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First Conference on Research and Resource Management in Southern Arizona National Park Areas

May 13, 1996

Extended Abstracts

Timothy J. Tibbitts and Gloria J. Maender, Editors

Casa Grande Ruins National Monument ✧ Chiricahua National Monument

Coronado National Memorial ✧ Fort Bowie National Historic Site

Montezuma Castle National Monument ✧ Organ Pipe Cactus National Monument

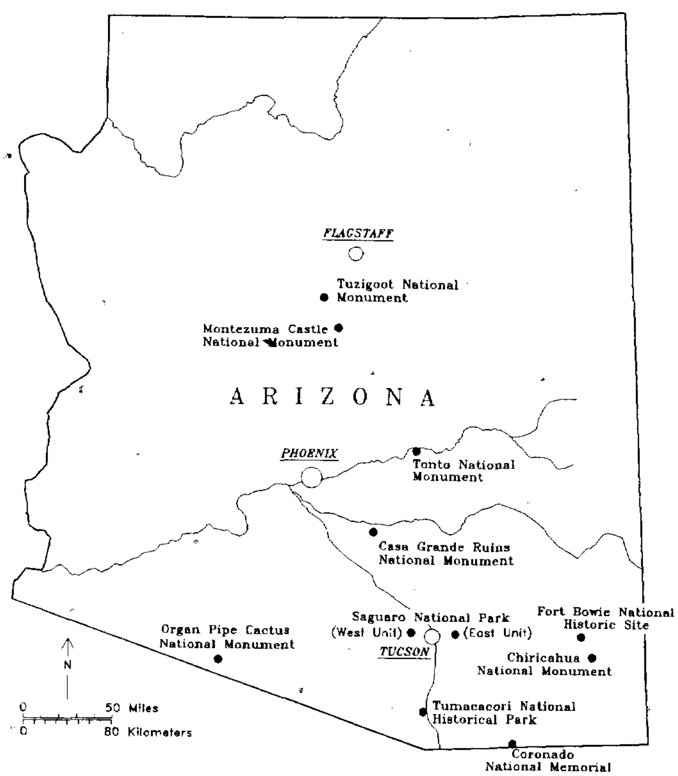
Saguaro National Park ✧ Tonto National Monument

Tumacacori National Historical Park ✧ Tuzigoot National Monument

Southern Arizona Group ✧ Southwest Parks and Monuments Association

Cooperative Park Studies Unit at The University of Arizona

Western Archeological and Conservation Center



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February 1998

Timothy J. Tibbitts and Gloria J. Maender, Editors

National Park Service, Organ Pipe Cactus National Monument
U.S. Geological Survey, Cooperative Park Studies Unit at The University of Arizona

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Tucson, Arizona 85721
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Introduction

The National Park Service is pleased to present the extended abstracts from the First Conference on Research and Resource Management in Southern Arizona National Park Areas. The ten park areas featured conserve a wide range of cultural and natural resources. Research and resource management topics in these areas are as diverse as the resources themselves: from Sinagua cliff dwellings to 18th-century Spanish colonial missions, from blistering desert plains to montane spruce-fir forests. These public treasures are the focus of local, national, and international attention among researchers, resource management professionals, and millions of visitors. They are important components of the cultural and natural heritage of southern Arizona, and contribute significantly to its economy.

Effective resource management involves free and frequent exchange of information among managers, researchers, and the public. Similarly, research on cultural and natural resources is of particular value when its focus considers resource management issues and public concerns. Finally, the public's appreciation of these resources and their stewardship is enhanced when it is able to understand research results and the influences driving management decisions. This conference sought to highlight and explore the relationships between National Park Service resources and neighboring lands, between researchers and managers, and between researchers, managers, and the public. Our goal is to improve the stewardship of natural and cultural resources through enhanced communication of contemporary research and resource management topics. This conference and those that succeed it are for all who are essential in this process: local, state, tribal, and federal resource managers; researchers; students; teachers; nongovernmental organizations; the general public, and; resource educators.

The conference was organized and hosted by National Park Service areas and cooperators. A brief description of each follows.

Casa Grande Ruins National Monument

Located in the Gila River Valley are the perplexing ruins of a large four-story structure call the Casa Grande, Spanish for "Great House." The massive building was constructed of high-lime desert soil sometime prior to A.D. 1350 by the Hohokam, an ancient people who lived and farmed throughout southern Arizona from approximately A.D. 300 to 1350. Among the Hohokam's many achievements was the construction of a vast network of irrigation canals that supplied water to their fields of corn, beans, squash, tobacco, and cotton. The Hohokam thrived for many years in the desert environment. However, for reasons unknown, their culture came to a mysterious end around A.D. 1450. The Akimel O'odham (Pima) people that live in the area today may possibly be the descendants of the ancient Hohokam. In 1892, the Casa Grande became the United State's first archeological preserve and was added to the National Park System in 1918. The structure remains the only surviving example of Hohokam "great house" construction. The Casa Grande and its surrounding structures are considered by archeologists to be the best preserved examples of Classic Hohokam village architecture. 1100 Ruins Drive, Coolidge, AZ 85228; 520/723-3172.

Chiricahua National Monument

Twenty-seven million years ago a volcanic eruption of immense proportions shook the land around Chiricahua National Monument. One thousand times greater than the 1980 eruption of Mount St. Helens, the Turkey Creek Caldera eruption eventually laid down 2,000 feet of highly silicious ash and pumice. This mixture fused into a rock called rhyolitic tuff and eventually eroded into the spires and unusual rock formations of today. At the intersection of the Chihuahuan and Sonoran deserts, and the southern Rocky Mountains and northern Sierra Madre in Mexico, Chiricahua represents one of the premier areas for biological diversity in the northern hemisphere. Of historic interest is the Faraway Ranch, a pioneer homestead and later a working cattle and guest ranch. It is a significant example of human transformation of the western frontier from wilderness to the present settlement. Faraway Ranch offers glimpses into the lives of Swedish immigrants. HCR-2 Box 6500, Willcox, AZ 85643; 520/824-3560.

Coronado National Memorial

Commemorating the first major exploration of the American Southwest by Europeans, Coronado National Memorial lies on the U.S.-Mexico border within sight of the San Pedro River Valley, through which the Coronado Expedition first entered the present United States in search of the fabled Seven Cities of Cibola. It is a cultural area situated in a natural setting comprised of 4,750 acres of oak woodlands. 4101 East Montezuma Canyon Road, Hereford, AZ 85615; 520/366-5515.

Fort Bowie National Historic Site

Fort Bowie commemorates the story of the bitter conflict between the Chiricahua Apaches and the U.S. military. For more than 30 years, Fort Bowie and Apache Pass were the focal point of military operations eventually culminating in the surrender of Geronimo in 1886 and the banishment of the Chiricahuas to Florida and Alabama. It was the site of the Bascom Affair, a wagon-train massacre, and the battle of Apache Pass, where a large force of Chiricahua Apaches under Mangus Colorados and Cochise fought the California Volunteers. C/O Chiricahua National Monument, HCR-2 Box 6500, Willcox, AZ 85643; 520/847-2500.

Montezuma Castle National Monument

Nestled into a limestone recess high above the flood plain of Beaver Creek in the Verde Valley stands one of the best-preserved cliff ruins in North America. The five-story, twenty-room cliff dwelling served as a "high-rise apartment building" for prehistoric Sinagua Indians over 600 years ago. Early settlers to the area assumed that the imposing structure was connected to the Aztec emperor Montezuma, but the castle was abandoned almost a century before Montezuma was born. The Montezuma Well unit preserves a large, spring-fed limestone sinkhole and prehistoric ruins that remain from early Hohokam and Sinagua occupation. Both cultures lived at the site and irrigated their crops with the water from the well. Remains of their ancient irrigation canals can still be seen. P.O. Box 219, Camp Verde, AZ 86322; 520/567-5276.

Organ Pipe Cactus National Monument

Organ Pipe Cactus National Monument celebrates the life and landscape of the Sonoran Desert. Here, in this desert wilderness of plants and animals and dramatic mountains and plains scenery, you can drive a lonely road, hike a backcountry trail, camp beneath a clear desert sky, or just soak in the warmth and beauty of the Southwest. The monument exhibits an extraordinary collection of plants of the Sonoran Desert, including the organ pipe cactus, a large cactus rarely found in the United States. There are also many creatures that have been able to adapt themselves to extreme temperatures, intense sunlight, and little rainfall. Route 1, Box 100, Ajo, AZ 85321; 520/387-7661.

Saguaro National Park

The giant saguaros, symbols of the desert West, crowd the desert floor in Saguaro National Park. Their tall, straight stance with uplifted arms has long mystified and fascinated visitors to this region. The saguaros may draw visitors to this park, which has the city of Tucson in its center, but many other memorable surprises await. Thousands of petroglyphs, ancient etchings in the stone, are discovered throughout the park. Scores of abandoned mines remind the visitor of the anxious search for gold a century ago. Remnants of ranches, lime kilns, and Civilian Conservation Corps structures are subtle evidence of bygone eras, as over 1,000 desert plant species reclaim this park for the extensive flora and fauna that have lived here for millennia. 3693 South Old Spanish Trail, Tucson, AZ 85730; 520-733-5100.

Tonto National Monument

Tonto National Monument was established in 1907 to preserve multi-room cliff dwellings occupied by the Salado culture from approximately A.D. 1250 to 1450. The people subsisted by farming along the nearby Salt River. They grew corn, squash, beans, amaranth, and cotton, and supplemented their diet with wild game and native plants. The Salado are best known for their exquisite polychrome pottery and delicate weavings. Today, the two largest dwellings, Lower Ruin and Upper Ruin, are open to the public by either self-guided or ranger-guided tours. Of additional interest is the high Sonoran Desert setting, with saguaro cactus, mesquite, jojoba, and paloverde dominating a rugged terrain. Wildlife documented on remote-sensing cameras include mountain lion, white-tail deer, javelina, ringtail, bobcat, and four species of skunk. HC02, Box 4602, Roosevelt, AZ 85545; 520/467-2241.

Tumacacori National Historical Park

San Jose de Tumacacori is probably the best preserved adobe mission ruin in the United States. This Franciscan church stands near the site first visited by Jesuit Father Eusebio Francisco Kino in January 1691. Tumacacori was a "visita," or visiting station, during the Jesuit period with its headquarters at Guevavi, where the priest lived. The Jesuits built the first church at Tumacacori in 1757 but were expelled 10 years later, and the Franciscans, who replaced them, built the present structure beginning in 1800. Abandoned in 1848, the mission was made a National Monument in 1908 and became Tumacacori National Historical Park in 1990 with the addition of two other mission ruins, Calabazas, and the old "cabecera" or headquarters church, at Guevavi. These ruins represent 157 years of Jesuit and Franciscan missionary efforts among the Pima Indians of southern Arizona and northern Sonora. P.O. Box 67, Tumacacori, AZ 85640; 520/398-2341.

Tuzigoot National Monument

Perched atop a ridge high above the Verde River lies Tuzigoot, the remnants of one of the largest pueblos built by the Sinagua. Tuzigoot, an Apache word meaning "crooked water," was built during the period of A.D. 1100 to 1450 and consisted of two stories and 110 rooms. The structure and the ruins of other sites in the surrounding area provided shelter for hundreds of occupants. C/O Montezuma Castle National Monument, P.O. Box 219, Camp Verde, AZ 86322; 520/634-5564.

Cooperative Park Studies Unit at The University of Arizona

The Cooperative Park Studies Unit at The University of Arizona was established by the National Park Service in 1973 to provide park managers with information that would help them manage natural and cultural resources. This information is obtained through research conducted by staff of the unit and by university researchers under a cooperative agreement. Principal cooperators include the School of Renewable Natural Resources in the College of Agriculture and the Department of Ecology and Evolutionary Biology in the College of Arts and Sciences. Unit scientists hold faculty or research associate appointments with the university. In November 1993, by action of Secretary of the Interior Bruce Babbitt, the research function of the National Park Service and several other Interior agencies was transferred to a newly created agency, the National Biological Service. In October 1, 1996, the new agency joined the U.S. Geological Survey, becoming its Biological Resources Division. The unit now has responsibility for conducting such studies for all land-management agencies. National Park Service projects that are conducted at the unit are those that have been given high priority by park managers and have been funded by either the National Park Service or the U.S Geological Survey. With the development of the Biological Resources Division, unit staff have been pursuing those projects that would involve funding by and cooperation with sources outside the National Park Service. The Cooperative Park Studies Unit is by such actions helping to foster an environment of cooperation and interdependence on the part of all agencies that manage lands in Arizona. 125 Biological Sciences East, The University of Arizona, Tucson, AZ 85721; 520/670-6885.

Southern Arizona Group

The National Park Service Southern Arizona Group provides technical and administrative support for research and management in nine national park units in southern Arizona. The Southern Arizona Group was established in 1970 to provide essential support, assistance, and guidance for superintendents and park staffs. Additionally, the Southern Arizona Group provides liaison between southern Arizona national park areas and other federal, state, and local agencies and governing bodies, and a variety of environmental organizations within Arizona in all matters relating to the National Park Service mission. Current staffing includes resource management, operations, contracting, personnel, and administration specialists. The level of staff involvement varies based on requests from park personnel. Park Central Mall, 3115 N. 3rd Ave., #101, Phoenix, AZ 85013-4334; 602/640-5250.

Southwest Parks and Monuments Association

Southwest Parks and Monuments Association is a nonprofit organization authorized by Congress, founded in 1938 to aid and promote the educational and scientific activities of the National Park Service. The association serves 52 National Park Service areas in 11 states, publishing interpretive material relating to the themes of these parks. These materials are made available to park visitors by sale or free distribution. All net proceeds support interpretive, educational, and research programs of the National Park Service. Southwest Parks and Monuments Association staff work cooperatively with National Park Service personnel at many park visitor centers; the association's main office is in Tucson, Arizona. 221 North Court Avenue, Tucson, AZ 85701; 520/622-1999.

Western Archeological and Conservation Center

The Western Archeological and Conservation Center in Tucson houses the only multi-regional National Park Service repository containing park collections from the arid Southwest—the largest area served by any National Park Service repository. Center history goes back to 1952, when Congress approved the purchase of Gila Pueblo in Globe, Arizona, "for archeological lab and storage purposes." The present location, about one mile west of The University of Arizona, was specially designed to consolidate functions and collections of the Western Archeological and Conservation Center. Staff curate over two million objects of archeological, ethnographic, historical, archival, and natural history significance from more than 60 park areas. Staff archeologists conduct archeological projects, including excavation for testing and data recovery, inventory surveys, monitoring, and archeological database management in parks throughout the West from the California deserts to the Texas coast and north to Montana. The center also has initiated a partnership program with sister agencies and neighbors, such as the Defense Department and private landowners. Public tours are scheduled annually during Arizona Archaeology Awareness Month. 1415 North 6th Avenue, Tucson. AZ 85705; 520/670-6501.

With the exception of the keynote address, which appears first in this volume, the extended abstracts are arranged alphabetically by principal author. The order of presentation at the conference is indicated in the following (an asterisk designates the presenter):

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- Estimation of Emission Rates in Mexico by Receptor Modeling, Kristi A. Gebhart* and William C. Malm
- Geomorphology of Chiricahua National Monument, Douglas Hall and John Bezy*
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- Between Desert and Sea: Identifying Hohokam Populations and Settlement Patterns in Western Papagueria, Adrianne Rankin
- Geographic Information System Analysis of Natural-cultural Correlations at Saguaro National Park, Joseph V. Svinarich
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- Ecology of the Mexican Rosy Boa at Organ Pipe Cactus National Monument, David A. Parizek,* Philip C. Rosen, Cecil R. Schwalbe, and Charles H. Lowe
- Tree Lizard Distribution and Saguaro Cactus Succession, Robert T. M'Closkey
- Ecology and Management of the Sonoran Mud Turtle at Quitobaquito Springs, Organ Pipe Cactus National Monument, Philip C. Rosen* and Charles H. Lowe
- Management Implications of Rattlesnake Relocation at Montezuma Castle National Monument, Erika M. Nowak
- Bat Monitoring at Quitobaquito Pond, Organ Pipe Cactus National Monument, Yar Petryszyn, Stephen Russ,* and Ami C. Pate
- Birds of Prey of Chiricahua National Monument, Russell B. Duncan* and Helen A. Snyder
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- Using Long-term Monitoring to Understand How Adjacent Land Development Affects Natural Areas—An Example from Saguaro National Park, Mark K. Briggs* and Lisa Harris
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Keynote Address

Interpreting the Cultural and Natural Pasts for the Public: A High-wire Act

Thomas E. Sheridan

Arizona State Museum, The University of Arizona, Tucson, AZ 85721

Interpreting the past for the public is one of those elusive crafts few of us master. Those of us who work in academia are so used to writing for or speaking to one another that we often forget we speak another language; jargon creeps into our prose even when we consciously set out to address that mythical creature, a "popular audience." But when professional writers attempt to interpret science or history for the public, they run the risk of presenting outmoded information or conveying complex issues in a simplistic fashion. A case in point is Southwestern archeology, which is changing at breakneck speed because of the explosion of contract research during the past twenty years. Whether it is Hohokam chronology or the beginnings of Southwestern agriculture, the old verities in the standard texts are crumbling, and new, often conflicting interpretations are sweeping across the field. Unless you master an enormous body of literature, much of it the so-called "gray literature" of contract reports, you may mislead more than you illuminate.

There are other challenges and pitfalls as well. As ethnohistorian Bernard Fontana (1994) states with tongue only partly in cheek, "History has nothing to do with the past." In his elegantly written *Entrada: The Legacy of Spain & Mexico in the United States,* Fontana argues:

> History, whether spoken or written, needs to be distinguished from the past itself. What we call "history" is a recitation of events selected from the past, which in its most literal sense is all that has preceded the present: a rock that fell, a dog that barked, an infant who cried, a woman who coughed, a prince who was enthroned king. All historians—and on occasion each of us is a historian—select from this infinity of events those we deem worth telling. The basis of that selection provides the built-in bias of history. History, more than being a debate about the past, is an argument about the present and future. It often tells us less about what was and more about who we are. It is a tool used by all of us either to justify or to condemn the status quo. It is a statement of the world either as we now perceive it to be or as we think it ought to be. The past is immutable, but history, a battleground for the public mind, is ever changing (Fontana 1994).

Whether you accept the commission or not, the National Park Service (NPS) is on the front lines of that battleground. No other agency in the United States is steward of more cultural and historic sites—sites that cover at least 12,000 years of human history and reflect the pasts of just about every ethnic group that has occupied, and contested for, North America. In an area like the West, where most residents are newcomers, the task of interpretation takes on formidable moral and political as well as scholarly dimensions. In southern Arizona, we live in a transient society—a society in constant flux; for every ten people who move to the region, seven move away within ten years. How do we create a sense of the past that nourishes a sense of community with one another when most of us don't even know our neighbors? And how do learn how to inhabit this dry and piercingly beautiful landscape that surrounds us when many of us live in microenvironments—refrigerated office buildings, air-conditioned cars, neighborhoods built around golf courses, or, in the Salt River Valley, artificial lakes—that deny the landscape? Whether we are resource managers or scientists, every so often we need to ask ourselves those questions as we develop policy or research designs.

The pitfalls in this process are deep and wide. I'll concentrate on a cultural example, because those are the ones I know best. Some of you are charged with managing and interpreting sites from the Spanish colonial period when southern Arizona was a tiny finger of northern Sonora. The most impressive of those sites are missions like Tumacacori or San Xavier, a structure Paul Schwartzbaum, head of conservation at New York's Solomon R. Guggenheim Museum, calls the Sistine Chapel of North America. Until the past ten years or so, our image of missions on the so-called Spanish Borderlands was shaped by historian Herbert Eugene Bolton and his students, who portrayed missionaries like Eusebio Francisco Kino as heroes. *Rim of Christendom,* Bolton's biography of Kino (1984), reads more like a historical novel than an analytical history. More to the point, Bolton and his students, many of whom were Jesuits, present missions themselves as institutions of civilization in a savage wilderness. Indians, on the other hand, are described as fickle, superstitious, childlike, or treacherous. Reading 20th-century scholars like Bolton, Peter Masten Dunne, or John Donohue is little different at times than reading 18th-century missionaries such as Juan Nentvig or Ignaz Pfefferkorn.

This historiographic interpretation of the missions has shaped publications and exhibits for at least two generations. But it has also influenced how the physical plants themselves have been restored. In a wonderful essay entitled "Harvesting Ramona's Garden: Life in California's Mythical Mission Past," archeologist David Hurst Thomas (1991) skewers the romantic reconstruction of Alta California's missions, especially the mission gardens. In his words:

> Thousands of tourists flock annually to California's restored missions, luxuriant amidst the jasmine and ever-blooming lantana. Today's California mission, with rare exception, hosts luxurious gardens of "stately palms mixed with colorful bougainvillea, banana and pepper trees, [recalling] the days when mission fathers and wealthy landowners planted gardens as a reminder of their native soil."
>
> The unfortunate truth is that these cornucopian mission gardens are pure *Ramona*-derived hyperbole. Period paintings, textual descriptions, photographs, and archaeology amply demonstrate that such flowery enchantment never existed in the original missions. The great plaza garden at Mission Carmel, with its majestic fountain, was barren dirt during mission times. The plaza at Santa Barbara—Queen of the Missions—was also vacant of vegetation. The patio gardens—to many, the most striking features of contemporary missions—are counterfeit, planted only in this century.
>
> The unvarnished truth is this: There were no pleasure gardens of any kind at the original California missions—no cloisters, no bird-of-paradise plants, no flower-bedecked cemeteries, no ornamental gardens, only hardscrabble reality. The magnificent mission gardens, hallmarks of today's restorations, are Anglo-Germanic interpretations, not historically accurate originals (Thomas 1991).

The garden at Tumacacori mission is one of my favorite spots in Tumacacori National Historical Park, but did it exist when Tumacacori was a working mission? I don't know, but I'm skeptical. What gardens such as those in the California missions do is reinforce myths of mission serenity, mission order, and mission prosperity—myths that engulf the senses and obscure the reality of what life was like in those institutions. The public loves them, but there are negative consequences as well. The lush, well-watered gardens encourage the destructive notion among treasure hunters that missions were fountains of wealth with stashes of gold and silver hidden on mission grounds. Those of us who belong to the Southwestern Mission Research Center and lead tours of the Kino missions in northern Sonora know what misguided treasure hunters can do to structures like Nuestra Senora del Pilar y Santiago de Cocospera.

