartium ribicola) (Source: NPS, 2013)*

What do we know since monitoring was initiated in 2004? Analysis of whitebark pine tree mortality in the GYE estimates the cumulative proportion of dead whitebark pine greater than 1.4 m tall is around 27% as of 2013 (GYWPMWG 2014). Of these, monitoring indicates that while some trees died with indications of fire, blister rust, and other mechanical damage, most of the mortality occurred in the larger diameter trees that are preferred by mountain pine beetles. A majority of the tree loss occurred in the largest, cone-producing trees, which has resulted in an estimated 80% of the whitebark pine

Figure 5. Red canopy indicative of mountain pine beetle (*Dendroctonus ponderosae)*. Inset: closeup of mountain pine beetle entrance hole *(Source: NPS, John Fothergill, 2009)*

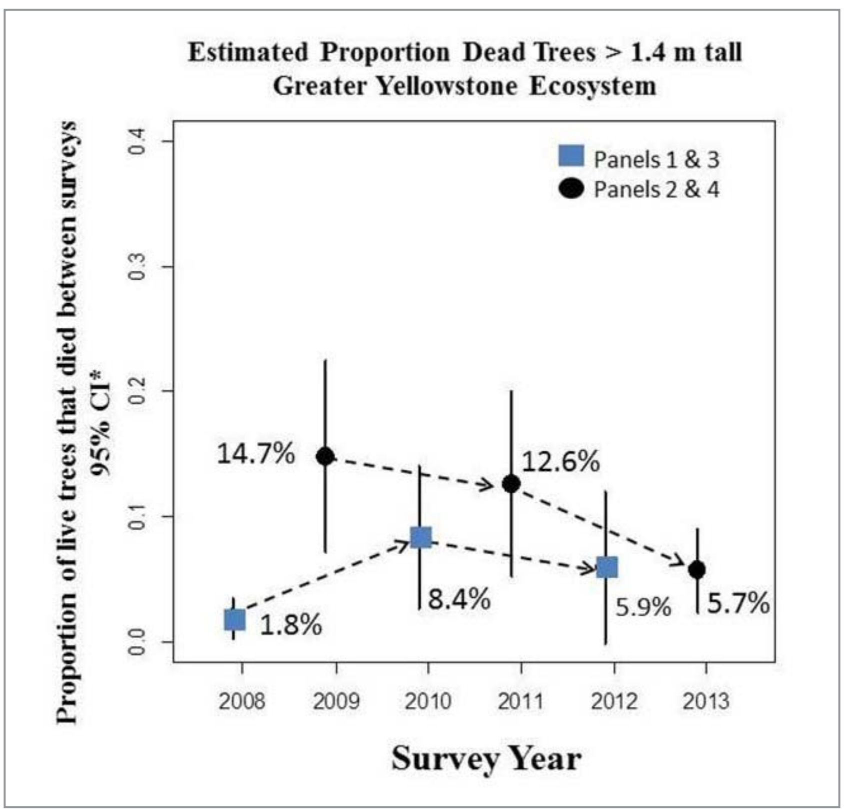


Figure 6. Ratio estimates for the portion of trees >1.4m tall that had died in the GYE since last surveyed. The directional arrows indicate the comparisons between panel survey years (panels 1 and 3 surveyed 2008, 2010, 2012 and panels 2 and 4 surveyed in 2009, 2011, 2013. *(Source: GYWPMWG, 2014)*

overstory being lost, based on overflight and remote sensing studies (MacFarlane et al. 2013). We have also documented a slower rate of tree mortality since 2009 and 2010, when the mountain pine beetle epidemic peaked (figure 6). In addition, we have recorded that over 250 tagged trees have been lost to wildland fire. Unlike mountain pine beetles that target the larger trees, wildland fire can remove any size tree depending on the fire intensity. During this time approximately 20%–30% of whitebark pines in the GYE were infected with blister rust, and the rate of infection stayed constant during that same time period (Shanahan et al. 2014). In contrast to mortality, we have also observed significant whitebark pine regeneration across the GYE, with some transects having high densities of over 600 whitebark pine seedlings (trees less than or equal to 1.4 meters tall). In addition, over 400 trees have grown greater than 1.4 meters tall and are now included in the permanently monitored population of over 5,000 tagged whitebark pine trees.

These monitoring results provide useful information to forest and park managers responsible for conserving this keystone species. Monitoring results and data are being used in ongoing USFWS species listing evaluations and numerous research

Figure 7. Whitebark pine (*Pinus albicaulis*) cones *(Source: NPS, John Fothergill, 2007)*

Figure 8. Grizzly bear (Ursus arctos horribilis) in the GYE *(Source: NPS, Jackie Skaggs, public affairs officer, n.d.)*

efforts. For example, these monitoring results were cited in a food synthesis document for the Yellowstone grizzly bear population, prepared by the Interagency Grizzly Bear Study Team (IGBST 2013). This food synthesis document addressed the potential response of grizzly bears to whitebark pine decline and changes in other food sources across the GYE. The USFWS is using the findings from this food synthesis document among other information to determine whether or not to proceed with a delisting proposal for the grizzly bear. In addition, monitoring results are being used during modeling efforts to project what might happen to whitebark pine as temperatures warm while timing and type of precipitation is predicted to change. These efforts fall under the auspices of the Greater Yellowstone Coordinating Committee–Whitebark Pine Subcommittee, which developed the Greater Yellowstone Whitebark Pine Strategy in 2011 (GYCCWPSC 2011). The subcommittee recognized that there was a dearth of information on how climate change could affect whitebark pine, and as a result, there have been numerous research efforts to fill in some of the gaps. The Greater Yellowstone Network has been participating in discussions, providing data, and field observations to inform these research efforts. We are also exploring how findings from the monitoring may relate to climate-related parameters (Thoma et al. 2015).

So in light of the significant loss of large, cone-producing whitebark pine trees across the GYE, the Greater Yellowstone Network is poised to record and help tell the rest of the story as it unfolds. We will continue this long-term monitoring program, adapting the program appropriately to gather information on when trees start to produce cones, whether

Figure 9. Whitebark pine (*Pinus albicaulis*) seedling found in 2014 growing in an area that burned in 2007 *(Source: NPS, Erin Shanahan, 2014)*

regeneration is stable, and what happens to the remaining live whitebark pine stands after disturbances like mountain pine beetle and wildland fire. We can use monitoring results to inform managers on the areas whitebark pine are more likely to survive so that they make decisions about the most effective restoration and protection strategies. All of this information is valuable for understanding and managing this important species into the future, under continued threats from disease, insects, fire, and a changing climate.

## For Additional Information Please Visit:

Yellowstone Network's website at http://science.nature.nps.gov/im/units/gryn/monitor/whitebark_pine.cfm

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Figure 10. Mature whitebark pine tree (*Pinus albicaulis*) *(Source: John Fothergill, 2007)*

—Natural Resources—

# A Paleontological Voyage on an Ancient Sand Sea: Discovering Past Life and Environments in the Fossilized Desert of the Nugget Sandstone in Dinosaur National Monument

*By Daniel J. Chure, Paleontologist, Dinosaur National Monument, dan_chure@nps.gov*

Dinosaur National Monument is world renowned for its great deposit of dinosaur bones exposed *in situ* in the sandstone of an ancient river system and protected within the Quarry Exhibit Hall. As spectacular and important as that quarry is, however, the twenty-two distinct rock formations within Dinosaur preserve a record of biological and physical changes that extends back over 1 billion years of Earth history. Documenting, protecting, and understanding each of the ancient ecosystems preserved in those formations are fundamental goals of the paleontological program at the monument.

Over the last several years, one major multi-institutional effort has investigated the paleontology and paleoenvironments of the Nugget Sandstone with spectacular results. The study area focused on outcrops within Dinosaur National Monument, along with some fieldwork on Bureau of Land Management land adjacent to the monument. Because our goal is to understand the Nugget ecosystem in detail, this paper summarizes all discoveries of that project, regardless of land ownership.

## Welcome to the Great Sandpile

Today the Intermountain West is arid, but in the Late Triassic and Early Jurassic, this area was a brutal desert, covered by a series of immense dune fields, some 2.2 million km$^2$ (850,000 miles$^2$) in extent and collectively larger than the dune fields of today's Sahara Desert. The preserved thickness of this great sandpile is up to 762 meters (2,500 feet). Known by a variety of names (Nugget, Navajo, Aztec, and Glen Canyon Sandstones), the rocks of this vast eolian ecosystem are widely exposed in the western United States. Outcrops occur in eight national park system units, eight other federal and state parks, and vast areas of Bureau of Land Management and US Forest Service administered lands. In spite of the different formation names, all the sediments are recognized as being deposited in a vast, terrestrial sand sea, known as an erg.

This ecosystem was relentlessly brutal and generally inhospitable to life. Much of the fossil record from this erg is in the form of trace fossils (footprints, trails, burrows), with just a handful of body fossils (bones, partial skeletons, and other parts of plants and animals). In the Dinosaur National Monument area, only a few reptile footprints had been previously reported. Although the Nugget had received little scientific attention in our area, we knew that the lack of fossils was not necessarily the same as the lack of life. Careful examination of the Nugget outcrops was needed, and once underway, fieldwork revealed a remarkable diversity of environments and numerous sites with fossil invertebrate trails and reptilian trackways. But most surprising of all was the discovery of a fossil lake that would produce bones in staggering abundance and of a surprising diversity, with virtually every species being new to science.

## Ancient Environments and Fossils

Although most of the erg sediments were deposited as great dune fields, there were times when some areas of the ancient desert were wetter and dune formation and migration stopped. In some areas between the dune fields, temporary bodies of water and permanent interdunal lakes appeared. Not all occurrences of each of these environments are preserved. Some were destroyed during subsequent desert growth and sediment deposition, others have been lost to erosion, and some still lay buried beneath the surface. However, enough occurrences have been found in the study area that our knowledge of the diversity of environments and life in this ecosystem has been dramatically expanded.

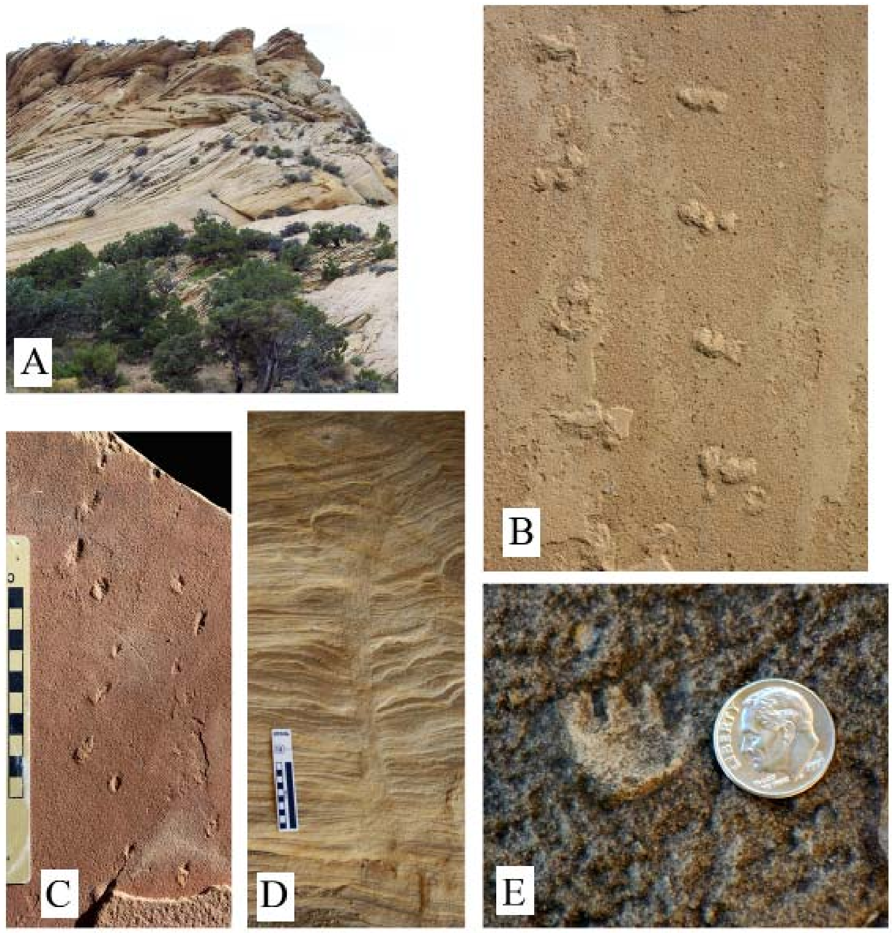


Figure 1. **Dune Deposits and Fossils.** A) Typical fossil dune deposit of the Nugget Sandstone, showing large scale cross-bedding, *2008*. B) *Paleohelcura*, part of a 6-foot-long scorpion trail. Each impression is made by a single leg, *2009*. C) *Octopodichnus*, a trail made by spiders, *2012*. D) Unnamed large scorpion or small reptile burrow cutting through sand dune beds, *2011*. E) *Brasilichnium*, the hind foot impression of a small reptile or primitive mammal, *2009*. Scale bar in cm. *(Source: Dan Chure, NPS)*

## Dunes

The Nugget Sandstone is dominated by sweeping cross-bedded deposits formed on the steep fronts of dunes (figure 1A). The dunes were tens to possibly hundreds of meters tall. Although finding fossils in such an environment would seem unlikely, abundant trace fossils occur in some dune sets (Good 2013; Chure et al. 2014). However, no body fossils have been found in these sediments.

Trace fossils come in two forms. The first group was made by nocturnal animals that roamed the dunes during the cooler evening temperatures. Among these are trails made by scorpions (*Paleohelcura*), spiders (*Octopodichnus*), and small mammal-like reptiles (*Brasilichnium*). The latter

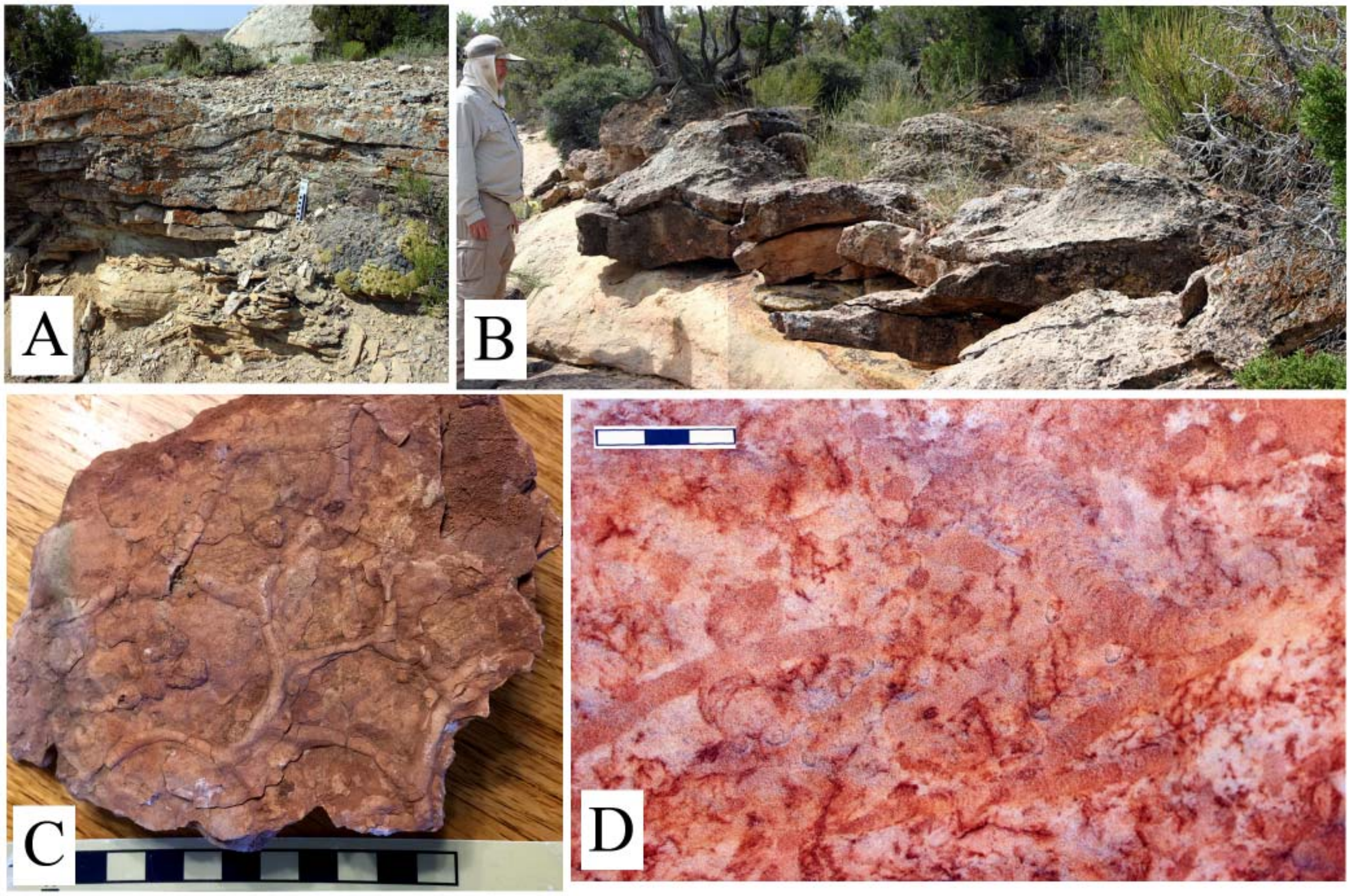


Figure 2. **Carbonate Lake Deposits and Fossils.** A) Typical shallow lake carbonate beds, *2009*. B) Series of large carbonate domes where carbonate rich groundwater seeped up through the desert sediments, *2009*. C) *Thallasinoides* burrows, made by an arthropod living in the lake sediments, *2014*. D) *Taenidium* burrows, made by arthropod larvae, *2010*. Scale bar in cm. *(Source: Dan Chure, NPS)*

occurs in the hundreds at one site (Engelmann et al. 2010).

Burrows were made by animals living, moving, and feeding subsurface on the dune front. Many of these (*Planolites, Entradichnus*, and *Taenidium*) were made by larval and adult arthropods, such as beetles (Good 2013). Larger burrows, perpendicular to the dune front and up to a meter in length, were made by either large scorpions or small vertebrates (Engelmann et al. 2014).

These trace fossils are often locally abundant in one or several dune sets, but missing in most dune deposits. Abundant occurrences are due to regional climate change and reflect periods of time with increasing moisture in the dune fields and greatly increased animal populations (Ekdale et al. 2007).

## Carbonates

Carbonate beds, such as limestone, are rare in the Nugget in this study area. These rocks form by chemical precipitation in bodies of standing water. Some are stromatolitic, indicating the presence of microbial biofilms on the depositional surfaces. Impressions of snails have been found at two sites and arthropod burrows (*Thalassinoides, Ophiomorpha*) have been found at others (Good 2013). The presence of fossils in some carbonates and not others likely reflects differences in water quality among interdunal lakes and ponds.

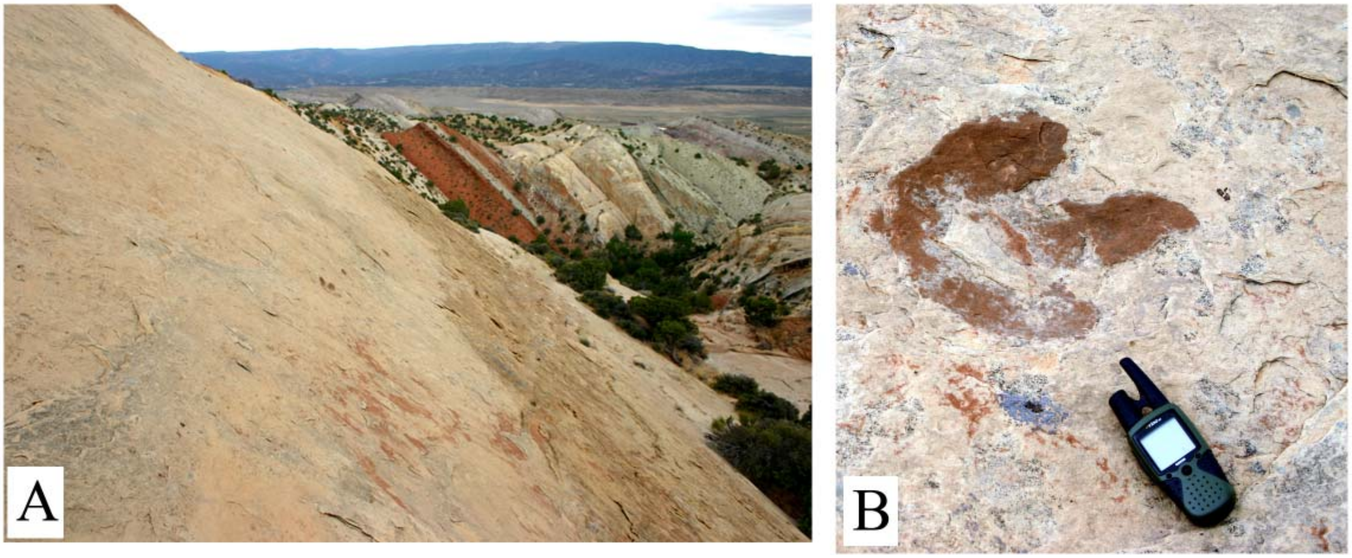


Figure 3. **Moist Interdunal Sediments and Fossils.** A) Outcrop preserving hundreds of dinosaur footprints, *2008*. B) Large *Grallator* track, made by a carnivorous dinosaur, *2006*. *(Source: Dan Chure, NPS)*

In several areas, large carbonate mounds, up to two meters in height, built up in areas where mineral rich spring waters flowed up through desert sands and spread outward from the source.