The gardens and the utopian image they convey also diminish and obscure the devastating consequences missionization had on Indians on the northern frontier of New Spain. In his book *Indian Population Decline: The Missions of Northwestern New Spain, 1687–1840,* historian Robert Jackson (1994) demonstrates conclusively that in Baja and Alta California and the Pimería Alta, missionization was a demographic catastrophe for mission Indians. Mission Indian population could not reproduce themselves, because death rates exceeded birth rates. High percentages of children and women of child-bearing age also died. The only way mission communities survived was by continually recruiting new converts—a point anthropologist Hank Dobyns (1976) made so well in his book *Spanish Colonial Tucson* nearly two decades ago for Mission San Xavier.

Jackson (1994) is careful not to treat missions as a monolithic system. He explores the cultural as well as biological reasons for demographic decline, and discusses the differences among the missions themselves. In the Pimería Alta, for example, epidemics of Old World diseases like smallpox and measles were "traumatic events that doubled or tripled normal death rates, but with no recovery or rebound through natural reproduction following the epidemic." In Alta California, by contrast, epidemics were merely blips in the chronically high death rates—death rates that were due to inadequate nutrition, poor sanitation, and overwork.

Jackson's critics might argue that high mortality characterized peasant and working class populations all over the world in the 18th and early 19th centuries. Jackson (1994) counters by pointing out that in both Alta California presidios and rural European villages, populations grew slowly despite high rates of disease and low birth rates, and that mean life expectancies were three times greater than in mission settlements.

These dismal demographic realities lead to another interpretative dilemma: Do we reverse field, run against the Boltonian tide, and portray missions as "charnel houses," as historian Edward Castillo argues? If we do, we run the very real risk of perpetuating La Leyenda Negra—the Black Legend—so entrenched in British and Anglo-American historiography and popular imagination. I wish I had a dollar—or at least a small CD—for every time someone in the audience has come up to me after a talk and comments on the cruelty of the Spaniards. When they do, I ask them, "Where do you find most living Indian peoples in North America? How many living Indians have survived in British North America?" That response usually gives them pause. New Spain, exploitative as it was, depended upon Indian labor and strove to incorporate Indians into its society. In the British colonies, on the other hand, Indians were pushed westward after they had served their purpose in containing the French or the Dutch. Neither histories are very pretty, but Spanish Indian policy was more humane—or, more accurately, less inhumane—than British Indian policy on this continent.

Perhaps the only way to walk this interpretative high-wire is to come clean with our audiences. In a recent review essay in *The Public Historian*, I reviewed four publications published by or for the National Park Service (Sheridan 1996). One of the publications that impressed me the most was called *Chaco: A Cultural Legacy: Chaco Culture Historical Park* by Michele Strutin (1994). What I liked most about the text is its focus on the process as well as the results of archeological research. Strutin traces the history of Chacoan scholarship from a U.S. military survey in 1849 to the sophisticated architectural, ceramic, and irrigation studies being carried out today. Her emphasis on how research is conducted helps the reader understand that archeology is an interpretive science constantly refining its techniques, employing new techniques, and reexamining the conclusions of earlier researchers.

Such a focus on the nature of research should become an essential part of interpreting NPS and other cultural sites. It also should be incorporated into "natural" sites as well, because landscapes are historical creations as well. Those who have immersed themselves into the controversies over vegetation change in southeastern Arizona during the past century—not to mention the Holocene—knows how complex and disputed such questions are. Were historic arroyos incised in drainages like the Santa Cruz the results of human impact or climate change? Of overgrazing or El Niño? Of channel modifications or increases, decreases, or shifts in precipitation patterns? The "past" is not necessarily some objective entity waiting to be discovered. On the contrary, our knowledge about the past is always conditional—upon the nature and quality of our data, and upon our political and epistemological assumptions themselves. We owe it to the public to make them aware of those conditional qualities for two major reasons. First, it helps them understand why it is so essential to preserve the past, whether it is an archeological site, a historic structure, or an archive; as scholarship becomes more sophisticated, we learn more from those sites and archives. There is no finite amount of information to be gleaned from them; if they are destroyed, advances in scholarship are destroyed as well.

Secondly, the public needs to know that the past is an ever-changing construct, so they can participate in its interpretation more effectively and more responsibly. Because the past is used to "justify or to condemn the status quo," as Fontana observes (1994), a healthy democracy requires citizens who can evaluate those justifications or condemnations. Otherwise, we relegate the interpretation of the past to antiquarians or demagogues.

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Preliminary Evidence Regarding Prehistoric Production Sources of Micaceous Schist-tempered Pottery in the Gila River Valley

David R. Abbott[1] and Elizabeth Miksa[2]

[1]*Arizona State Museum, The University of Arizona, Tucson, AZ 85721*
[2]*Desert Archaeology, 3975 North Tucson Boulevard, Tucson, AZ 85716*

Introduction

Differentiated by geological and ceramic compositional studies, the prehistoric production sources of Hohokam pottery are now being discriminated with remarkable precision. Consequently, thousands of ceramics can be classified quickly and inexpensively. Pottery exchange is being traced over short distances, permitting the interaction between Hohokam neighbors to be monitored in a new and richly informative way. As a result, the structure of local social networks, their articulation with the irrigation economy, and organizational changes at various levels in the sociopolitical system, which are all pivotal topics in Hohokam archeology, have come under the purview of ceramic research (Abbott 1994a, 1994b, 1995a; Heidke 1993, 1995; Heidke and Stark 1995; Lombard 1987; Miksa 1994).

The new ceramic approach has been successfully applied in the lower Salt River Valley, the Tucson Basin, and the Roosevelt Lake area. In this paper, we briefly review the Salt River Valley research to exemplify the methods and strategies of the new approach. We then describe our attempt to expand the work into the Queen Creek area and the middle Gila River Valley, which met with surprising results. We have found that it is impossible to simply transfer previously used research tactics to the new region. In addition, our data imply that one of two extraordinary patterns of ceramic production and exchange probably existed during ancient times. As described, our ongoing research has been reorganized to investigate which of these practices pertained to the middle Gila River Valley.

Previous Research

In the lower Salt River Valley, variable compositions of the sands eroding from surrounding mountains have led to the definition of discrete, small-scale sand-composition zones, called petrofacies, which were the sources of ceramic temper (Abbott 1994b; Miksa 1994). Petrographic analyses of the temper (Miksa 1994; Schaller 1994) and chemical assays of the clay fraction in sherds with an electron microprobe (Abbott 1994a, 1994b, 1995a) demonstrated a strong association between temper and clay types, indicating that Hohokam potters relied heavily on the most locally available materials and verifying temper as an excellent indicator of production source. This work has made it possible to determine the production sources of thousands of ceramics without specialized equipment or costly sample preparation during typical projects in the Salt River Valley. Not all social relationships can be determined on the basis of pottery exchanges alone. Nevertheless, ceramics were frequently exchanged over short distances, and tracking the movement of the containers between Hohokam neighbors is tantamount to mapping some of the principal lines of interaction among the Hohokam people.

Current Research

Our attempt to expand the ceramic research to the Gila River Valley and Queen Creek began with an extensive sampling program of bedrock units and sands from the beds of washes scattered across the general area. Nearly 100 rock and sand specimens were collected and analyzed. This effort was conducted in coordination with research at Casa Grande Ruins National Monument (Miksa 1995a) and the Mesa Southwest Museum (Miksa 1995b). Petrographic analysis of the rock and sand samples demonstrated considerable compositional variation across the area, allowing the region to be preliminarily subdivided into eight mutually discrete petrofacies. A similar analysis, presently in progress, of an additional 114 samples will refine the zonal model. These results were expected to provide a geological basis with which to distinguish the sand compositions available at various pottery production sources.

One particularly important finding concerns coarse-grained micaceous schist, which is known to temper large quantities of Hohokam plainware, redware, and buffware ceramics. This rock type is present only along Queen Creek, in sections of the Gila River Valley north of the river, and in isolated pockets on the south side of the Gila at Pima Butte and the northwest tip of the Sacaton Mountains. Also, a reconnaissance of the dry bed of the Gila River and the cobble bars on the first terrace overlooking the river's southern bank confirms the absence of the coarse-grained schist in the southeast quarter of the middle Gila River Valley. Consequently, we expected that much of the pottery at Hohokam settlements in the southeast quarter would not contain micaceous schist and, instead, would be tempered with the locally available materials.

To our surprise, an analysis of the temper in the plainware and buffware collections from Casa Grande (Abbott 1995b) and the adjacently located Grewe site (Abbott 1995c) indicated that nearly all of the pottery contained amounts of micaceous schist. Casa Grande and Grewe are located in the valley's southeast quarter and outside the areas where the schist is naturally found. Could it be that all of the pottery at two of the largest villages in the Gila River Valley was imported from distant production areas probably located on the opposite side of the Gila River, where micaceous schist was abundantly available? Previously, some prehistorians theorized that the decorated red-on-buff types found throughout the Hohokam culture area were mass-produced in the Gila River Valley (Doyel 1981; Rafferty 1982; Walsh-Anduze 1993a). However, there has never been speculation that some utilitarian plainware ceramics were centrally manufactured and distributed by specialist producers to a broad-scale exchange market.

Despite the available data, the centralized production of massive amounts of utilitarian pots seems far-fetched. It is hard to imagine commerce on such a scale by people whose socioeconomic organization was probably on a tribal level. Perhaps a more credible explanation, which may be the only alternative, is that the schist temper, not the pottery, was transported to Casa Grande and Grewe. If this hypothesis is correct, then either artisans from these sites travelled considerable distances to procure raw schist for tempering their wares or the schist sources were exploited by groups that inhabited the schist areas and widely traded the schist as a raw commodity to distant potters. Our research in conjunction with current excavations at Grewe by Northland Research, Inc., is devoted to determining if the schist or the schist-tempered pottery was imported to the site and to better understanding the organization of ceramic production.

There are two pieces of available information that pertain to these issues. First, a sample of 15 plainware and 15 buffware sherds from Grewe have been thin-sectioned and petrographically analyzed. The analyses indicate that all but one were made with crushed-schist temper rather than schist-bearing sand. This result is important because it reveals a pattern of raw-material use but, unfortunately, also implies that our petrofacies model of sand-type distributions may have only limited utility for distinguishing pottery made in different parts of the Gila River Valley. Second, previous field work has documented a large number of schist mines gouged from the sides of Gila Butte (Rafferty 1982; Walsh-Anduze 1993b). Based on volumetric measurements of the quarry cavities supplied by Walsh-Anduze (1993b), at least enough schist to cover a football field in a layer 2 m (6.5 ft) deep was extracted from the butte. The quantity of Grewe pottery tempered with Gila Butte schist has become a central issue. If it can be shown that all or most of the schist temper in the ceramics at Grewe came from Gila Butte, we must ask whether a concentrated source area was associated with controlled and exclusive access of the resource. Either a valued raw commodity was traded, or large-scale and centralized pottery production was practiced near Gila Butte.

Walsh-Anduze (1993b) has already demonstrated the ability to chemically distinguish raw schist from Gila Butte and Pima Butte using Inductively Coupled Plasma-Emission Spectroscopy (ICPS). It is our intention to expand her study with ICPS assays from other schist bedrock units with the hope of chemically fingerprinting each of the sources. In addition, pieces of raw schist recovered from Grewe will be chemically and petrographically analyzed to determine their provenance. We will also evaluate the relevance of the schist pieces for ceramic production at Grewe using a spatial analysis of their relationship with other raw materials, groundstone implements, and features that may have been used for making pottery.

Finally, we will use the electron microprobe to assay the clay components in samples of pottery from Grewe and elsewhere. Thus far, this work has demonstrated a chemical difference between the schist-tempered plainware pottery at the Gila Butte site and the schist-tempered plainware pottery from two sites located along Queen Creek. We are encouraged by this result because it shows that source-related variation is distinguishable in the chemical data. Sampling additional collections is planned, including sherds from Grewe and other sites both within and outside the area where micaceous schist is naturally found. We expect that the degree to which the Grewe pottery is chemically similar or different from the ceramics at the other sites will be informative as to whether the Grewe pottery was locally made or if the pots themselves were brought to the site.

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Montezuma Castle Construction Sequence

Keith M. Anderson

Western Archeological and Conservation Center, 1415 North 6th Avenue, Tucson, AZ 85705

In 1988, National Park Service archeologists made a detailed study of the architecture of Montezuma Castle. This included a record of wall joints and vertical alignments in order to reconstruct the building sequence. Unfortunately, there are no direct dates for this sequence, although it is assumed that the castle belongs to the Tuzigoot Phase (A.D. 1300–1400) of the southern Sinagua culture. Perhaps some future dating technique will tell when the castle was built. (POSTER)

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The Ecological Monitoring Program at Organ Pipe Cactus National Monument

Jonathan F. Arnold, James A. Barnett, Charles W. Conner, and Ami C. Pate

Organ Pipe Cactus National Monument, Route 1, Box 100, Ajo, AZ 85321

Introduction

The Ecological Inventory and Monitoring Program (EMP) has existed at Organ Pipe Cactus National Monument for more than a decade. Through this program, cooperating scientists and monument Resource Management Division staff have developed baseline data, monitoring protocols, and long-term data sets on reptiles; amphibians; endemic fish; nocturnal rodents; bats; birds; terrestrial invertebrates; special status plants; nonnative plants; vegetation structure and diversity in natural communities; climate; air quality; land-use trends on property adjacent to the monument, and; night-sky brightness.

Area Background

Organ Pipe Cactus National Monument is located in southwestern Arizona. The monument is approximately 132,275 ha (330,689 ac) in size and is located geographically near the center of the Sonoran Desert. Approximately 95% of the monument is designated wilderness, and the area was recognized as an International Biosphere Reserve in 1977. The monument borders Mexico to the south, the Tohono O'odham Nation to the east and northeast, Cabeza Prieta National Wildlife Refuge on the west and northwest, and Bureau of Land Management lands on the north.

Two distinct vegetation zones of the Sonoran Desert converge in Organ Pipe Cactus. The eastern portion of the monument contains the Arizona Upland subdivision, which is characterized by mixed cactus/paloverde and evergreen scrubland communities. Here grow the large columnar cacti such as saguaro *(Carnegiea gigantea)* and the monument's namesake, organ pipe cactus *(Lemaireocereus thurberi)*. The Lower Colorado subdivision covers most of the western portion of the monument, with creosotebush/bursage communities making up more than 80% of this region. Representatives of a third vegetation zone, the Central Gulf Coast subdivision, are also found in a few areas of the monument. These species, such as senita cactus *(Lophocereus schotti)*, elephant tree *(Bursera microphylla)*, and limberbush *(Jatropha cardiophylla)*, are near the northern limits of their range here.

The park herpetofauna is rich and is strongly dominated by lizard and snake species. Sixteen lizard, 25 snake, 5 amphibian, and 2 turtle species are known to occur within the monument. There are 54 species of mammals, including desert bighorn sheep *(Ovis canadensis mexicana)*, white-tail deer *(Odocoileus virginianus)*, the endangered Sonoran pronghorn *(Antilocapra americana sonoriensis)*, and the largest known maternity colony in the United States of the endangered lesser long-nose bat *(Leptonycteris curasoae)*. The monument also supports a relatively rich Sonoran Desert avifauna, with more than 270 bird species occurring here. Research associated with recent inventory work recorded more than 1,000 species of invertebrates. One species of fish, the endangered Quitobaquito desert pupfish *(Cyprinodon macularius eremus)*, inhabits the springs, channel, and pond at Quitobaquito.

The Ecological Monitoring Program

Why undertake an inventory and monitoring (I&M) program in a National Park Service (NPS) area? To begin with, laws such as the National Environmental Policy Act, Endangered Species Act, the Forest and Rangeland Renewable Resources Act, and Clean Water Act require, directly or indirectly, the inventory and monitoring of natural resources on all federal lands in the United States. A host of other legal mandates also exist. But we believe our obligation was best expressed in the 1994 NPS Strategic Plan, which stated plainly that the most important thing the agency can do is "develop a scientific basis for resource management decisions." Knowing the status and trends of park resources should be the core of this scientific basis. This knowledge will help answer questions like what effect outside influences are having on the health of park and regional ecosystems.

Despite its remoteness from population centers, Organ Pipe Cactus, just like most national parks, has its share of outside influences that can affect, in a myriad of ways, park ecosystems. Issues like continued urbanization and agricultural development across the border in Sonora, Mexico, are accompanied with problems like pesticide contamination, the invasion of nonnative plants and animals, and groundwater depletion in the Sonoyta Valley, which includes portions of the monument. It was these issues that were in mind when, in September 1986, a group of 27 scientists and managers met to plan the development of a program to both assess ecosystem conditions at Organ Pipe Cactus and to monitor components through the future.

Modelled after the successful Channel Islands National Park I&M initiative, a step-down planning technique was used to efficiently organize the management goals and objectives of the program. The primary goal of the program was to 1) determine the condition of park ecosystems, 2) determine alternatives available for ecosystem management, and 3) determine the effectiveness of implemented action programs. Although the program was estimated to cost $1.4 million in 1986, only a third of this was made available. Priorities were established, which included initiating baseline research studies of park resources. From these baseline assessments, monitoring protocols would be developed.

Baseline Research

By 1988, baseline research associated with 12 studies was underway:

1. *Land-use Trends Surrounding Organ Pipe Cactus National Monument*
   Conducted by Bruce Brown to determine current land uses of properties adjacent to the monument with particular emphasis on the Rio Sonoyta Valley in Sonora, Mexico. Acreage in agricultural production, types of crops raised and associated acreage, and annual groundwater pumpage rates were determined. Monitoring protocols to guide the collection of this information annually were developed.

2. *Inventory and Assessment: Birds*
   Conducted by R. Roy Johnson and Kathy Hiett to provide information about the distribution and relative abundance of monument birds, with special emphasis on breeding birds in the vicinity of the permanent study sites.

3. *Inventory and Assessment: Terrestrial Invertebrates*
   Conducted by Kenneth Kingsley to determine the important invertebrate species in monument ecosystems and identify indicator species for long-term monitoring. Approximately 4,200 invertebrate specimens were added to the Organ Pipe Cactus museum collection.

4. *Inventory and Assessment: Reptiles and Amphibians*
   Conducted by Charles H. Lowe and Phil Rosen to provide information about reptile and amphibian species occurrence, distribution, and relative abundance. Criteria were established and lizard species were selected to monitor as indication of ecosystem health and long-term change.

5. *Inventory and Assessment: Nonnative Plants*
   Conducted by Richard Felger. Identified 62 species of nonnative vascular plants located in or adjacent to the monument. This represents about 11% of the park flora and may be an overestimation because 1) some "nonnatives" may actually be natives, 2) some species are present but not reproducing, and 3) some are in adjacent Sonora but have not been seen in the monument.

6. *Inventory and Assessment: Mammals*
   Conducted by Yar Petryszyn and Steve Russ to provide information on species distribution and relative abundance of monument mammals. Criteria were established for selection of mammal indicator species, and nocturnal rodents were selected to be monitored.

7. *Inventory and Assessment: Special Status Plants*
   Conducted by George Ruffner to determine geographic distribution, abundance, natural history, ecology, and potential to sustain viable populations for 18 plant species in Organ Pipe Cactus. Long-term monitoring protocols were developed for 6 of the 18 plants.

8. *Recovery of Monument Ecosystems Since Termination of Cattle Grazing*
   Conducted by Peter Warren. In 1977, shortly before the removal of cattle from the monument, vegetation plots, rodent transects, and photopoints were established to gather baseline data on ecosystem recovery responsive to the removal of cattle. The purpose of this study was to reread these existing plots and transects. Relationships between rodent distribution and vegetation cover was established.

9. *Climatological Monitoring*
   Since 1988, extensive climate data including air and soil temperatures, relative humidities, rainfall, solar radiation, and windspeed and direction have been collected by 9 automatic weather stations located at, or near to, long-term study sites. Repeated failures in recent years and normal wear and tear required the replacement of weather stations in 1995 and early 1996. There are now a total of 12 new Handar stations, powered by solar panels, which collect much the same type of climate data as before.

10. *Vegetation Community Patterns on the Boundaries of Organ Pipe Cactus National Monument*
   Conducted by Peter Warren to examine and document patterns along the park boundary to determine the cross-boundary effects of changes outside the monument on plant communities inside the monument.

11. *Vegetation Structure and Diversity in Natural Communities*
   Conducted by Charles Lowe and Betsy Wirt to provide baseline data on perennial and ephemeral plants at each study site. Quadrats 20- x 50-m were established at each of the permanent study sites, and measurements of presence, density, frequency, coverage, and diversity were taken for perennial plants. For ephemeral plants, presence and density were measured within four 1-m^2 quadrats within 20- x 50-m permanent quadrats. A monitoring protocol was designed to provide an account of the variation of vegetation structure and diversity between sites, as well as measuring the change of these parameters on a given site over time.

12. *Treaties, Agreements, and Accords Affecting Natural Resource Management at Organ Pipe Cactus National Monument*
   Conducted by Carlos Nagel, who compiled the treaties, agreements, and memoranda of understanding between the United States and Mexico that affect the management of natural resources in and around the monument, and provided a mechanism for keeping this information current.

An important part of the research phase was that resource management staff worked extensively with the principal investigators in the field. Resource Management Division staff were involved in protocol design, and in 1990 and 1991, field-tested the protocols. Communication between researchers and resource management staff has been identified as a very important part of all program phases.

The majority of baseline research and subsequent long-term monitoring has been conducted at permanent study sites selected to represent the various ecological communities of the monument. Some sites were selected on the south boundary to monitor impacts from agricultural development and urbanization on adjacent Mexican lands.

Now there are 18 sites ranging in size from 2.5 ha (6.25 ac) to 126 ha (315 ac). Permanent plots including small mammal quadrats, bird lines, lizard transects, perennial vegetation plots, and weather stations have been established at most study sites. Most sites have been mapped using global positioning systems and added to the monument's geographic information system (GIS).