## Moist Interdunal Areas

Dinosaur footprints occur in some interdunal sands that were frequently moist but not in standing bodies of water (Chure et al. 2009; Engelmann et al. 2009; Anderson et al. 2011). Often these sandstones consist of interbedded white and iron oxide mineral-stained, brick-red layers that weather to a dark brown. This color distinction allows such beds to be identified at a distance.

Dinosaur trackways occur at multiple levels within these intervals, and often the sands are heavily bioturbated by the dinosaurs. Hundreds of dinosaur tracks (*Otozoum, Eubrontes, Grallator*) occur at some very large sites (Lockley 2011). Additionally, one locality has produced rare plant fossils of horsetail rushes.

## Oasis Lake Deposits

Rarely, interdunal intervals consist of pure sand deposited in shallow interdunal lakes that were part of a desert oasis. At one locality a horizontally bedded sandstone is sandwiched above and below by large dune bed deposits. This is the site of the Saints and Sinners Quarry, a bone bed in a 1 m (3.28 ft) thick sandstone deposited in the shallow margin of such a lake. This locality is, by far, the most important vertebrate body fossil deposit in the entire erg system. Although surface exposure is limited (~60 $m^2$ [650 $ft^2$]), over 11,000 bones have been mapped and collected, and collecting and preparation activities continue (Britt et al. 2010, 2011; Engelmann et al. 2011, 2012, 2013; Chure et al. 2013; Vanosdall et al. 2012, 2013). Preservation is spectacular, and in spite of the thinness of the bone (many skull elements are only a few millimeters thick), minimal compaction of the sand after burial preserves the bones in an uncrushed state. Because the sandstone's radiodensity differs substantially from that of the bone, microcomputed tomography (CT) scanning has revealed remarkable details of bone still hidden in rock. These CT slices have been processed to produce rotatable 3-D images of bones and skeletons.

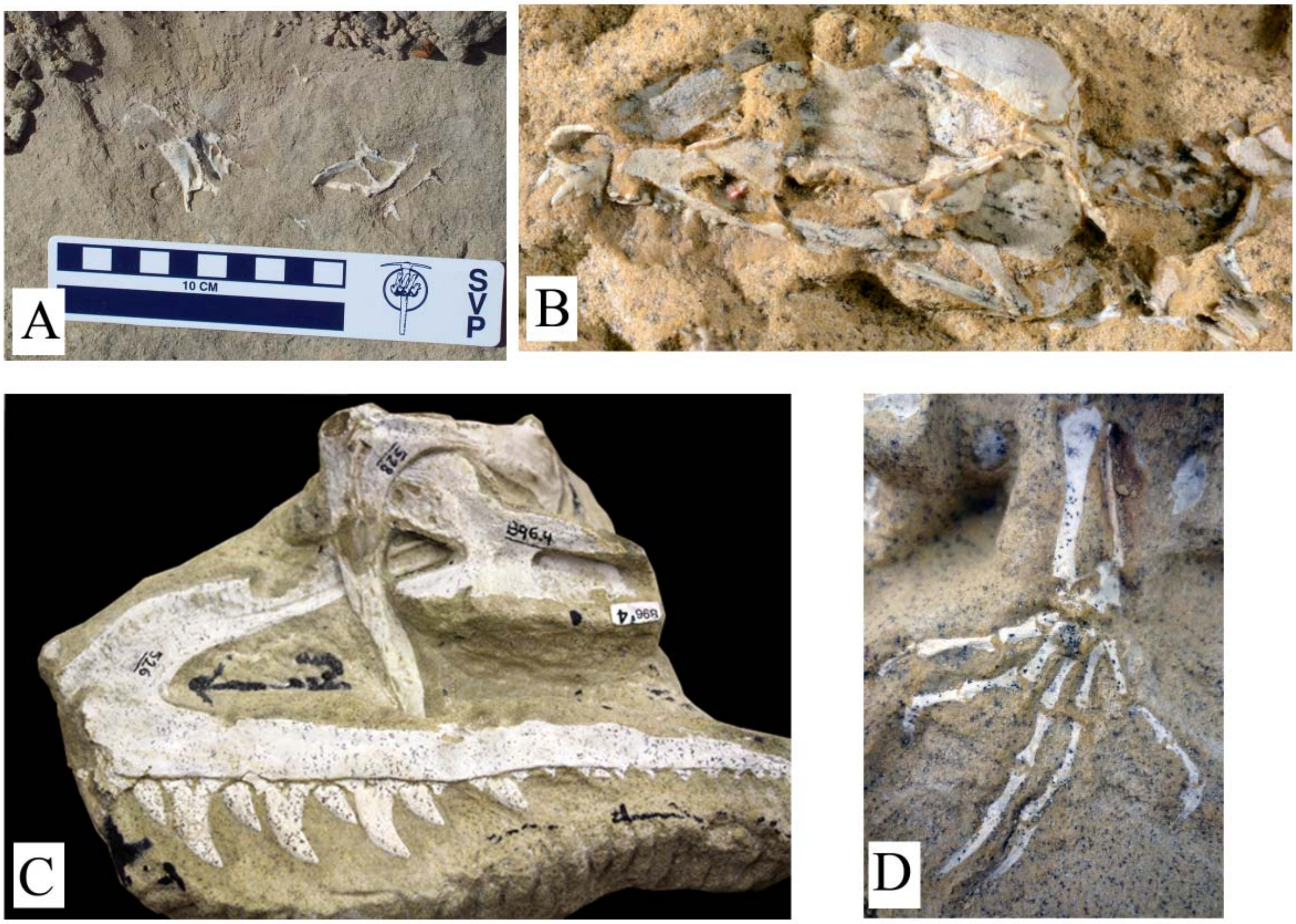


Figure 4. **Oasis Fossils.** A) Small carnivorous dinosaur vertebrae naturally weathering out of oases sands, *2008*. B) Skull of an unnamed small sphenosuchian, an agile, running reptile close to crocodiles, *2013*. C) Part of a disarticulated dinosaur skull, showing sharp recurved teeth, *2009*. D) Perfectly preserved foot of an unnamed drepanosauromorph reptile, *2012*. Scale bar in cm. *(Source: Dan Chure, NPS)*

The Saints and Sinners Quarry is our best window into the life of the erg system, and virtually every species discovered in it is new to science. The most common animal is a small carnivorous dinosaur (~3m in length), known from a minimum of 22 individuals of small to large growth stages. Nondinosaurian animals living in and around the lake include two species of small, lizard-like sphenodonts, at least 12 small crocodilian-like sphenosuchians, multiple skeletons of an alien-like drepanosaur, and the second most complete pterosaur specimen (flying reptile) from the Triassic and Jurassic of the Western Hemisphere. Both the sphenosuchians and drepanosaurs are known from multiple, 3-D preserved skeletons with skulls. Unidentified bones scattered throughout the quarry suggest the presence of other groups. No other site has produced such a rich and diverse record of vertebrate life in this ancient desert. Although plant remains are rare, parts of cycad fronds are preserved as faint impressions and dinosaur footprints are found in rocks deposited along the shoreline.

The long-limbed dinosaurs were capable of traveling long distances in the erg system; however, the small sphenosuchians, sphenodonts, and especially drepanosaurs


Figure 5. **Pre-Erg Fossils.** A) Rock overhang near the base of the Nugget Sandstone showing long, thin, invertebrate trails and abundant *Brachychirotherium* footprints, *2010*. B) Close-up of *Brachychirotherium* footprint, *2010*. Scale bar in cm. *(Source: Dan Chure, NPS )*

could not. Thus, the latter groups, coupled with the remains of cycads (plants of notoriously slow growth rates) indicate that the lake was permanent, not ephemeral or seasonal, and must have existed for many, many decades.

## Pre–Erg Sediments

In the study area, the lower 10 meters of the Nugget Sandstone consist of sediments not deposited in a dune system. During the time of their deposition, the environment was slowly becoming more arid, but water was frequently present, and the erg system had not developed. These sediments often contain ripple marks, with trackways and burrows impressed in the soft muddy sediments. Within this interval, we find a diverse dinosaur footprint fauna (*Grallator, Pseudotetrasauropus, Tetrasauropus*) and large, quadrupedal, nondinosaurian reptiles (*Brachychirotherium*) (Anderson et al. 2011). These trackways are not found in the Nugget after the extensive dune fields come into existence.

## Management Implications

Federal land managers are required by law to protect and preserve paleontological resources on land under their jurisdiction (Omnibus Public Land Management Act 2009). Rocks of the erg system are extensively exposed on public lands across the western United States (Utah, Idaho, Wyoming, Colorado, New Mexico, Arizona, Nevada, and California) and are frequently impacted by energy development, road building, construction, as well as wilderness designation, resource management activities, etc. However, because the potential for encountering fossils is low, land managers often view it as a formation of minimum concern.

Historically, the published record for fossils in the Nugget in the study area was limited to a few dinosaur footprints. However, the current multi-institutional effort in and adjacent to Dinosaur National Monument has revealed a remarkably diverse fossil record and mosaic of ancient environments. Conventional wisdom notwithstanding, the Nugget desert was not barren. At times, in some areas, it was home to dinosaurs, small crocodilians, pterosaurs, and other reptiles, as well as scorpions, spiders, beetles, and other arthropods.

This project has contributed greatly to our fuller understanding of Dinosaur National Monument's remarkable record of life on earth, provided new and exciting interpretive opportunities, and generated outstanding opportunities for scientific research. However, it has also has given us important lessons for managing and protecting these paleontological resources across a mosaic of land management agencies.

Given the wide range of environments, sediment types, and fossils that can be discovered in these erg sediments, the published scientific literature should be considered an unacceptable level of documentation for a given area. Understanding the distribution and significance of the fossils requires new inventories conducted by qualified earth scientists. Investigators need to be familiar with a wide range of fossils, ranging from the delicate impressions of a spider's leg, to the skeleton of a predatory dinosaur, to the faint remains of plant foliage. Inventory fieldwork should carefully search for the sandy interdunal lake beds that preserve bone, the rarest of fossils in desert environments. No longer can the massive dune deposits simply be written off out-of-hand because those dune sediments preserve the tracks, trails, and burrows of vertebrates and invertebrate inhabiting the driest part of the ecosystem.

Although we have intensively investigated the Nugget Sandstone within our study area, our area is only a small part of the erg deposits. There is undoubtedly a great deal remaining to be discovered in other areas, and those discoveries will reveal more about a wondrous lost and hostile world of dunes, interdunes, lakes, ponds, dinosaurs, crocodiles, scorpions, spiders, and other creatures.

## Acknowledgments

Our study, extending over nearly a decade and still on-going, was conducted by three PIs; Dr. Dan Chure (DINO), Dr. George Engelmann (University of Nebraska – Omaha), and Dr. Brooks Britt (Brigham Young University). Partial funding came via the CESU network, but external support also came from UNO and BYU. Significant fieldwork and research was also provided by externally funded undergraduate and graduate students from BYU, UNO, and the University of Utah. Interns from the Geocorps Geologist-in-Park (GSA)/ (NPS) also assisted in the project and made important discoveries.

Steamboat Rock, Dinosaur National Monument *(Source: NPS, n.d.)*

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Southeast arms of Yellowstone Lake *(Source: NPS digital slide file, R. Robinson, n.d.)*

## —Submerged Resources—

# Yellowstone's Underwater Wonders

*By Dave Conlin, Submerged Resources Center Chief, Intermountain Regional Office, dave_conlin@nps.gov*

Yellowstone National Park, our nation's first national park, is a study in contrasts—a place of great natural beauty and displaced urban issues, where people on holiday sometimes jostle for peace and quiet or a simple moment of connection to the rugged beauty and wonder that is omnipresent. Firmly planted in the heart of the park, Yellowstone Lake, with more than 100 square miles of surface area, dwarfs the other 75 ponds and lakes in the park. Centuries before the idea of the world's first national park was discussed around a frontier campfire, Yellowstone Lake was the focus of much human activity. American Indian groups had long been moving through the area, hunting and living along the shores of this high-altitude, volcanic lake. How many aboriginal sites occur along the lake shores is unknown, but evidence indicates a long history of human occupation and use of the unusual area associated with Yellowstone Lake. Mocking this relatively short-term occupation of the area by humans are the millions of years of earth history told in the geology and hydrology of the region.

Figure 1. Yellowstone Lake *(Source: NPS digital slide file, Harlan Kredit, 1976)*

While most Americans know about Yellowstone and its natural wonders above water, many would be surprised to learn that some of its most fascinating and spectacular jewels lie in the frigid waters of the lake that bears the park's name. Here beneath water that rarely warms above 40 degrees Fahrenheit and literally is within a stone's throw of one of the busiest areas of the park—the Lake District—lie natural and cultural gems that very few have seen.

The earliest Euro-American activities in the area mirrored those of American Indians, but by the 1870s, these activities shifted toward scientific studies and, before the end of the nineteenth century, included recreation, with heavy influence from concessionaires catering to the growing tourist trade. Euro-American sites, many of which are integral to the park's history, are numerous around Yellowstone Lake, although the number and full range of these sites are not yet known. Park management has recognized the importance of these archeological sites and begun a program to survey, inventory, and evaluate them in a manner necessary for their management, protection, and interpretation.

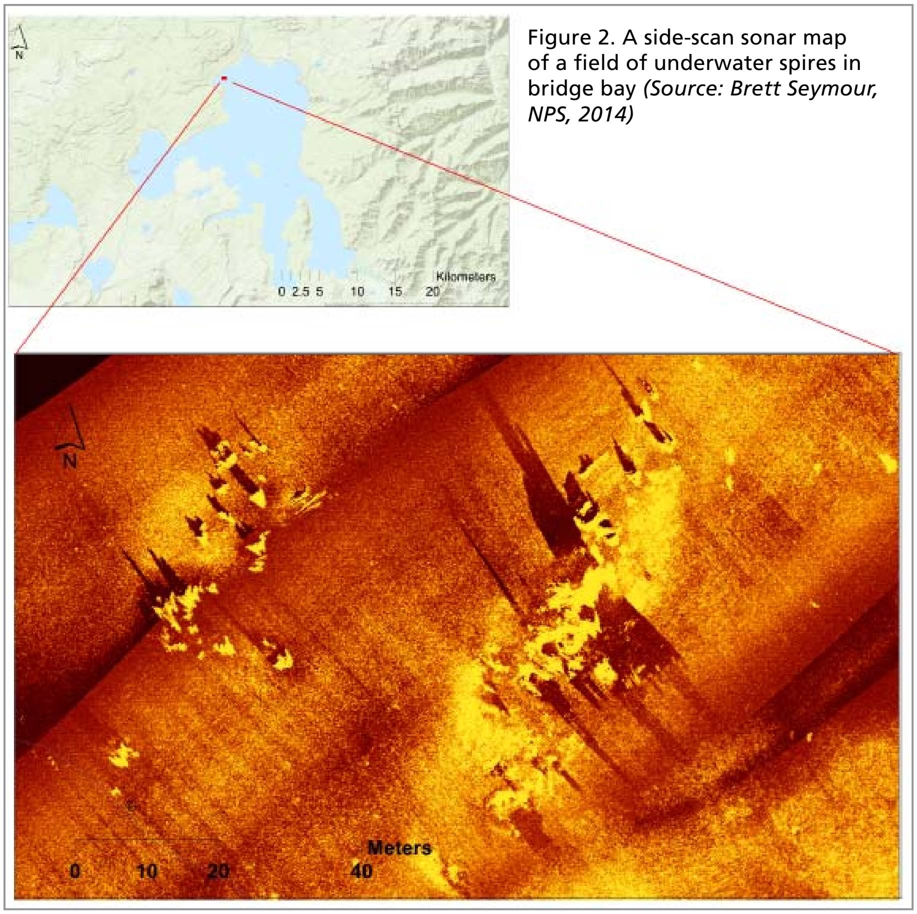


Figure 2. A side-scan sonar map of a field of underwater spires in bridge bay *(Source: Brett Seymour, NPS, 2014)*

Terrestrial archeological surveys and excavations have been conducted in many park areas, including along the Yellowstone Lake shoreline.

Underwater, the National Park Service has been similarly diligent; beginning in 1996, the Submerged Resources Center (SRC) began a program to survey, inventory, and evaluate both cultural and natural resources in a manner necessary for their management, protection, and interpretation. In 1996, side scan sonar revealed a clear sonogram of a cluster of small boats about 0.2 miles southeast of Lake Hotel.

A single dive on these small craft confirmed four boats sitting in about 23 feet of water. All four are of similar design and oriented in the same direction. As noted by former SRC Chief Dan Lenihan in his field notes from 1996, “these craft are all approximately the same size with enough variations to suggest nonassembly-line production. They seem fragile and as if they have been there quite some time.” They compare exactly with the rental boats shown in historical photographs of the Lake Hotel, which date to 1941 and were apparently scuttled after becoming obsolete.

In June of 2014, with our NPS diving intern Yasmeen Smalley in tow, the SRC fielded a team to complete a proof of concept test for an underwater, 3-D laser scanner provided by the Boulder, Colorado, firm of 3-D at Depth. While 3-D scanning of archeological sites and NPS structures is increasingly common, application of this technology underwater is fraught with thorny technical issues that few companies have been able to solve. 3-D at Depth was incredibly generous in

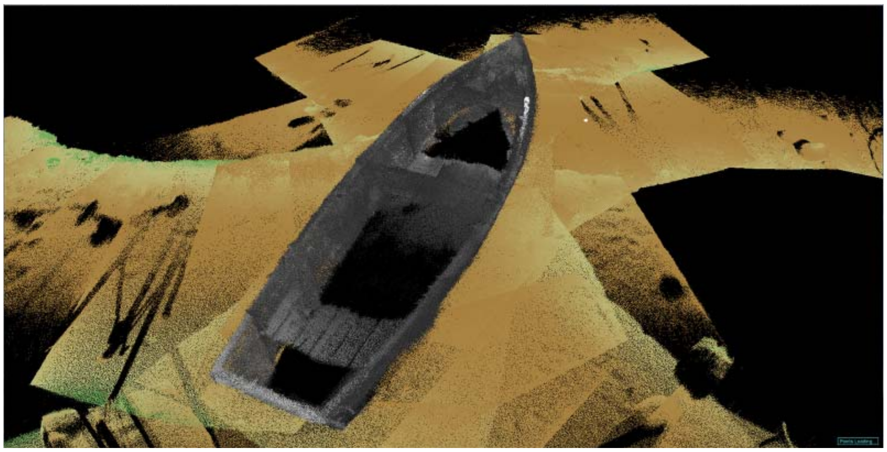

Figure 3. 3-D laser scan of one of the Yellowstone boats *(Source: Brett Seymour, NPS, 2014)*

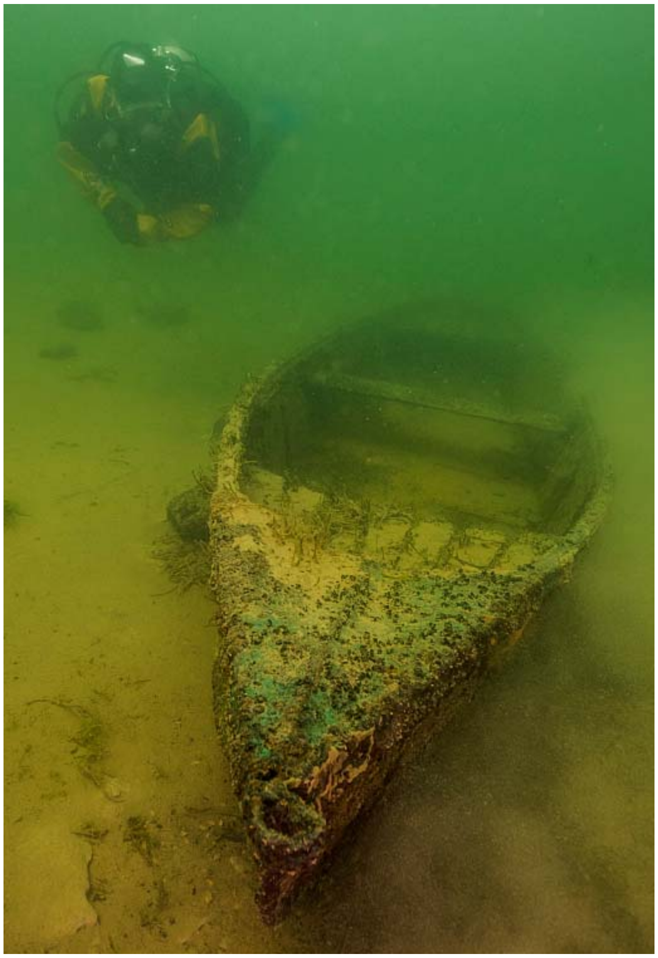

Figure 4. 2014 NPS dive intern Yasmeen Smalley swims past one of the small boats sunk in front of Lake Hotel *(Source: Brett Seymour, NPS, 2014)*

Figure 5. 2014 NPS dive intern Yasmeen Smalley swims through a submerged forest of underwater spires in Bridge Bay *(Source: Brett Seymour, NPS, 2014)*

providing the equipment and an operator for the successful project. Future plans include upscaling the documentation effort to address larger underwater structures in parks systemwide.

While the SRC prides itself on its abilities to document submerged cultural resources, on many occasions the natural resources we observe reach out and smack us with a firm, "this is spectacular," slap. Nowhere is this more apparent than in Yellowstone Lake's Bridge Bay, where submerged geothermal spires that formed in air more than 13,000 years ago lay like quiet sentinels above the muddy bottom at depths between 30 and 90 feet. Diving on these majestic features reminds you, again, why our parks are so special and why, on a good day, we have the best jobs in the world.

Taken together, the small boats and submerged spires on the floor of Yellowstone Lake comprise a remarkable diptych of our natural and cultural heritage, joined together and protected by water, preserved unimpaired for the enjoyment of the hardy few of this and future generations willing to brave the cold and make the dives.

## For Additional Information Please Visit:

http://www.owuscholarship.org/blog/2014/07/welcome-to-jellystone/

http://www.owuscholarship.org/blog/2014/07/yellowstone-2-0/

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Rough water on Yellowstone Lake *(Source: NPS digital slide file, Harlan Kredit, 1976)*

—Natural Resources—

# Desert Waters, Desert Frogs – Exploring the Natural Dynamics of a Rare Amphibian and Its Habitat

*By Don E. Swann, Biologist, Saguaro National Park, don_swann@nps.gov; Erin R. Zylstra, PhD student, University of Arizona, School of Natural Resources and the Environment, ezylstra@email.arizona.edu; Robert J. Steidl, Professor, University of Arizona, School of Natural Resources and the Environment, steidl@email.arizona.edu; Kris Ratzlaff, Biological Technician, Saguaro National Park, kris.ratzlaff@gmail.com*

Although aridity is their defining characteristic, deserts of western United States also provide habitat for a surprising number of amphibians. Many of these are toads and spadefoots that spend most of their lives underground, compressing their reproductive and foraging activities into the incredibly brief periods when rains come and water temporarily floods their world. Couch's spadefoots *(Scaphiopus couchii)*, for example, are capable of eating enough lipid-rich termites in a single rainy night to sustain them for up to two years until they can feed again. Seeking mates and breeding in temporary ponds, they produce eggs that become tadpoles and then metamorphose into small toads in as few as 10 days. In contrast, other desert-adapted amphibians, including aquatic frogs, have very different life histories that depend entirely on rare springs, seeps, and streams where water is available year-round.

Figure 1. Lowland leopard frog *(Source: Erin Zylstra)*

The lowland leopard frog (*Lithobates* [Rana] *yavapaiensis*; figure 1), which occurs in scattered populations throughout southern Arizona, southwestern New Mexico, and northern Mexico (Sredl 2005; Wallace et al. 2010), is an aquatic species that must remain wet to survive. Unlike toads and spadefoots, its tadpoles typically require at least three, and up to nine, months in permanent water before they metamorphose. Although resilient to natural cycles of drought and floods, lowland leopard frogs are vulnerable to large-scale reductions in the surface waters on which they depend. The species was once widespread in large rivers in southern Arizona. However, many valley populations have become extirpated as perennial flow in the Santa Cruz River and its tributaries ceased, principally in response to water diversion for human use, and the frogs are now mainly found in small, isolated habitat patches in mountain canyons. Lowland leopard frogs are considered sensitive everywhere they occur, including in Saguaro National Park in southern Arizona.

In recent decades, declines of amphibians across North America and worldwide have alarmed many conservationists (Wake and Vredenburg 2008). These declines have been attributed to many factors operating across a range of spatial scales, including habitat loss, disease, and climate change, and understanding their causes is a priority for conservation efforts. Because there are few long-term, detailed studies of the natural dynamics of most amphibians, however, differentiating between long-term declines and short-term fluctuations in amphibian populations can be challenging, especially in environments where the natural range of conditions is highly variable (Pechmann et al. 1991).

We began monitoring lowland leopard frogs in Saguaro National Park in the late 1990s. Initially, our efforts were largely exploratory; in 1996, park biologists received a report of a leopard frog from two US Geological Survey researchers, Cecil Schwalbe and Todd Esque, who were studying the effects of desert fires on saguaros and desert tortoises. When no one on the staff could answer the questions of which leopard frog species occurred in the park or where they occurred, we began systematic surveys in the park's Rincon Mountain District, an area of approximately 27,200 hectare (105 mi$^2$). After locating several small, isolated populations of lowland leopard frogs, we began regular monitoring of areas where conditions seemed appropriate for supporting frogs. We have continued this effort to the present, supplementing it with additional range-wide surveys and research on frog habitat (Wallace et al. 2010), diseases that include those caused by chytrid fungus (Ratzlaff 2012), interactions with wildland fire (Parker 2006; Wallace et al. 2006), and basic life history of amphibians that inhabit the

Figure 2. Tinaja habitat of the lowland leopard frog in Saguaro National Park; tinaja means "earthen jar" in Spanish and is a local term for bedrock stream pools *(Source: NPS, Don Swann, 2015)*

park. We recently completed a technical report on the first 16 years of monitoring of lowland leopard frogs (Zylstra et al. 2013) and a peer-reviewed paper in the journal *PLoS ONE* (Zylstra et al. 2015.)

Over the past nearly 20 years of research and monitoring, our main questions have been basic and focused on conservation: what are the natural population dynamics of this frog in the park? How do patterns of distribution and abundance change over time, and what natural and anthropogenic forces drive these changes? Are there long-term trends that we should be concerned about? What are the major threats, and—most importantly—how can we mitigate them to ensure persistence of this and other aquatic species in the park?

## Survey and Analytical Methods

In Saguaro National Park, lowland leopard frogs occur generally in small bedrock pools in mountain streams that are known locally as *tinajas*, meaning "earthen jar" in Spanish (figure 2). Tinajas maintain water during dry periods, and many are spring-fed. They are scattered throughout the Rincon Mountains, and vary greatly in size, water volume, sediment volume, and vegetation. In addition to supporting leopard frogs, tinajas are essential

Figure 3. University of Arizona PhD student Erin Zylstra conducting visual encounter survey for leopard frogs in Chimenea Canyon, Saguaro National Park *(Source: NPS, Don Swann, 2015)*

sources of drinking water for both wildlife and backcountry hikers.

Since 1996, we have mapped and surveyed repeatedly more than 240 tinajas in 9 streams in the park. We use binoculars to quietly survey tinajas and their terrestrial perimeters for frogs from a distance of 10–20 meters (figure 3), then approach the pool edges. We count individuals we see or hear—they make a distinctive "plop" when entering the water (Wallace et al. 2010). With a few exceptions during research projects, individuals have not been captured or handled during the nearly 20 years of monitoring. We classify frogs into stage classes: adult, juvenile, tadpole, or egg mass. In addition to recording the number of leopard frogs, we note the amount of water in tinajas and photograph the pools from established points to document changes in vegetation and sediment over time. We also record observations of other aquatic herpetofauna, including Sonoran mud turtles (*Kinosternon sonoriense*), black-necked gartersnakes (*Thamnophis cyrtopsis*), canyon treefrogs (*Hyla arenicolor*), and Sonoran desert toads (*Bufo alvarius*).

Although we have aimed to visit most pools twice annually since 1996, the extent and frequency of survey effort has varied over time. For our recent analysis (Zylstra et al. 2013), we restricted data to those collected during late spring (May–July) and fall (October–December) between May 1996 and December 2011.

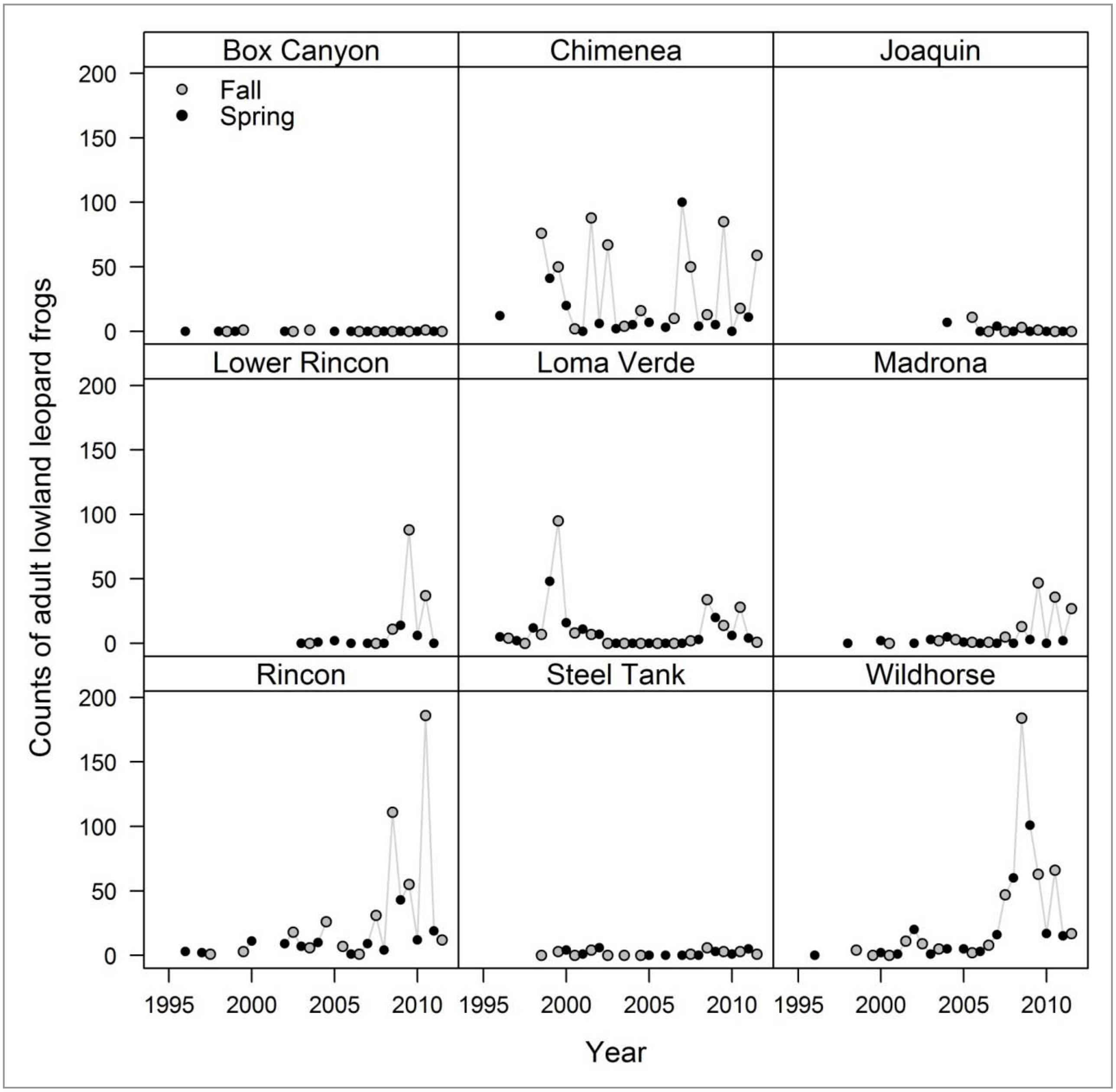


Figure 4. Maximum counts of adult lowland leopard frogs during each spring and fall survey season between 1996 and 2011 for nine drainages in the Rincon Mountains *(Source: Zylstra et al. 2013)*

Because the tinajas are often in close proximity, we based analyses on pool complexes, which we defined as collections of adjacent pools that were separated from other pools by at least 120 meters, so that within a survey season, frogs would be unlikely to move among complexes.

Although field experience helps, frogs are cryptic and easy to overlook during surveys, even for expert surveyors. To overcome the limitations of these imperfect surveys, we used hierarchical models for analysis that allowed us to explore how site- and season-level characteristics, such as elevation, distance to nearest habitat patch and availability of surface water affected abundance and occupancy, but also to account for characteristics that might have affected the efficiency of survey, such as survey effort or date.

## Results of 16 Years of Monitoring

Between 1996 and 2011, park staff and volunteers completed 470 surveys during spring and fall seasons. Leopard frogs were observed at least once in >95% of drainage reaches (n = 21). In general, counts of frogs were highest in drainages that were south-facing and that had a high density of pools below 1200-meter elevation (figure 4).

Water availability throughout the 16-year period was a primary driver of population dynamics. The probability of occupancy for adult frogs at both drainage and pool-complex scales increased with the number of pools and availability of surface water and was not associated strongly with distance between adjacent populations. Within pool complexes, abundance of adult frogs varied seasonally, with higher numbers of frogs observed in fall than in spring. Similar to occupancy dynamics, rates of adult recruitment and survival increased with availability of surface water (figure 5). Despite highly dynamic populations, over the 16 years of monitoring we found no evidence of a systematic positive or negative trend in populations of lowland leopard frogs (figure 6).

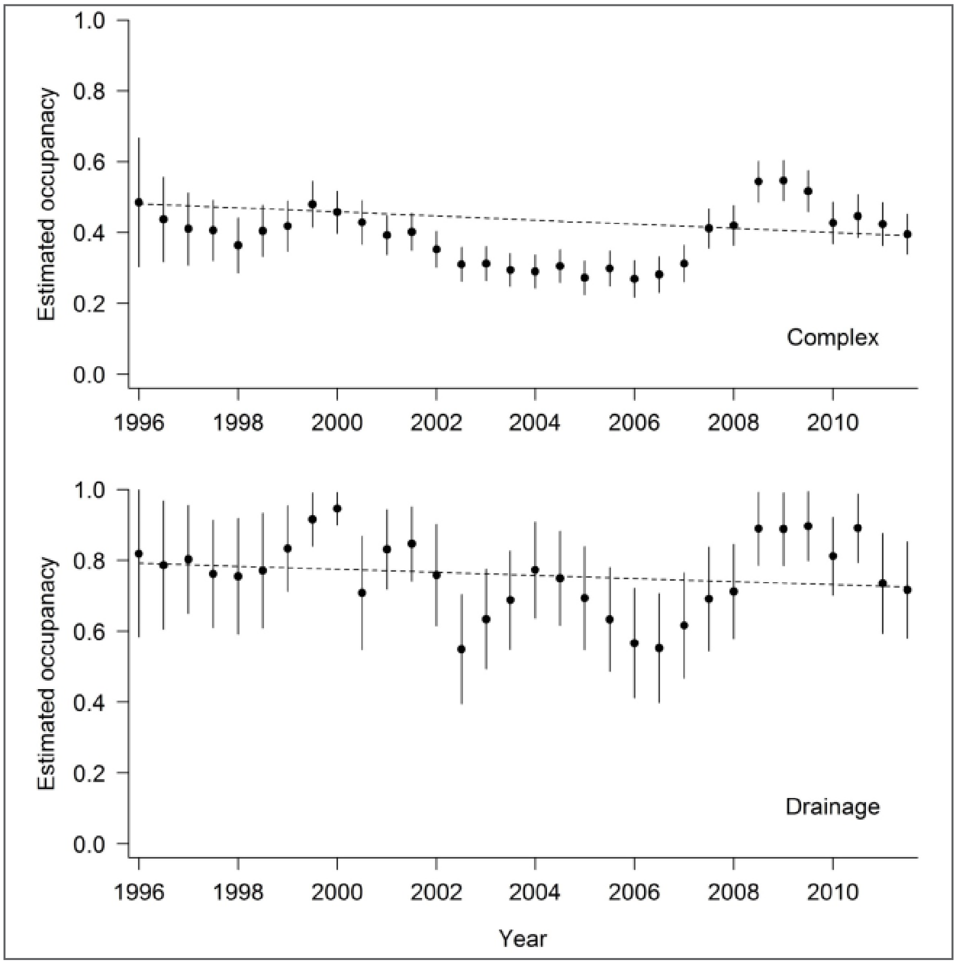


Figure 5. Estimated occupancy (± 1 SE) of pool complexes and drainages in the Rincon Mountains each spring and fall season between 1996 and 2011. Estimated trends in occupancy (dashed lines) were not significant at the complex (P-value = 0.70) or drainage scale (P-value = 0.65). *(Source: Zylstra et al. 2013)*

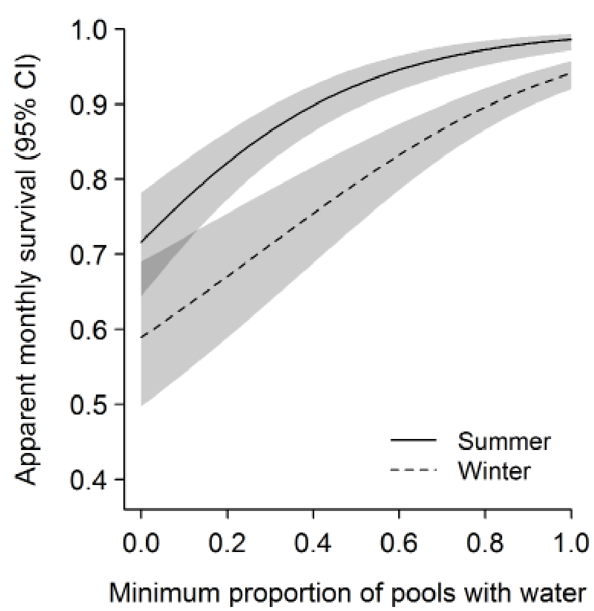


Figure 6. Predicted monthly survival (with 95% confidence interval) of adult lowland leopard frogs in the Rincon Mountains as a function of the minimum proportion of pools in a complex with water during the previous survey season *(Source: Zylstra et al. 2013)*

## Implications: The Importance of Desert Waters for Leopard Frogs

One of the more striking results of monitoring lowland leopard frogs in Saguaro National Park during the past two decades has been recognizing the tremendous dynamics of their populations in time and space. In some years, leopard frogs were abundant in nearly every stream in the park—but in other years, frogs were rare. For example, in the spring of 2006, following a series of dry years, adult frogs inhabited only one pool complex on the western side of the park, with tadpoles metamorphosing in only a single pool. Yet the population rebounded from these low numbers during the years of above normal precipitation that followed.

**...we remain concerned about the vulnerability of this species in the park, particularly because of the strong associations between availability of water and rates of extinction, recruitment, and survival.**

Although we found no evidence of a systematic trend over 16 years of monitoring, we remain concerned about the vulnerability of this species in the park, particularly because of the strong associations between availability of water and rates of extinction, recruitment, and survival. Climate-change scenarios predict increases in the severity of droughts and decreases in winter precipitation in the desert Southwest (Seager et al. 2007). In addition, the much higher temperatures observed around Saguaro National Park during the past two decades (Monahan and Fisichelli 2014) have the potential to reduce the volume of water through increased evapotranspiration. Snowmelt appears to be an important factor driving the water dynamics in tinajas and springs in the park; we do not monitor snowpack directly at Saguaro, but reductions in mountain snow and the length of time that it persists are being observed throughout the western United States.

Long-term, we are concerned that the water needs of a growing population in Tucson, now a city of approximately 1 million people, have the potential to impact tinajas and springs in the park. Ground and surface water are often tightly linked in desert water systems (Stromberg et al. 1996). Preliminary evidence from isotopes suggests that some of the current groundwater input into tinajas fell as rainfall before fallout from testing atomic bombs entered the atmosphere in the 1940s, suggesting a potential connection of the pools with regional aquifers outside the park. However, we still know very little about the hydrology of tinajas and other park waters. We are working with a range of partners, including the National Park Service Water and Geological Resource Divisions, Sonoran Desert Inventory and Monitoring Network, Sky Island Alliance, Geological Society of America, US Geological Survey, The University of Arizona Geosciences Department, and many others, to try to improve our knowledge. In March 2014, we sponsored a group of geology and hydrology graduate students to study tinajas through a Park Break program with the George Wright Society and the US Geological Survey, and we are receiving support from the Friends of Saguaro National Park, Nina Mason Pulliam Charitable Trust, and other nonprofit partners to support additional student projects.

## Fungal Disease, Fire, and Other Threats

The chytrid fungus (*Batrachochytrium dendrobatidis*, or Bd) has been implicated in declines of many amphibians, including ranid frogs in Arizona (Bradley et al. 2002). Bd has been known to exist in Saguaro since we first

Figure 7. Tinaja in Saguaro National Park in 1999 before the Box Canyon Fire, and in 2001 following the fire, showing post-fire sedimentation *(Source: NPS, Don Swann, 1999 and 2001)*

began testing for it in the 1990s, and may play a role in governing dynamics of these populations. However, disease is certainly not the only factor influencing rates of mortality and local extinction given the associations we observed between surface water and temporal variation in occupancy and abundance of leopard frogs. Recent studies have demonstrated that some populations of lowland leopard frogs in Saguaro have persisted while maintaining low rates of infection (Ratzlaff 2012), but we are continuing to try to better understand the interactions of this disease with other environmental factors.

An additional factor that affects leopard frog populations is loss of habitat associated with large wildland fires. On two occasions since we began monitoring leopard frogs, erosion following large fires has inundated tinajas with sediment, dramatically reducing the amount of water available for frogs (figure 7). These very large fires appear to be a product of years of fire suppression, although the timing and severity of the events remain unpredictable. Frog populations in at least two major canyons became extirpated following large fires and are still not recovered after more than 16 and 11 years. Geormorphological monitoring suggests that sediment moves through these tinaja systems on the order of decades rather than years (Parker 2006; O'Brien et al. 2015), which has long-term implications for management of frogs and fire on a landscape scale. In response to the potential for losing populations, we are collaborating with a local neighborhood association (the Historic Notch Neighborhood), the Arizona Game and Fish Department, and the Rincon Institute to encourage park neighbors to develop backyard pond refugia for leopard frogs and native fish for potential future replenishment of natural populations.

## Value of Long-Term Monitoring of Amphibians in National Parks

When is the loss or decline of a wildlife population a cause for concern or action, and when it is simply part of a natural cycle? Answering this question can be very challenging for managers who do not want to call out every decline as a crisis—but also do not want to see species disappear on their watch. In the case of amphibians in arid environments, it is clear that populations fluctuate greatly in response to natural processes related to variation in climate, disease, and many other factors. On the other hand, some species have declined catastrophically in western national parks, so it's essential that we take proactive steps when there is the possibility of a crisis.

The value of long-term monitoring is to provide context for making these decisions.

Monitoring leopard frogs in Saguaro National Park, while necessarily limited by fiscal constraints, provides us with some regional and temporal context by which to interpret changes in local populations and has also indicated that this desert-adapted aquatic frog is remarkably resilient. Our results also validate our original concern from the 1990s—that this species is one of the more vulnerable vertebrates in the park. Our hope is that by combining our understanding of the relationships between these frogs and their aquatic environment, we can not only protect frogs, but also the rare and unique desert waters that sustain them.