Monitoring

Full implementation of monitoring protocols has been accomplished since 1991 and required on average 2,000 hours per year. Data management and reporting generally added another 500 to 700 hours. In recent years (1994 and 1995), as additional monitoring programs have been incorporated (e.g., bats, night-sky brightness, air quality), staff hours have correspondingly increased. It must be stressed that an I&M program of this nature requires an extreme degree of flexibility and tolerance, on the part of both data collectors and administrators, for the unusual and highly variable work schedules of data collectors. The organisms and systems being monitored necessitate data gathering at virtually every hour of the 24-hour clock. With travel time, environmental conditions, and equipment preparation also considered, the long field season becomes a challenge in avoiding employee burnout. Considerable latitude must be granted field workers in scheduling their field time, to accomplish data collection and assure that they reach the more sedate weeks of data management.

In addition to monitoring protocols arising from the baseline research studies, the following monitoring protocols have been added to the EMP: 1) Air Quality—consists of National Atmospheric Deposition Program sampling equipment, ambient monitoring of airborne particulates, and radiation sampling; 2) Bats—developed in 1994 as a part of a rotating resource base-funded project. In addition to establishing baseline information on monument bats, protocols were developed to monitor bat species diversity and relative abundance at five permanent sites using mist-net techniques; 3) Quitobaquito desert pupfish—implemented since 1975, the objective of this monitoring is to provide an estimate of population size and distribution of age classes for this endangered species, as well as thoroughly inspect the area for the presence of nonnative fish that may detrimentally affect the pupfish population; 4) Groundwater—implemented quarterly since 1981, water level measurements have been taken at selected wells to establish seasonal and long-term trends in monument groundwater in response to impacts from Mexican agriculture. As of now 10 wells are being monitored; 5) Night-sky brightness—developed in-house in 1995, stellar photometric technique is used to measure night-sky surface brightness and monitor the effects of light pollution and light trespass on monument night skies.

Important Aspects of an Ecological Inventory and Monitoring Program

By definition, for any monitoring program to be truly long-term, consistent and accurate data collection must be maintained. The data collection methods must be repeatable, clearly defined, and produce reliable results. Some of the key elements that have been important to the success of the Organ Pipe Cactus EMP have included the following:

1. One of the contract specifications for many of the baseline studies was that principal investigators provide protocols that would provide clear, step-by-step instructions for monitoring. Included would be detailed descriptions of sampling methods, site maps, and guidance on data interpretation. In late 1994, Organ Pipe Cactus developed an interagency agreement with the National Biological Service [now the U.S. Geological Survey Biological Resources Division or BRD] to review, edit, publish, and distribute a monitoring handbook combining all individual monitoring protocols into a single document. Also included in this interagency agreement was the publishing of final reports and annual reports.

2. In response to the need for outside expertise and guidance, the Ecological Monitoring Program Assistance Committee (EMPAC) was established in 1993 to serve as a steering committee to guide the direction of the program. Made up of six permanent members including BRD scientists, The University of Arizona researchers, and NPS resource managers, this committee is responsible for the evaluation, integration, and assessment of the monitoring program. Of the nine goals established for the EMPAC in 1995, all were completed including 1) an evaluation of current study sites and the selection of two new sites; 2) the review of the final reports, monitoring handbook, and annual report prior to publication; and 3) assisting in the development of the database management system.

3. Another "must" for a long-term monitoring program is good communication between resource management staff and principal investigators during all program phases. Not only was it important to work extensively in the field with principal investigators during baseline research and protocol design and testing, it has also been critical to maintain good communication during the current phase of protocol implementation and program refinement. Though most monitoring protocols are clearly written and implementation has been fairly straightforward, it is not possible for protocols to anticipate every possible contingency. Questions and issues sometimes arise that need clarification from the principal investigators or review from EMPAC. In a few cases these issues have been resolved to result in a modification to the original protocol. All such modifications must be carefully documented.

4. The lifeblood of a long-term monitoring program are the field workers. In the National Park Service in particular, the traditional approach for rangers is to stay in a park for two to four years, then move on to another park. This mobility won't work in a long-term monitoring program, where it takes years to begin developing a working knowledge of ecosystems. True, the program must be able to stand up to change in personnel over time, and this transition can be made less problematic by having clear monitoring protocols and other training materials on hand. Still, management has a responsibility to hire the best, and then retain them for a long time. As discussed above, a comprehensive I&M program will place extreme demands on staff; it is important to have highly dedicated, skilled, and tenacious employees.

5. Of course, the level of commitment that upper management has toward an I&M program decides its fate early on. The present superintendent [Harold Smith, now retired] has set a legacy for creating an unusually favorable atmosphere for

research and resource management at Organ Pipe Cactus. He took to heart more than 10 years ago what has been stated only recently in NPS planning documents that the primary mission of the NPS is resource stewardship. In addition, the present chief of resource management [Jim Barnett, now retired] has been exceptionally creative in coming up with new sources of money and positions that are tied directly to the I&M program. Few park science and resource management programs receive more than 6% of the park budget; at Organ Pipe Cactus these programs constitute 30% of the budget. This type of management support and commitment are the cornerstones of the monitoring program.

6. An important part of any monitoring program is the reporting of field results. An annual report format has been developed to summarize monitoring data in table and graph form with a brief discussion of findings. As mentioned earlier, these reports for 1993 and 1994 have been published as a part of the interagency agreement with BRD.

7. Sharing importance with the reporting of monitoring results is data management. During the 10 years of research and monitoring, a lot of data are on hand. As a part of their contracts, researchers had a responsibility to provide the data collected during their studies. These datasets were submitted in a great variety of formats including tables, spreadsheets, and databases, and using quite a few different software applications. We've been largely maintaining the structure of some of these separate databases as they were submitted, in addition to developing a few of our own when needed. As the datasets grow and more questions are asked about how one dataset relates to another, it is becoming increasingly important to have, instead of separate databases, one unified system. In a cooperative agreement with the BRD and The University of Arizona, work is presently underway to integrate these diverse inventory and monitoring data sources into a single GIS-based relational database management system. This new system is scheduled to be up and running by the next monitoring season.

In keeping the database management aspects, as well as the entire monitoring program in good perspective, it sometimes helps to reflect on the advice given by one of the researchers for us to, above all else, get to know the resources that we're monitoring. Early on when asked for input on databases, he replied: "You need to guard against the temptation to allow computer work and other minutiae to detract from the essential, required field time. It's easy to fall into the novice's ecology trap, that time spent with computers is more important than time spent with the lizards in the park, or the bears, or the plants in the park. I emphasize the need for *extra worktime* (that should be *regular worktime*) to be allotted to the field staff in order to *learn* the resources, in addition to worktime spent monitoring the resources. At that point your team will be professional ecologists, not amateurs, and you will have given real meaning to the monitoring results."

Closing Words

During the next 10 years of the monitoring program, we'll likely be grappling with, among other things, issues associated with impacts from the North American Free Trade Agreement. Whatever issues we face, we hope we can use the monitoring program to measure their impacts on Organ Pipe Cactus as well as regional ecosystems, and that we can develop and implement sound management programs based on this scientific knowledge, and that these programs will stand the test of time as being good management programs based solidly on science.

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A Spirit of Cooperation: The Southwest Archaeology Team and the National Park Service Working Together at Tumacacori National Historical Park

Sam Baar and Kris Wooley

Southwest Archaeology Team, P.O. Box 159, Scottsdale, AZ 85251

The Southwest Archaeology Team, founded in 1979, is as unique as it is successful. Established to utilize the capabilities of both professional and avocational archeologists, its original objective was to excavate archeological sites in danger of being destroyed and where no funding was available. Recently, the Southwest Archaeology Team has expanded both the scope and location of its projects. Recent projects include the restoration of the Sirrine house and the stabilization of the Hohokam platform mounds at Mesa Grande and Pueblo Grande. This change in focus of the organization has led the team to enter into a relationship with the National Park Service. Since 1994, the National Park Service and the Southwest Archaeology Team have worked together to stabilize the historic ruins and features of missions Tumacacori, Calabazas, and Guevavi. By working together, we have slowed the erosion at mission Guevavi, stopped the deterioration at mission Calabazas, and have preserved and stabilized numerous historic features at mission Tumacacori.

Physiological Response of Trees in a Semiarid Forest to Their Environment: An Active Monitoring Approach to Understanding Tree Physiology

Christopher H. Baisan,[1] Harold C. Fritts,[1] and William Gensler[2]

[1]*Laboratory of Tree-Ring Research, The University of Arizona, Tucson, AZ 85721*
[2]*Agricultural Electronics Corp., 1850 West Grant Road, Tucson, AZ 85745*

We describe a multi-year project to actively monitor physiological processes in three species of *Pinus* in Chiricahua National Monument. Platinum probes were inserted into the cambial tissue of the main bole and branches of six adult trees to monitor physiological status. Electronic and mechanical dendrometers provided measurements of stem size. Measurements of stem size, hydration, and acidity were collected every 15 minutes throughout the growing season. Environmental parameters (air temperature, soil moisture, and available light) were also measured. Both diurnal and seasonal patterns are clearly evident in the data. Additionally, environmental fluctuations such as changes in soil moisture result in rapid changes within the plants. The coupling of these data with detailed analysis of wood tissue produced will greatly enhance our ability to reconstruct past environments from tree-rings as well as improve predictions of plant responses to changing environmental stresses.

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Quitobaquito: The Challenges of Managing Natural and Cultural Resources at a Desert Oasis

James J. Barnett

Organ Pipe Cactus National Monument, Route 1, Box 100, Ajo, AZ 85321

Situated approximately 18 m (60 ft) north of the boundary with Mexico, in Organ Pipe Cactus National Monument, Quitobaquito is an oasis in the Sonoran Desert. It is one of the few authentic desert oases in North America. Natural springs flow into a man-made channel and pond; these support lush riparian growth and are habitat for an endangered endemic desert pupfish. The area has a rich cultural history with human occupancy from prehistoric times through the historic period. Three hundred years of grazing and ranching caused profound ecological change before the National Park Service assumed full responsibility of Quitobaquito in 1956. Attempts to clean up, restore, and improve the site exacerbated rather than mitigated the situation. Scientific research in the area spans over one hundred years. An interdisciplinary study undertaken between 1982 and 1985 inventoried natural resources. Modifications to the spring delivery system were made, culminating in 1989 with an extensive habitat improvement project. In 1993, Quitobaquito was incorporated into the ecological monitoring program and a full archeological survey of the area was initiated. In 1995, a joint resource management/research project was begun in cooperation with the U.S. Air Force to address a variety of issues, including the invasion of nonnative species, impacts to the groundwater (spring) system, impacts to resources due to visitor use, potential impacts of the major Mexican highway adjacent to Quitobaquito, and, the need for baseline data on the native plant and animal species and communities of this region. This presentation will provide an overview of past, present, and future natural and cultural resource management efforts at Quitobaquito.

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Revegetation and Restoration Program at Organ Pipe Cactus National Monument

James J. Barnett

Organ Pipe Cactus National Monument, Route 1, Box 100, Ajo, AZ 85321

For the past sixteen years, Organ Pipe Cactus National Monument has had an active revegetation program designed to restore impacted and disturbed areas to natural conditions. In 1978, 95% of the monument was designated as wilderness, resulting in the closure of approximately 137 km (85 mi) of primitive roads. The Resource Management Division began growing native plants in a makeshift nursery near monument headquarters in an attempt to recover these areas. A trial-and-error method used in the nursery paid off fairly quickly and resulted in successful methods for growing creosotebush *(Larrea tridentata)* and many other species from seed. During the summer of 1988, a new nursery and greenhouse complex was completed at the Sonoran Desert Biosphere Reserve Center, located near monument headquarters. Also in 1988, the revegetation program expanded beyond revegetating abandoned roads. Nursery-grown plants have been used to stabilize soil in erosion areas within the monument, and to reclaim other disturbed areas such as construction and development sites. Approximately 10 years of work is still needed to fully restore abandoned roadways. In addition, revegetation efforts continue to become a necessity for many other projects that require plant salvage and restoration. A program of long-term viability is being developed to address present and future revegetation issues. Such a program will possess the vision of having Organ Pipe Cactus National Monument serve as a leading example of restoration and rehabilitation of natural plant communities in the Sonoran Desert.

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National Park Service, Southern Arizona Group: Role and Function in Resource Management and Research

Lee Benson

National Park Service, Southern Arizona Group, Park Central Mall, 3115 North 3rd Avenue #101, Phoenix, AZ 85013

The Southern Arizona Group Office of the National Park Service (NPS), was established in 1971 in the state capital of Phoenix, Arizona, for the purposes of:

> Providing support, assistance, and guidance to superintendents and staffs of nine park areas comprised of Casa Grande Ruins National Monument, Chiricahua National Monument, Coronado National Memorial, Fort Bowie National Historic Site, Montezuma Castle National Monument, Organ Pipe Cactus National Monument, Saguaro National Monument (now Saguaro National Park), Tonto National Monument, Tumacacori National Monument (now Tumacacori National Historical Park), Tuzigoot National Monument, and Walnut Canyon National Monument.
>
> Providing liaison between all NPS areas and other federal, state, and local agencies and governing bodies, and a variety of environmental organizations within the state of Arizona in all matters of interest in attaining goals and objectives established at the national, state, or local agency level(s) in efforts to accomplish the NPS mission.
>
> Providing information and other visitor services to visitors of the heavily populated Phoenix metropolitan area and its surrounding communities. Tourism provides the principal economic base for Arizona, within whose boundaries lie 22 NPS areas.

During its 25 years since establishment, Southern Arizona Group areas of expertise have included but have not been limited to park management, ranger activities, maintenance, natural resource management, cultural resource management, interpretation, and administration.

Administrative changes in recent years have resulted in the withdrawal of Saguaro National Park from the group and the realignment of the NPS Southwest Region to include Walnut Canyon National Monument. The recent reorganization of the NPS resulted in the line authority of the individual superintendents being vested in the deputy field director, Southwest Cluster. As a result, the general superintendent position of the Southern Arizona Group is now titled superintendent. All other functions performed by the group remain basically the same. In recent years, the scope of support and assistance has informally expanded beyond the traditional parks to include parks in other areas within Arizona.

The Southern Arizona Group superintendent provides overall management support and direction to staff functions for administration, natural resource management, cultural resource management, research, planning, maintenance, visitor services, and park operations. The superintendent provides professional and technical support to National Park System areas throughout Arizona in the fields of law enforcement, fee collection, structural fire, search and rescue, safety, and tort claims. The superintendent serves as liaison with the U.S. Attorney's Office and the solicitor.

The superintendent serves as state coordinator for the NPS, representing managers from Washington, D.C., Intermountain Field Area Office, cluster system support offices, and individual park areas as liaison in areas of mutual interest between other federal, state, and local agencies, organizations, and the private sector, which includes responsibility for statewide public relations and coordination of programs.

The administrative team is responsible for providing consultation services and technical support for all administrative programs including human resources, contracting, procurement, property management, budget and fiscal, government housing, information management, and internal controls. These services are provided to management and staff at parks within the group, system support offices, and other clientele both within and outside the federal government. Services include but are not limited to computer network installations/support and a broad range of information management assistance, full recruitment and staffing services, classification, and administering agreement partnerships with state/local institutions and universities.

The Division of Cultural Resources provides technical expertise to the group office superintendent and park superintendents and their staff relating to monitoring, protection, preservation maintenance and stabilization of prehistoric and historic ruins and structures. The division assists field staff with writing and reviewing planning and compliance documents, and provides a link with natural resource programs. The division works with management and preservation personnel from other parks, system support offices, and field area offices, and other federal, state, and local agencies. Division staff may represent all or individual park managers in meetings and serves on technical committees relating to resources and research.

The Division of Natural Resources provides professional and technical advice and assistance to the group office superintendent, park superintendents, and field staff on National Park Service, Department of Interior, and interagency programs and plans regarding natural resource management and research. The division identifies, conducts, and oversees resource management and science projects, and provides a link with cultural resource programs. The division assists field staff with writing and reviewing environmental planning and compliance. Resource programs and research include vegetation, wildlife, threatened and endangered species, cave, grazing, pests, nonnative species, fire, air quality, water, aircraft overflight, collections, abandoned mine lands, and trails. Division staff represents all or individual park managers in meetings and serves on technical committees relating to resources and research. Individuals work systems support and Washington offices on special assignments. (POSTER)

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Using Long-term Monitoring to Understand How Adjacent Land Development Affects Natural Areas: An Example from Saguaro National Park, Arizona

Mark K. Briggs[1] and Lisa Harris[2]

[1]*Rincon Institute, 7290 E. Broadway Blvd. #M, Tucson, AZ 85710*
[2]*Harris Environmental Group, Inc., 1749 E. 10th St., Tucson, AZ 85719*

Introduction

Managers of protected natural areas across the country are increasingly concerned with the effects that adjacent land development have on parks, preserves, forests, and wildlife sanctuaries. Despite this concern, relatively few efforts have been undertaken to evaluate how protected natural areas are affected when adjacent natural land becomes urbanized. In the Rincon Valley, Arizona, immediately adjacent to Saguaro National Park and the city of Tucson, two efforts have been initiated to monitor the wildlife populations and riparian ecosystems over the long term. Since the monitoring efforts have been initiated prior to construction, it will be possible to document the effects of development on the natural resources in seldom-achieved detail.

On the outskirts of Tucson, Saguaro National Park was created in 1933 to protect the fauna and flora of the Sonoran Desert. At the time of its creation, the park was relatively remote; it was miles from development with access only by dirt roads. In the past 25 years, however, Tucson's metropolitan population has almost tripled, and the city has expanded to the boundaries of the park and other surrounding protected areas (Pima County 1992).

During the next 10 years, the Rocking K Ranch Development, an 1,802-ha (4,450 ac) mixed-development community of 6,000 homes and 2 resorts, will be placed in the Rincon Valley, immediately adjacent to Saguaro National Park. The development shares 8 km (roughly 5 mi) of boundary with the park. Currently, this area is rural, consisting of several ranch houses, undeveloped roads, abandoned agricultural fields, and large expanses of natural Sonoran Desert vegetation.

As Tucson continues to expand, Saguaro National Park will become an island in a sea of urbanization, as the natural ecosystems bordering it are replaced by houses, golf courses, and commercial development. The dramatic changes in population and land use that will occur adjacent to Saguaro will not only affect scenic beauty and visitor enjoyment, but will also place a strain on natural resources.

To better understand how adjacent land-use changes will affect park resources, natural resource practitioners need answers to a variety of critical questions, including: How will wildlife densities and diversities in the park be affected by adjacent development? When does adjacent land development reach a point where it significantly threatens a protected area's natural resources? How will adjacent vegetation communities and soils be altered in response to changes in water and sediment runoff? How will groundwater levels be affected by the demands of development, and how will these changes affect flows in nearby streams and the condition of local vegetation communities?

Conservation Research Opportunities in an Urbanizing Landscape

To help answer these and other questions, two long-term monitoring projects are underway in the Rincon Valley to assess the effects of development on wildlife and riparian ecosystems. The first inventory for both monitoring efforts was completed prior to the initiation of large-scale urbanization. Future inventories will be conducted at various times during construction and after the Rocking K Development and other development projects are completed. The Rocking K Development will be the first large development initiated in the area (construction activities will likely begin during 1996) and will be constructed largely on native, undisturbed, vegetation communities that include desertscrub [paloverde (*Cercidium microphyllum*)/acacia (*Acacia* spp.), mixed cacti, creosotebush (*Larrea tridentata*) upland, and creosotebush floodplain], semi-desert grassland, riparian scrubland, and riparian woodland (mesquite (*Prosopis velutina*)/acacia and deciduous woodland) (Rocking K Specific Plan 1990).

Monitoring the Effects of Development on Wildlife

In 1993, the Rincon Institute, the School of Renewable Natural Resources, and the National Biological Service [now the U.S. Geological Survey, Biological Resources Division] Cooperative Park Studies Unit at The University of Arizona, and Harris Environmental Group, Inc. began a long-term effort to monitor vertebrate species on the Rocking K Ranch and adjacent Saguaro National Park (Harris and Schwalbe 1995). The initial baseline study was conducted over a two-year period. This study comprised an inventory of the mammals (excluding bats), birds, reptiles, and amphibian species, and a description of the vegetation communities on the property. Each of the inventories was conducted separately, using methodologies specific to each taxa.

Forty-two permanent plots were established on the Rocking K Ranch property, six plots for each of the seven proposed land cover categories: natural open space, resort, golf course, very low-density housing (1 home/ac), low-density housing (1–4 homes/ac), medium-to-high-density housing (4–18 homes/ac), and commercial research and development. In addition, 12 permanent plots were selected in a control study site (six plots each within desertscrub and riparian woodland). The control site encompasses 760 ha (1,877 ac) within the Rincon Mountain District of Saguaro National Park adjacent to the Rocking K Ranch, allowing a comparison of wildlife diversities and densities between urbanizing and undisturbed areas.

Plot locations within each of the land-use categories were determined by computer-generated random grid coordinates. Each plot is a minimum of 200 m from other plots. The location of the center of each of plot was entered into a global positioning system (GPS), assuring that monitoring will be done at the same location once development has begun.

Inventories of all study plots will be repeated at 2- to 4-year intervals for at least 20 years. In addition, as the monitoring effort progresses, density studies of wildlife species whose populations have demonstrated significant increases or decreases in numbers as a result of urbanization will be conducted.

Monitoring the Effects of Development on Riparian Ecosystems

In 1993, the same research team initiated a long-term (> 20 years) effort to monitor riparian ecosystems along Rincon Creek, a major drainageway of the Rincon Valley. The objective of this research is to investigate the long-term impacts of development on riparian ecosystems. The principal reason for focusing on riparian ecosystems is that, despite comprising only a small percent of the total land area of the arid Southwest, they are inordinately important to wildlife. In addition, many riparian ecosystems in the southwestern United States are threatened by a host of human-related activities, which makes understanding the reasons behind their decline that much more important (Fenner et al. 1985; Ohmart et al. 1988; Betancourt and Turner 1991).

Methods

The Rincon Creek monitoring effort will document the effects of development on riparian ecosystems from a broad perspective (Briggs et al. 1996). The methods developed for this monitoring effort are based in part on experiences gained from an evaluation of the effectiveness of past riparian rehabilitation efforts in the southwestern United States (Briggs 1996). The monitoring effort will provide data that not only describe how adjacent land development affects riparian ecosystems over the long term (> 20 years), but also the underlying reasons for the changes.