### For Additional Information Please Visit:

Technical Report on 16 Years of Monitoring of Lowland Leopard Frogs:
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4452645/).

Lowland Leopard Frog:
http://www.reptilesofaz.org/Turtle-Amphibs-Subpages/h-l-yavapaiensis.html;

Creating Backyard Ponds and Restoring Habitat for Lowland Leopard Frogs:
http://www.nps.gov/sagu/learn/nature/upload/backyard-pool-pond-resource-brief.pdf

Arizona Game and Fish Department-Animal Abstract:
http://www.azgfd.gov/w_c/edits/documents/Ranayava.fi_000.pdf

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# Feature Program—Historic Preservation

## Preserving Active Agricultural Landscapes in Intermountain Region Parks: A Joint Cultural and Natural Resources Venture

*By Jill Cowley, Regional Historical Landscape Architect, Historic Preservation Programs, Cultural Landscapes, jill_cowley@nps.gov; Lloyd Masayumptewa, Superintendent, Hubbell Trading Post National Historic Site; Christine Ford, Integrated Resources Program Manager, Grant- Kohrs Ranch National Historic Site; Jason Smith, Natural Resources Management Specialist, Grant- Kohrs Ranch National Historic Site; Terry Fisk, Chief of Resources Management and Science, Capitol Reef National Park*

### Introduction

Many national parks preserve landscape resources related to historic and precontact agricultural activity. However, there are a number of parks that preserve historic landscapes with contemporary active agricultural operations. Park active agriculture includes preserving cattle ranching culture in Montana, managing historic orchards in Utah, and reintroducing farming and livestock operations at a historic trading post in the Four Corners region. Park employees within the National Park Service (NPS) Intermountain Region (IMR) are actively applying cultural landscapes management principles and natural resources science, and they are working with associated communities to preserve and interpret active agricultural heritage in national parks. Managing all cultural landscapes inherently involves coordination between cultural and natural resource staffs. Nowhere is this more so than in the management of active agricultural landscapes, where both abiotic and biotic landscape elements contribute to historic significance, and where both historic and ecological integrity need to be maintained.

Preserving evidence of historic agriculture and maintaining contemporary agricultural operations based on historic methods are equally important for keeping the stories of past relationships with the land alive, and scientific research is needed for both to be effective. While preserving agricultural heritage of all types is challenging, the challenges of managing landscape for active contemporary agriculture (e.g., case studies in this article) can be a little different from preserving evidence of historic agriculture (e.g., at Pecos National Historical Park and Salinas Pueblo Missions National Monument). For instance, with active agriculture, integrity needs to take into account the need to accommodate some contemporary agricultural methods. This article looks at how landscape treatment guidance provided by cultural landscape reports (CLR) combines with results of natural resource science to facilitate preservation of active history-based agriculture at three IMR parks: Capitol Reef National Park, Hubbell Trading Post National Historic Site, and Grant-Kohrs Ranch National Historic Site. The historical research and analysis in a CLR identifies the "what" (the specific historic patterns and features and overall historic character) that needs to be preserved, and natural resources science informs the "how"—the specific preservation maintenance protocols.

## Capitol Reef National Park

The Fruita Rural Historic District within Capitol Reef contains approximately 25 hectares of historic orchards and pastures first established by late-19th-century Mormon pioneers (figures 1 and 2). As noted in the orchard condition report (Routson and Nabhan 2007, p.6), "The management of the orchards indirectly or directly interacts with water management, weed management, deer management, traffic management, archeological site and historic building management, and pest management in the park." The *Fruita Rural Historic District Cultural Landscape Report* (Gilbert and McKoy 1997) identified historic landscape resources to be preserved, which included the open ditch irrigation system (figure 3), specific heirloom fruit tree varieties associated with various historic individuals, and the characteristic mosaic of younger and more mature orchards. The *Inventory, Condition Assessment, and Management Recommendations* for the orchards (Routson and Nabhan 2007) detailed overall orchard health, recommended actions for specific orchards, and guided the park's 5-year orchard operations plan, which included specific direction on annual and cyclical planting (figure 4), pruning, irrigation system monitoring, soil management, and integrated pest management needs.

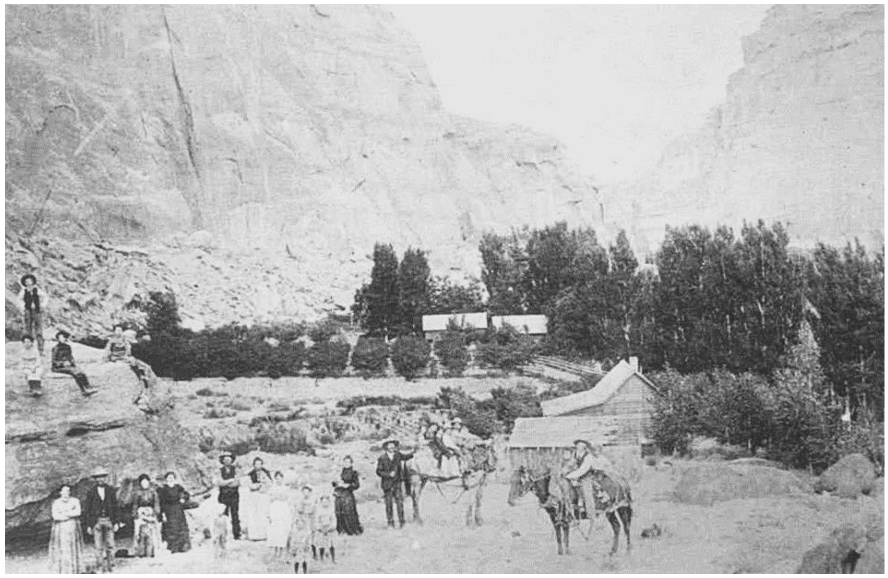

Figure 1. Mormon settlement in Capitol Reef area *(Source: park photo files, CLI file HG_890148, n.d.)*

Figure 2. Historic orchard trees adjacent to and within the nonhistoric campground *(Source: NPS, Vicky Jacobson, c. 2005)*

Maintaining the active historic orchards involves challenges and trade-offs. For example, while open ditches are still the primary water delivery device throughout the historic district and need to be preserved to retain historic character, some sections of the irrigation system are piped

Figure 3. Characteristic open irrigation ditch *(Source: NPS, Vicky Jacobson, c. 2005)*

Figure 4. Sierra Club volunteer, Utah Conservation Corps worker, and CARE ranger Ray Budzinski planting a new orchard tree during a 2013 Volunteer Day *(Source: NPS photo, 2013)*

or use pressurized water in response to the challenges of ditch sedimentation, flooding, and low water volume (T. Fisk, pers. comm., 2015). Also, in order for the park to maintain its popular "you-pick" visitor fruit harvesting program, a few of the orchards are managed as noncontributing landscape elements to accommodate needs of the you-pick program, which includes more consistent ripening times than within the contributing historic orchards. Thus, historic integrity is retained and orchard management remains relevant to park visitors.

## Hubbell Trading Post National Historic Site

John Lorenzo Hubbell ran an active trading post on the Navajo Reservation in the 19th and 20th centuries. Besides the trading post, Hubbell's operation also included growing crops and keeping livestock (figures 5, 6, and 7). Hubbell Trading Post National Historic Site was established in 1967, and the trading post remains active. Following cultural landscape report recommendations (P. Froeschauer-Nelson 1998), the park embarked on an effort to reintroduce active agriculture to the site in order to restore

Figure 5. Hubbell Trading Post circa 1931 *(Source: Park photo files; CLI files AS_850109-1)*

historic landscape character. The Hubbell Trading Post's farm plan (Regenesis 2005) provided initial guidance, and irrigation was reestablished shortly thereafter (figure 8). The irrigation water comes from the historic source, but uses piping rather than an open ditch system.

Ten years later, Hubbell Trading Post now takes care of 31 reintroduced sheep, ram, and goats (figure 9). Navajo high school students will again participate in the Hubbell Trading Post agricultural and livestock program, working with the post's Student Conservation Corps farmer Ethelynn Ashley, through a memorandum of agreement with the Ganado High School agricultural program (figure 10). Hubbell Trading Post continues to coordinate with IMR natural and cultural resources programs, including ongoing work on the integrated pest management plan. The national historic site also continues to consult with IMR Historic Preservation Programs and the Navajo tribal and Arizona State Historic Preservation Office on such issues as how best to balance parking needs for traditional community events with preservation of historic field areas. Reintroducing historic crops such as alfalfa has proved difficult in the face of invasive weeds and other challenges (figure 11). According to current Superintendent Lloyd Masayumptewa (a traditional farmer himself) additional research on soils, invasive weeds, and ethnio-botanical plants would be very useful in optimizing agricultural efforts at Hubbell Trading Post (Masayumptewa, pers. comm., 2015).

Figure 6. Historic farming at Hubbell *(Source: Park photo files, CLI files AL_8500232, n.d.)*

Figure 7. Remnant headgate from historic open ditch irrigation, with fallow fields between it and trading post buildings *(Source: NPS, J. Cowley, late 1990s)*

## Grant-Kohrs Ranch National Historical Site

Grant-Kohrs Ranch preserves the history of cattle ranching in the western United States, from 18th-century open range to 20th-century feedlot operations (figure 12). Cattle are contributing historic landscape elements, and as part of the overall nutrient cycle, they

Figure 8. Former Hubbell Trading Post Superintendent Nancy Stone supervises reintroduction of irrigation to a field area. *(Source: NPS, c. 2005)*

Figure 9. Reintroduced livestock at Hubbell. *(Source: NPS, Ed Chamberlin, c. 2011)*

Figure 10. Local Navajo high school students sheering sheep at Hubbell. *(Source: NPS, Mick Castillo, c. 2011)*

Figure 11. Reestablished historic farming terraces at Hubbell Trading Post. *(Source: NPS, Mick Castillo, c. 2010)*

are also tools for maintaining healthy soils and vegetation within the Grant-Kohrs Ranch historic landscape (figures 13 and 14).

The *Cultural Landscape Report, Part One* for Grant-Kohrs Ranch (John Milner Associates 2004) provides an exhaustive analysis of landscape history, characteristics, and character; and describes and analyzes nine component landscapes, a number of landscape systems (including irrigation), and 420 contributing landscape elements(including hay fields, beaver lodges, and wells). All biotic contributing landscape elements are both "natural" and "cultural" at the same time. The *Cultural Landscape Report, Part Two* (Shapins Belt Collins 2009) provides landscape treatment goals, for instance, for the Upland Pasture component landscape: "Manage vegetation in the Upland Pastures to reflect

Figure 12. Feeding cattle and horse at Grant-Kohrs Ranch ca. 1934 *(Source: NPS, Grant-Kohrs Ranch NHS files, GRKO 16107b)*

the long history of these lands i.e., native prairie in the dry uplands and introduced pasture species in irrigated areas . . . continue to use grazing as a tool for preserving these plant communities (Shapins Belt Collins 2009, p.25)." The 2013 *Best Management Practices Report* guides implementation of the cultural landscape report recommendations. For example, it provides details on the chemistry of animal and green manure and how to use these nutrient sources to benefit soil and plant health (B. Olson and B. Leinard 2013, p.9–12A).

Figure 13. Cattle grazing at Grant-Kohrs Ranch NHS *(Source: NPS, Christine Ford, 2009)*

Park partners are also important to the overall effort of maintaining a healthy cattle herd and telling the park's story to the public (figure 15). Grant-Kohrs' staff continues to work with Montana State University Range staff, through the Rocky Mountain Cooperative Education Studies Unit, with key input provided by the regional Exotic Plant Management Team, and the Inventory and Monitoring Program. Colorado State University faculty are conducting oral histories on the historic irrigation system, and the park hosted 178 K–12 students during the 2012 Montana Range Days Program (J. Smith, pers. comm., 2015).

Figure 15. Grant-Kohrs Ranch volunteer Laura Newman caring for a calf *(Source: NPS, Christine Ford, 2004)*

## Conclusion

Sharing approaches to active management of agricultural landscapes within parks and protected areas is of interest to local, regional, and international communities and land managers. The International Scientific Committee on Cultural Landscapes, one of several committees of the International Council on Monuments and Sites, recently initiated a World Rural Landscapes project.

Information on the IMR parks' agricultural landscapes is also available on the ISCCL website, with the potential to reach those involved worldwide in the preservation, conservation, and interpretation of historic and traditional agriculture. While preserving heritage agriculture within parks and protected areas may not be as complex as outside of protected areas, sharing NPS efforts and challenges may be useful to those trying to manage heritage agriculture outside of protected areas.

Figure 14. Winter cattle feeding: Cattle manure provides nutrients for hay that is grown in the summer *(Source: NPS, 2009)*

## For Additional Information Please Visit:

International Scientific Committee on Cultural Landscapes World Rural Landscapes Project http://www.worldrurallandscapes.org/english/outstanding-projects/

For more information on the NPS Cultural Landscapes Program and management of agriculture within parks nationwide, visit http://www.nps.gov/cultural_landscapes.

## Acknowledgments

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—CULTURAL RESOURCES—

# Building Common Ground: Bighorn Canyon National Recreation Area Tribal Field School

*By Suika Rivett, Cultural Resource Manager, Bighorn Canyon National Recreation Area, suika_rivett@nps.gov*

In 2010, tribal consultation meetings with the National Park Service (NPS) and American Indian tribes generated a request for additional historic preservation training for tribal staff and officials. In response, Bighorn Canyon National Recreation Area (BICA) began an accredited field school to host both Crow and Northern Cheyenne tribal members and students from three colleges within the NPS Intermountain Region (IMR): Northwest College, Little Bighorn College, and Chief Dull Knife College. Bighorn Canyon is located in northcentral Wyoming and southcentral Montana. The park provided the venue for the tribal field school from 2011–2014 and offered a unique opportunity for participants to explore an environment that was home to hunter-gatherer groups year-round for more than 10,000 years.

Figure 1. View of the Bighorn Canyon from 500 feet above the Bighorn River *(Source: NPS, 2010)*

Since the 1996 inception of the Tribal Historic Preservation Office, the need for better cultural resource training for tribal personnel has grown dramatically. In April 2010, the National Park Service hosted a workshop at Little Bighorn Battlefield National Monument with associated American Indian tribal leadership. During the workshop, representatives from the Crow, Northern Cheyenne, Fort Peck, Rose Bud Sioux, and other associated tribes discussed how the National Park Service could provide better support for the tribes (NPS 2011, p.37). That discussion resulted in the following requests from the tribes to the National Park Service—develop additional publications and workshops to assist and/or train tribal government historic preservation staff and tribal officials; build greater communication with tribes, state historic preservation offices, and archeological societies/communities to reverse the clash of the paradigms in the public's eye; provide training sessions for the public to include state, tribal, and archeologists' perspectives; and develop both online and face-to-face training for the historic preservation staff and tribal historians.

In response to these requests, Bighorn Canyon began planning an accredited field school to host both Crow and Northern Cheyenne tribal members and students from three different colleges within the IMR. In order to provide the educational background for the field school, Bighorn Canyon began collaborating with local colleges, with whom—through the Rocky Mountain Cooperative Ecosystems Studies Units (CESU)—the park could partner and provide NPS funding for the field school. Assistance from the CESU made possible the funding distribution and coordination for the Bighorn Canyon Tribal Field School.

Most students received scholarships through CESU funds provided to Northwest College in Powell, Wyoming. Although initially the institution was not a member of the CESU, the issue was rectified through the tenacious efforts of Chris Finley, the former archeologist at Bighorn Canyon. Northwest College, with an enrollment of 2,111 students, became one of the smallest partners in the CESU beginning in 2014. Since then, all Bighorn Canyon Tribal Field Schools have been in partnerships with either the University of Wyoming or Northwest College.

While Chris Finley worked at Bighorn Canyon, he began reuniting members of local tribes, including his Crow family, with the Bighorn Canyon. He encouraged tribal elders and others to visit and continue traditional ceremonies within the park—several which hadn't been practiced for many years. These visits have not only allowed the associated tribes to continue cultural practices on native lands encompassed by Bighorn Canyon, but they also increased park staff's knowledge of the importance of the area and management of the site's cultural resources.

**These visits have not only allowed the associated tribes to continue cultural practices on native lands encompassed by Bighorn Canyon, but they also increased park staff's knowledge of the importance of the area and management of the site's cultural resources.**

Bighorn Canyon provides a unique environment for a tribal-focused field school. This landscape provided for the needs of hunter-gatherer groups occupying the area year-round for more than 10,000 years. Winter months were spent in caves or wooden huts, which allowed occupants to maintain a ready supply of fire fuel. Tipis provided shelter during spring months throughout the varied ecological zones, providing opportunities for occupants to hunt and collect edible plants. Summer saw the loss of snow on the Pryor Mountain tops; thus providing a place to find and hew new tipi poles and hunt both game and plants. Native peoples spent fall in the grasslands region and "annually gathered for the communal bison hunt, meat and hide processing and preservation and engaged in many social and ceremonial activities" (Van West 1979, p.26).

The Bad Pass Trail provided a travel corridor to the many seasonal sites and other parts of the plains. The trail cuts a jagged north-south line through Bighorn Canyon and was utilized by both prehistoric and historic man well over 10,000 years ago. The trail provided a treacherous route from the Shoshone River near Lovell, Wyoming, to Grapevine Creek in Ft. Smith, Montana, following a mostly parallel path along the Bighorn River through what is now park land. In addition to over 700 cairns that mark the trail, there are also deep ruts that line most of the trail's more heavily used corridors. These ruts were created by countless bison, humans, dogs, and horses. Later, trappers and explorers would use the trail

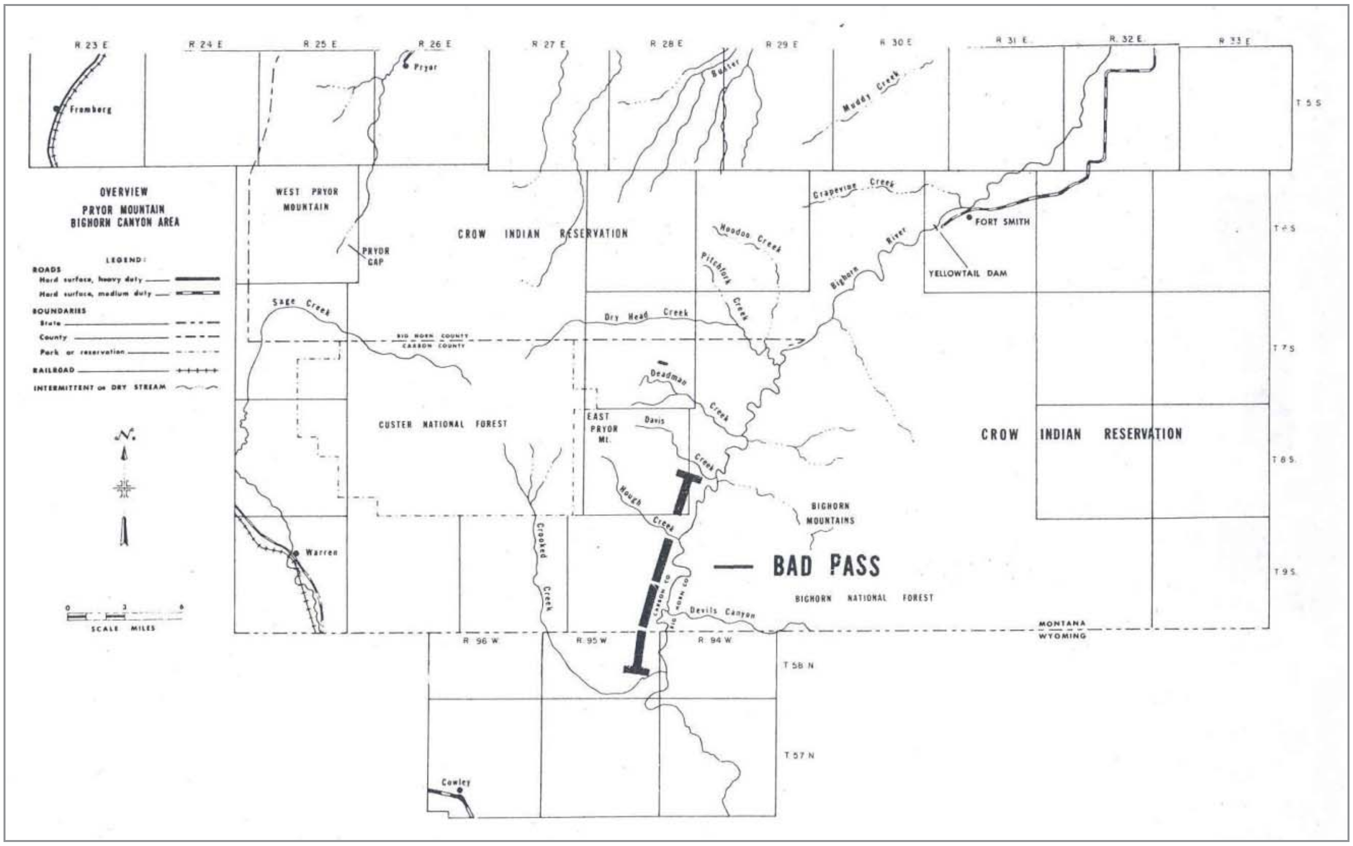


Figure 2. Map of Bighorn Canyon and general path of Bad Pass Trail *(Source: Wisehart, 2005)*

as an overland pass, making an easier route during times of the year when the river routes became dangerous. While explorers mapped the trail, trappers reconnoitered it to find areas that harbored pelt-bearing animals. Trappers would spend months at a time in the region trapping animals for trade at outposts further north and south of the Bighorn Canyon (Bearss 1970).

Figure 3. Several cairns of the Bad Pass Trail *(Source: NPS, n.d.)*

Prior to the 1950s, most of the cultural resources of Bighorn Canyon were unknown. During the 1950s, small surveys by the Smithsonian Institute identified 37 sites within the park (Van West 1979, p.118–136). During the 1960s and 1970s, Larry Loendorf and an archeological crew surveyed the park and identified 122 sites, including the Bad Pass Trail and some of its associated occupational sites (Loendorf 1974, p.96–99). Loendorf identified 12 basic classes of sites within the

Bighorn Canyon: occupation sites, tipi ring sites, wooden structures, caves/rock shelters, buffalo jumps, burials, fortified sites, quarries, rock art sites, vision quest sites, a medicine wheel site, and cairns/rock alignments (Van West 1979, p.118–136). The majority of the sites known to Bighorn Canyon staff prior to 2000 had been identified by Loendorf and his crew. NPS identified eight sites between 1979 and 1999; during Chris Finley's tenure as Bighorn Canyon's archeologist, another 183 sites were discovered prior to 2009.

Figure 4. Chris Finley recording a cairn of the Bad Pass Trail *(Source: NPS, 2014)*

During Larry Loendorf's original surveys of the Bighorn Canyon, the team based their camp at the Ewing-Snell Ranch in the park. This ranch has now been converted into a science center which houses the field school, with students spending 3 to 6 weeks living in tents on the historic ranch site.

Figure 5. Tipi ring overlooking the Bighorn River *(Source: NPS, 2014)*

In this way, and through trips to see other historic ranches in the park, students also learn about Bighorn Canyon's historical resources and receive instruction on the major legislation associated with cultural resource management, basic archeological field methodology, the National Historical Preservation Act (NHPA) / section 106 decision-making process, and basic artifact and feature identification.

Field studies include recording primary features in an occupational site, generally a tipi ring or stone circle. Students learn to accurately record these circles using a tipi quick, which is a small wooden board, usually 1-foot square or smaller, with directional degrees drawn around it in a circle. Students flag stones within the tipi circle, then as one student measures components of the tipi circle and stones, another notes the degree direction and draws the corresponding information on a sheet of paper. In that way, each stone circle is accurately drawn to scale.

Overall, Bighorn Canyon Tribal Field School participants complete 300 hours of combined coursework and archeological surveys in the park to obtain 6 hours of college credit and receive a nationally recognized certificate of training from Northwest College. Several of the field school's first students are now instructors for the school, and many others work for their tribal cultural programs. A 2012 field school participant, Sarah Jacobs, is now working on the Bad Pass Trail cultural landscape inventory as a

Figure 6. Recording a tipi ring / stone circle (note flagging) *(Source: NPS, 2012)*

Figure 7. Use of a tipi quick *(Source: NPS, 2012)*

graduate student. Listed in the National Register of Historic Places in 1979, the trail has benefited from the field school which provided research data for this inventory.

During the field school, Bighorn Canyon hosts tribal elders to teach both the students and park staff their history of the park lands. This information, combined with the hundreds of additional sites that have been recorded by the summer field school students, has provided park staff with a much greater understanding of Bighorn Canyon's cultural resources. Thanks to the Bighorn Canyon Tribal Field School, more than 137 new sites have been documented since 2009, and the boundaries of several large sites have been redefined. This has included not only identification of new sites within areas of previous surveys, but also sites in areas that past archeologists had thought were not viable for use or habitation. Cultural sites range from lithic scatters and historic roads to entire prehistoric occupational sites. With the data gained from the field schools, personnel at Bighorn Canyon have the ability to better plan and manage the park's current and future utilization and to improve protection of cultural resources from impacts of visitor use, natural occurrences, wildlife, and ranching activities. Projects developed to support these cultural assets also provide

Figure 8. A Crow elder teaching at the field school at the Ewing-Snell Science Center *(Source: NPS, 2010)*

Figure 9. Students learning to flint knap *(Source: NPS, 2012)*

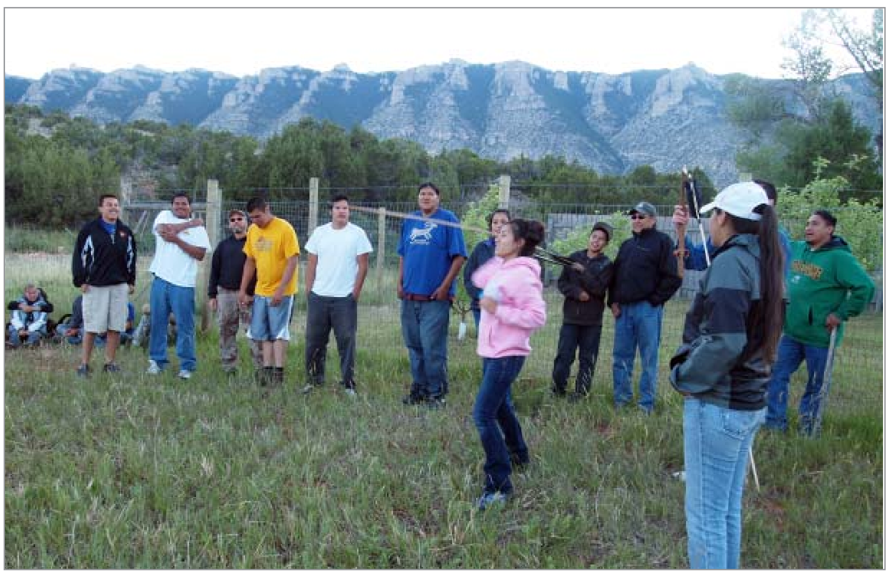

Figure 10. Students learning to throw the atlatl *(Source: NPS, 2010)*

information that enhances park interpretation for visitors.

As with all parks, Bighorn Canyon's cultural resources face many threats, including landscape impacts from wild horses of the Pryor Mountain Wild Horse Range and from over 2,500 head of cattle that are trailed through the park each season. Nature-driven impacts include flash floods (common throughout most of the previously inhabited portions of the park), high winds, heavy snows, and extreme hot and cold temperatures. General erosion from recent ground-disturbing park projects and human-caused damage (including looting of some sites) has affected several of the Bad Pass Trail cairns near the park's main road (Bad Pass Trail Park Road). The field school has helped to identify and map impacted sites and features on the Bad Pass Trail and throughout Bighorn Canyon that need additional care and protection. Because of this, implementation of park projects and required maintenance has been successfully redesigned to avoid damaging the historic trail and other recognized cultural sites, as well as allowing for enhanced interpretation by park staff.

The Bighorn Canyon Tribal Field School's success has been demonstrated through the reconnection of tribal members with their past and bringing the next generation into Bighorn Canyon, providing training for current and future tribal preservation personnel, adding vital information to Bighorn Canyon's overall cultural resource program, and publicizing the park through articles in peer-reviewed journals and NPS publications.


Figure 11. 2010 Field school students presenting their preservation certificate *(Source: NPS, 2010)*

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—CULTURAL RESOURCES—

# Border Archeology at Chiricahua National Monument: Data Recovery at CHIR00021

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## Introduction

In southeastern Arizona, the incredible history of Chiricahua National Monument is threatened by modern, human-caused impacts, ranging from cross-border smuggling to climate change. But thanks to an ongoing cooperative project, several sites are being relocated, recorded, and preserved. This is the story of the Garfield Peak Cave, which spans nearly 100 human generations.

Among the steep canyons and rugged mountains of Chiricahua National Monument, much of the rough landscape appears uninhabitable. However, humans have been living in the Chiricahua Mountains for thousands of years. In fact, evidence of human habitation in the area of the monument has been found dating to the Middle Archaic period (ca. 5500–3500 BCE). Archeological evidence also shows that subsequent American Indian groups lived in and around Chiricahua until the arrival of Anglo American settlers and soldiers in the late 19th century.


Figure 1. Jake DeGayner looks out from Garfield Peak Cave *(Source: Matt Guebard, 2014)*

Today, direct and indirect human impacts are negatively affecting those resources. The monument is located within a corridor commonly used for the trafficking of illegal narcotics from Mexico. Trails and campsites used by smugglers are often discovered within the boundaries of archeological sites and result in destructive impacts. Global climate change is also a threat. Rising temperatures and drought have increased the size and intensity of wildfires in the region (Holtz et al. 2014). For example, in 2011, the Horseshoe Two Fire burned approximately 12,000 acres within the Chiricahua National Monument boundary (Southwest Fire Science Consortium 2015). The intense heat caused by wildfires can damage and destroy artifacts, and the loss of vegetation accompanying a fire often results in the erosion of site features and artifact deposits.

In 2010, the National Park Service (NPS) partnered with

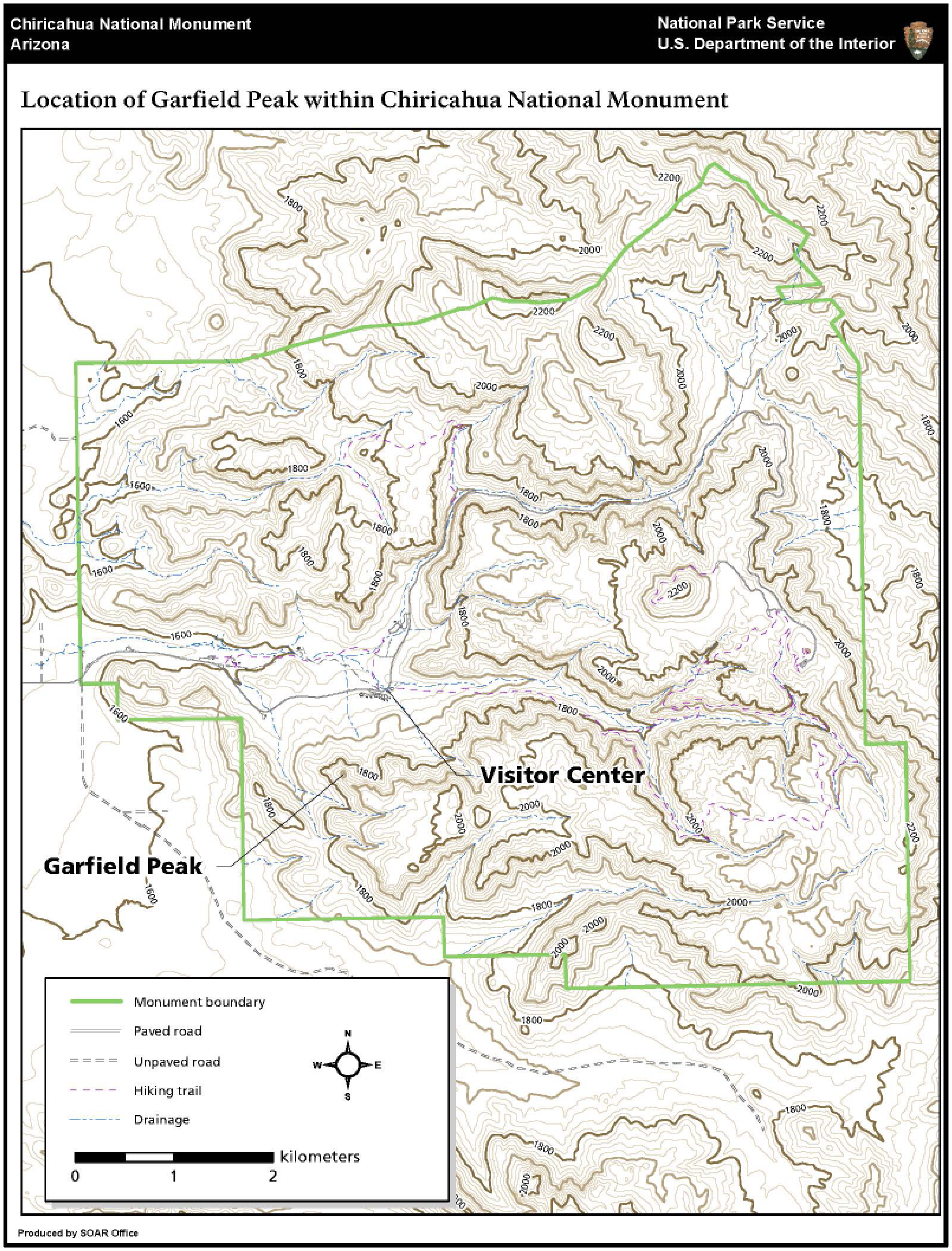


Figure 2. Map of Chiricahua National Monument showing the location of Garfield Peak
*(Source: Southern Arizona Office, 2015)*

the University of New Mexico (UNM) to assess and record damage to archeological sites caused by drug trafficking. Following the Horseshoe Two Fire, the partnership was extended to include inventory and condition assessment of archeological sites within the burn area. As part of the ongoing cooperative project, UNM and NPS archeologists relocated known archeological sites threatened by wildfires and narcotics trafficking.

## CHIR00021: The Garfield Peak Cave

One of the first sites to be relocated was CHIR00021, a small rock shelter located on the southeast side of Garfield Peak. The site was first discovered and recorded by NPS archeologists in 1971. At that time, two artifacts were reported in the cave: a large, globular basket made of coarsely coiled bunch grass and a buried hunting net made of twined yucca fiber. The National Park Service initially adopted a "preservation in place" strategy, wherein these fragile artifacts were left in the location they were found. A chain link fence and rock wall were constructed at the mouth of the cave to provide additional protection by restricting animal and human access. NPS archeologists soon determined this strategy was ineffective and that rodents were damaging the basket. In 1980, NPS archeologist Donald Morris removed the coarsely coiled basket, but left the partially buried net in place (Morris 1981).

Figure 3. CHIR00021 with chain link fence torn down *(Source: Thaddeus Liebert, 2013)*

Figure 4. The net is packaged and ready to remove from the CHIR00021 cave *(Source: Matt Guebard, 2014)*

CHIR00021 was relocated by UNM archeologists in 2013. By that time, the chain link fence had been pulled down and the hunting net was exposed. Park resource managers feared that the cave might be used as temporary shelter for smugglers or that a wildfire could irrevocably damage the exposed and fragile net. Management guidelines in Director's Order 28: *Cultural Resource Management* state that "Significant archeological or other scientific data threatened with loss from the effects of natural processes, human activities . . . are recovered, recorded, or otherwise preserved" (NPS 2015). Hunting nets, like the one found at CHIR00021, are extremely rare; this is due in part to the fragility of the plant fibers from which they are made. A collections survey some 40 years ago (Kaemlein 1971) found only 16 nets known in the American Southwest; of these, only one other net had been found in the Chiricahua Mountains.

In 2014, an interdisciplinary team of cultural resource specialists from the Southern Arizona Office, Western Archeological and Conservation Center (WACC), and UNM convened to determine appropriate measures for documenting, protecting, and preserving the net. After careful consideration, it was decided that the net should be removed from the cave and curated at WACC. A data recovery and conservation plan was drafted to outline methods for removing, transporting, and storing the fragile artifact. Copies of the plan and a memorandum of agreement were reviewed by the Arizona State Historic Preservation Office, the park's traditionally associated American Indian tribes, and the Advisory Council on Historic Preservation.

## Recovery and Analysis of the Net

In May 2014, data recovery at CHIR00021 began. A strenuous, 2.5-hour hike over difficult and steep terrain was necessary each day because pack animals, helicopters, and off-road vehicles could not be used to access the area. Once there, the small size and low ceiling of the cave made work uncomfortable, and steep drop-offs from the cave made conditions dangerous. Excavators were required to wear respirators to protect against cave dust containing silicon dioxide and rodent feces. Two 1-meter units were methodically excavated over three days. Sediment was carefully removed from around the net using brushes and passed through 1/4-inch and 1/8-inch sifting screens. Prehistoric ceramics, net fragments, charcoal, and plant remains were found in the screens and collected for future analysis. The net was extensively documented before, during, and after excavation, using digital photography, digital video, hand mapping, and digital photogrammetry.

Following excavation, the net was carefully lifted and placed into a box built of cardboard, ethafoam, and cotton batting.

Figure 5. Brian Haas removes the net from the CHIR00021 cave (Source: *Matt Guebard, 2014*

Figure 6. Brian Haas carries the packaged net on his back *(Source: Matt Guebard, 2014)*

Figure 7. The net is carefully transported from CHIR00021 *(Source: Matt Guebard, 2014)*

The box was built on-site to provide customized support, so the net would not move or be damaged during transportation. The box was then secured to a specialized backpack called a cache pack, designed for carrying large and heavy objects. The box containing the net was then carefully hauled off the mountain on the backs of archeologists.

The net was transported to WACC, where it underwent rigorous curatorial treatment. Before entering the conservation lab, the net was frozen to -30°C (-22°F) for 48 hours. This extreme temperature was necessary to kill any living pests that might damage the net, as well as to destroy dangerous pathogens, such as hantavirus. Sediment was carefully removed from each strand, using low-powered vacuum suction. Additional artifacts entwined within the net were carefully recorded and removed. Each individual strand, of which there were hundreds, was also carefully mapped.

Much has been learned about the net since it arrived at WACC in 2014. For instance, it is made of yucca fiber (*Yucca* sp.), a sharp-leafed perennial shrub that is widely available in the local area. To build the net, prehistoric people collected large amounts of yucca leaves, then pulverized them to extract the fibrous tissue. Hundreds of stringy fibers were then twined together to create long, thin strands of cordage. One individual strand measures over 6 meters (19.68 feet) in length, and hundreds of square knots were tied to give the net its shape and size, representing many hours of tedious labor.

Ethnographic evidence suggests that hunting nets like this one were used to catch rabbits (Steward 1938). Similar but complete hunting nets found elsewhere in the American Southwest measure up to 73 meters (239.5 feet) in length (Kaemlin 1971). At this size, a net would have been too large for one person to handle and would have required a coordinated group effort. To successfully catch rabbits, many people would have been required to hold and position the net, while many others were responsible for driving rabbits into the net. Once entrapped, rabbits could be killed with clubs or arrows.


Figure 8. CHIR00021 net after its arrival at WACC *(Source: Brynn Bender, 2014)*

The size of the CHIR00021 net was much smaller than other more complete specimens found in the Southwest; this was because it had become severely damaged by rodents. The orientation of intact sections, however, suggests the net was originally folded and placed directly on the floor of the cave, perhaps for long-term storage or safekeeping between hunts. Two small sections also appear to have been gathered in handfuls and cut with a sharp-edged tool, perhaps as a means of salvaging portions of the net for other purposes.

A date range for the creation of the net is approximately 930 (+/-30) BP (Before Present) (Hood 2014). This suggests it was made and used by the Mogollon archeological culture, a group of prehistoric farmers living in the Chiricahua Mountains from AD 300–1200. Plain brown ware ceramic sherds found with the net also date to this period, suggesting that CHIR00021 may have also contained ceramic storage vessels that were broken or removed prior to the 1971 discovery of the cave.

## Reanalysis of the Coarse Coiled Basket

A reanalysis of field notes and artifacts associated with Donald Morris's excavation at CHIR00021 was also conducted as part of the project. Of particular interest was the coiled grass basket removed from the cave in 1980. The basket is made of split beargrass leaves (*Nolina microcarpa*) and wild bunchgrasses (*Setaria macrostachya*, *Muhlenbergia monticola*, *Trachypogon secundus*), all locally available materials (Morris 1981). Carbon 14 dates acquired from the grasses indicate they were harvested around 3340 (+/-190) BP (Linnick 1983). This places use of the basket within the Late Archaic / Early Agricultural period, a time associated with the earliest known use of maize and other domesticated plants in southern Arizona. Interestingly, Morris found fragments of maize kernels inside the basket. If the basket and kernels are contemporaneous, then

Figure 9. Brynn Bender cleans and examines the CHIR00021 net *(Source: NPS, 2014)*

CHIR00021 may be one of the earliest agricultural sites yet known in the American Southwest. UNM and NPS archeologists are developing a sampling plan to date the kernels using accelerator mass spectrometry (AMS) radiocarbon technology. The resulting AMS dates will determine whether kernel fragments are contemporary with the basket. If the kernels are 3,000 years old, the team will suggest genetic sequencing as a means of helping future archeologists to track the adoption of maize agriculture in the American Southwest.


Figure 10. The coiled basket removed from CHIR00021 by Donald Morris in 1980
*(Source: Matt Guebard, 2015)*


Figure 11. Fragments of maize kernels found within the basket
*(Source: Matt Guebard, 2014)*

## Conclusion

The coarsely coiled basket is over 2,000 years older than the hunting net. This indicates that CHIR00021 was used for the storage of important objects over the span of 100 human generations. Although the reuse of dry caves is common in the archeological record, CHIR00021 is particularly small and extremely difficult to access. What distinguishes CHIR00021 from other caves in the area, and why was it used repeatedly for many years? The answer may lie in the shape and size of the cave itself. Although CHIR00021 is small, it is over five meters (16.40 feet) deep from front to back. This is deeper than many other alcoves in the area and provides a dry, protected spot for the short-term storage of food and hunting equipment. This type of environment is also optimal for the preservation of these organic objects for thousands of years.

Chiricahua National Monument contains steep canyons and rugged mountains with a rich record of human history. Impacts such as illegal drug trafficking and wildfires create serious challenges but also opportunities for scientific investigation. Archeologists are only beginning to fully understand the importance of the artifacts found within the CHIR00021 cave. Future study of these objects will increase scientific understanding of prehistoric life at Chiricahua National Monument and throughout the American Southwest.

Figure 12. Schott's Yuccas
*(Source: NPS, n.d.)*

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Figure 13. View from Massai Point, Chiricahua National Monument *(Source: NPS, Katy Hooper, n.d.)*

—Natural Resources—

# Application of New Technologies Supporting Paleontological Resource Inventory and Monitoring in Intermountain Region Parks

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## Introduction

The Intermountain Region (IMR) of the National Park Service (NPS) preserves a diverse and scientifically important fossil record, which extends from the top of the Rocky Mountains in Glacier National Park to the cliffs along the Rio Grande Wild and Scenic River. Collectively, fossils documented within 73 parks in the region span more than a billion years of Earth's history and provide exceptional opportunities for scientific research and public education. The challenges associated with the management and protection of nonrenewable paleontological resources resulted in the development of innovative practices and collaborative partnerships within the IMR parks. The use of new and improved technologies, including digital photogrammetry and unmanned aviation systems, were utilized for inventory, monitoring, protection, and interpretation of fossils within IMR parks during 2014 and 2015 (Santucci and Koch 2003; Santucci et al. 2009).