The riparian monitoring effort will consist of a series of natural resource inventories repeated at four- to six-year intervals over an extended period of time. Before commencing the initial inventory, information describing the Rincon Creek environment prior to significant large-scale land disturbances was gathered. Historic photographs (ground photographs from circa 1900 and aerial photographs from 1936) were collected, long-term residents were interviewed, and well records from as early as 1932 were analyzed.

As part of the initial inventory, four study sites along a 12-km reach of Rincon Creek were established. Two of the four study sites are upstream and two downstream from where a major mixed-resort community will be developed. For each study site, data describing the streamside vegetation communities, channel morphology, streamflow, and sediment movement are collected. In addition, monthly groundwater elevations are recorded from four abandoned wells to monitor elevation changes of the potentiometric surface of Rincon Valley's shallow aquifer.

Crest-stage gauges installed in the Rincon Creek channel provide data for calculating peak discharge. Comparing the peak discharge of flow events that passed through upstream study sites to those that occur downstream provides information on transmission loss per stream length. Scour-and-fill chains, which provide data describing how sediment moves during flow, were also installed in the Rincon Creek channel. For each study site, at least three transects perpendicular to the channel were surveyed, providing a detailed description of channel and floodplain morphology. Two 80-m^2 (262.5 ft^2) plots were positioned within each of the vegetation communities identified along the transect to collect vegetation data describing density and diversity of all woody vegetation.

Future Implications

Future inventories for both the wildlife and riparian monitoring programs will be conducted every two to four years. The locations of all of the study plots for both studies were entered into a GPS, assuring that monitoring will be done at the same location once development has begun.

The before, during, and after nature of these two monitoring efforts provides a rare opportunity to assess the effects of various intensities of adjacent development on natural resources. In addition, these monitoring projects analyze the effects of development from a broad perspective that takes into consideration a significant portion of the Rincon Valley/Saguaro National Park ecosystem. From this perspective, changes to the biotic and abiotic components of the ecosystem will be documented. For example, changes in wildlife densities and diversity can be discussed in light of changes in vegetation communities, which, in turn, can be discussed with regard to changes in streamflow and groundwater characteristics.

Data from both of these monitoring efforts will be entered into a geographic information system (GIS), allowing researchers to organize and interpret the complex information that is being gathered. Ultimately, after the results of several future inventories have been incorporated, a dynamic model will be developed that will allow managers in Saguaro National Park and other protected natural areas to predict habitat change, given various intensities and types of adjacent land development. Such a predictive tool will assist natural area managers in formulating strategies that will help to reduce the impacts of land development on the natural resources of adjacent areas.

Such research efforts are critical not only for Saguaro National Park, but for the many other protected natural areas across the country threatened by rapid development. From a conservation perspective, it is crucial that we learn how adjacent land uses affect natural resources so that strategies can be developed to minimize their impacts. To accomplish this, we need to focus research efforts on urbanizing landscapes. In addition, monitoring efforts of more than 10 years need to be implemented so that the long-term changes to natural resources can be documented.

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Saguaro Cacti as "I" Beams? Allometry of Saguaro Height and Finite Element Analysis

Stephen L. Buchmann,[1] Marcus J. King,[2] and Karl J. Niklas[3]

[1]*U.S. Department of Agriculture, Agricultural Research Service, Carl Hayden Bee Research Center, 2000 E. Allen Rd., Tucson, AZ 85719*
[2]*Industrial Research Ltd., P.O. Box 20028, Christchurch, New Zealand*
[3]*Section of Plant Biology, Cornell University, Ithaca, NY 14853*

We conducted allometric studies of growth in saguaro cacti *(Carnegiea gigantea)* and obtained values for stem diameter versus height for 701 cactus species, 190 nonwoody species and 480 dicot and gymnosperm trees. From these regression models we quantified variables including Young's elastic modulus, critical buckling height, and allometric scaling coefficients for saguaro and other columnar cacti. The intraspecific allometry of saguaro height differed from allometries determined for trees, nonwoody species, and cacti. The interspecific allometry of cacti height had a scaling exponent of 1.68. This indicates taller saguaros are disproportionately more slender than shorter saguaros. The consequences of this positive, aniosometric relation on the elastic stability of stems were estimated by computing the critical buckling height for each of 118 saguaro stems on the basis of mean density-specific stiffness (Young's modulus) determined from a mature stem. A constant "safety-factor" for saguaro stems appeared to be size-dependent because it decreased with increasing height; heights were well below the critical buckling height. Also, stems become stiffer as they increase in size and age, and the rate of growth decelerates over time. In nature, we believe most saguaros topple not from critical buckling or other stem mechanical failure, but from high winds following rains that wet (loosen) the soil. Recently, we conducted preliminary Finite Element Analyses (FEA) on saguaro computer models for individuals with and without arms. These FEA studies should be instructive because stem stiffness increases from the tip to the base of the growing stem. This trend may be significant because in bending, compressive and tensile stresses increase toward the base, where older tissues can accommodate greater stresses.

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Night-sky Brightness Monitoring at Organ Pipe Cactus National Monument

Dennis Casper,[1] Dan Duriscoe,[2] Tom Potter,[1] and Jon Arnold[1]

[1]*Organ Pipe Cactus National Monument, Route 1, Box 100, Ajo, AZ 85321*
[2]*Sequoia-Kings Canyon National Park, Three Rivers, CA 93271*

A major resource of Organ Pipe Cactus National Monument is the occurrence of clear night skies, resulting in excellent opportunities for viewing faint celestial objects not commonly seen near urban centers. The greatest threat to this resource comes from light pollution, or the proliferation of outdoor lighting in areas outside the monument. A visibly noticeable glow in the southwestern part of the night sky emanating from the border town of Sonoyta, Sonora, Mexico, represents a degradation of the wilderness values of the monument. Casual observations indicate that the glow has become more noticeable in recent years, and that in the future that trend can be expected to continue. The monitoring of night-sky brightness and the reporting of results are important and powerful tools in dark-sky protection. In winter 1995, an all-sky survey of the monument night-sky brightness was conducted. The objectives of this study were to collect baseline data quantifying the visual appearance of the night sky and to develop a protocol for long-term monitoring. Survey methods included standard photoelectric photometry technique. Measured sky brightness near the zenith was very close to the predicted natural background at 22.1 magnitudes per square arcsecond. The sky glow from the Phoenix metropolitan area, more than 200 km (124 mi) distant, recorded the highest brightness at 20.4 magnitudes per square arc second, followed by Sonoyta approximately 15 km (9 mi) distant, at 20.6. Monitoring protocol implementation includes 1) conducting calibration procedures by taking readings on extinction stars, 2) conducting the sky glow survey, 3) data reduction, and 4) reporting results. (POSTER)

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Applications of Infrared Triggered Photography in Wildlife Research

Tricia L. Cutler,[1] Don E. Swann,[1] Cecil R. Schwalbe,[2] Michael L. Morrison,[1] and William W. Shaw[1]

[1]*Wildlife and Fisheries Sciences Program, School of Renewable Natural Resources, The University of Arizona, Tucson, AZ 85721*

[2]*U.S. Geological Survey, Cooperative Park Studies Unit, The University of Arizona, Tucson, AZ 85712*

We present results of wildlife studies using infrared triggered photography in southern Arizona. At the Cabeza Prieta National Wildlife Refuge, remote photography was used to determine the species composition of vertebrates using water developments and to assess the effects of developments on endangered Sonoran pronghorn *(Antlocapra americana sonoriensis)*. At Tonto National Monument, we used remote photography to assess and monitor damage to archeological resources by native mammals, and to identify and photograph mammals as part of a general vertebrate inventory. Composition of individuals detected at water developments was dominated by coyotes *(Canis latrans)*, turkey vultures *(Cathartes aura)*, and desert mule deer *(Odocoilius hemionus crooki)*. Sonoran pronghorn were not detected. We determined that wildlife damage at archeological sites was due to rock squirrels *(Spermophilus variegatus)*, and we verified the presence of 15 mammal species on the monument. Use of infrared triggered photography can be a valuable tool in wildlife research; potential applications include determination of species richness and abundance, species interactions, and daily activity patterns. (POSTER)

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Representative Sampling of Resource Projects at Montezuma Castle and Tuzigoot National Monuments

Robert Del Carlo

Montezuma Castle and Tuzigoot National Monuments, P.O. Box 219, Camp Verde, AZ 86322

Montezuma Castle and Tuzigoot national monuments represent a unique mix of cultural and natural resources including both prehistoric Native American cliff dwellings and pueblos, and rich, diverse riparian areas. There are currently a number of projects at both parks that address these issues. The following texts accompany photographs included with the poster display.

For the last six years efforts have been ongoing to maintain, preserve, and stabilize the Works Progress Administration (WPA) restoration, during the 1930s, of the original walls at Tuzigoot National Monument. Damage to these fragile resources results from several causes, including rodents (such as rock squirrels), and weather (wind, rain and freeze/thaw cycles). As two of the pictures on the poster highlight, park maintenance employees are restabilizing the original WPA restoration with natural soil material mixed with cement and a red-tone cement coloring. The eventual goal of this effort is to get back to the original color and quality of the WPA project.

Natural resource projects at Montezuma Castle and Tuzigoot national monuments are represented by several pictures detailing research projects conducted by the U.S. Geological Survey, Colorado Plateau Research Station, Northern Arizona University. Through their efforts, a broad-based inventory of the flora and fauna of Montezuma Castle is nearly complete. This survey effort has provided detailed information on terrestrial vegetation, aquatic and terrestrial invertebrates, fish, amphibians, reptiles, birds, and mammals, as well as a series of historic photos documenting changes in the area.

Three pictures from the poster depict a rattlesnake relocation study conducted at both park units that is attempting to establish how relocation impacts rattlesnakes in the monument (see also Nowak, E.). When rattlesnakes are observed in the vicinity of the visitor areas, they are carefully captured and taken to the Verde Veterinary Hospital in nearby Cottonwood, where they are anesthetized and surgically implanted with a small radio transmitter near the tail. Using special radio receivers, researchers can determine the location of these rattlesnakes. So far the study indicates that none of the relocated rattlesnakes have returned to their original home range. Information has been gained concerning range of activity, weight gain or loss and likelihood of injury, capture by a predator, or starvation.

Other pictures included on the poster show several projects including a small mammal baseline inventory, and an inventory of native and nonnative fish species using dip netting techniques. Finally, a project to repair flood damage to the rip rap at a bridge over the Verde River near Tuzigoot National Monument is detailed. The picture shows work on a temporary dam and silt fence used to minimize siltation downstream. (POSTER)

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Fire Management at Chiricahua National Monument

Carrie Dennett and Alan Whalon

Chiricahua National Monument, HCR #2, Box 6500, Willcox, AZ 85643

Wildland fires have played a major role in shaping and maintaining the floral and faunal associations of the southwestern "Sky Islands." Through the combined effects of grazing, timber cutting, agriculture, and fire suppression, the natural fire regimes and subsequent structure of the plant communities have been drastically altered. As a consequence, land managers who pursue reestablishment of a more natural role for wildfires have the challenge of determining fire frequencies, timing, and intensity to assure the best approximation of fire effects in ecosystems. Managers must still be concerned with protecting valuable cultural and natural resources from destructive wildfires. Chiricahua National Monument's fire program dates to 1979, when park staff began setting deliberate fires to accomplish a variety of objectives. Through various levels of staffing and funding, this program has continued with mixed success. The fire program objectives are described in the park Resources Management and Fire Management plans: to take advantage of the natural role of fire, and to reduce the harmful effects of large, uncontrolled wildland fires. Fires fall into the following categories: prescribed natural fire, management-ignited prescribed fire, and suppression fire.

Prescribed Natural Fire

The objective is to permit natural fires to burn in selected areas within predetermined prescriptions. The park has yet to see the appropriate combination of factors that will permit managers to allow a natural ignition wildland fire to continue to burn in this relatively small, central portion of the park. Additional coordination is needed with neighbors to make this an effective program.

Management-ignited Prescribed Fire

Objectives include allowing fire to resume its natural role, and accomplishing desired resource management objectives (restore/maintain natural ecosystems; influence successional patterns; modify sensitive species habitat; control exotic species; maintain historic scene; and reduce fuel loading). Park staff, with assistance from qualified specialists from other parks and agencies, have burned in Lower Rhyolite and Bonita canyons, Sugarloaf Mountain, and Little Picket Canyon. The park began a fire effects monitoring program in 1988 to gather data that will assist in understanding the effects of these fires on vegetation and fuels, and help determine if objectives for burning are being met. A barrier to maintaining this effort at an effective level is the small staff size of the monument, and the absence of necessary skills required to properly and safely conduct these burns. For this program to be successful, a corps of qualified individuals must be available during the proper season. This would probably be a combination of park staff from Chiricahua and Saguaro National Park, and National Park Service Prescribed Burn Module staff.

Suppression Fire

Despite the goal of allowing natural fires to burn, and even including management-ignited prescribed fires, it still becomes necessary at times to suppress wildland fires. This is done to protect historic structures and other cultural resources, and to protect life, property, and sensitive natural resources. The monument has averaged one to two wildland fires per year. Monument staff also assist with suppression efforts on surrounding private and federal lands. It is critical that the monument be able to maintain a trained staff and dependable equipment.

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The Development of a Natural Resource Bibliographic Database in Southern Arizona National Park Service Areas

Elena T. Deshler and Charles van Riper III

U.S. Geological Survey, Colorado Plateau Research Station, P.O. Box 5614, Flagstaff, AZ 86011

Proper data management of natural resource information is largely based on the ability to store and easily retrieve pertinent data. These data are a valuable component to ongoing natural resource inventories and can contribute significantly to the development of future monitoring programs. The need for readily accessible baseline data is recognized by the National Park Service in its servicewide Inventory and Monitoring Program (NPS-75). NPS-75 identifies the development of annotated bibliographic information as one of the most important datasets needed by parks. Previous inventories of park biological baseline data from southern Arizona national park areas have shown that, in some instances, park natural resource information is not readily accessible. Many studies and natural resource management decisions would be influenced by information from existing studies, but only if park managers are aware of the study results or have easy and rapid access to the findings. It is important to develop methodologies that will allow park managers to maintain and expand their natural resource bibliography, in order to integrate new information. Park management decisions that are made will be affected by the accessibility of these natural resource documents. (POSTER)

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Habitat Selection Patterns by Sonoran Pronghorn in Southwest Arizona

James C. deVos, Jr.

Arizona Game and Fish Department, 2221 West Greenway Road, Phoenix, AZ 85023

Introduction

The Sonoran pronghorn *(Antilocapra americana sonoriensis)* is one of five pronghorn subspecies, a genus found only in North America (O'Gara 1978). The U.S. population was designated as endangered by the U.S. Fish and Wildlife Service (USFWS) on 11 March 1967. In Mexico, Villa (1978) referenced the Sonoran pronghorn as a subspecies in critical danger of extinction, now listed there as endangered (Secretaría de Desarrollo Social 1994).

Determining historic distribution or population level for the Sonoran pronghorn is difficult as it was not afforded separate taxonomic status until 1945, after both range and population level had declined (Arizona Game and Fish Department 1981; Wright and deVos 1986). Scientists generally agree that Sonoran pronghorn occupied northeastern Baja California Norte, southeastern California, southwestern Arizona south of Interstate 10 as far east as the Tohono O'Odham Nation, and from northwestern Sonora, Mexico, south to Hermosillo and west of Highway 15 (Monson 1968; Arizona Game and Fish Department 1981; U.S. Fish and Wildlife Service 1982; Hoffmeister 1986).

The present distribution is greatly restricted from the historic range. Although there continue to be unverified Sonoran pronghorn observations north of Interstate 8 west of Gila Bend, only one recent sighting (13 September 1976; Arizona Game and Fish Department 1981) has been verified. As there has been no recent verified observation on the Tohono O'Odham Nation, the current range in the United States is probably west of Arizona Highway 85 and south of Interstate 8.

From 1983 to 1991, the Arizona Game and Fish Department (AGFD) maintained radiotelemetry collars on pronghorn in southwestern Arizona. Due to collar failure caused by battery limitations, there was approximately a one-year period (1986–87) when no telemetered animals were detected. Except during this one-year period, locations were obtained from telemetered pronghorn as frequently as possible. In all, 1,181 locations were obtained.

Due to difficulty in obtaining additional data on the Sonoran pronghorn, using these data to develop recovery recommendations is essential. To understand habitat requirements for the Sonoran pronghorn better, I analyzed the telemetry-based locations from previous studies in relationship to habitat characteristics such as vegetation type and distance to various habitat features. To accomplish this, additional data on habitat characteristics were collected and incorporated in a GIS database.

Study Area

The boundaries for this study area are Interstate 8 to the north, an arbitrary line just west of the Mohawk Mountains, the International Boundary to the south, and Highway 85 to the east. The total area within the study area is 12,035 km^2 (4,647 mi^2). The area is administered by various entities, with most in federal holdings.

Vegetation

The entire study area is contained within the Sonoran Desert biome. Two subdivisions, the Lower Colorado River Valley and the Arizona Upland, are contained in the study area. Of these, the Lower Colorado River Valley subdivision is most common, generally occupying the broad alluvial valleys that occur between the mountain ranges. The Arizona Upland subdivision is found in the mountains, and extending in some areas into the higher fringes of the bajadas (Turner and Brown 1982).

This biome's vegetation is derived from subtropical elements and is most closely related to vegetative communities to the south. Unlike other desert biomes in North America, the Sonoran Desert has a diverse assemblage of both arboreal species and large cacti. Even in the most arid portions of this desert, succulents are present along drainages and other favored habitats (Turner and Brown 1982).

The Sonoran Desert has distinct summer storms that originate from the Gulf of Mexico, and winter storms from the Pacific Ocean. Because of this rainfall pattern, the Sonoran Desert has two distinct annual floras. Winter annuals germinate from November to March in response to winter rains and cool temperatures; summer annuals germinate in July and August in response to convectional monsoon storms and high temperatures (Inouye 1991).

Regardless of the plant associations present, vegetation is sparse. In localities where Sonoran pronghorn are present, Hughes and Smith (1990) reported total ground cover to be 13% in 1988. They found that the area occupied by Sonoran pronghorn was generally more densely vegetated than the area where Sonoran pronghorn were absent.

Geology

The topography is typical of the Basin and Range physiographic province of southwestern United States and northwestern Mexico. The area is dominated by long, linear mountain blocks that tend to range from the northwest to southeast. These mountains are of two types: the "sierra" type of linear, jagged mountains; and the "mesa" type of relatively flat, volcanic ranges (Simmons 1966). Between these mountains are the basins of various widths that dropped along the vertical faults. Since the block faulting occurred, sand and other debris have been carried from the mountains to the valleys (Chronic 1983), leaving broad alluvial fans that maintain a vegetative transition between the mountains and valleys.

Methods

Capture and Telemetry

Pronghorn were captured with a hand-held net gun fired from a helicopter (Firchow et al. 1986). Once captured, all animals were checked by a veterinarian, medicated as needed, fitted with radiotelemetry collars and released.

Two capture efforts (October 1983 and October 1987) were used in this study with 19 successful captures; 1 mortality occurred in 1987. Three animals from the first capture were captured in the second; thus, 16 individual animals were captured. The original telemetry protocol called for weekly telemetry flights. Conflicts with military training missions precluded many flights; therefore, no regular flight schedule was maintained. Airplanes were fitted with a forward-phased, twin-Yagi antenna mounted on each of the wing struts for general signal location. A belly-mounted, rotatable, two-element "H" antenna was used to pinpoint locations (Carrel 1972). The locations were plotted on 7.5-minute U.S. Geological Survey (USGS) topographic maps, and subsequently converted to Universal Transverse Mercator (UTM) coordinates within 0.1 km (0.06 mi) of the mapped location. The UTM coordinates were entered into an ARC/INFO file for analysis.

Vegetation Mapping.

The first step used in developing a detailed vegetation map was to obtain the existing digital maps for the area. These were the Arizona GAP project vegetative cover (Graham 1995) and the AGFD statewide vegetation map (Arizona Game and Fish Department, unpublished data). These maps were overlaid into a single GIS cover to identify areas classified differently on the two maps. Areas of discrepancy between these maps were the focus of field verification efforts. Additionally, polygons from either source that had shapes not likely to occur in natural vegetative communities were investigated.

Three methods were used to verify the extent and vegetative classification of each polygon. Ground-truthing was used in areas where ground-based access was possible. Where possible, high points were accessed and binoculars used to establish the boundaries between polygons and to identify the vegetative communities present. These boundaries were put on USGS 7.5-minute maps and subsequently digitized into the final vegetation cover. Another ground-based method entailed obtaining GPS locations from within the polygon and recording the plant species present at the point.

For areas where ground access was unavailable due to military closures or wilderness status, aerial flights were used to establish the extent of the vegetative associations and to identify dominant plant species. Identification of all plant species present was impossible from the air. Methods used included contacting experts in the area, extrapolating information from similar areas, and use of satellite photography. Densely vegetated ephemeral washes generally were too narrow to detect using satellite imaging. This habitat type was taken from the satellite photos, plotted on USGS topographic maps, and digitized into the final GIS vegetative cover.

Mapping of Waters, Roads, and Ephemeral Riparian Areas

Existing GIS-based covers for water sources and road networks were used to analyze habitat use patterns. The cover was compiled from various sources and field verified. This cover includes all waters believed to be permanent or nearly so based upon field observation. The road cover was developed from the Luke Air Force Base Land Use Plan (The University of Arizona 1986).

Data Analysis

The analysis for all habitat features used a similar approach. The GIS Sonoran pronghorn location cover was overlaid on the appropriate habitat cover with the buffers established. Chi-square contingency tables were used to assess if use was significantly different from random. In all cases where a significant test was found, Bonferroni confidence intervals (Neu et al. 1974; Byers et al. 1984) and Jacobs' D analysis were used to decide the magnitude and direction of use (Jacobs 1974).

Results

Capture and Telemetry

In 1983, four male and six female Sonoran pronghorn were successfully captured. In 1987, five males and five females were captured, with a female killed in capture. The mortality resulted when the spine was fractured after being hit by a weight from the capture net.

The initial telemetry flight occurred on 5 November 1983, with flights continuing until 10 February 1991. During these flights, a total of 1,181 locations was collected. There was approximately a one-year period, 4 October 1986 to 20 December 1987, when no collared animals were detected.