Rapid advances and the increasing affordability of powerful computers, software, and advanced digital photography enable the creation of precise 3-D models. Among these advances is photogrammetry software that uses overlapping digital photographs to find the 3-D aspect of an object and then recreate an accurate virtual model (Wood and Santucci 2014). Photogrammetric imaging of *in situ* paleontological resources has been recently undertaken at several IMR parks including: Arches National Park, Capitol Reef National Park, Florissant Fossil Beds National Monument, Glen Canyon National Recreation Area, Grand Canyon National Park, White Sands National Monument, and Wupatki National Monument. The photogrammetric data support scientific evaluation and long-term monitoring of fossils.

The application of emerging technologies in IMR parks points the way to future advances in paleontological research, monitoring, and protection.

### Arches National Park

Paleontological field inventories within Arches National Park, Utah, over the past decade have yielded several rare and important fossil discoveries (Madsen et al. 2012). An unusual series of trace fossils preserved at one locality in the Lower Cretaceous Cedar Mountain Formation in Arches National Park may represent evidence of vertebrate feeding behavior. A repeated pattern of parallel groups of 4–8 grooves are being interpreted (Martin et al. 2014) as semicircular feeding traces by a beaked vertebrate, such as a bird or pterosaur (figure 1). The biogenic features form semicircular patterns suggesting a small vertebrate standing or floating in shallow water and shifting laterally to systematically mine the surface for food. Photogrammetric

Figure 1. Vertebrate feeding traces preserved in the Early Cretaceous Cedar Mountain Formation at Arches National Park, Utah *(NPS Photo, 2002)*.

images of the feeding traces enhance the ability to remotely describe and precisely measure the morphological patterns preserved in these unusual features.

## Capitol Reef National Park

Through a cooperative agreement between the NPS Geologic Resources Division and the Utah Geological Survey, paleontological field inventories were undertaken at Capitol Reef National Park, Utah, between 2013 and 2014 (Kirkland et al. 2014). During field evaluations of the Late Triassic Chinle Formation, a fossil plant locality with 8 to 10 *in situ* casts of the tree-like large horsetail known as *Equisetites* (sp.) was discovered in the Monitor Butte Member. These fossils are preserved in growth position and occur in three distinct sedimentary layers. This rare occurrence of standing fossil horsetails contributes to the understanding of these ancient plants and the paleoenvironment during deposition of the Chinle Formation at Capitol Reef National Park (Dubiel 1987).

The *Equisetites* forest is an unusual occurrence, with only a few locations known with this fossil in growth position outside of Capitol Reef National Park (Dubiel 1987). In response, staff from the NPS Geologic Resources Division traveled to the park to document the locality through photogrammetry (figure 2). The photogrammetric data are being used for scientific description of the paleontological locality and will be available for long-term monitoring of the stability and condition of the site (Kirkland et al. 2014).

Figure 2. Photogrammetric documentation of *in situ Equisetites* casts in the Late Triassic Monitor Butte Member of the Chinle Formation at Capitol Reef National Park, Utah *(Source: UGS, 2014)*.

## Florissant Fossil Beds National Monument

In May 2014, photogrammetry specialists from the Bureau of Land Management and the National Park Service met with staff at Florissant Fossil Beds National Monument, Colorado, to document a trio of large Eocene sequoia (ancient redwood) fossil stumps. Although the *in situ* petrified stumps are beneath a protective open-sided structure, they are subjected to seasonal and often extreme temperature fluctuations and freeze-thaw effects. Photogrammetric images were obtained to provide baseline data for the park paleontologist and staff in order to further enhance monitoring of the stability and condition of the petrified stumps (figure 3).

Figure 3. Photogrammetric image of petrified redwood stumps at Florissant Fossil Beds National Monument, Colorado
Inset: NPS staff acquiring imagery for photogrammetric modeling *(NPS Photos, 2015)*

## Glen Canyon National Recreation Area

Hundreds of fossil track localities are preserved in the Early Jurassic Navajo Sandstone and other Mesozoic strata along the shores of Lake Powell in Glen Canyon National Recreation Area, Utah. Most of the fossil localities preserve footprints of dinosaurs and occasionally tracks of early mammals or mammal-like reptiles and insects. Paleontological resource monitoring was established to evaluate the stability and condition of fossil track localities subject to periodic submersion and emergence with fluctuations in the water levels of the lake (Kirkland et al. 2011). Historically low water levels at Lake Powell has recently led to the discovery and documentation of several new and important fossil track localities during paleontological resource monitoring at Glen Canyon National Recreation Area.

Figure 4A. The Megatrack Block at Glen Canyon National Recreation Area, Utah, contains a variety of dinosaur tracks within the Early Jurassic Navajo Sandstone *(Source: NPS, 2009)*

In 2009, a team of paleontologists from the Utah Geological Survey and the National Park Service

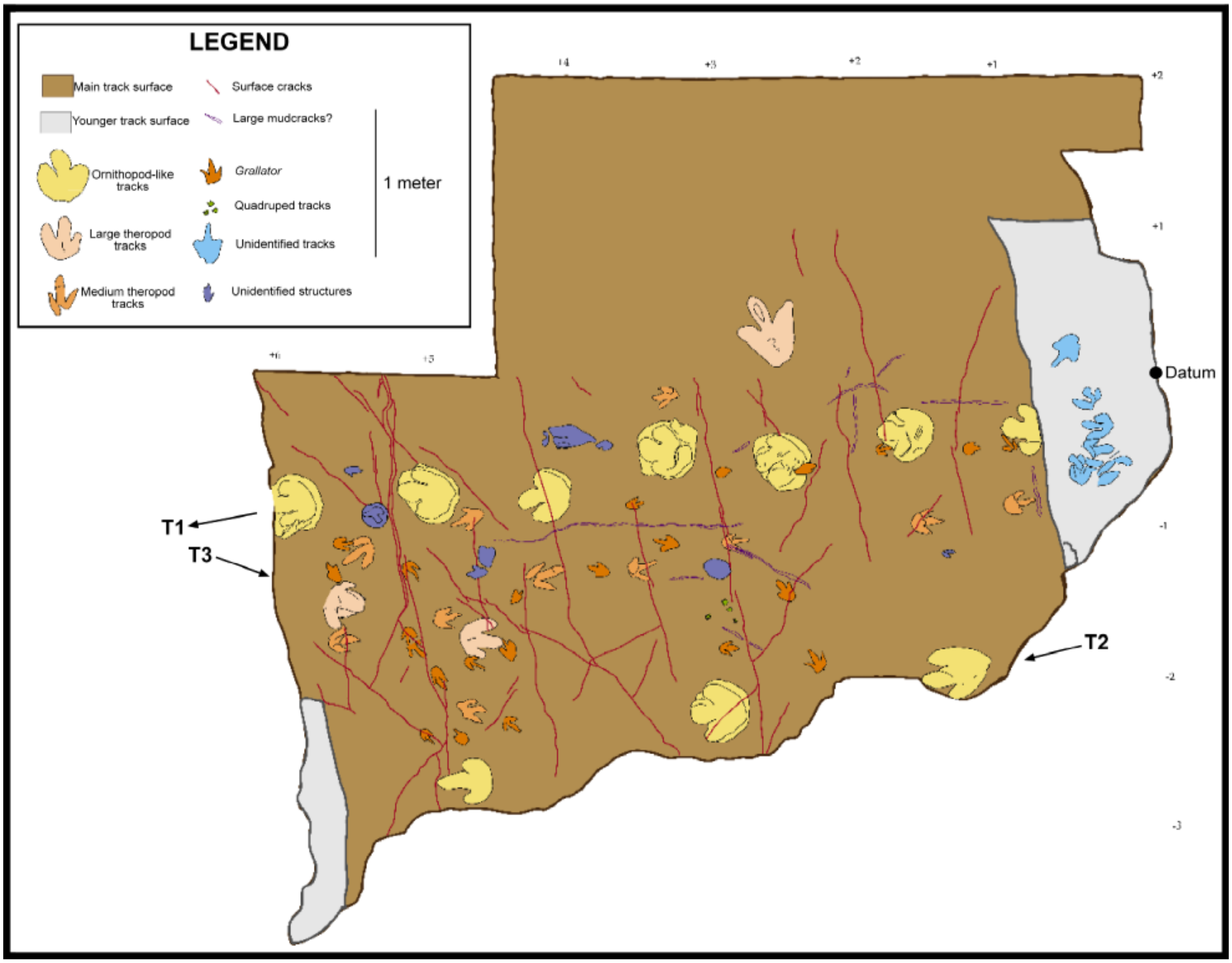


Figure 4B. Detailed surface mapping of the Megatrack Block reveals the occurence of seven distinct vertebrate track morphotypes *(Source: A. Milner, 2011).*

documented a large block of Navajo Sandstone containing dozens of individual footprints, representing at least seven different types of fossil tracks (known as morphotypes) (figures 4A–B). On the main track-bearing surface of the block is a prominent trackway consisting of what appear to be tracks made by a large bipedal ornithopod-like dinosaur. In order to facilitate the study of this megatrack block and to initiate long-term monitoring of the paleontological locality, photogrammetric documentation was undertaken in 2014.

Due to the low lake levels in 2014, another new and important fossil track locality was discovered and documented in the Navajo Sandstone at Glen Canyon National Recreation Area. The newly exposed locality preserves more than 100 fossil footprint impressions identified as *Brasilichnium*, which are believed to be associated with small early mammals or mammal-like reptiles (figure 5). Photogrammetric documentation of this fossil track locality during the period of low lake level will enable continued study when the site becomes resubmerged with a rise in the lake water level.

Figure 5. NPS geologist photogrammetrically document a partially submerged *Brasilichnium* trackway along the lake shore at Glen Canyon National Recreation Area, Utah *(Source: NPS, 2014)*.

## Grand Canyon National Park

Grand Canyon National Park, Arizona, preserves one of the greatest concentrations of Late Paleozoic tetrapod (four-legged [quadrupedal] animal) tracks in the world. During the 1920s, Smithsonian paleontologist Charles Gilmore studied and made extensive collections of fossil tracks and trackways from the Early Permian Coconino Sandstone within the park (Gilmore 1926, 1927, 1928). Since Gilmore's research at the Grand Canyon, new fossil track localities have been documented in park strata. A massive detached block of Coconino Sandstone, discovered during 2013 by paleontology intern Cassandra Knight, preserves one of the most important fossil track localities known in the park. On one surface of the block, several exceptionally preserved trackways of large tetrapod footprints occur and are identified as *Chelichnus* (figure 6A).

Figure 6A. *Chelichnus* trackways exposed on the surface of a block of Permian Coconino Sandstone in Grand Canyon National Park, Arizona *(Source: C. Knight, 2013).*

Photogrammetric documentation of *Cassi's Fossil Track Locality* was accomplished in September 2014. Digital 3-D models were generated using the photogrammetric images to enhance scientific analysis and description of the Paleozoic tetrapod trackways (figure 6B). The photogrammetric images also yield baseline data for long-term monitoring of this important paleontological locality.

## White Sands National Monument

An extensive Late Pleistocene fossil megatrack site has recently been documented within and around White Sands National Monument,

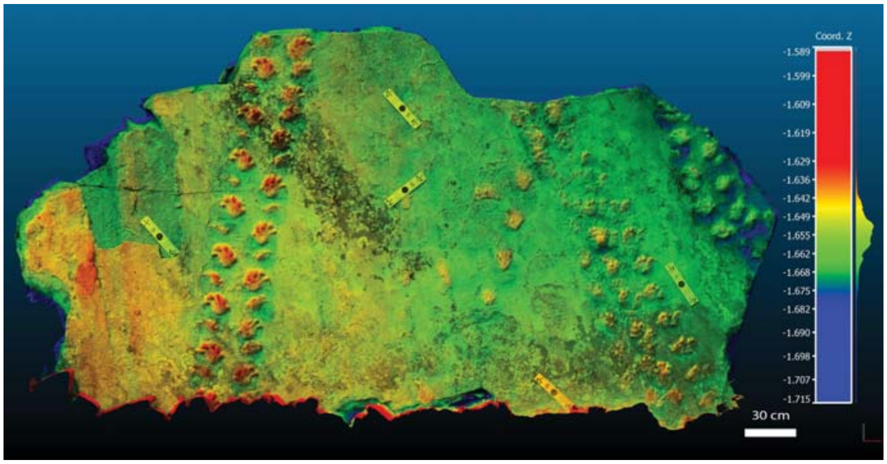


Figure 6B. Photogrammetric image of the same *Chelichnus* trackway block where color variation is based upon the depth of surficial features including the fossil footprints *(Source: NPS, 2015)*

Figure 7. Photogrammetric image of a large felid track preserved in Pleistocene sediments at White Sands National Monument, New Mexico *(Source: NPS, 2013)*.

New Mexico (Santucci et al. 2014). Thousands of fossil tracks and trackways produced by extinct ice age animals, including mammoths, camels, carnivores, and possibly giant ground sloths, are preserved in the gypsum-rich sands associated with dry lake beds (figure 7). The nature of the loosely compacted gypsiferous sediments, in which the fragile footprints are preserved, results in their rapid weathering by wind and storms. Once exposed at the surface, tracks are ephemeral and temporary geologic features. Processes which erode the tracks will also help to exhume new ones from the subsurface as the sand shifts and abrades the underlying fossiliferous deposits.

Monitoring of the ephemeral fossil tracks preserved within the monument continuously reveals new fossil track occurrences, as well as documents the rapid deterioration of previously recorded fossil tracks. Traditional ground level monitoring and photogrammetry of fossil trackways require close proximity to the fossil tracks by the photographer. This approach to photodocumenting the tracks generates disturbance to the adjacent soft sediments and fossils at or near the surface.

Collaboration between the Department of Defense, Bureau of Land Management, United States Geological Survey, and the National Park Service during 2014 enabled the use of an unmanned aviation system, specifically an RQ-16 Tarantula-Hawk (T-Hawk), to be employed in restricted airspace to obtain aerial photography and videography of portions of the Late Pleistocene megatrack site at White Sands National Monument (figure 8). This proof of concept project represents the first time a T-Hawk platform has been used to support paleontological research and resource management. The aerial photography and videography enabled centimeter-scale resolution and geospatial data collection while minimizing impacts and ground disturbances to the fragile paleontological resources.

Figure 8. Interagency team, consisting of staff from the NPS, BLM, USGS, DOD and the RQ-16 Tarantula-Hawk, during documentation of ice age fossil tracks at White Sands National Monument, New Mexico *(Source: NPS, 2014)*.

## Wupatki National Monument

A fossil vertebrate track with skin impressions was discovered in 2004 at Wupatki National Monument, Arizona. This rare preservation exhibiting early reptilian skin was associated with a fossil track identified as *Chirotherium* from the Lower–Middle Triassic Moenkopi Formation (figure 9). *Chirotherium* is a five-toed (pentadactyl) footprint believed to be produced by an unidentified early reptile (pseudosuchian). To date, several footprint specimens that preserve skin impressions have been collected at Wupatki National Monument and are maintained within the collections at the Museum of Northern Arizona.


Figure 9. *Chirotherium* track with skin impressions from the Triassic Moenkopi Formation at Wupatki National Monument, Arizona *(Source: NPS, 2014)*.

During September 2014, photogrammetric images were obtained of the Wupatki *Chirotherium* tracks with skin impressions. The high resolution 3-D images enhance the ability to view the morphological features of the ancient reptilian skin. The photogrammetric models will be available for use by researchers and for public interpretation of this rare evidence of early reptile skin.

## Conclusion

The use of photogrammetry and unmanned aviation systems have increased opportunities for inventory and monitoring of paleontological resources in Intermountain Region parks. In some instances, the innovative applications of these new technologies have been employed to reduce potential impacts to fragile resources while enhancing paleontological resource management activities (Wood and Santucci 2014). The NPS Geologic Resources Division website includes some examples of paleontological resource photogrammetry projects.

The extreme precision of the ground-based and aerial photogrammetry enables documentation, monitoring, and subsequent remote scientific study of *in situ* paleontological resources. The acquisition of high resolution images provides a methodology for evaluating changes in the stability and condition of fossils and fossil localities due to either natural processes, such as weathering, or human impacts.

Digital photogrammetric data can be used to generate mathematically precise 3-D models, which are able to be printed or electronically shared for public education or scientific study. The 3-D models will allow millions to enjoy the fossils virtually or in person with no resource damage, truly leaving no trace and protecting the actual location of sensitive fossil localities. The use of photogrammetry will likely yield opportunities for other resource management and interpretation applications, support long-term resource preservation, and expand analysis of paleontological resources.

## For Additional Information Please Visit:

http://www.nature.nps.gov/geology/monitoring/photogrammetry/

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—Cultural Resources—

# Reading Desert Stones: Archeology in Big Bend National Park

*By David Keller, Senior Project Archeologist, Center for Big Bend Studies, flatbilly2@gmail.com*

It had already been a long day, one of many spent under the relentless sun in the sweltering west Texas heat. Two archeologists—David Keller and Warren Kinney—walked up a rocky slope to determine the boundaries of the sixth prehistoric site of the day. Wiping the sweat from their brows, they could make out a linear rock alignment just ahead. “It’s just an old two-track road,” said Warren. However, as they grew closer, they could not see a second parallel alignment or any indication of tire ruts. They followed the serpentine line as it snaked uphill, where it intersected a second line of rocks coming in from the northwest. “I’ll be,” David exclaimed, “It looks like a petroform!” (an archeological term for rocks purposefully arranged upon the ground).

Figure 1: A stone ruin frames one side of Cerro Castellan, a prominent landform in the southwestern portion of the park *(Source: David Keller, 2005)*

They walked further upslope and found a small rock ring, and then a large cluster of limestone cobbles; then a second; and a third. By this time, they realized they had chanced upon something significant. David called the rest of the crew over. The eight archeologists fanned out across the site, looking for additional clues. Within a few minutes, archeologist Sarah Loftus called out, “I found a dart point!” David looked up from his clipboard and started toward her just as she called out again, “Here’s a second point!” He quickened his pace. “Don’t move!” he yelled, “Don’t touch them!” By the time he arrived she had spotted several more. Within a few minutes, a total of eight chipped-stone points had been discovered within a two meter area. Based upon the point types, it appeared they had stumbled upon a 4,000 year-old dart point cache!

Figure 2. One leg of the serpentine petroform at a 4,000 year old dart point cache site *(DSCN8791, Source: Brian Dailey, 2006)*

It was the highlight of a long and arduous project—one that spanned almost two decades and that involved an intensive archeological survey of more than 60,000 acres of land in one of the most remote and rugged landscapes in the United States. In fact, the Big Bend National Park project was a study in superlatives. For one, it was the biggest archeological survey in the state's history. For another, it produced an unprecedented amount of new data, including documentation of 1,566 archeological sites and 1,300 isolated features and the collection of more than 2,000 artifacts, almost all of which were temporally or functionally diagnostic. In the course of collecting this mountain of data, more than 17,000 photographs were taken, and more than 32,000 discrete locations were recorded. In other words, it was one monster of a project!

Although the project documented thousands of thermal features and artifacts commonly found across the region, it also resulted in the discovery of feature types and artifacts unknown to science. Among these were a new type of thermal feature (cobble-lined hearth), both ritual and utilitarian artifact caches, a variety of zoomorphic, anthropomorphic, and abstract petroforms, unusual tool forms, and exotic ceramics, in addition to artifacts representing human occupation spanning at least 10,000 years. The range of site complexity was similarly broad, from sites as basic as a single hearth or artifact scatter to those containing prehistoric structures with contiguous room blocks, multiple stratified buried occupations, or those whose features and artifacts span more than a square mile. After tens of thousands of pages of paperwork, photographs, and proveniences, the project had made one of the largest archeological contributions in the history of the region.

Figure 3. Crew members recording a stone enclosure on top of a cuesta with the Chisos Mountains in the background *(DSCN4708, Source: David Keller, 2007)*

The Big Bend National Park project began almost 18 years ago, at a time very different from today both with regard to the field of archeology and the interests of the National Park Service (NPS). The research design was not set up to test hypotheses or build a model of population dynamics. The goals were much more pragmatic. For the NPS—having mostly management-related concerns—the predictive model for prehistoric site occurrence would be a useful tool for planning purposes. In addition, the project would significantly increase the surveyed acreage and site inventory, bringing the park closer to compliance with federal mandates and the National Historic Preservation Act. Sites would also be evaluated for inclusion in the National Register of Historic Places, and visitor interpretation services would be updated by providing better, more detailed information to the general public about the park's cultural resources.

In terms of the academic contribution, the project would bear on a variety of archeological questions, such as the range of site, artifact, and feature types, unique archeological signatures, the array of stone technology, and inter-site relationships, as well as prehistoric subsistence and settlement patterns. Although the project informed all those things, it did not make systematic inroads into any one of them. Surveys such as this offer a kind of "shotgun approach" that is spatially expansive but focused on providing more of an inventory of material culture than an analytical treatise. In this sense, the project harkened back to classic normative archeology; old school field archeology at its best, albeit with a few new gadgets and a few new tricks. However, if the project appeared unsophisticated by modern standards, it was largely so by necessity: archeologically speaking, the region is still in its infancy. Because of this, the project was a pioneering effort—one that provided a baseline of site assessments, as well as a solid foundation for future studies, while bringing the region closer to the level of archeological knowledge attained in other parts of the state.

Figure 4. Typical set up of a front country, roadside basecamp *(DSCN_226, Source: Candace Covington, 2009)*

Figure 5. Crew members filtering water from a spring seep at a remote backcountry basecamp *(DSCN2234, Source: David Keller, 2010)*

The areas to be surveyed consisted of 58 separate survey blocks spread widely across the park, which caused the logistics to be challenging. One to three crews were used—depending on the availability of personnel, the location of the blocks, and logistical concerns—with each crew consisting of three to eight archeologists. Fieldwork took

## Big Bend Prehistoric Chronology

- 12,200-8500 BP — Late Paleoindian period
- 8500-4500 BP — Early Archaic period
- 4500-3000 BP — Middle Archaic period
- 3000-1300 BP — Late Archaic period
- 1300-400 BP — Late Prehistoric period

place in both the spring and fall, each with three to four ten-day sessions, separated by four days off. Backcountry roadside campsites were used when possible; however, when more remote access was required, crews backpacked in and established a base camp close to their survey area. Due to the heat and aridity, water was always a concern. In some cases, mules were used to pack water into the backcountry. At others, crews were on their own to filter water from springs or *tinajas* (stone depressions that can hold water for weeks following a rain).

Starting at one corner of the survey block, archeologists spread out at 30-meter intervals and surveyed the ground surface while walking parallel lines across the landscape to assure complete coverage. Upon reaching the far end of the block, the line pivoted to cover an adjacent swath on the return transect. When a site was discovered, all cultural features and diagnostic artifacts were flagged before crew members began their respective duties: one filling out a site form, another recording features, a third recording artifacts, a fourth taking photographs, etc. Once a site had been thoroughly documented, flags were pulled, the crew lined out once more, and the survey resumed.

Although both historic and prehistoric sites were amply represented, almost 74% of all sites documented during the project were exclusively prehistoric. By contrast, a small minority (representing only 4% of all sites) was exclusively historic. An additional 22% of sites had both historic and prehistoric components.

While distinguishing between prehistoric and historic sites was nearly always obvious, chronological control of prehistoric sites was provided almost exclusively by projectile points, making them critical to interpretation and analysis. Those collected during the project represent some 10,000 years of human occupation in the region—from the Late Paleoindian period to the Late Prehistoric. Although many factors can influence projectile point density, these points served as rough proxies for past human population levels. The projectile point

Figure 6. Contracting stem dart points collected during the survey; just a handful of more than a thousand projectiles recovered during the project.
*(Img_5553, Source: Bobby Gray, 2014)*

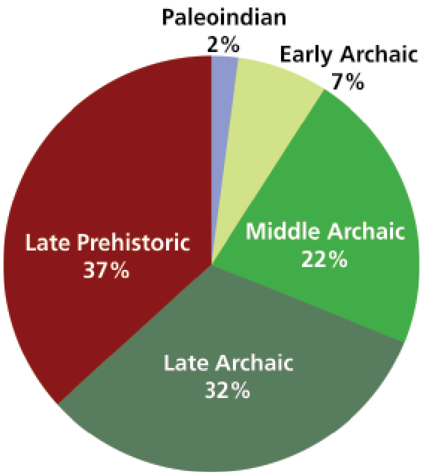


Figure 7. Breakdown by time period of projectile points collected during the project *(Source: NPS, 2015)*

distribution suggested that population density rose throughout prehistory, but not in the steady linear fashion one might assume. In fact, the data indicates that against a general trend of increasing population, there were significant spikes, most notably during the Middle Archaic, Late Archaic, and Late Prehistoric periods.

Prehistoric sites were placed in one of six different site types based primarily on features and artifacts contained within them or by the setting in which they occurred. The vast majority (90%) of sites are open campsites, followed by artifact scatters, special use sites, natural shelter sites, food processing sites, and stone enclosure sites. Of the 60 sites that contained only historic materials, most were homesteads, followed by campsites, dumps, cemeteries, dams, artifact scatters, mining related sites, quarries, graves, survey-related sites, water tank sites, wax camps, and a handful of outliers, such as a lime kiln site, a ranching site, a water well, and a civil aeronautics administration tracking station.

Figure 9. One of hundreds of kid-goat shelters recorded during the survey; expedient shelters such as these were used to protect baby goats from the sun during the heat of the day while their mothers browsed *(DSCN3161, Source: Lisa Weingarten, 2007)*

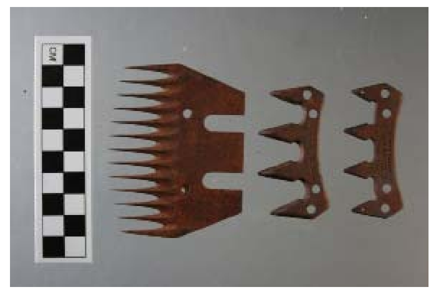

Figure 10. Shearing blades used to shear sheep and goats; a few of the hundreds of historic artifacts collected during the project *(IMG_8013, Source: Bobby Gray, 2014)*

Figure 8. Crew members recording historic graves on a remote mesa in the southern part of the park *(DSCN6110, Source: Candace Covington, 2005)*

The analyses of survey data were restricted to prehistory since the most pressing archeological questions in the region relate to this period. The analyses performed essentially focused on examining temporal and spatial site data in an effort to illuminate relationships between them. The primary variables were the temporal affiliation, size, distribution, and archeological “richness” value (based on the range of material culture) of sites in addition to site content. Sites that had temporal attributes (sites where temporally diagnostic artifacts were recovered) were examined with regard to their location on the landscape, and their distribution was measured against expected values; in this case, the percent of total area surveyed in any one environmental zone. Thus, if 30% of the surveyed area occurred in the uplands, then with all things being equal, we should expect 30% of sites to also occur in the uplands. This deceptively simple exercise provides a relevant metric from which we can measure divergence. The greater the divergence, the more likely that particular zone is more or less significant to any one time period.

In a broad sense, the analyses suggested there were notable changes in population density, social structure, site distribution, and subsistence strategy throughout prehistory in the Big Bend and that these changes were complex and nonlinear. Despite a very small sample size, the data support prevailing beliefs that during the Late Paleoindian period, groups tended to be small and highly nomadic with an adaptive focus on lowland areas. This indicates that, during the early Holocene, these areas may have offered the best suite of resources.

Figure 12. One crew member uses a GIS-compatible global positioning unit to record a provenience while another examines a stone artifact *(Source: Amie Meade, 2008)*

Adaptive strategies appear to have changed during the Early Archaic, which coincide with the Holocene Climatic Optimum (a warm period around 7,000 years ago), when higher elevation landforms became preferred over the lowlands. Although population levels were significantly higher than in the preceding period, group size appears to have remained small and highly nomadic. Among their technological adaptations was a newly discovered feature type (cobble-lined hearths) that may be completely restricted to this period, possibly reflecting specific resource processing or increased thermal efficiency.

Dramatic cultural changes appear to have occurred during the Middle Archaic period—a

Figure 11. Project crew members surveying on hands and knees in a dense prehistoric midden deposit *(DSCN0948, Source: David Keller, 2006)*

sort of cultural flowering that, in many aspects of material culture, far exceeded periods before and after. The data suggest there was a huge leap in both population and group size, likely with large seasonal aggregations of people. Increased specialization is indicated by the wide variation in site type and size. The use of earth oven technology; (where hot rocks are used as thermal elements in an underground oven) appears to rise during this period, possibly signaling a shift toward increased use of succulents such as cacti. Many of these findings also support the idea that Middle Archaic people enjoyed a rich spiritual life, as suggested by their use of abstract petroforms and ritual caches, such as the Lizard Hill dart point cache that Sarah discovered.

The Late Archaic witnessed a major shift away from the patterns of the Middle Archaic. Although population levels appear to have continued to rise, the data suggest that group size declined significantly, possibly reflecting higher mobility and increased opportunism in foraging patterns. In fact, Late Archaic sites are distributed more uniformly across the landscape than any other time period. The data also suggest changing subsistence strategies, as reflected in a possible shift away from the use of earth ovens and an increase in the use of ring hearths (hearths consisting of a circle of rocks). Attendant with smaller group size and increased mobility, it appears that specialization also decreased as sites became more uniform in size and composition.

Figure 12. Crew members examining a stone enclosure on a peak top at the mouth of a canyon south of the Chisos Mountains *(P4290009, Source: David Hart, 2009)*

During the Late Prehistoric, it appears that both population levels as well as group size increased, although the latter did not rise to that achieved during the Middle Archaic. The data also suggest that mobility decreased from the Late Archaic as lowlands assumed increasing importance, especially as base camps. The use of earth oven technology, as well as stone-based wikiups, appears to have increased, or at least occur in greater numbers within individual sites.

Although this summary of findings provides a quick and easy way to present the results of analysis, in fact, the data are far more nuanced than such generalizations can reveal. What is significant is that most of these preliminary, tentative conclusions are derived from many different analyses, which demonstrated greater consistency than chance alone would allow. In doing so, the confidence level in both the data and the veracity of results was bolstered.

These findings have significance beyond what they tell us about prehistoric human behavior. They also bear on prevailing concerns about survey-level data, as opposed to excavation data. Many believe that the integrity of survey data—

primarily resulting from natural and human-caused disturbance—is compromised to a degree that it cannot be used as a basis for analysis. However, the results of analyses in this project appear to demonstrate that survey data can, indeed, rise to the occasion, even if its accuracy must be conditioned not only by the quality of the data, but by its quantity as well. In other words, if enough high-quality survey data is collected, it can cut through the "noise" caused by such disturbances.

The Big Bend National Park Project was a pioneering effort that is helping to rewrite the prehistory and history of the Big Bend as we know it. By learning to read the desert's stones—the lithic legacy of bygone peoples—the project has allowed us to gain a much better understanding of the rich cultural heritage of one of our greatest national parks.

## For Additional Information Please Visit:

Center for Big Bend Studies: http://cbbs.sulross.edu/

Big Bend National Park: http://www.nps.gov/bibe/index.htm

Texas Beyond History-Trans Pecos Mountains and Basins: http://www.texasbeyondhistory.net/trans-p/index.html

# Intermountain Region Climate Change Strategy and Action Plan

*By Tom Olliff, Chief, Landscape Conservation and Climate Change Division, Intermountain Region, tom_olliff@nps.gov; Pam Benjamin, Climate Change Coordinator, Intermountain Region, pam_benjamin@nps.gov*

## Introduction

The Intermountain Region (IMR) has a staggering diversity of parks that encompass mountains and beaches, deserts and prairie, and range from sea level to over 14,000 feet in elevation. Global climate change is affecting all aspects of IMR park operations—facilities, resources, staff, and visitors. We are adjusting to changes in temperature and precipitation, storm frequency and flooding, drought, changes in snowpack, sea level rise, and longer growing seasons. These changes are ongoing, and many fluctuations are predicted to accelerate in the future and require a coordinated and forward-looking National Park Service (NPS) management response.

Figure 1. Glacier National Park is expected to lose all of its namesake Glaciers in the 21st Century including Sperry Glacier, pictured above *(Source: NPS, Tim Rains, n.d.)*

The NPS climate change response operates within several federal directives introduced since 2007 to reduce emissions of greenhouse gases (GHGs), achieve sustainability, and implement science and planning tools for adaptation. These directives focus on two fundamental tactics: (1) mitigation (activities that reduce GHG emissions or enhance their removal from the atmosphere) and (2) adaptation (activities that help people and natural systems better cope with climate change effects by moderating harm or exploiting beneficial opportunities). The 2010 NPS *Climate Change Response Strategy*, coupled with two implementation plans—the *Climate Change Action Plan*, and the *Green Parks Plan*—put the federal directives for climate change adaptation and mitigation into practice for the National Park Service (NPS 2010, 2012a, 2012b).

This regional climate change strategy and action plan supplements the NPS guidance with specific goals and actions to integrate climate change into planning and management that the IMR will aspire to in the next five years. Each of the nearly 5,000 employees of the IMR can contribute to and benefit from achieving these goals as we prepare for and manage under climate change and uncertainty. We can serve as a model for ways that we, as a society, can take steps that will lead to the best possible present and future outcomes.

## Ongoing Climate Change

The fifth assessment report from the Intergovernmental Panel on Climate Change (IPCC 2013) states: "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia, [and] it is extremely likely that human influence has been the dominant cause of the observed warming trend since the mid-20th century (p. 15)." In other words, the planet is warming, and scientists are 95%–100% certain that human activities are the cause.

Parks in the IMR are already experiencing a changing climate. Monahan and Fisichelli (2014) evaluated climate change exposure in parks. Across the IMR, most parks are already at the extreme warm end of historical conditions, and some parks are also extreme dry or wet (figure 1). Seventy-five of 78 parks (96%) evaluated were categorized as "extreme warm"; none as "extreme cold." As an example, at Grand Canyon National Park, annual mean temperature measured over the last 30 years has been warmer than 99% of all periods of equal length since 1901. For precipitation, seven IMR parks (9%) were "extreme wet," 14 parks (18%) were "extreme dry," and 57 parks (73%) did not have any recent extreme precipitation variables (figure 2).

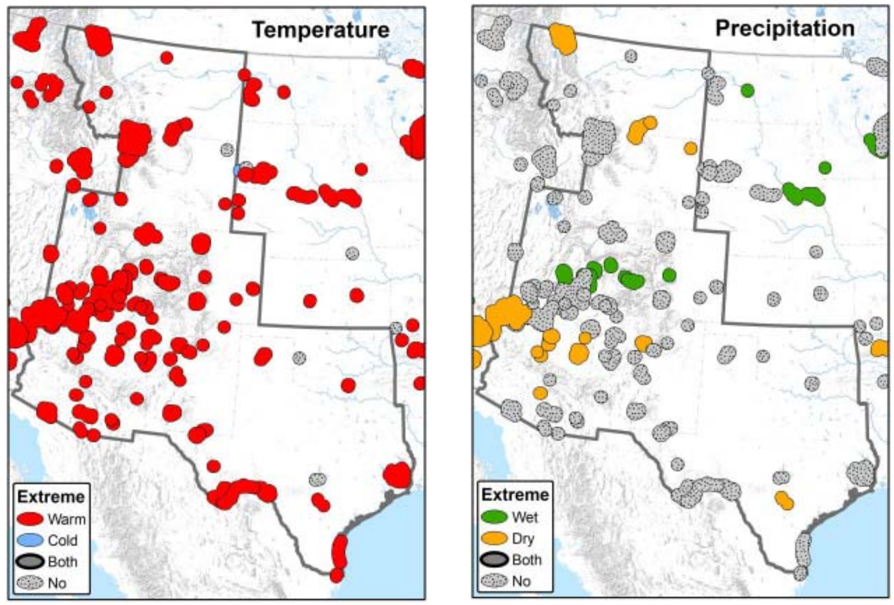


Figure 2. Summary of parks with recent (past 10–30 years) mean temperature (above left) and precipitation (above right) more extreme than 95% of the historical range of conditions (1901–2012). Intermountain Region outline is depicted in dark gray. *(Source: Modified from Monahan and Fisichelli, 2014)*

## Future Climate Change

The rate of climate warming in the coming century is projected to be 2.5–5.8 times higher than that measured in the past century for national parks and surrounding ecosystems throughout the nation (Hansen et al. 2014). Projected warming is uneven across the Intermountain Region, but annual average temperatures are projected to rise by 5.5°F to 9.5°F by 2070–2099, with the greatest increases in the summer and fall (Shafer et al. 2014; Garfin et al. 2014). More winter and spring precipitation is projected for the northern United States, and less for the Southwest. Snowpack and streamflow amounts are projected to decline in parts of the Southwest, decreasing surface water supply reliability for cities, agriculture, and ecosystems (Shafer et al. 2014; Garfin et al. 2014). In the Southwest, future droughts are projected to be substantially more intense, and for major river basins such as the Colorado River Basin, drought is projected to become more frequent, intense, and longer-lasting than in the historical record (Garfin et al. 2014).

Figure 3. High-elevation species, such as the whitebark pine, and aquatic species, such as the Yellowstone cutthroat trout, are vulnerable to climate change *(Source: NPS, n.d.)*

Figure 4. Climate change caused the loss of snowpack, increased summer temperatures, and loss of connectivity that will likely reduce wolverine populations *(Source NPS, Eric Peterson, n.d.)*

## Impacts to Resources

Climate change will increasingly affect the region's natural and cultural resources. Increased warming, drought, and insect outbreaks, all caused by or linked to climate change, have increased wildfires and impacts on people and ecosystems throughout the region (Shafer et al. 2014; Garfin et al. 2014; Hansen and Phillips 2015). Some of the changes found in IMR parks include increases in tree mortality in Rocky Mountain National Park (van Mantgem et al. 2009) and reduction of snowpack at Glacier National Park (Pederson et al. 2011). Projections suggest that biomes may be vulnerable to extensive shifts (Gonzalez et al. 2010; Hansen and Phillips 2015), and individual species such as American pika (Jeffries et al. 2013), cutthroat trout (Haak et al. 2010), whitebark pine (Chang et al. 2014), and limber pine (Monahan et al. 2013) may be vulnerable to range shifts, mortality, and decreased abundance. Widespread tree death and wildfires, which are already occurring, are projected to increase in frequency and severity (Westerling et al. 2006).

The NPS *Climate Change Response Strategy* noted that significant cultural resources are disappearing rapidly due to high rates of erosion, intense weather events, and other factors related to climate variability. Buried archeological resources and historic architectural

Figure 5. Extreme rain events can impact all historic buildings, but have the potential to literally dissolve earthen structures. A heavy monsoon rain in 2010 overwhelmed the drainage system on the mission church at Tumacácori and infiltrated the adobe walls. The result was the loss of tons of plaster and adobe from the north wall of the church sacristy. *(Source: NPS, n.d.)*

resources are vulnerable to changes in moisture, potentially accelerating deterioration. Cultural resources are unique, and once gone, their ability to contribute to the story of human history is lost forever. Earthen architecture is particularly vulnerable to heavy rainfall events, which may increase in some areas of the region. Areas with significant climate change may experience large impacts on historic architectural resources because the local climate has the potential to be considerably different than the environment in which these resources were constructed (Jeffery and Burghardt 2014). Ninety-one of 260 IMR collections facilities (35%) are projected to be vulnerable to climate change–induced flooding (NPS 2014).

Figure 6. Drought-killed pinon impacting archeological site in the Bandelier region. Fallen trees not only damage fabric, but add hazard fuel loading to a site. *(Source: NPS, n.d.)*

## IMR Climate Change Strategy Goals and Actions

The shifts in climate that have already occurred, projections of even greater shifts, and the potential harm to resources in national parks has lead the Intermountain Region to develop a climate change strategy. These IMR goals and actions are intended to provide encouragement and guidance to park programs that seek to incorporate climate change adaptation, mitigation, communications, and partnerships into their practices and operations.

### Goal 1: Improve Climate Change Knowledge and Communication

The amount of information about climate change has grown exponentially in the last 20 years. For example, Cook et al. (2013) found 11,944 climate change manuscripts were published from 1991–2013. Many IMR resources managers have a higher-than-average understanding of climate change terminology and science (Garfin et al. 2011), yet all employees could benefit from climate change training. The IMR parks and staff are ideally positioned to increase public understanding of climate change and its impacts on parks. Actions include: encouraging and enabling all IMR superintendents, interpretive rangers, and resource managers to take the climate training modules; identifying appropriate staff to take advanced training such as Climate-Smart Conservation (offered through the National Conservation Training Center); helping parks develop key climate change and sustainability talking points; assisting parks in creating interpretive products and programs for general audiences and youth about the impacts of climate change; and developing messages (through existing venues) that provide information on climate change programs and help employees share successes and challenges.

### Goal 2: Manage Resources for Ongoing and Future Change

As we gain experience incorporating climate change impacts into our planning and management, we have also begun to move toward Climate-Smart Conservation in all aspects of park management (Stein et al. 2014). Adaptation includes natural systems, human

Figure 7. The unique gypsum dunefield of White Sands National Monument could be impacted by dryer conditions and lower water tables predicted under climate change scenarios *(Source: NPS, n.d.)*

and cultural systems, facilities and assets. The National Park Service is well-positioned to be a leader in understanding, preparing for, and managing climate change impacts, thus implementing one of the key characteristics of Climate-Smart Conservation—safeguarding people and nature. The actions to manage resources include: encouraging consideration of climate change and associated uncertainty in all planning and strategic documents and reports; developing resource-specific vulnerability assessments for natural and cultural resources and facilities; and using information from planning and vulnerability assessments to evaluate, select, and implement adaptation actions, then monitor effectiveness of those actions toward achieving conservation goals.

### Goal 3: Effectively Implement the Green Parks Plan

The *Green Parks Plan* defines a collective vision for integrating environmental stewardship into facility management and for educating park staff and visitors about climate change and sustainability in a manner consistent with the mission of the National Park Service, as well as all relevant laws, executive orders, and secretarial and director's orders. The actions to implement the plan include: developing park-based environmental management systems (EMS) and sustainability action plans; tracking GHG emissions; working toward all IMR parks becoming Climate Friendly Parks by 2020; and meeting the DOI Sustainable Building Implementation Plan and the Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings.

**Goal 4: Build and Strengthen Climate Change Partnerships**

The scale of climate change impacts will far exceed the ability of any one park, agency, or organization to effectively respond as a single entity. Well-informed responses to climate change will require building connections at local to regional scales and among people with a wide range of technical expertise within the NPS, the Department of the Interior, other agencies, and existing partners and stakeholders. National park system units are high-value areas within the larger landscape; working through partnerships and collaborations will provide the IMR with opportunities to highlight these values within a connected system of protected areas while acknowledging that we cannot protect these high-value resources in isolation. The actions being taken include: IMR parks and programs will consider a broader context in managing resources by engaging with ecosystem- and landscape-scale partnerships; helping parks and programs understand and apply climate change science and engage in climate science partnerships; engaging partners such as the International Committee on Monuments and Sites and the National Trust for Historic Preservation; and strengthening local partnerships to enhance climate change adaptation and sustainable actions.