Vegetative Mapping

The vegetative associations observed fell within two subdivisions of the Sonoran Desert biome; the Lower Colorado River Valley and the Arizona Upland subdivisions as described by Turner and Brown (1982). Within these subdivisions, 18 distinct natural vegetation associations were documented.

Water Use Patterns

Analysis of habitat use patterns around water sources revealed nonrandom use ($X^2 = 564.4105$, df = 9, $p < 0.0001$). For buffers that were 10 km (6 mi) or less from the water source, the Jacobs' D value was always positive. The largest positive selection occurred in the <1-km (0.6 mi) buffer (0.4843) and declined only slightly to the 6-km (3.8 mi) buffer after which the Jacobs' D value approached 0. The greatest Jacob's D value was avoidance of the >10-km buffer (6 mi) where the Jacobs' D value was -0.6630.

Roads

Chi-square analysis indicated that use of the buffers around roadways was significantly different from the expected values ($X^2 = 113.5157$, df = 5, P <0.0001). Sonoran pronghorn selected against the two closest buffers (Jacob's D = -0.2100 and -0.2061, respectively) and selected for the buffer >5 km (3.1 mi) from roads (Jacob's D = 0.2806). Although use of three of the six buffers was significant, none of the Jacobs' D values were largely different from 0, indicating that selection and avoidance were not strong.

Ephemeral Riparian Zones

Analysis of the use patterns in and around the ephemeral riparian zones showed nonrandom use patterns for all buffers. Chi-square analysis indicated that use of all buffers was significantly different from the expected value ($X^2 = 539.03$, df = 6, $p < 0.0001$). Sonoran pronghorn showed selection for all buffer classes within 2 km (1.2 mi) of the ephemeral riparian areas. This was particularly true for the within-riparian zone (Jacobs's D = 0.3189) and the 1-km (0.6 mi) buffer (Jacobs' D = 0.4798). In contrast, Sonoran pronghorn avoided those buffers beyond 2 km (1.2 mi) with avoidance increasing with distance.

Vegetation Associations

Sonoran pronghorn did not use vegetative associations in proportion to their availability ($X^2 = 295.48$, df = 9, $p < 0.0001$). For five of the vegetation categories in this analysis, use was nonrandom. Sonoran pronghorn avoided the creosotebush-mesquite association (Jacobs' D = -0.7696), brittlebush-paloverde-mixed cacti (Jacobs' D = -0.7577), big galleta-creosotebush-bursage (Jacobs' D = -0.6941), and the combined associations where bare rock is the dominant feature (Jacobs' D = -0.0926). The only association where positive selection was shown was for the creosotebush-bursage/paloverde-mixed cacti association (Jacobs' D = 0.4563) and the ephemeral riparian association, excluded from this portion of the analysis and treated elsewhere.

Discussion

All of the analyses indicated that Sonoran pronghorn use habitats in a nonrandom pattern. Having knowledge about habitat features will allow managers to incorporate this information in land-use planning activities. Although Sonoran pronghorn are in an area with limited human access, there are potential impacts from military activities. The analyses show that densely vegetated riparian areas, areas in proximity to water sources, and the creosotebush-bursage/paloverde-mixed cacti vegetation are preferred habitats, and impacts to these areas should be avoided. Conversely, areas avoided by Sonoran pronghorn could be used with a reduced likelihood of adverse impacts to Sonoran pronghorn populations.

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Air Resource Management: Transboundary Implications For the National Park Service

Miguel I. Flores

National Park Service, Air Resources Division, P.O. Box 25287, Denver, CO 80225

The National Park Service Air Resources Division has been participating in negotiations between the governments of Mexico and the United States in efforts to reduce air pollution emissions from two new, coal-fired electricity generating stations located in Coahuila, Mexico, 32 km (20 mi) south of the U.S.-Mexico border. Uncontrolled growth in air pollution emissions associated with the passage of the North American Free Trade Agreement (NAFTA) and rapid population growth along the U.S.-Mexico border will cause significant degradation of air quality in national parks and monuments and make air resource management in these areas more difficult. Binational strategies dealing with transboundary air pollution will be discussed including the activities of the Binational Big Bend Air Quality Work Group, the Grand Canyon Visibility Transport Commission, the U.S.-Mexico Border 21 Air Work Group, and the Commission on Environmental Cooperation created under NAFTA.

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Salvage Excavations at the Upper Ruin, Tonto National Monument

Gregory L. Fox

Western Archeological and Conservation Center, 1415 North 6th Avenue, Tucson, AZ 85705

Introduction

The Western Archeological and Conservation Center was requested to conduct archeological investigations at Tonto National Monument in the Gila phase cliff dwelling commonly referred to as the Upper Ruin. This project was required prior to stabilization efforts to mitigate the adverse effects of water seepage on two masonry rooms at the rear the cliff dwelling in a location commonly referred to as Area A. The pre-stabilization archaeological excavations were considered necessary prior to the installation of drainage control features in the back of the shelter, as only limited excavations have been conducted in this area, and those excavations date to the 1940s.

A total of five excavation units encompassing a surface area of 7.5 m^2 (24.6 ft^2) were placed in Area A of the shelter. These excavations removed and processed a total of 2.14 m^3 (7 ft^3) of sediment matrices. Excavations in Area A were located at the southwest corner of room 19 and along the west wall of Room 17.

Excavation units 1–4 encompassed a 3.5 m^2 (11.5 ft^2) area and exposed a 2-m (6.5 ft) long profile along the western margin of excavation units 1 and 2. That profile revealed a 5-cm (1.9 in.) deep layer of soil cement overlying a shallow sediment/midden deposit that in turn overlaid an irregular travertine deposit sloping to the south and east. In addition, at the intersection of units 1 and 2, a small, irregular deposit of adobe approximately 25 cm (9.8 in.) in diameter was identified on the travertine floor of the excavation units. The smear of adobe does not line up with any existing wall construction and may represent discard/waste adobe associated with room construction.

The travertine base of the excavation units is irregular. A low rise in the travertine in the southern end of these excavation units effectively forms a barrier to water and diverts water seepage directly into the southwestern corner of room 19. A single exception to that impediment to water flow was noted at the southwest corner of the excavation unit and the irregular western margin of excavation unit 4. A narrow [<10 cm (3.8 in.) wide] erosional channel is etched into the base of the low travertine parapet and actually undercuts the shelter wall.

Excavation Unit 5

The purpose of excavation unit 5 was to alter the contour in the northeastern corner of Area A to reduce drainage into unexcavated room 16 and divert flowing water out of the ruin through the previously excavated rooms 17, 12, and 10. This was achieved by cutting a channel through a low ridge that trends east to west.

The soil profile of unit 5 depicts a single stratum of unconsolidated aeolian sediments mixed with high frequencies of organic materials. Artifact recovery included shell beads, squash seeds, cucurbit rinds and stems, walnut shells, decorated and plain ceramic sherds, projectile points, lithic debitage, fiber, textiles, vertebrate faunal remains, wood, agave needles, and non-bone faunal remains.

Stratigraphy

The stratigraphy revealed by the 1995 excavations is predictable and fairly simple. Sediments overlying the travertine deposits in the area of units 1–4 are composed primarily of sandy, organically enriched soil interspersed with a high frequency of small fragments of broken travertine and roof-fall materials. The soil profile suggests a midden deposit, given the high frequencies of charcoal flecks and cultural materials exposed in the excavation wall. However, based on the distribution of historical-period materials in the sediments, the deposits in this portion of Area A are considered to be disturbed. This interpretation is supported by the highly fragmented nature of botanical remains recovered from these units when compared with those remains recovered from excavation unit 5.

The overall integrity of the Upper Ruin ranges from fair to good. Unlike the Lower Ruin, which was nearly totally excavated by Steen and Pierson (Steen et al. 1962), the Upper Ruin has been subjected only to limited yet widespread trenching conducted in concert with stabilization excavations. However, the integrity of the deposits in the area of units 1–4 (west of room 19) is considered to be markedly different from the integrity of the deposits in the vicinity of unit 5 (west of room 17). That is, the presence of historical-period artifacts extending to the basal layers of the deposit west of room 17 suggests these deposits are disturbed. That presence, when coupled with the observation that the botanical remains in that area are highly fragmented lends support to a determination that there is a lack of integrity of cultural deposits west of room 19. Conversely, the low frequency of historical-period artifacts recovered from unit 5, coupled with the nearly pristine preservation of botanical and textile materials suggests that the area west of room 17 retains much of its integrity.

Dendrochronology studies of intact wood from the Upper Ruin were initiated in 1995. The results of these analyses are somewhat disappointing. Most of the samples from the ruin proved to be of nonconiferous species (*Populus* [cottonwood] or *Platanus* [sycamore]), which are generally unsatisfactory for tree-ring dating, or *Juniperus*, which often has ring series unsuitable for dating south of the Mogollon Rim.

Two dates were derived from this project, although not from specimens collected in 1995. Specimen TON-68, GP771 from room 5 in the Lower Ruin is a confirmation of a previous determination of A.D. 1106, and the other (GP-785) is a new placement of a previously collected sample. Both the species and date of the TON-68 sample are anomalous within the context of the Tonto Ruins. This upright post is the only Douglas fir *(Psuedotsuga menziesii)* timber in either site, and the tree from which it was derived obviously did not grow anywhere near the Tonto Ruins. The nearest naturally occurring Douglas fir trees grow in the canyons and high elevations of the uplands, the Sierra Ancha and Mogollon Highlands, north and east of the site.

The date from GP-785, which has a probable cutting date of A.D. 1303, obviously is more compatible with the ceramic and radiocarbon evidence for the placement of the Tonto Ruins. In addition to the dates generated in 1995, Steen reports that Haury obtained a weak date of A.D. 1346 from a juniper pole lying on the ground in front of room 5 at the Upper Ruin.

Three specimens were selected from the excavated charcoal specimens and organic materials in the Upper Ruin and submitted to Beta Analytic for radiocarbon assays. One charcoal sample, and two maize cobs were submitted to the lab. Maize cobs were selected over charcoal because they represent annual growth and dating this single growth year sample may serve to mitigate problems of old wood and mixed charcoal samples.

Selection of the samples for radiocarbon dating was based on an attempt to select samples that would reflect a period representing an early occupation, an intermediate occupation, and a late, near terminal occupation. To this end, a maize cob sample was selected from excavation unit 2, level 4 [25 cm (9.8 in.) to bedrock], and represents what is interpreted as an undisturbed basal level of the midden at the rear of the shelter. The second sample selected for radiocarbon assay consisted of charcoal collected from the subfloor hearth discovered in room 7. The final sample was selected from the top 10 cm (9.8 in.) of excavation unit 5, an undisturbed midden deposit west of room 17.

The results of the radiocarbon assays are interesting because they mimic the assumptions in the sample selections, that is., those samples thought to represent the earliest, intermediate, and terminal deposits dated accordingly. At one sigma, uncalibrated, the three dates are (earliest to latest) A.D. 1300, A.D. 1350, and A.D. 1550.

Although not the most conservative estimate, the laboratory-calibrated results at one sigma (68% probability) may be the most instructive way to view the dates. The maize cob from the basal deposits in excavation unit 2 dates at the intercept of the radiocarbon age with the calibration curve at A.D. 1305. The subfloor hearth in room 7 dates from the intercept of the age and calibration curve at A.D. 1395. The sample from the top 10 cm (9.8 in.) of excavation unit 5 dates with the age calibration interface at A.D. 1470.

Simply stated, an alternative to the accepted view of the occupation is that construction of the cliff dwelling started with people who were still producing locally made black-on-white ceramics (Roosevelt phase peoples). This group continued to occupy the site at some unknown population level (Gila phase peoples) until abandonment. Participants in the recent Bureau of Reclamation-sponsored archeological research project in the Tonto Basin settled on two sets of dates for the Roosevelt and Gila phases. Those participants agreed upon the dates of the Roosevelt phase as beginning ca. A.D. 1250–1270 and ending ca. A.D. 1320–1350. For ease of reference, the participants settled on a standard archeological representation of A.D. 1250–1350. For the Gila phase, archeologists participating in the project agreed on a beginning date of A.D. 1320–1350 and a terminal date of A.D. 1450 (for standard representation a date range of A.D. 1350–1450). If we view the archeological record more as a continuum than as the punctuated time line we commonly use, then the Upper Ruin could be viewed as an occupation location where production of black-on-white ceramics gradually ceased with a subsequent "replacement" production of Tonto polychromes.

Discussion

Past and present attempts to produce a precise suite of absolute dates for the Upper and Lower Ruins have been less than satisfactory. At best, Haury's weak tree-ring date of A.D. 1346, added to the 1995 tree-ring dates from the "Tonto Ruins" and the three radiocarbon assays, not unexpectedly place the Upper Ruin well within the Gila phase. When coupled with the presence of a limited number of Roosevelt phase ceramic horizon markers recovered by Steen and the 1995 excavations, the radiocarbon and tree-ring dates do, however, suggest that the occupation of the cliff dwelling may originate in the late 12th century and possibly extend beyond the mid-15th century.

Doyel's (1976) proposal that the Gila phase occupies the time niche from A.D. 1300 to 1450 perhaps should be reexamined, as the Late Roosevelt phase ceramic signature from the Upper Ruin can be considered very weak given the number and frequency of sherds relating to the phase recovered from the Upper Ruin. Regardless, the dates presented here add to the limited absolute dates generated for the Upper Ruin and provide us with possible support for the construction sequence at the site (i.e., construction began in the back of the shelter and proceeded outward).

Although the Tonto National Monument cliff dwellings often are cited in the literature pertaining to the Tonto Basin, those references focus more on the unique location and recovered perishables rather than on incorporation of the overall site data into regional analyses and syntheses. We attempted to produce a report detailing the data collected in 1995 for others' future use and did not attempt to produce a report that provides large-scale "interpretation" of that data. Our purpose primarily was to recover archeological data and to document variation in that data from the archeological record prior to ground-disturbing stabilization efforts. Due to the fact that the small-scale 1995 excavations fall under the rubric of "salvage archeology," we have avoided, for the most part, any attempts to tie our results into the research design, interpretations, and conclusions of the recent Roosevelt project sponsored by the Bureau of Reclamation. We have, however, attempted to be highly systematic in our recovery and analytical protocols.

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Estimation of Emission Rates in Mexico by Receptor Modeling

Kristi A. Gebhart

National Park Service, Air Resources Division, Research Branch CIRA, Colorado State University, Fort Collins, CO 80523

Big Bend National Park, Texas, and Chiricahua National Monument, Arizona, are located on or near the United States-Mexico border. Particulate and optical data are collected at these sites as part of the Interagency Monitoring of Protected Visual Environments (IMPROVE) network (Joseph et al. 1987; Eldred 1988; Sisler et al. 1993; Malm et al. 1994). Historically, it has been observed that air usually arrives at Big Bend and frequently arrives at Chiricahua after having passed over Mexico (Bresch et al. 1987; Gebhart and Malm 1991; Malm 1992). The monitoring data show that sulfur concentrations at Big Bend are higher than at any other IMPROVE monitoring site in the western United States. They are about two times higher than at parks on the Colorado Plateau, three times higher than at sites in the Rocky Mountain region, and five times higher than at parks in Northern California and Oregon (Sisler et al. 1993; Malm 1994).

Mexico does not require the tracking of emissions of sulphur dioxide (SO_2) or other air pollutants in any detailed way. The only reliable emissions estimates are for large point sources such as coal-fired power plants and some smelting activity. There are a few publications with estimates for some pollutants indicating total air emissions for the entire country (Bustani and Cobas 1993) or for specific areas in Mexico (Beaton 1992; Mejia and Cortes 1995; Romo and Mejia 1995), but the published information is quite sparse.

The objective of this paper is to use a receptor modeling technique to calculate emission estimates for source areas in Mexico that may influence the visual air quality at national parks in the southwestern United States. Input data include particulate data collected at Chiricahua and at Big Bend. Supplemental data from 12 other sites in the western United States were also used. Back trajectories were calculated using the Air Resources Laboratory's Atmospheric Transport and Diffusion (ATAD) Model (Heffter 1980) for 1989–92.

First, the distributions of sulfur and carbon at each park and the characteristics of the meteorology were examined for days when air masses arrived from Mexico versus days when air masses arrived from the United States. Some hypotheses about the influence of each country were created from this information. Then, simple estimates of transport and diffusion based on the wind speed and mixing depth in the trajectory were calculated. By knowing the distributions of the concentrations and using the estimated mean transport and diffusion, preliminary estimates of emissions in the western United States and northern Mexico were generated. These were then compared to published emissions information.

Summary and Conclusions

At Chiricahua, air masses arrived with roughly equal frequency from the United States, from Mexico, and from mixed countries. At Big Bend, 60% of the days had air masses arriving primarily from Mexico, 11% primarily from the United States and 30% from mixed countries, and air arrived primarily from Mexico nearly every day during the summer months.

At Big Bend, concentrations of sulfur and carbon species were generally higher if the air mass arrived from Mexico than if it arrived from the United States. The reverse was true at Chiricahua. Concentrations of most species were higher at Big Bend than at Chiricahua. However, arsenic, copper, lead, and zinc were all higher at Chiricahua. Examination of the meteorological data indicates that these differences are not entirely due to transport/transformation, but must also be influenced by emission rate differences.

Preliminary estimates of SO_2 emission rates indicate that the 10 northern Mexican states emit a total of approximately 4,800 mt (5,300 t) per day of SO_2. These total emissions are nearly equivalent to the total SO_2 emissions of the 13 western U.S. states considered. Similarly, fine elemental carbon emissions in northern Mexico were estimated at approximately 180 mt (200 t) per day or approximately 25% of that in the western United States. These estimates, though preliminary, indicate that any long-range transport modeling of air pollutants to receptors in the southwestern United States for assessment of visibility impacts or other air quality-related issues cannot neglect the probable impacts of sources in Mexico.

Due to the method used to generate the input fields for the emissions estimates, the results will necessarily be smeared out along the transport pathway. Therefore, it is expected that these results will be underestimates for grid cells that contain large sources and overestimates for grid cells that have low emissions but lie along the same transport pathway. Rough estimates of multi-year average dispersion, deposition, and conversion were used as input. Sensitivity of the results to changes in these values has not been explored, nor are the values used necessarily the "right" values. For all these reasons, these results should be considered preliminary. The purpose of the study is to begin to address the huge inadequacy of the current knowledge about air emissions in Mexico. As has been shown, at Big Bend air masses are much more likely to arrive from Mexico than from the United States. Therefore, approximations of the strength and location of sources south of the border are necessary to understand air quality-related issues in this region.

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Geomorphology of Chiricahua National Monument

Douglas Hall[1] and J. Bezy[2]

[1]*University of Illinois at Chicago, Department of Geological Sciences, 845 West Taylor Street, Chicago, IL 60607*
[2]*Saguaro National Park, 3693 South Old Spanish Trail, Tucson, AZ 85730*

Chiricahua National Monument in southeastern Arizona is notable for its tall, slender columns formed in a Miocene ash flow tuff. Such a vertical landscape, while bordering on the pathological in its improbability, presents several interesting questions to the process geomorphologist.

First, why are columnar landscapes characteristic of the tuffs? Ash flow tuffs frequently exhibit columnar cooling joints. Analysis of aerial photographs reveals that column geometries in both cross section and plan view are controlled by two locally radiating, vertical joint sets and a third horizontal joint set. The column bounding joints are a subset of the pervasive, randomly oriented cooling joints. The radial subset was selected out of the cooling joints by a radial stress field during resurgence of the Turkey Creek Caldera. Differential compaction of the tuff may also have led to jointing. The resultant joint planes provide avenues for water migration and consequent focusing of chemical weathering. Three orthogonal joint sets, two vertical and one horizontal, have been identified. All three joint sets can be explained by a locally resurgent vent or intrusion.

Second, how can we arrive at the rate of formation of such landforms? The total amount of material erosionally removed from the entire Turkey Creek Caldera ash flow facies present in the monument watersheds was calculated using a digital elevation map. This was verified by estimating the volume of the alluvial fan to the west of the monument's watersheds from seismic reflection profiles. Then, an average denudation rate of 0.017 mm/yr was calculated for the watershed based on the eroded volume.

Third, the column ages determined by the denudation rate and the prevalence of different erosional processes, each with its own efficiency, during different climatic periods, suggest a two-stage erosional history with rapid erosion during glacial periods and slow erosion during interglacial periods. Glacial-period erosion was characterized by freeze-thaw and fluvial processes. Interglacial erosion is characterized by weathering from salt, clay, and lichens. Details of current weathering processes were investigated by rock thin sections, X-ray diffraction analysis of weathering products, stream water chemistry, and debris buckets.

Fourth, how mechanically stable are the "balanced rocks" and "hoodoos"? Strength parameters (e.g., uniaxial compressive strength, tensile strength, Young's modulus, Poisson's ratio, coefficient of static friction across joints) for the tuffs were measured. Six columns with very different profiles (e.g., tall and slender cylinders, symmetrical overhangs, asymmetrical overhangs) were measured and then modelled by finite element meshes, with the laboratory rock strengths into a two-dimensional, static-stress computer model. Despite their fragile appearances, all columns were well within their static mechanical failure limits. Average "overdesign" factors are 4,100% and 12,700% for compressional and tensile failure, respectively. Failure by slip along joint surfaces is the most likely block failure mode, but is greatly minimized by erosional necking of columns into hourglass shapes. Necking causes the principal stresses in the column to rotate out of vertical and focus on the neck. The redirected stresses act as a normal confining stress across dipping joints that would, in the absence of the neck, imperil the column.

Fifth, what can the preservation of columns tell us about the seismicity of southeastern Arizona? The dynamic loads of an earthquake should induce resonances that would greatly imperil the larger, thinner columns. The uniformity of column heights suggests that either rare, high velocity winds or prehistoric seismicity cropped the previous generation of columns. An estimate of the resonant frequencies of a typical column provides some idea of the dynamic response of the columns to seismic shaking. Based on dendrochronology and lack of evidence of rockfall, the columns were unaffected by the magnitude 7.2 Pitaycachi earthquake of 1887 epicentrally located 120 km (75 mi) to the south. The calculated erosional rate suggests an average age for the highest columns of 2.4 million years. Based on a series of topographic benches and an accompanying uniformity of maximum column heights, it appears, therefore, that the last column-destroying quakes occurred 2.4 million years ago.