## Conclusion

The NPS IMR has an important leadership role to play in understanding and communicating about climate change and in responding with effective adaptation and mitigation actions. Our parks have long been leaders in adopting new best management practices for cultural and natural resources. Some of our most iconic parks—Glacier National Park, Rocky Mountain National Park, Grand Canyon National Park, and Yellowstone National Park, for example—have enabled national discussions on issues such as fire management, ungulate management, managing for natural sounds and night skies, and the impacts of climate change. The IMR Climate Change Strategy tiers from national and servicewide guidance and provides guidance to IMR parks and programs to fulfill that leadership role. It is designed to focus on a coordinated set of actions while promoting flexibility to incorporate new knowledge, new initiatives, and changing circumstances as the future unfolds.

## For Additional Information Please Visit:

Climate Training Modules

NPS New Superintendents Academy Climate Change Training
http://www.nps.gov/training/LD/html/new_superintendents_academy.html

Interpreters Training
http://idp.eppley.org/ICC

Climate-Smart Conservation Training http://training.fws.gov/NCTCWeb/catalog/CourseSearch.aspx (search keywords: Climate Smart Conservation)

Climate-Smart Conservation http://www.nwf.org/What-We-Do/Energy-and-Climate/Climate-Smart-Conservation/Guide-to-Climate-Smart-Conservation.aspx

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—CULTURAL RESOURCES—

# 100 Years: The Nature of Culture and the Culture of Nature: Toward Holistic Resource Management

*By Pat O'Brien, Desert Southwest Cooperative Ecosystem Studies Unit Coordinator, pat_o'brien@nps.gov*

I recently received an email from Casa Grande Ruins National Monument Superintendent Karl Pierce. He shared a site for an audio visual experience called *Bella Gaia (Beautiful Earth): A Poetic Vision of Earth from Space* (www.bellagaia.com). Created by Kenji Williams, it is a production of music, art, and science that illustrates the beauty and unity of our planet. It is an important work, especially for resource managers, as it underscores the interrelatedness of natural and cultural systems.

We often imagine our world as separated into natural and cultural realms. The relationship of nature and culture is one of the greatest questions in resource management. And while many scholarly investigations of these relationships often center on various formulae and data, we seldom investigate how these ideas are played out on the landscape. Our ideas of nature and culture are so much a part of our world that we often act upon them automatically, without considering their origins or questioning their validity.


Figure 1. Kelly, Walt. Pogo Cartoon for Earth Day 1971, Anchorage Daily News newspaper 18 April 1971. *(Source: version courtesy of http://otegony.com/we-have-met-the-enemy)*

After the 1968 space photographs of the Earth were made public, the poet Archibald MacLeish noted that "Men's (sic) conception of themselves and of each other has always depended on their notion of the earth." But everyone on the globe sees thing differently. Many peoples do not have our binary resource concept divided into natural and cultural disciplines; they see themselves and their world as one entity. Their approach is an ancient one and confirms what historian Marc Bloch noted in the 1940s when he said "Is not humanity the greatest variable in nature?" Climate change would seem to support Bloch's observation. But many still resist the notion that human activity has any significant effect regarding our changing planet, and cultural professionals often have a difficult time making themselves heard in the halls of science, even though the climate change discussion has been of record for some time.[1]

Separate resource spheres and their respective administration are of record. For example, at the UNESCO conference on natural resources in Paris in 1964, the following was noted by a presenter:

> The old fashioned idea that there is a kind of antagonism between man and nature dies hard. . . I do not like the expression, which is often used today, of "man versus nature", but would much prefer "man in partnership with nature."[2]

More recently, Kim Sorvig, research professor at the School of Architecture and Planning at the University of New Mexico, noted in his articles "Linguistics and Language of Design" and "Nature/Culture/Words/Landscapes" the various ways that language manifests itself on the landscape, echoing other scholars like Henry Nash Smith and Roderick Nash in the exploration of landscape imagery and meaning. Sorvig notes that "Splitting Nature from Culture is an ancient habit of the Western or European mind." Under a subheading of "Why Bother," Sorvig notes that an understandable vocabulary is essential to understand our relationship with both culture and nature and their relationship to each other. He quotes scientist David E. Fisher, who startlingly observes: "The question is not one of philosophical interest only, its answer will form the basis of our response to the most important danger facing us today: How do we respond to the changes in our environment which we ourselves have wrought?"[3]

Unfortunately, little has changed in our divided management of resources. However, today, natural phenomena is underscoring the interconnectedness of nature and humanity. Rapid climate change, its origins and its consequences, can hardly be ignored. If climate change has any positive effects, perhaps one is the long overdue dialogue between natural and cultural fields in a unified and integrated resource management concept.

How we got to the division of natural and cultural resource administration in the US government is complicated—but worth reviewing, at least in part. It started with the establishment of federal agencies. In 1849, the Department of Interior (DOI) assumed management of the United States' ever-increasing empire, which doubled in less than fifty years. In 1862, President Lincoln established the US Department of Agriculture (USDA). Competing administration and philosophies of management occurred between the two agencies into the 1890s, with the USDA assuming more influence as Euro-American farmsteads overtook American Indian lands in the West and native peoples were forced onto reservations. These events, combined with the advent of rail transportation, changed America's relationship to the land and nature forever. Limitless prairies became fenced farmsteads; farmers and miners exploited the natural bounty of the land, ending centuries-old relationships between humanity and environment. European cattle

[1] Archibald MacLeish, The New York Times, December 25, 1968, p. 1; Bloch, 197; Cooper, pp. 500–520 http://cecelia.physics.indiana.edu/life/moon/Apollo8/122568sci-nasa-macleish.html

[2] Worthington, p 2

[3] Smith, Nash, passim; Sorvig "Linguistics and the Language of Design", 2–12 and "Nature/Culture/Words/Landscapes", 1–14. Sorvig's quotation from Fischer, "The Nature of Nature", p. 134

breeds largely replaced the native bison and Spanish longhorn cattle. Wheat strains originally from Turkey (hence the name "Turkey Red") enabled German Mennonite farmers from the Russian Crimea to extend their growing seasons and to establish a wheat and milling industry in Kansas unrivaled anywhere in the world—but one that would sacrifice large portions of the native stands of prairie grasses and their attendant ecosystems. The introduction and use of technology sped up the process, piling the bones of wildlife into fertilizer for cultivated crops and plowing under millions of acres of native flora. Indeed, cultural/technological wonders like locomotives, combine reapers, and river dams could be both awesome and fearsome things.[4]

Government agencies mirrored the transformation of the American West. In 1876, USDA established a one person office that became the US Forest Service (USFS) in 1897. In 1879, the US Geological Survey (USGS) was established. In 1881, the USFS Division of Forestry began operations. In 1905, Theodore Roosevelt moved the Interior's former public lands and forest reserves to the USDA and USFS. On June 8, 1906, President Theodore Roosevelt signed into law the Antiquities Act, a piece of legislation that had resulted from a quarter of a century of lobbying and negotiation by cultural resource advocates. Under section 2, the president was empowered to designate national monuments on federal lands.[5]

The 1906 Antiquities Act was one of the first pieces of American legislation to address threatened resources. It served as a harbinger of 20th-century environmental legislation, both cultural and natural. But as resource protection became more pronounced, so did the rift between natural and cultural camps. The USDA occupied a distinctly cultural stance with its management and utilization of resources. The DOI continued to view resources and the aboriginal peoples within them as a natural unit—even to the point of American Indians and the Bureau of Indian Affairs (originally established in 1824) included as a subset the DOI administrative structure.[6]

The bureaucratic welter of federal offices, programs, and administrations continued to increase—and so did the distance between resource philosophies. This polarization manifested in the relationship between John Muir and USFS's Gifford Pinchot. Originally friends, they fell out over concepts of resource use and preservation. Pinchot saw resources in a utilitarian context; Muir's mystical vision of wilderness and its positive effects on society were evident in his description of California's Sierra Nevada Mountains: "every one of its living creatures . . . and every crystal of its rocks . . . is throbbing and pulsing with the heartbeats of God." Muir opposed projects like Hetch Hetchy (1908–1913), and many utilitarian advocates saw his opposition as backward

4 Marx, 5; White, 455–486, passim; Murdoch, 5; O'Brien, p. 28–30

5 http://www.doi.gov/index.cfm; http://www.fs.fed.us/learn/our-history; Sellars, pp. 35–37; Ise, 188–89, 279, 282, 440; Foresta, 14–17, 19–21, 26, 30–32, 46, 118; http://www.foresthistory.org/ASPNET/Publications/100years/sec1.htm

6 http://www.cr.nps.gov/local-law/anti1906.htm; http://www.nps.gov/archeology/tools/laws/antact.htm

and reactionary. Muir and the natural lobby looked upon the valley reservoir project as an assault on basic preservation principles, particularly since it was located within the boundaries of Yosemite National Park (1890). The controversy continues today.[7]

After the 1906 Antiquities Act, a larger and larger rift developed between federal resource managers. NPS designations of "natural parks" and "cultural parks" reflected an administratively bifurcated mindset. Some within NPS thought the agency had been weakened by the addition of eastern park properties and civil war battlefields. Indeed, in 1936 the National Parks Association called for the "purification" of the national parks system.[8] The USFS continued to manage resources through a measured system of harvest and prudent consumption; NPS concerned itself with the preservation of nature and culture, with consumption limited to resource appreciation and tourism. Nature had a decided edge in NPS resource philosophies and policies, and cultural programs usually found themselves in second place when it came to budgets and programs. The expansion of the national register program in the 1960s and its inclusion in the formulas for NEPA and other protective legislation increased the public visibility of the NPS cultural program; however, parks remained largely natural preserves.

How do we bring culture and nature together? Or, rather, how do we get professionals in both camps to acknowledge the essential truth that the world as humans define it is an imagined cultural construct visited upon the physical reality of nature itself? It will require a fundamental shift in the way we see the world in which we live. The most efficient and sensible way to ensure resource protection is through a scientific, integrated resource management system that reflects the holistic truth of the nature and our place within it.

The Statue of Liberty is a good example of what might be achieved through a hybrid model of resource management. The cultural effects of the 12-acre spot of ground, originally known to Europeans as Bedloe's Island (today Liberty Island), in New York Harbor is evident—even if one is not aware that Fort Wood preceded it and today serves as its base. The island also served as a POW camp during the Civil War.

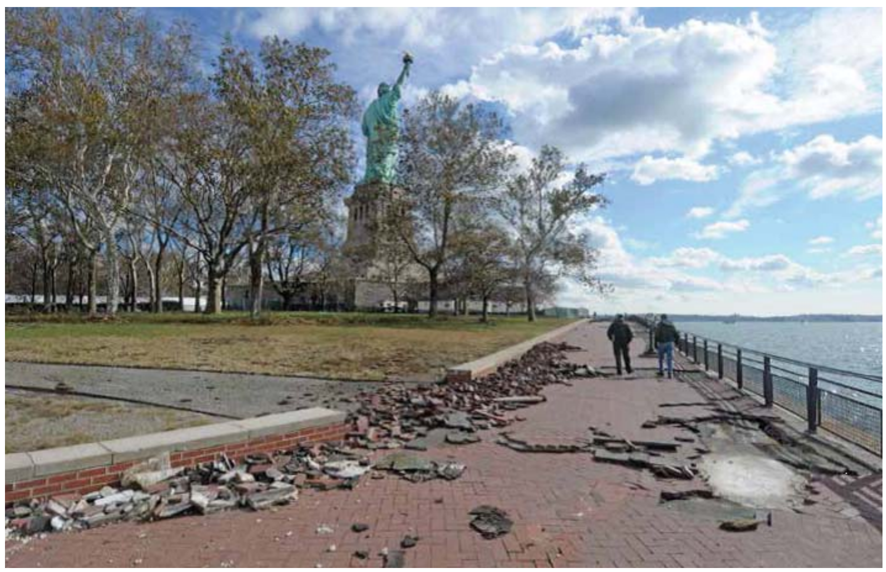

Figure 2. Devastation by Hurricane Sandy *(Source: National Landmarks at Risk, Union of Concerned Scientists, pg. 8, n.d.)*

The 305 ft. image, constructed out of 3/32 copper sheets (about the thickness of two modern pennies, according to one source), captured the imagination even before it was dedicated in 1886, and its beckoning image is culturally fixed in our minds.[9]

[7] Muir, as quoted in Foresta, 15; http://www.archives.gov/legislative/features/hetch-hetchy/

[8] Sellars, 143

[9] http://dmna.ny.gov/forts/fortsT_Z/woodFort.htm; https://patriciahysell.wordpress.com/tag/statue-of-liberty/; http://dmna.ny.gov/forts/fortsT_Z/woodFort.htm


A hydrangea macrophylla, native to Japan and used in landscaping *(Source: National Park Service, Statue of Liberty National Monument)*

But less fixed in national memory are the island's natural features. Little is said of them and the park's entire natural resource collection consists of 332 plant specimens collected in the 1990s. The interaction of the famous monument with its natural surroundings has been limited largely to restoration and maintenance of the statue and its base. Oxidation rates, combined with storm water run-off ratios, have been the subject of at least one scientific paper from scholars in Stockholm who briefly reference the Statue of Liberty and her copper skin. But more regular and intensive monitoring of natural resources at the park are needed as well, particularly those specimens of nonnative plants that have been established as landscape elements. The health of New York harbor's estuarine environment is monitored through investigation of the island's formerly famous shellfish beds and other natural features traditionally used by the Lenape Indians. Archeology has been done on the island, revealing not only modern cultural artifacts but also information regarding the natural and cultural environments prior to European contact, as well as their later interactions. The damaged sustained during 2012 Hurricane Sandy and its effects underscore the need for integrated resource management within the context of changing climate patterns.[10]

During the years of the 1950s and 1960s, a post–world war California counterculture centered on the outdoors, and rock climbing established itself at a base camp known as Camp 4. There were conflicts between NPS park administration and the climbers, but in 1997, when Yosemite administrators attempted to remove what they deemed an environmental detriment and nuisance by establishing park housing on the site, the "rock bums" (by this time a well-heeled confraternity, including contacts with businessmen and attorneys) decided to nominate Camp 4 to the National Register of Historic Places. NPS reaction was initially one of outrage by many agency members. But after some NPS historians and others made the case for the significance of the site in outdoor industry history, the Keeper of the National Register of Historic Places relented, and the site was listed in the register. In an article entitled "When Nature Becomes Culture: The National Register and Yosemite's Camp 4, a Case Study," the authors chronicled this interesting turn of events that illustrates the imaginary line between humanity and nature—and as the authors so succinctly note,

> All of these efforts illustrate that when nature becomes culture historic preservation takes on new meaning, and that historians and the caretakers of America's National Parks will need to broaden their conception of preservation as the lines between environmental and cultural preservation continue to blur.[11]

[10] Hedberg and Wallinder, 2, 956–959; Griswold, "Archeology of a Prehistoric Shell Midden Statue of Liberty National Monument, New York", Griswold, ed. 1–6, "The Ground beneath Her Feet: The Archeology of Liberty Island, Statue of Liberty National Monument, New York, New York" p. 1, passim; Waldman, p.5, http://www.nps.gov/elis/learn/historyculture/natural-resources.htm; http://www.nps.gov/stli/learn/historyculture/archeology-native-american-and-historic-use-of-liberty-and-ellis-islands.htm

[11] Kirk and Palmer, pp. 496–506. Thanks to Ms. Cannon Daughtrey of the PLN 564 graduate seminar for recalling this subject to my attention, http://www.nasa.gov/multimedia/imagegallery/image_feature_1249.html


Figure 3. National Register of Historic Places marker in Yosemite National Park *(Source: Ron Gaunt, 2012)*

While the Camp 4 controversy was hailed by certain outdoors enthusiasts as a significant legitimization of their specific history, it also highlighted other issues. For example, the upper-middle class's reverential experience of the Yosemite natural landscape was forced to make room for a cultural phenomenon that ultimately realized itself as a billion dollar industry. Passive interaction and appreciation of the landscape was sacrificed in part for active interaction with nature—literal rock-hugging. Many of the young Camp 4 pioneers of the 1950s and '60s were the children of the middle-class Americans who had previously valued Yosemite's natural symbolism, seemingly devoid of human mark. As the authors note, at Yosemite's Camp 4, the artificial line between nature and culture blurred. Today, the American climbing saga is alive and well. Companies like Camp 4 Collective continue to build on the symbolism of the original Camp 4 experience.

There is another side to the Camp 4 controversy as well. In some ways, it says more about economics and class struggle in postwar America than it does about the scenic magnificence of Yosemite, its place in American imagery, or nationalistic pride in landscape. In one sense, the Camp 4 conflict can be seen as evidence of a healthy democracy, in which the voice of everyone is heard and acknowledged. But in another, Camp 4 can be interpreted to reflect a change in national priorities. In this case, significance is negotiated, as well as documented. Active gentrification of nature is now seen as legitimate (the poor seldom rock climb)—whereas before Yosemite and its natural symbolism was larger than any one interest group. It is hard to say what the final effect of the Camp 4 nomination will be for future resource protection and management, but it is clear that national parks have entered a new era of public interface. And blurring of the natural and cultural realms can only point to the very real need for integrated resource management programs.

We finally saw our planet from space in 1968—and we have been reassessing things ever since. Science enabled the image from space—and culture has made it an icon for humanity and its future. We need to keep that "Earthrise" image in our mind's eyes—in our collective human imaginations. We can only do that by realizing that there are no meaningful boundaries between culture and nature—they constantly combine to make the world in which we live. It is only by humanity's acknowledgment of ourselves as nature's "greatest variable," as noted by Bloch, that the problem can be completely assessed and addressed. We must see ourselves as part of an integrated system, instead of the commanders of it. If not, "Earthrise" as we first observed it in 1968 may never look the same.[12]

Traditionally, NPS resources have been managed by competing natural and cultural administrative structures that often pit one discipline against the other instead of fostering cooperation that supports the conservation of both. Today, the National Park Service is in a position to lead the way in holistic resource management. Recently, restoration ecology scientists have acknowledged the importance of a "reciprocal relationship between people and the landscape"—a statement that turns from contemporary views of history's irrelevance in a rapidly changing world to one that acknowledges historical/cultural constructs as being more important in such instances—not less.[13]

One approach to the integrated resource management model is found in the curriculum design of the Tohono O'odham people of Southern Arizona. The Tohono O'odham Community College at Sells, Arizona, requires that the tribe's concept of *Himdag* be respected and included in all curricula. Himdag sees the world as a single, related entity. The Tohono O'odham and other traditional cultures use centuries-old models of integrated resource management that are sustainable. Their neighbors, the Apache, compare wisdom to water—supporting life and indispensable to human existence. Partnerships based on proven approaches to nature and people can lead to new models of resource management. We can then truly say that we have envisioned our futures by learning from the past, and, in the words of the Tohono O'odham, we will "walk a (good) path."[14]

Similar ideas are also found in post-World War II European and American historiography. It is what Lucien Febvre (Marc Bloch's colleague and mentor), Fernand Braudel, and others in the French *Annales* school of history called *mentalités*—the histories of ideas and beliefs, combined with a concept of *longue durée* or vast period of time. This view of history led to works such as Braudel's magisterial work *La Méditerranée et le monde méditerranéen à l'époque de Philippe II* (1949) (The Mediterranean and the Mediterranean World in the Age of Philip II). *La Méditerranée* acknowledges a basic truth about existence and humanity's attempts to recount it over time—the world as a total, interrelated entity that we continuously experience and imperfectly interpret. It is a whole of which we are each a part—or to quote our national motto: *E pluribus unum*—From many, one.[15]

Individual national parks are leading the way in contemporary applications of holistic management. For example, cattle ranching in the West can be an arena for integrated resource management. At Grant-Kohrs Ranch National Historic Site in Montana and Lyndon B. Johnson National Historic Site in Texas, cattle ranching plays an important role in the interpretation, management, and interface with natural and cultural resources and is of prime concern for park managers. On the East Coast, thirty parks are participating in a Coastal Risk Assessment that hopes to serve as a model for national parks in general. These and similar efforts show how resource diversity and integrated programs can benefit parks resource protection and management.[16]

Parallel changes in administration and budgets can help guarantee integrated resource management that

[12] Bloch, 197

[13] Higgs, Falk, et al, p. 1. Also see Hobbs, et. al. passim

[14] Tohono O'odham Community College Catalog 2014–2016, p. 4, http://www.tocc.edu/CatalogFinal2014-6(1).pdf; Cohen, 17–41; Darling, 4; Basso, 73 also 53–90

[15] Bloch, 5-18; Hutton, pp. 237-259

[16] http://www.nps.gov/grko/getinvolved/planning.htm; http://www.nps.gov/lyjo/planyourvisit/lbjranching.htm; file:///C:/Users/pat/Downloads/2013%20%20GRKO%20BMP%20Report%20Lienard%20Olson.pdf; http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=18811

complements and protects all resources. Natural and cultural resource professionals need to be included at the table for all resource committees and efforts, including maintenance and interpretation. An integrated four-point resource concept of natural, cultural, interpretation, and maintenance programs should be the base for any park effort. Integrated resource management plans need to be created and implemented that acknowledge federal administrative boundaries while acknowledging and cooperating with neighboring systems and resources.

A more comprehensive and integrated approach to resource management can be achieved. We can adopt approaches that are holistic and inclusive instead of divided and separate. We can support a new era of cooperative and integrated resource management that treats all resources as varied elements of one ecosystem. We can share the contemporary images and sounds of Kenji Williams' *Bella Gaia* and remember and honor poet Archibald MacLeish's hopeful 1968 vision: "To see the earth as it truly is, small and blue and beautiful in that eternal silence where it floats, is to see ourselves as riders on the earth together. . ."[17]

[17] Macleish, New York Times, December 25, 1968

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