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Managing the Landscape—Society's Changing Perspectives

William L. Halvorson

U.S. Geological Survey, Cooperative Park Studies Unit, 125 Biological Sciences East, The University of Arizona, Tucson, AZ 85721

Introduction

Resource management is a people management problem as much as it is an ecology or landscape problem. It is a healthy reflection on the status of the human population that ecosystem and landscape management have taken on the importance that they have. People are coming from thinking that all wildness must be subdued and tamed, toward beginning to see that humans cannot survive much longer with a strictly exploitative attitude toward the land.

Human attitudes toward natural resources have evolved in response to changes in spiritual understanding and technological knowledge. For most of recorded history the earth's resources were considered to exist solely for the well-being of humans. Depending on the technological capacity, rampant resource exploitation was the norm with minimal accounting of costs to others or to the depletion of natural capital. In keeping with this viewpoint, landscapes were valued primarily in terms of their potential for human exploitation. Deserts, mountains, and swamps, for example, were considered to have little value because they were exploited only with great difficulty.

Once humans got beyond the point of feeling fear of the wilderness, a utilitarian view of nature became dominant—a view that natural resources are for people to use and abuse because they are unlimited and renewable. This view tended to come with an understanding that when one area was cleared of its resources, humans could just migrate to another area while the first area "healed." It also tended to include the notion that someone else's resources were yours for the taking if you were strong or smart enough. This was a time in earth evolution when the primary concern was survival; when your only concern is survival, you don't much think about conservation.

The next phase came into being with the development of cities and the industrial revolution, when portions of human populations were no longer primarily concerned with survival, when some began to have "leisure" time. Then the concepts of wildlands as scenic and pleasuring grounds began to creep into thoughts, philosophy, writings, and art. With that came the ideas that wildlands might have intrinsic values that stand apart from economic ones and that some wildlands ought to be protected and preserved.

The last phase to come in our evolution is the philosophy that people and nature are actually interrelated. With this philosophy has come an understanding that humans need to care for earth so that earth continues to provide all that it can for our well-being. This thinking has been getting stronger as the population of the earth continues to rise and populations see that 1) there are no frontiers to go off to, and 2) it is increasingly hard to go take your neighbors' goods and lands through war. There is also a growing realization that people, even though they might be from different "tribes," are also interrelated and need to care for each other to have prosperity, peace, and harmony on earth.

With this change in world-view and attitude, managers are quickly moving from protectionists to developing an understanding of the ecology of their management, to taking a broad landscape view of resources. Cooperative management of landscapes or even of a single management unit requires that a number of barriers be moved or overcome: 1) multiple-use mandates, 2) interagency working relations, 3) the need to build constituencies and consensus among disparate groups, 4) the vast amount of information that must be obtained and managed, 5) the vast array of environmental and administrative regulations, and 6) financing and political pressures. We have come to a time in history when many adjustments have to be made to allow more information, more people, more wants, and desires to be considered in all land-management decisions. As a people, we are moving away from decisions by and for the good of the few to decisions by and for the good of the many. It is not an easy transition for anyone.

Changing Concepts and Expectations of Landscape Management

Many supporters of conservation initially viewed land protection only from a "park" perspective; that is, conservation could be achieved by simply setting aside parcels of land, thus saving them from exploitation. Others, however, began to recognize that conservation goals could only be achieved by viewing protected areas in the context of their surrounding landscape. An example of this idea is seen in the concept of core protected areas surrounded by a buffer in which sustainable human use is permitted. The intensively managed landscape elements of agriculture and housing developments occur outside the buffer zone. In a pluralistic democracy such as that of the United States, this type of conservation action requires that all interests in a landscape (farmers, ranchers, developers, businesses, government agencies, et al.) be involved in planning.

Humans require places to live and land dedicated to the production of commodities. Human livelihood therefore needs to be tied to conservation. Conservationists need to effectively communicate the understanding that human life is dependent upon natural systems. This has been difficult, and current efforts have been mostly ineffective. The counter view more commonly seems to prevail, which is that unless resources can generate some economic benefit, their protection is not worthwhile. Developing effective ways to deal with this problem is probably the single biggest difficulty facing the conservation community. The solution to this problem involves managing landscapes on a sustained basis and will require the investment of all stakeholders. Tough decisions will have to be made concerning the harvest of fish, wildlife, and vegetation, and the number of people a given landscape can support in the long term. A balance between private rights and public responsibilities will have to be established.

Most conservationists have concluded, though the debate rages on, that managing the landscape for the greatest good of the greatest number of people requires preserved areas (e.g., national parks, wilderness areas, other reserves) combined with more ecologically sensitive management of the remaining landscape. Landscapes run a continuum from the vacant lots of inner cities to the most protected natural areas. Both of those extremes are ill-suited to serve the daily needs of the human population. Somewhere between these extremes, the human population can live in sustainable harmony.

Multiple Use Mandates

We have a greater understanding today that no park is an island. Transboundary forces influence natural area ecosystems, and they must be identified and addressed to adequately protect natural resources. The myth of isolated natural areas and wilderness, separate and apart from the rest of the world, has been deposed by research, and the message is quickly getting to the public at large. It appears that what is needed is a larger scale of the biosphere reserve concept that was developed by the United Nations' Man in the Biosphere Program. Its aim is to protect natural biodiversity while protecting the economic well-being of local human populations. At its most basic, each protected area (biosphere reserve) has a core area or core areas of maximum protection (wilderness or natural area), surrounded by a zone of minimal use, and an outer zone or buffer of moderate use (forestry, range, campgrounds, mineral and energy development). This entire reserve sits in a matrix of land used for agriculture or urban development.

Interagency Working Relations

Since we are moving away from managers only having to be concerned with management of their own lands and resources, each manager now must develop a working relationship with each of his/her neighbors. For some this becomes a rather large group that includes some folks who are at a great distance from the borders of the park. For instance, Organ Pipe Cactus National Monument managers must recognize neighbors at distances away from the park because of the importance of highway 85 going through their lands.

Building Constituencies

Management today involves a whole community of people. It is as if we are experiencing the ecological principle that all parts are connected to all other parts. Now when someone tries to do something, there are all manner of folks—interest groups, stakeholders, regulators, legislators, and so forth—who are there to help make the decision. And these folks tend to get very angry if they are not invited to the table.

Developing the institutional framework that allows all the people who want a say in the decision is a challenge we have yet to master. Our representative form of governance is breaking down, and there is no longer trust that the people's representatives are in fact representing them, in the legislative or administrative branches of government. Since people are feeling like their interests are not being represented, they want to be in on the process.

Information Management

While managers are developing monitoring programs and moving into a better understanding of how the systems they manage work, they are also finding that it is necessary to develop ever more sophisticated data management systems to make sense of it all. To add to the data management problem, they are finding that the constituency groups that are coming together, also want access to the information.

Landscape management ideally must start with an inventory and a map. These tools will help identify areas of high or significant biodiversity and allow one to associate these sites with land ownership and development patterns. In many areas new partnerships between government and private groups are being created that allow inventory data commonly scattered among many different offices to be centralized in one site. For example, in Arizona, state agencies are joining with a number of federal agencies to develop one database that pulls information from the state heritage program, The Nature Conservancy, the GAP Analysis Program, and other programs and agencies and offices that wish to participate. These kinds of programs emphasize providing the best scientific information possible to aid in policy development and implementation.

The next step in landscape management brings together as much geographic information as possible into one database so that realistic maps can be produced. Based on mapped information for a reasonably sized area, land-use decisions may then be made that incorporate the full range of available information.

Financing and Politics

Related to the issue above, all of us are experiencing the pressure that we are being asked to perform management in such a way that it is impossible to do with the people and money resources we are given to do it. This pressure is so great and causing such frustration and fatigue that a great number of government workers, including many of our own National Park Service colleagues, have said, "Enough! I'm 'otta' here!" and have gone on to other, more pleasant lives.

Summary

We are quickly moving from management by belief-based directives of the few to management by scientific understanding and broad consensus. With this change the idea that natural areas can be protected by simply putting a fence around them is giving way to a realization that natural areas will only be protected in the context of a protected landscape. That is, the core natural area must be surrounded by landscape units that have minimal use and will buffer the natural area from damage due to inappropriate or illegal uses.

The management of landscapes that will provide for long-term well-being of both natural populations and human populations requires the cooperative efforts of all who live in and manage that landscape. It also requires that decisions be based on scientific knowledge about the health and dynamics of that landscape, including all of the systems, natural and man-made, that exist on that landscape.

To arrive at this scientific knowledge, extensive ecological monitoring programs must be developed so that information on changes to the systems will be available. Research will be necessary where there is a need to know why changes are happening. The management of the information that is being developed for landscape-scale areas, requires a jump in the size and complexity of computer systems to handle the data. Geographic information systems and computer networks will be standard fare in the coming years as the demand for data increases.

One of the reasons that it is necessary to manage on a landscape scale is the continued increase in the earth's population. We must learn to live, on a long-term basis, with what is available. Failure to develop protected landscapes that give protection to natural biodiversity and provide for conservation of natural resources in such way as to also provide for the harmony of people and nature will result in the manifestation of the fear that development and exploitation will simply overrun all natural areas. There still is the possibility that our landscapes could be littered with ghost towns and barren eroded lands. It will take continual shifting away from our tendencies toward individualism to come to grips with our needs for community, connectedness, and interdependence to provide for the long-term sustainability of human populations.

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Integrated Pest Management at Historical Structures in Southern Arizona National Park Areas

Gerry Hoddenbach

G & L Consultants, P.O. Box 750128, Torrey, UT 84775

The National Park Service embarked on a program of Integrated Pest Management (IPM) in the early 1980s in response to a presidential proclamation mandating all federal agencies to use both less and safer pesticides. The National Park Service IPM program saw rapid development during the last decade. Today, IPM is practiced in all of the park areas, and the program has become a model for other federal agencies. One important development of the program is the preparation of comprehensive IPM plans and specific IPM Action Plans for individual sites. The plans not only document the successes and failures of prior pest control efforts and provide rational alternatives for a hierarchy of control measures, but also outline action levels. We will touch on various plans being written for a number of historical National Park Service structures in New Mexico and Arizona and discuss how the plans will enhance the preservation of such irreplaceable inheritances.

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Agave delamateri: A Pre-Columbian Cultivar?

Wendy C. Hodgson

Desert Botanical Garden, 1201 North Galvin Parkway, Phoenix, Arizona 85008

Susan D. McKelvey collected numerous *Agave* specimens in central Arizona during the late 1920s and early 1930s. Among these were a series of specimens of an unknown agave collected in and around the Sierra Ancha Mountains, Globe, and Coolidge Dam, Gila County. Unsure of the identity of these specimens, McKelvey sent them to William Trelease for study (McKelvey 1929). In a letter to McKelvey, Trelease tentatively recognized her collections as a new species, calling it *Agave repanda* based on the obvious s-shaped leaves (Trelease 1929). Even though McKelvey suggested that Trelease publish *A. repanda* (McKelvey 1929), he never did. Liz Slauson and I chose not to recognize Trelease's epithet, and instead named this species *Agave delamateri*, or the Tonto Basin agave (Hodgson and Slauson 1995), in memory of Rick DeLamater whose contributions to the knowledge of this taxon were invaluable.

Agave delamateri is most appropriately placed within Gentry's Group Ditepalae and appears to be most closely related to *Agave fortiflora* and *A. palmeri*. *Agave delamateri* is distinct from both in a number of characteristics, including the production of numerous rhizomatous offsets and leaves that can be cut easily (Hodgson and Slauson 1995).

The distributions of *A. delamateri*, *A. palmeri*, and *A. fortiflora* are also distinct (Hodgson and Slauson 1995). *Agave delamateri* is only known from a small geographic area in central Arizona, while *A. palmeri* occurs from southern Arizona and southwestern New Mexico into northern Sonora. *Agave fortiflora* is only known from two small, isolated mountain ranges in northwestern Sonora and may be extinct.

Agave delamateri is known from about 90 isolated sites, occurring in Gila County from near Coolidge Dam and Globe, north to Young and west to Sedona, Yavapai-Coconino County border, at elevations ranging from 725 to 1,554 m (2,380–5,100 ft) (Hodgson 1994b). The greatest concentration of sites occurs along the south end of Tonto Creek near the northwest end of Roosevelt Reservoir in an area referred to as Tonto Basin, situated between the Mazatzal and Sierra Ancha Mountains. Plants are generally found on open, level to moderately steep, cobble and gravelly slopes of alluvial fans or old dissected terraces, often overlooking major drainageways.

Agaves have been an important source of food, fiber, and beverage for many indigenous cultures. As a result of recent work by Humberto Suzanne and Paule Fish, and others (Fish et al. 1985, 1990, 1992), extensive prehistoric agave cultivation in south-central Arizona was deduced from the strong association of roasting pits and mescal knives with rock pile fields, man-made terraces, and check dams covering tens of thousands of hectares of desert bajada slopes. *Agave delamateri* also persists in or near indigenous cultural landscapes, rather than landscapes unmodified by past cultures (Hodgson 1994b). Plants are found in direct or indirect association with archeological features including single and multi-room foundations, agave knives, potsherds, linear alignments, rockpiles, and check dams (Hodgson et al. 1989; Hodgson 1994b).

Agave delamateri is believed to have been grown for food or fiber by the Salado puebloid-culture, similar to the cultivation of *A. murpheyi* by the Hohokam (see Hodgson 1994a). The Salado inhabited the area northeast of Hohokam territory, probably extending from the foothills of the Mazatzal Mountains north and northeastward towards the Mogollon escarpment (Mogollon Rim). Despite the importance of "wild" agaves in the subsistence patterns of indigenous peoples, no agave was known to have been aboriginally cultivated in the arid and semiarid regions of the southwestern United States and northern Mexico prior to the discovery of *A. murpheyi* and its role in pre-Columbian cultures (Hodgson 1994a). *Agave delamateri* is the second documented case of prehistorically cultivated, living germplasm conserved *in situ* within the ancient cultural landscape (Hodgson et al. 1989; Hodgson 1994b).

The topography and climate of an area influenced not only the type of agave planted by pre-Columbian cultures, but also how these agaves were managed. *Agave murpheyi* occurs in the Lower Colorado Valley subdivision of the Sonoran Desert, an area characterized by gently sloping bajadas and an annual precipitation of only 80–250 mm (3–9.8 in) (Shreve 1951). Here it is found on low-gradient slopes and benches in direct association with runoff features such as linear rock alignments, rockpiles, and check dams, which were presumably used to increase soil moisture and organic matter retention and discourage small mammal herbivory (Hodgson 1994a). In contrast, *Agave delamateri* is found in the Arizona Upland subdivision of the Sonoran Desert, an area largely characterized by small mountains, hilly plains, and old dissected terraces with an annual precipitation of 250–410 mm (9.8–16 in) (Shreve 1951). In these habitats, *A. delamateri* is found only on top of the alluvial terraces overlooking drainage systems (Hodgson et al 1989; Hodgson 1994b).

In Tonto Basin, numerous extensive linear alignments and check dams were constructed in the drainages above the Tonto Creek and Salt River floodplain, presumably for less-adapted annual crops, such as maize, beans, and squash (Hodgson 1994b). Agaves, which can tolerate less water and nutrients, were grown above the drainages and farther from the floodplain. Apparently, there was little or no effort to construct runoff and channeling systems for the cultivation of *A. delamateri* in Tonto Basin and the surrounding area (Hodgson 1994b).

Where and how *A. delamateri* originated is unknown, although it is believed to have originated elsewhere, possibly further south, in northern Mexico. There are several known present-day agave distributions that have been influenced by man. Gentry (1982) suggested that *A. applanata* was dispersed from Veracruz and Puebla as far north as Durango and Chihuahua "by man's hand in historic or prehistoric times." Sporadic localities in the northern distribution of *A. applanata* are found along the old Native American trail between central Mexico and Casa Grandes, Chihuahua. *Agave murpheyi* may have originated further south than its present range, its numerous pups or bulbils probably grown and transported by the Hohokam (Hodgson 1994a). Another unknown agave was recently found growing amidst extensive archeological features in Deer Creek Canyon, Grand Canyon National Park. Deer Creek Canyon was inhabited and farmed extensively by the Anasazi (Robert Euler, pers. comm. 1994) and possibly historically, by the Southern Paiutes (Helen Fairly, pers. comm. 1994). This large agave produces offsets and leaves that are easily cut. It shows no similarities with others in the area and is believed to have originated further south and dispersed northward (Hodgson and Slauson 1995). Similarly, it is hypothesized that *A. delamateri* may have also originated elsewhere, perhaps further south in Mexico, and was transported to its present day range (Hodgson 1994b). Planted and grown for prized attributes, such as its robust size, easily cut leaves, and profuse offset production, pre-Columbian peoples may have gradually dispersed *A. delamateri* northward through migration (Hodgson and Slauson 1995). The rhizomatous offsets could have been easily carried or traded, then planted and grown.

Flower stalks of *A. delamateri* begin to emerge in May and early June, and mature in late June through July (Hodgson 1994b). *Agave delamateri* has not been observed to produce mature fruits or seeds, as the flowers usually abort. Reproduction appears to be vegetative, via the production of numerous offsets.

The apparent lack of sexual reproduction in *A. delamateri* may be due to several reasons. It may be of hybrid origin, but there is little evidence to suggest this assumption. Self-sterility is another possibility, as agaves are primarily obligate outcrossers; that is, they require pollen from another plant of a different clone. If *A. delamateri* at a single site represents plants derived from a single genetic clone, these plants would be largely incompatible and produce little or no fruits/seeds (Hodgson and Slauson 1995). If individual plants from different clones or sites represent different genotypes, the large distances between the majority of plants would significantly decrease the chances of cross-pollination occurring between sites or genotypes. Another agave with a limited and sporadic distribution with low-fruit set is *A. parryi* var. *huachucensis*. Sutherland (1984) found that fruit set in this taxon was less than 4% and suggested that it is probably a clonal inbreeding population (Sutherland 1982).

Lack of pollinators may also reduce sexual reproduction, but it is most likely not a factor in *A. delamateri* (Hodgson and Slauson 1995). Larger numbers of insects and birds have been observed to visit its flowers. The structure, color, and musty odor of its flowers suggest that pollination is probably primarily by bats. However, adequate pollination and subsequent fruit set does occur in *A. palmeri*, a species with similar flower characteristics, when visited by animals other than bats during daytime hours only (Slauson, in press). Pollination studies may shed light on other problems, such as whether distances between plants inhibit cross-pollination (Liz Slauson, pers. comm. 1996).

Climatic factors may affect the mode of reproduction in agaves, and are not well understood. Growth and methods of reproduction in agaves are often altered by environmental conditions different from their natural habitats. Certain species that readily offset in habitat have been observed to remain solitary in cultivation, and vice versa, at the Desert Botanical Garden. Some species that normally flower, produce fruit, and rarely, if at all, offset in their native environments have been observed to abort flowers and produce offsets and/or bulbils from vegetative shoots in cultivation (Hodgson and Slauson 1995). If *A. delamateri* originated from a site further south in Mexico and was gradually dispersed northward by pre-Columbian people, it may require different temperature and/or moisture regimes for flower and fruit development. Gentry (1982) noted that flower and seed development is inhibited for a number of agaves due to the intensity of summer temperatures when grown in desert gardens in Arizona. It is possible that flower and fruit development is inhibited due to climatic conditions where *A. delamateri* is presently known to occur.

Despite the fact that *A. delamateri* has not been observed to produce fruit or seed, it is believed to have persisted for centuries, as a result of vegetative reproduction. Whether *A. delamateri* can adapt to changing conditions or is relatively short-lived with respect to geological time, it appears to have played a significant role for several centuries in the subsistence patterns of pre-Columbian people in the arid Southwest.

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Wildlife Use of Water Catchments in the Tucson Mountain District of Saguaro National Park

Natasha C. Kline

Saguaro National Park, 3693 South Old Spanish Trail, Tucson, AZ 85730

To mitigate some potential impacts of the Central Arizona Project on Saguaro National Park large mammal populations that may have been cut off from historic water sources by the canal, the Bureau of Reclamation funded the restoration of two water catchments in the Tucson Mountain District. Remote camera monitoring systems were installed at these catchments in 1989. After two years of preliminary data collection, wildlife use of these water sources was monitored continuously from 1991 through 1993. I present the results of the catchment visitation patterns of several species, including javelina *(Dicotyles tajacu)*, desert mule deer *(Odocoileus hemionus crooki)*, and mountain lion *(Felis concolor)*. (POSTER)

Results of Roadkill Surveys in Saguaro National Park

Natasha C. Kline and Don E. Swann

Saguaro National Park, 3693 South Old Spanish Trail, Tucson, AZ 85730

To begin to quantify the sink effect of roadways on wildlife in Saguaro National Park, Resource Management Division staff collected weekly roadkill data from January 1994 through December 1995. We present the results of these systematic surveys, as well as opportunistic roadkill observations. In addition to quantifying the impacts to wildlife of vehicular traffic in the park, other benefits of collecting roadkill data include 1) identification of "hot spots" along roads that may warrant special management (e.g., animal crossing signs, special crossing structures, or even road closures); 2) verification/specimens of rare or previously unknown species in the park; and 3) obtaining other ecological or natural history information on park wildlife resources (e.g., activity patterns, distribution/movements, and reproductive data). (POSTER)

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The Ecology of Chiricahua Fox Squirrels: Trapped on a Sky Island

John L. Koprowski

Department of Biology, Willamette University, Salem, Oregon 97301

Chiricahua fox squirrels *(Sciurus nayaritensis chiricahuae)* are a subspecies of the Nayarit or Mexican fox squirrel that is found only in the Chiricahua Mountains of southeastern Arizona (Brown 1984; Hoffmeister 1986). This subspecies was considered a separate species (Goldman 1933) from its Mexican relatives, the Nayarit and Apache fox squirrels, due to its uniquely rich rust coloration on the underside. However, more recently mammalogists have determined that the Chiricahua population of squirrels has likely not diverged enough to warrant specific status (Lee and Hoffmeister 1963). Described more than 50 years ago by naturalists as a rare species deserving of protection (Cahalane 1939), the U.S. Fish and Wildlife Service listed Chiricahua fox squirrel as a Category 2 species in 1991 due to the paucity of information on the species. I initiated a study to obtain basic information on the ecology of this uncommon species beginning in May 1994. The specific ecological objectives of the study were 1) to census populations and identify habitat preferences of Chiricahua fox squirrels in Chiricahua National Monument and 2) to identify the basic natural history of Chiricahua fox squirrels including reproduction, food habits, and activity patterns.

Chiricahua National Monument (1,573–2,228 m [4,999–7,313 ft] in elevation), located along the west slope of the northern Chiricahua Mountains, 55 km (88 mi) southeast of Willcox (Cochise County) Arizona, served as the study location. The mountains function as a sky island of relatively mesic montane habitat rising above the Sonoran Desert to the west and the Chihuahuan Desert to the east. The monument is dominated by rugged terrain with rocky cliffs and outcroppings covered with desert scrublands. The two major canyons (Bonita and Rhyolite) that drain east to west within the monument are served by numerous small washes. The canyon bottoms at the lower elevations are dominated by a shrub cover of manzanita (*Arctostaphylos* sp.) and a canopy composed primarily of Arizona oak *(Quercus arizonica)*, Emory oak *(Q. emoryi)*, silverleaf oak *(Q. hypoleucoides)*, alligator juniper *(Juniperus deppeanna)*, Arizona cypress *(Cupressus arizonica)*, and Arizona madrone *(Arbutus arizonica)*. Chihuahuan pine *(Pinus leiophylla)*, Arizona pine *(P. arizonica)*, Apache pine *(P. engelmannii)*, and Douglas fir *(Pseudotsuga menziesii)* are common at higher elevations.

The monument was traversed on foot to locate the characteristic leaf nests of squirrels in the branches of trees. I found 207 such nests, 98% of which were restricted to the mature forests in the canyon bottoms of the monument. Only 166 nests were in usable condition, and given the fact that squirrels may use more than one nest, the population of Chiricahua fox squirrels appears to be low within the Chiricahua National Monument. Chiricahua fox squirrels did not demonstrate any fine preferences for riparian forest, lower or upper Madrean forest, or montane forest within these canyon bottoms. However, squirrels do prefer to nest in the tallest trees with the greatest diameter at breast height and with a number of branches in contact with surrounding trees when nest trees are compared to randomly selected trees in the forests. No other characteristics of sites surrounding nest trees or of the nest trees themselves appear important in determining where squirrels may be found. As a result, Chiricahua fox squirrels appear to be relegated to canyon-bottom forests that only account for 13% of the available habitat in the Chiricahua National Monument and demonstrate a preference for large trees only within these restricted habitats.

The behavior and natural history of Chiricahua fox squirrels were documented by following individual squirrels at a distance to record behaviors and food habits at one-minute intervals (28,035 minutes of observation). Squirrels leave their nests soon after sunrise and return just before sunset throughout the year; however, during the long, hot, summer days, activity peaks in the early to mid-morning and late afternoon, with a midday lull in activity during which squirrels typically loaf on a shaded branch. During winter, squirrels are active throughout the short days with a midday peak in activity. Females spend most of their days resting either inside or outside their nests. Conversely, males are more attentive to feeding during winter just prior to the breeding season and spend more time in locomotion during the spring/early summer breeding season. Similarly to other tree squirrels (Gurnell 1987), preferred foods during both summer and winter were cypress nuts, pine nuts, acorns, and other tree seeds. However, squirrels did feed heavily on fungi and mistletoe berries when available.

Young appeared from the nest in May through August. Although other species of tree squirrel have litter sizes that average 2.5 to 3.0 young (Gurnell 1987), Chiricahua fox squirrels appear to have fewer young, with litters restricted to 1 or 2 young. This low reproductive rate in combination with the restricted habitat requirements of Chiricahua fox squirrels and the low densities within prime habitat in Chiricahua National Monument suggests that the species does indeed share many characteristics in common with rare species.

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The Development of Geographic Information Systems, Global Positioning Systems, Geolink Data Acquisition, and Artificial Intelligence Vegetation Classification Models at Chiricahua National Monument

Michael R. Kunzmann,[1] Susan M. Skirvin,[2] Peter S. Bennett,[1] and D. Phillip Guertin[2]

[1]*U.S. Geological Survey, Cooperative Park Studies Unit, 125 Biological Sciences East, The University of Arizona, Tucson, AZ 85721*
[2]*Advanced Resources Technology Program, School of Renewable Natural Resources, 325 Biological Sciences East, The University of Arizona, Tucson, AZ 85721*

The U.S. Geological Survey, Cooperative Park Studies Unit and the Advanced Resources Technology Program at The University of Arizona are actively developing numerous inventory techniques and geographic information system (GIS) artificial intelligence (AI) modeling applications that utilize global positioning systems (GPS) technology. The GPS-based field mapping techniques and data acquisition software dramatically increase the speed of data collection and overall precision. Reliable GPS data and cost-effective GeoLink data attribution techniques are critical in developing adequate GIS AI models. Using Motorola LGT 1000 GPSs and GeoLink software, it has become much easier to integrate and field validate necessary GIS thematic data and database classification tables as required to develop and rapidly test the effectiveness of AI models. These field technologies coupled with AI models are now being utilized at Chiricahua National Monument, Arizona, to produce a new vegetation map and to expedite the development of a Brown, Lowe, and Pase vegetation classification system. These techniques could be easily adapted to other parks and refuges throughout North America. (POSTER)

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Sonoran Biosphere Communication Network: A Building Block for Ecosystem Management in the Western Sonoran Desert/ U.S.-Mexico Border Region

Wendy Laird[1] and Dominick Cardea[2]

[1]Sonoran Institute, 7290 East Broadway Blvd., Suite M, Tucson, AZ 85710
[2]Organ Pipe Cactus National Monument, Route I, Box 100, Ajo, AZ 85321

Efforts to develop a transborder, ecosystem approach to resource management in the western Sonoran Desert/U.S.-Mexico border region are hampered by limited access to information and lack of communication, the results of linguistic, cultural, and legal barriers, isolation, inadequate phone systems, intermittent electricity, and poor mail service. The Sonoran Institute, in collaboration with Organ Pipe Cactus National Monument, El Pinacate and Upper Gulf Biosphere Reserves, and more than 30 partners are working to develop the Sonoran Biosphere Communications Network (SBCN). Successful completion of SBCN will serve to link federal, state, and tribal agencies; nongovernmental organizations such as the Sonoran Institute, Friends of Pronatura, and International Sonoran Desert Alliance; academic/research institutions; and social service organizations. In addition to providing e-mail capabilities, SBCN will serve as a gateway to Internet, MABnet, World Wide Web, and so forth. Phase I (purchase of computer equipment) has already been completed. Phase II will link Organ Pipe Cactus and El Pinacate, using solar packet radio equipment. Installation of this wireless alternative (no phone lines are necessary) takes advantage of a technology that may well be the next generation in digital communication. Upon successful completion of Phase II, the network will be expanded to include Upper Gulf of California Biosystem Reserve managers. In addition, separate grants are currently being sought to obtain geographic information system hardware/software and training in monitoring and inventory.

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The Concomitant Demise of Feral Honey Bee Colonies Due to Mite Infestations and the Arrival of Africanized Honey Bees in Saguaro National Park and the Adjacent Area

Gerald M. Loper

USDA Agricultural Research Service, Carl Hayden Bee Research Center, Tucson, AZ 85719

The honey bee *(Apis mellifera),* first introduced into North America in the 1600s, came from Western Europe and was well-adapted to our temperate climates. Both by natural migration (swarms) and man-assistance (especially via Panama to California) the honey bee reached Arizona at least by the 1870s. In southern Arizona, they have done very well, many of them nesting in rock cavities.

I began locating, sampling, and studying such feral colonies in 1988, starting in an area north of Oracle Road along Camp Grant Wash. By June 1993, I had found 245 nesting sites with 208 (85%) live colonies. Beginning in 1991, I began, with park rangers' help, to locate and sample feral colonies in Saguaro National Park. While no exhaustive survey in Saguaro was made, by March 1996, 12 nests in the Rincon Mountain District had been located, including 1 in a saguaro cactus *(Carnegiea gigantea).* Most of the nests found in the park were alive when first found; however, the saguaro nest died of exposure after a large arm fell off the cactus. Of the 12 found, 5 nests were concentrated in one cliff just south of the Freeman house ruins and 1 nest was in the lime kiln ruin.

In both study sites, twice yearly censuses were conducted to determine winter survival (March) and result of swarming (June). In some years, a third census was conducted in late October or early November. At least once a year, all colonies (if accessible) were sampled. As much as possible, samples were analyzed by morphometrics, mitochondrial DNA (mt DNA) and for allozymes. Mt DNA is only inherited through the mother, while morphometrics and allozymes are influenced by both parents.

Beginning in 1989, a parasitic mite *(Acarapis woodi,* the honey bee tracheal mite, HBTM) was found in samples of feral bees in southern Arizona. In 1992, a second parasitic mite *(Varroa jacobsoni)* was found in domestic colonies in the Tucson area. Both mites have increased in population and have become ubiquitous, resulting in the death of numerous colonies (both domestic and feral). During the period of 1989–92, large numbers of colonies died from the HBTM in the Tucson-Sierra Vista area, but the surviving colonies had a measure of resistance. The loss of feral bees north of Oracle Road, due to HBTM, occurred during the winters of 1993–94 and 1994–95 when up to 60% of the population died.

The abnormally heavy rains during January–February 1993 in southern Arizona led to the flowering of many plants and an unusually numerous production of honey bee swarms. Many of the empty feral nests were reoccupied and new nests established in other adjacent rock cavities. During 1993, the first Africanized (AHB) colonies and swarms were found in southern Arizona, but also the Varroa mite spread throughout the area. The first obvious losses of feral colonies due to Varroa occurred during the fall and winter of 1995. Because of the hot, dry summer of 1995, the lack of fall flowers, and the Varroa mite, the feral colony population was almost annihilated. At the site north of Oracle, only 8 of the 208 colonies alive in June 1993 were still alive on 20 March 1996. In my last survey of the feral colonies in the Rincon Mountain District, conducted on 26 March 1996, I found that all were dead!

The first AHB swarm caught in the Rincon Mountain District was in June 1994; the first documentation of Africanization in the park district came in late March 1995 when two colonies showed AHB introgression (allozyme analyses). Both colonies were near the top of a cliff just south of the Freeman house ruins. A third colony, which was inaccessible for sampling, was seen in the fall of 1995, but died the following winter. I removed a swarm from a water meter box near the administrative buildings on 2 May 1995; by morphometric analysis it had a 100% probability of being AHB. All park rangers and volunteers in southern Arizona should be aware that any and all swarms and live colonies are likely to be AHB. Policies should be in place to deal with them and any emergencies that may arise.

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Current Cultural and Natural Resource Management Projects at Fort Bowie National Historic Site

Larry Ludwig and Patrick Myers

Fort Bowie National Historic Site, Box 158, Bowie, AZ 85605

Fort Bowie National Historic Site is distinctive for its mandate that it be preserved in its remote (non-auto access), abandoned, rustic, primitive state. Visitors reach the fort via a 2.4-km (1.5 mi) "walk through history" trail that meanders past historic ruins surrounded by a wilderness setting. Each resource management decision must be weighed in light of this special mandate. Fort ruins are stabilized but not reconstructed. Mesquite (*Prosopis* sp.) trees are reduced to protect the ruins physically and visually, as historic photos indicate that mesquites are recent intruders at the site.

Less that 5% of the historic site has been archaeologically surveyed. A new tradition of annual surveys is yielding essential information that then translates into better interpretation. Interpretation at Fort Bowie is broadening to include more of the Apache culture, women's history at Apache Pass, and natural history themes such as ethnobotany. Traditional themes such as the Butterfield Stage and Fort Bowie history are also being developed in light of new archaeological research.

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Flash Flooding in Chiricahua National Monument with Apparent Differences in Watershed Response

Michael Martin and Gary Smillie

National Park Service, Water Resources Division, 1201 Oakridge Dr., Suite 250, Fort Collins, CO 80525

Introduction

During the period of 28–31 August 1993, Chiricahua National Monument experienced multiple episodes of flash flooding caused by precipitation associated with a Pacific tropical storm. While there were no injuries, these floods threatened campgrounds and structures within the monument, raising the question of long-term flood safety. The Water Resource Division of the National Park Service (NPS) characterized these flood peaks with the goal of establishing a recurrence interval for each drainage.

Characterization of rare, high-magnitude flood events is important for the design of hydrologic structures, and in planning for the use of floodplains or riparian corridors. Estimates of the magnitude of low-probability floods contain inherent variability and associated errors. A factor that almost always complicates this uncertainty for wildland managers is that very few streams in the "backcountry" have any type of flow record. In many types of wildlands, visitor use is often restricted through access and, therefore, the threat to human life associated with high magnitude floods is low relative to more populated areas. However, "wildlands" managed by the NPS are often an exception to this rule. By its original authority under the 1916 NPS Organic Act, the NPS is committed to providing visitor access to many areas that would otherwise be relatively inaccessible. Additionally, by creating campgrounds, visitor centers, trails and other visitor-use facilities, the NPS sanctions and encourages use of these areas. Following Executive Order 11988, which mandates appropriate use of floodplains by Federal Facilities, the NPS adopted Floodplain Management Guidelines (Special Directive 93-4) to provide additional visitor and resource safety. Knowledge of local flood characteristics and accurate floodplain estimation is essential for providing safety within NPS units. However, basic data in the form of systematic streamflow records is usually limited or completely absent in most park units. This necessitates the use of extrapolated data, usually in the form of regional regression equations. Use of recurrence intervals derived from purely statistical methods for specific floods may not illustrate the "true" probability of the occurrence of extreme events.

Background

Chiricahua National Monument is located in the Chiricahua Mountains of southeastern Arizona, a region characterized by intense thunderstorms and streambeds prone to flash floods. Two principal streams drain the park, Bonita and Rhyolite creeks. Although these two streams drain adjacent watersheds and are of similar size, significant differences exist in their channel morphology and response to large precipitation events. Bonita Creek, an intermittent stream, drains the northern portion of the park and flows through the campground. Rhyolite Creek drains most of the southern portion of the park and flows by the park visitor center. This stream is ephemeral and only flows in response to large precipitation events. Just below the visitor center the two streams join and flow by the superintendent's residence and Stafford Cabin/Faraway Ranch interpretive area before exiting the park.

Bonita Creek has a stable channel morphology with little evidence of extremely high flows and sediment loads. Rhyolite Creek, on the other hand, has a very unstable channel with large amounts of coarse sediment deposited in areas along the stream. This stream is evidently prone to large runoff events and sediment transport rates, and has a much higher gradient than Bonita Creek immediately upstream of the confluence. Bonita Creek, below the confluence, is in a larger valley and has a lower gradient. In this area the channel is more stable than Rhyolite Creek but also has a greater sediment load than upper Bonita Creek. The bedload is poorly sorted and ranges in size from fine sand to cobbles and small boulders. Flow is spatially intermittent, but the entire length of the channel can convey water in response to rainfall events.

During the morning of Saturday, 28 August 1993, large floods occurred in both Rhyolite and Bonita creeks. In Rhyolite Creek, water backed up behind the box culvert under the park road and partially inundated the visitor center parking lot, approaching the building itself. Damage occurred to paved surfaces and erosion was widespread. Bonita Creek partially flooded the park campground and a tributary, Surprise Canyon, overtopped the road and destroyed one campsite. No campers were injured. Below the confluence of the creeks, high water rose nearly to the superintendent's house before receding.

In the early morning of Tuesday, 31 August, an additional pulse of rain produced the largest flood for many years in Rhyolite Creek, with water rising to within about two vertical feet of the visitor center. The superintendent's house was severely threatened by flood waters that broke out of the main channel upstream. These waters filled a side channel on the opposite side of the structure from Bonita Creek, effectively isolating the house from any overland escape route. Fortunately, flooding in Bonita Creek through the campground was much less severe and no loss of facilities or injury resulted. The last of the flooding episodes occurred later in the morning of 31 August and was less intense than the earlier two events.

Methods

Survey data for several areas were collected using a Lietz Set-4 total station. A total of fifteen cross sections, which included high water marks left by the flood, were surveyed. Two of these cross sections were located near Stafford Cabin, downstream of the confluence of Rhyolite and Bonita creeks, and eight were located in Rhyolite drainage, above the visitor center. Four cross sections in the Bonita campground area and one from the vicinity of the superintendent's house were also used to estimate flood discharges on those reaches.

Flood magnitudes were estimated using a stage-discharge computer model, XSPRO, developed by the U.S. Bureau of Reclamation (Grant et al. 1992). This program uses Manning's equation to estimate discharge given a specified depth of flow in a particular cross section. Energy slopes of the water surface are required by the program and were estimated using channel slope values collected at the time of the survey. A measure of resistance to flow, Manning's roughness coefficient, was estimated for each cross section surveyed.

Flood frequency information was developed for different points in both Rhyolite and Bonita creeks using regional linear regression equations developed by the Arizona Department of Transportation in cooperation with the U.S. Geological Survey (Roeske 1978). These estimates were compared to estimates of the magnitude of the August 1993 flood at selected points to establish recurrence intervals at each area of interest.

Results/Discussion

Indirect estimates of the flood peak at the most downstream cross sections, located near Stafford Cabin, indicate that the discharge at that point was about 98–112 m^3 per second (3,500–4,000 cubic feet per second, or cfs). This is somewhat higher than the calculated 100-year discharge of 92 m^3 per second (3,300 cfs) for this watershed, but may be considered approximately a 100-year flood event along that reach of Bonita Creek. Farther upstream, in the vicinity of the superintendent's house, another indirect estimation produced a discharge value of about 56 m^3 per second (2,000 cfs). This lower value is the result of a substantial amount of flood water being conveyed to the side channel in this area.

Above the confluence with Rhyolite Creek, discharge in Bonita Creek was distinctly less. At two cross sections below Bonita Campground, the discharge was estimated to be about 17 m^3 per second (600 cfs). This is approximately a 5-year flood event. Above Bonita Campground, the estimated discharge was about 10 m^3 per second (350 cfs), which was below the discharge value for the 5-year flood. The noticeable increase in discharge through Bonita Campground is attributable to input from the Surprise Canyon watershed.

Indirect discharge estimations in Rhyolite Canyon were both much greater in relative magnitude and variability between cross sections. Of the eight cross sections surveyed, four were used to produce a reasonably reliable estimate of flood magnitude. Peak discharge on Rhyolite Creek was about 90 m^3 per second (3,250 cfs). This value is somewhat below the calculated 500-year flood of 98 m^3 per second (3,500 cfs) for this watershed and represents a very rare event. Because of the magnitude of this flood, Rhyolite Canyon underwent substantial geomorphic changes through both scour and deposition of boulder and cobble size bedload material. It should be noted that any major channel alterations that take place after the occurrence of high water diminishes the quality of the indirect discharge estimates. Additionally, in reaches where there are backwater effects on the water surface elevation, the Manning equation is not very accurate. For these two reasons, four of the eight cross sections surveyed in Rhyolite Canyon were not used in the analysis.

The wide difference in recurrence interval for Bonita (approximately 5-year flood) and Rhyolite creeks (approximately 500-year flood) is surprising. Observation of flood debris indicated that the magnitude of discharge was considerably different during these floods, and evidently much greater flow in Rhyolite Creek is not an uncommon phenomenon. Differences in the flow of Rhyolite and Bonita drainages were noticed in the early 1960s, when it was hypothesized that a difference in degree of bedrock fracturing and/or thickness of alluvial fill existed between the two watersheds (Johnson 1962). Whether these physical differences between the watersheds are enough to account for the dramatically different flood discharges is not clear.

When substantial physical differences exist between two or more watersheds in a common hydro-meteorological area, then derivation of recurrence intervals from purely statistical methods may not truly describe the flooding nature for each watershed. In the absence of site-specific stream gage records, the preferred manner to develop hydrologic data is through extrapolation of information collected at similar locations, usually by using regional regression equations. However, if broad differences exist between two streams, how can one regional relationship apply to both? If one assumes that Bonita Creek is less flashy in nature than the "average" southeastern Arizona stream and that Rhyolite is more flashy, the effect on the estimated recurrence intervals based on the regional information would be to underestimate the recurrence interval for Bonita Creek and overestimate for Rhyolite Creek. This partially explains the wide difference in estimated recurrence intervals between these two adjacent creeks.

Another likely difference that would have contributed to substantially different discharges is varying rainfall over the two watersheds. Rainfall amounts and intensities are commonly quite variable over small distances in the Southwest. Therefore, it is easy to believe that, indeed, rainfall distribution was not even during the August 1993 events. However, while for a given storm it is conceivable that Rhyolite received much more precipitation than Bonita, over a long time period it is not likely that this would systematically be the case. Regardless of the distribution of precipitation input, major geomorphic differences exist between these two watersheds and these differences likely contributed to variable flood peaks.

A third contributing factor to the difference in apparent discharges is the presence of substantial sediment load within the Rhyolite drainage. When large volumes of channel and bank material are mobilized in a flood, the actual discharge through the channel and floodplain is a combination of the flood waters and the sediment flux. This combination serves to increase flood stage dramatically and create a flood that appears more rare than it would be with "clearwater" flows.

Summary and Conclusions

The flood peaks that took place in Bonita and Rhyolite drainages were substantially different. However, the calculated recurrence intervals were dramatically different, at 5- and 500-year frequency for Bonita and Rhyolite, respectively. Application of published regional regression equations distorted the difference of associated recurrence intervals and made the Rhyolite Creek discharge appear more rare than it likely was.

These estimated recurrence intervals should be used as a relative comparison for the magnitude of events between the two watersheds and not as an absolute measure of the rarity of events on any one drainage. The flood event that took place in Rhyolite drainage may be far more common than the 500-year recurrence interval implies. Consequently, a "true" 500-year flood would likely be more devastating than the August 1993 event.

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Tree Lizard Distribution and Saguaro Cactus Succession

Robert T. M'Closkey

Department of Biological Sciences, University of Windsor, Windsor, Ontario, Canada N9B 3P4

Ecological succession is the temporal change in the distribution and numbers of individuals in populations. The changes are caused by the colonization and eventual extinction of local populations at specific sites or habitats. There is considerable interest in the ecological processes that occur during succession (Connell and Slatyer 1977). The presence of one or more species during ecological succession may either facilitate or inhibit colonization of the site by other species. Paine and Levin (1981) emphasized the importance of dominance competition during ecological succession as an important process in community recovery. Ecological succession is often linked to disturbances in communities that generate open space and permit colonization by species.

Animal species often respond to changes in the plant community during ecological succession. I discovered such a response in the distribution of a lizard (*Urosaurus ornatus*, tree lizard) associated with different stages of senescence of the saguaro cactus (*Carnegiea gigantea*). From 1986 through 1995, we periodically assessed the distribution and numbers of tree lizards in the mesquite-paloverde-saguaro association in the Rincon Mountain District of Saguaro National Park.

In this habitat, tree lizards occupy honey mesquite (*Prosopis juliflora*) trees that serve as centers of territory and home-range activity. Males defend territories against other males (M'Closkey et al. 1987a; M'Closkey 1992) so that territories are non-overlapping. One or more females occupy undefended home ranges within male territories. Many of the lizards also use saguaro cacti as vantage points for territory defense and feeding. Females may oviposit at the base of saguaro cacti in the loose soil beneath woodrat (*Neotoma albigula*) nests (M'Closkey 1990a).

Methods

Two study plots contained 137 sites that consisted of living, dead standing, and dead prone saguaro cacti. Plots were surveyed for tree lizards in 1986, 1987, 1988, 1992, and 1995. In each year, a site was counted as used by lizards if a resident lizard (captured during two or more census periods) was present. At the beginning of the study, in 1986, there were 91 living saguaro cacti of 5 m (16 ft) height, 25 dead standing, and 21 dead prone cacti. Due to the death of living cacti over the nine-year period, by 1995 there were 79 living, 26 dead standing, and 32 dead prone cacti. Each site was numbered so the status of the cacti and the pattern of use by lizards could be followed through time.

Results and Discussion

Over the nine-year span of the study, 12 living saguaros died. Eleven dead standing saguaros fell during the study and became dead prone. Therefore, the numbers of cacti in each category varied from 79 to 91 for living (86.8 ± 2.46), 24 to 28 for dead standing (25.6 ± 0.68), and from 21 to 32 for dead prone (24.6 ± 2.06).

During the study, only 3 of 91 (3.3%) living cacti were used by lizards. In contrast, 73% (27 of 37) of dead standing saguaros and 12.5% (4 of 32) of dead prone cacti were used in at least one year of the study. In 12 cases, living plants died and remained standing. It typically required one to three years for the cacti to be composed only of a cylinder of woody ribs. Of the 12 sites, 7 were eventually used by lizards. Eleven other sites showed a transition from dead standing to dead prone. In all cases the dead standing cacti had been used in at least one year of the study, but none was ever used as dead prone.

The yearly use of the three classes of saguaros was very different, although there was little variation among years for any category. For example, living cacti were rarely used (1.32 ± 0.64%), dead standing cacti were frequently used (48.6 ± 1.93%), and dead prone cacti averaged 9.3% (± 1.37) use over all years. The ranges of percent use reflected consistent patterns of occupancy of saguaro classes among years (0–3% for living, 42–51% for dead standing, and 6–15% for dead prone). We found no lizards using living cacti in 1992 or 1995.

During the study, living saguaros comprised an average of 63% of all sites, dead standing 19%, and dead prone 18%. In contrast, an average of 79% of all lizard records were from the use of dead standing cacti. Only 7% of lizard records were from living saguaros. For example, in 1992 there were 15 cases of tree lizards using saguaro cacti, but 13 of those records (87%) were from dead standing cacti. The most frequent use of living saguaros occurred in 1987, when 3 of 18 records (16.7%) were from living plants. Analysis of the pattern of use of the classes of cacti showed a highly significant saguaro effect, no significant differences in use among years, and no significant saguaro class by year interaction. Multiple comparisons showed significant differences between percent use of living and dead standing cacti ($P = 0.000$), between living and dead prone cacti ($P = 0.016$), and between dead standing and dead prone cacti ($P = 0.000$).

Saguaro cacti provide opportunities for exploitation of a distinct microhabitat resource (primarily dead standing cacti) by tree lizards. Tree lizard populations in Saguaro National Park reach their highest density in riparian woodlands dominated by mesquites (M'Closkey et al. 1990a, b). In this habitat, tree lizards spend virtually all of their time in mesquite trees.

However, in flatland desert scrub, the use of saguaro cacti provides an additional spatial dimension to tree lizard territories and home ranges. It appears that dead saguaros are quickly recognized and exploited by tree lizards, which allows an expansion of the territory and home-range boundaries of individual lizards. It is also well established that distinct boundaries of male tree lizards provide the opportunity for mate defense polygyny (M'Closkey et al. 1987a, b). Lizards defending two or more mates are polygynous, and use of microhabitat types (dead standing cacti) in addition to mesquite trees can improve the opportunities for polygyny.

An interesting scenario for tree lizard abundance may develop as a consequence of the Mother's Day fire, 1994. In 1984, I surveyed the area that burned. Tree lizards were present, but not numerous in 1984. The greatest number of lizards was found in riparian woodland, then flatland desert, with lowest abundance in the rocky hillsides. High mortality of saguaro cacti at the burn site would generate a new microhabitat resource for tree lizards. In 1995, I found very few tree lizards at the burn site, and none were using saguaro cacti. Long-term monitoring of this site would allow us to evaluate the response of a common lizard to changes in the status of a dominant plant species in the Sonoran Desert.

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National Parks in the Context of Biosphere Reserves

Joaquin Murrieta-Saldivar

School of Renewable Natural Resources, 325 Biological Sciences East, The University of Arizona, Tucson, AZ 85721

Introduction

Biosphere reserves are multipurpose areas that are nominated by the National Committee of the Man and the Biosphere (MAB) program and designated by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) to serve as demonstration areas for cooperation in building harmonious relationships between human activities and the conservation of ecosystems and biological diversity. The biosphere concept is a framework for regional cooperation involving government decision makers, scientists, resource managers, private organizations, and local people.

Natural resource policies in the United States and other countries increasingly encourage cooperation in conserving biological diversity and meeting the needs of human communities for social and economic development. Biosphere reserves help implement these policies by providing international recognition of important regional efforts and a focus for "stakeholders" (biosphere participants) to cooperate in developing the knowledge, technologies, and perspectives needed to solve complex resource problems (U.S. Man and the Biosphere Program 1995).

The U.S. MAB seeks to facilitate the discovery of practical solutions to complex conservation and development problems by providing a framework for policymakers and resource managers to interact with an interdisciplinary community of natural and social scientists and other stakeholders (U.S. Man and the Biosphere 1994).

Basic Concepts and Purpose of the Biosphere Model

The term "biosphere reserves" emerged in 1971 from UNESCO-MAB, which is an international and multidisciplinary research program whose major objective is to provide the necessary knowledge and trained personnel needed for sound and sustainable management of land resources (Batisse 1986). The objectives of the biosphere program are to develop using the natural and social sciences 1) as a basis for rational use and conservation of resources on earth, 2) for the improvement of the relationship between man and the environment, and 3) to predict the consequences of today's actions on tomorrow's world and thereby increased man's ability to manage efficiently the natural resources of the biosphere (Batisse 1993).

The MAB program is a worldwide program of international scientific cooperation dealing with people-environment interactions. It attempts to provide tools for understanding and diminishing the impacts on the environment from the different types of human activities and interventions. Two of the key components of the MAB program are the involvement of decision makers and local people in research projects, training and demonstration in the field, and the pooling of disciplines from the social, biological, and physical sciences in addressing complex environmental problems. Under this idea, the concept of the "biosphere reserve" was intended to be a series of protected areas, linked through a coordinated international network, which would demonstrate the value of conservation and its relationship with development and/or other human activities (United Nations Educational, Scientific, and Cultural Organization 1984).

According to Tangley (1988), many early declarations of biosphere reserves were areas already under protection, such as national parks. At the present time the number of designated biosphere reserves is more than 300 in 82 countries.

In 1976, UNESCO designated the first biosphere reserve in the United States. The United States has the largest domestic network, with 47 biosystem reserves. Organ Pipe Cactus National Monument is included in this system of land management (U.S. Man and the Biosphere 1994).

Basic Roles and Spatial Distribution of the Biosphere Model

The three main concerns of the biosystem reserve scheme include 1) the need for reinforcing the conservation of genetics resources and ecosystems and the maintenance of biological diversity *(Conservation Role)*; 2) the need to set up a well-identified international network of areas directly related to MAB field research and monitoring activities, including the accompanying training and information exchange *(Logistic Role)*; and 3) the need to associate concretely environmental protection and land resources development as a governing principle for research and education activities of the new program *(Development Role)* (Batisse 1993). It is the combination—and harmonization—of these three concerns that characterize the biosphere reserve (Man and the Biosphere 1987).

One of the essential ways of combining these three basic roles is through the zoning of the biosphere reserve with *core areas*, which have to be strictly protected to meet conservation objectives; a *buffer zone*, which should be clearly delimited for management purposes; and a *transition area*, which can extend over the territory where cooperation with local people for sustainable development can be organized. The instrument for success is normally the adoption by all concerned of a management plan covering the whole area (Batisse 1993).

Realities of the MAB Model

Biosphere reserves accept an implicit responsibility to take account of the social impact of conservation policy in a given region and to consider the needs of the local human inhabitants as equal to those of the nonhuman components in the surrounding environment. Biosphere reserves offer a "humanistic" approach to nature conservation such that plants and animals are not presumptively considered more important than humans. The MAB approach is to use the buffer zones as a link between the protected-area management and the surrounding social systems to reduce the potential for direct conflict with local residents (Kaus 1992). With this, the MAB program is systematically trying to use social knowledge as a complement to economic and technical knowledge by providing a forum that puts policymakers, planners, and technical experts in a position to explicitly recognize the centrality of the primary factor in the development process, the embodiment of what Cernea (1991) calls "putting people first."

The biosphere reserve concept has become recognized as one of the most innovative means to promote participatory approaches to the conservation of biodiversity in combination with the sustainable use of biological resources (Lasserre et al. 1993). The biosphere program was indeed the first intergovernmental forum to discuss and promote what is now called "sustainable development" (Batisse 1993). However, despite the lofty goals of MAB, the articulation of conservation and development in biosphere reserves never passed to the next step of actually putting the concept into practice (Kaus 1992).

Making a comparison between any particular biosphere reserve and the general model often shows that little attention has been paid to the transition area, where many of the activities relating to the development role can best take place. One major reason for this neglect lies in the open, undelineated character of the transition zone. Whereas administrative responsibility for the core areas and the delineated buffer zone is usually very clearly established—and in the majority of cases rests upon a single authority—the administration of the transition area is almost inevitably split among a variety of public and private bodies, with little or no attempt having been made to organize coordination and cooperation among them. This situation is demonstrated by the relatively large number of designated biosphere reserves that have no real transition areas, which are in fact "limited" to a core area, surrounded or not by some kind of buffer zone and that often merely bear the name of an already existing national park or conservation area (Batisse 1986). Such is the case of the Pinacate/Upper Gulf of California biosystem reserve in Mexico, and Organ Pipe Cactus National Monument in the United States, both areas located at the international border between Sonora and Arizona. These two areas are adjacent to the Tohono O'odham reservation on the U.S. side, and on the Mexican side the Tohono O'odham hold communal land. They are trying to conserve their cultural and natural resources in these areas.

Researchers also have found MAB's interdisciplinary approach appealing but difficult to implement, particularly for research that crosses the boundary between the natural and social sciences. Most important, there is little integration of local knowledge and land-use practices with research activities or documentation of the effects of different forms of land use in the buffer zones (Kaus 1992).

The International Sonoran Desert Alliance (ISDA) is attempting to overcome these realities of the MAB model by approaching local institutions, where, according to Cernea (1991), informal leadership identified through ethnographic analysis can provide efficient structures for reaching the communities with sustainable development concepts for natural resource use. The alliance is combining the local institutions with the MAB model to create the body of sociological knowledge in the design of policies to accomplish sustainable use of natural resources. With this, ISDA is becoming the "hearing system" (Cernea 1991), able to amplify the listening for managers, policymakers, and communities of the Pinacate and Organ Pipe Cactus biosystem reserves. The region lacks an effective governmental framework for coordinating economic development and environmental protection. Thus the MAB model is providing a framework to incorporate a tri-national and tri-cultural organization (Mexico, Tohono O'odham Nation, and United States) to promote cooperative protection of resources, ecologically sound economic development, and improve responsiveness of public policy to local needs (U.S. Man and the Biosphere 1995).

Final Remarks

At the UNESCO-MAB level, innovation—new programs, ideas, or problem solving—is one of the expectations from the national committees. According to Martin and Meyerson (1988), when innovation is the objective, people may be more willing to accept ambiguity. Ambiguity may provide a key to understanding the process of innovation. When expectations, preferences, and evaluation criteria are unclear, there is no apparent right or wrong outcome. Because there is no risk of being wrong, experimentation, and thus creativity, is encouraged. If objectives are not clear presumptively, they can be permitted to emerge. This is what UNESCO is trying to promote among the MAB national committees by giving them the freedom to plan their own goals and objectives within the biosphere model. In this way, ambiguity can produce innovation and greater utilization of the resources (Martin and Meyerson 1988). As an example of this ambiguity and innovation paradigm, the ISDA case is mentioned as a new effort within the framework of the MAB program to reduce the gap between the conflicts of human activities and natural resource use.

Dyer and Holland (1988) conclude that if MAB or its equivalent did not exist now, it would have to be invented. There are simply too many different types of problems throughout the world for individual bilateral programs between industrialized and developing countries to add up to a meaningful multidimensional effort. Man and the Biosphere needs to be careful not to fall into the political versus scientific dichotomies; more science needs to be integrated into policy and vice versa. Man and the Biosphere is and continues to be at the forefront of science and politics for many issues in the world community.

Conclusion

Finally, what the MAB program provides with its structural framework are ways to be more efficient in the utilization of three of the most scarce resources on earth: cooperation, respect, and the understanding to integrate the other two in the ecosystem management of the Sonoran Desert. We need to remember that ecosystems become a reality within the human dimension of natural resources and "ultimately, the meaning of a total ecosystem is to be found in ourselves, not in Nature. If we are to insert ourselves into Nature in some sophisticated and constructive way, we must study ourselves as much as we study Nature, perhaps more" (Bennet 1990).

Criticisms of UNESCO abound, the pessimistic points of view among these critics are many, and the optimistic voices are relatively few. This attempt at analysis of the UNESCO-MAB program lays out the framework for further study to find ways to reduce the conflicts between ideology and reality for a more sustainable integration of human dimensions and natural resource use, and to increase cooperation and community development instead of building cultural and physical walls between us.

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Faraway Ranch Historic District: A Case Study

Kathrine Neilsen

Chiricahua National Monument, HCR #2, Box 6500, Willcox, AZ 85643

In 1979, Faraway Ranch was added to Chiricahua National Monument. Situated 1.6 km (1 mi) east of the entrance to Bonita Canyon, the purchase included 178 ha (440 ac), a ranch house, nearly a dozen outbuildings—and the contents of the buildings!

Thinking about the Landscape

Prior to the acquisition of Faraway Ranch, Chiricahua was known for its rock formations, "sky island" ecology, and hiking trails. Now would come the chance to exhibit the home of the individuals who pushed so hard to protect the Wonderland of Rocks.

By 1988, the ranch house was ready for public inspection. Some of the outbuildings were converted to office and maintenance space. Several others were stabilized and, with the contents removed, were opened to viewing. Still others were filled with less sensitive objects and the doors locked.

The interpretive story included the homesteaders, Neil and Emma Erickson, their children, Lillian, Ben, and Hildegarde, and a Lillian's husband, Ed Riggs. Neil and Emma built up the farm and a small cattle operation. Lillian and Ed established a guest ranch. From a two-room, picket style cabin in 1888 to a cattle and guest ranch by 1930, Neil, Emma, Lillian, and Ed had a comfortable life. Ed's love affair with the Wonderland of Rocks led to his lobbying efforts for its protection. In 1924, he was rewarded when Chiricahua National Monument was established. With a background in engineering, Ed worked on the boundary crew that surveyed the new park, and as a foreman with the Civilian Conservation Corps (CCC), he helped lay out the roads and trails.

For the National Park Service (NPS), the emphasis was on Faraway Ranch house itself. An Historic Furnishings Plan was written and implemented. The excess collection was sent to the NPS Western Archeological and Conservation Center. Because of a renovation to the kitchen in 1962, and because Lillian, "The Lady Boss of Faraway," was alive until 1977, it was determined that the house would look the way it did in 1963.

For interpreters, talking about the 1960s was never enough. Nineteenth century neighbors like Ja Hu Stafford and Luis Prue immediately became part of each tour. Apaches, Buffalo Soldiers, and the CCC would not be denied their part in the story. Underlying tales of miners, ranchers, and Spaniards were there, too.

Waysides began to dot the grounds. An exhibit from Harper's Ferry was installed in Neil's Den. Tours of the house were formal, and there was talk of living history demonstrations.

Visitors accept museum information as authoritative. A curator's exhibit is taken as fact, when in reality it is an opinion, albeit an educated one. Thus, the authority of the curator is an essential element in building the historical perspective of a park with cultural features.

Now consider the original features of the property. The buildings are not the only features defining the landscape. There is also placement of those buildings in the landscape, the land use, the circulation of people, and the vegetation related to land use.

How has the landscape changed and what should be the era interpreted? The house, while important to the landscape, has been treated singularly. It is part of the landscape integrity, but no more so than the outbuildings or the agricultural patterns. There is a risk of failing to establish a proper time frame for the *exteriors* of Faraway Ranch. Rapid alteration of the landscape that is occurring will only make decisions harder if we delay.

The account books indicate Faraway Ranch had its best year in 1933. Facilities were modern: there was indoor plumbing, oil heat, and electricity. Gardens, orchards, game, and domestic stock meant meals were plentiful and wholesome. The typical guest was from back east, staying a week, and paying $2.50 per night; three meals included, horses extra. Activities included bird watching, hiking, swimming in the split-level pool, and riding horseback into the Wonderland of Rocks. The evenings were filled with music, tall tales, and slide shows. Relaxation was the key, and many guests were repeating their visits. There were no agendas at Faraway, and the only rules were to be on time and to dress for dinner.

The stock were fit, buildings and machinery well maintained. The house had a new stucco exterior finish painted "mansion yellow" in keeping with Swedish tradition. In spite of the hard times in this country, life in Bonita Canyon was good.

Compare that to the 1960s, the date set for the interiors. Neil and Emma were dead, and so was Ed Riggs—who could fix anything with baling wire and who performed all of the upgrades in the 1920s. Lillian was blind. She had had a series of ranch mangers, none of whom she trusted. She eventually befriended Andy Anderson, and he would become companion and oversee the operation. With very little in the way of skill, Andy could not keep up with the repairs. The orchard died, and only a few of the "regular" guests signed the guest book. The grounds were covered with debris from broken machines, and corrals were repaired with whatever was handy—or simply left to rot.

So, is it necessary to present the exterior of Faraway Ranch in the same time frame as the interior? Is it fair to Ed Riggs, who worked so hard to make the ranch a success? Can the decision be made at an emotional level? Can the era of choice be decided or dictated by Chiricahua's division of interpretation alone? No. The park maintenance division must repair (and generally pay for) and rehabilitate the structures and grounds. The division of resource management must document and research the landscape. The curatorial division must collect and exhibit the objects. Fire management must control the vegetation. The interpretation staff must create exhibits that visitors can understand. The superintendent must manage all the above and incorporate the historic district into the total park planning.

A prime example of a landscape dilemma is that of the replacement of native tall grasses by invasive alligator junipers *(Juniperus deppeana)*. When Ja Hu Stafford entered Bonita Canyon in 1879, there was open range from canyon wall to canyon wall with Arizona sycamores *(Platanus wrightii)* and "wide-spreading oaks" along Bonita Creek. The stream flowed 10 months out of the year. Stafford quickly and successfully established a quarter mile of orchard and several gardens. He built an irrigation system based on a number of springs, one of which offered warm water.

Today, only 80 years after Stafford's death, the magnificent orchard is choked with alligator juniper. The canyon has less than two dozen fruit trees, 95% of them within the yard of the ranch house, where they get sufficient water.

In 1879, the open space from Stafford's cabin to the Sulphur Springs Valley was interrupted only by the ribbon of oaks *(Quercus* sp.*)* and sycamores along Bonita Creek. Today 10% of that open space remains. Junipers, mesquites *(Prosopis* sp.*)*, and chollas *(Opuntia* sp.*)* are the result of livestock grazing. Nearly all of the sycamores and many of the oaks have been replaced by Arizona cypress *(Cupressus arizonica)*.

One proposal is to remove all or most of the junipers, to manage fire hazards and restore to some degree the plant associations of before livestock overgrazing. An earthquake in 1887 turned Stafford's warm spring cold, but changes in climate along with agricultural demands in the Sulphur Springs Valley have modified the water table. Restoration of the Stafford orchard is not suggested, due to decreasing amounts of water and lack of staff to maintain an irrigation system. But return of the grassland is acceptable and even desirable.

The other proposal is to return the corrals, grounds, and outbuildings to their appearance in the early 1930s. An earlier date is not recommended, since the house received its stucco and color in 1932.

So again the question is: Can two time periods live successfully in a historic district? For the sake of the landscape heritage they have to. We must decide to interpret concepts and not just objects. We must do this as a whole community. Faraway Ranch has always been the story of how "People live on the land, shapes the land, and in turn, the land shapes them."

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Rattlesnake Relocation at Montezuma Castle National Monument

Erika Nowak

Northern Arizona University, Flagstaff, AZ 86011

Venomous snakes inhabiting many areas of the United States are capable of seriously injuring or killing people with whom they come in contact. A telephone survey of 26 national park and monument areas in the Southwest showed that human-rattlesnake encounters are a common management issue. Though the problem is generally recognized and specifically referred to in National Park Service (NPS) management documents, (e.g., NPS-77), there is no specific guidance provided, and different park areas have developed their own formal or informal management policies.

A common management practice involves relocating rattlesnakes from visitor access and housing areas, although the reasons for their presence in these areas, and even their normal home-range size, are generally unknown. Although relocation of rattlesnakes from human use areas for public safety is well-intentioned, it is not known whether such management is effective, nor what effect relocation has on the snakes and on the local natural communities.

To address this issue, a radiotelemetry study of rattlesnakes is being conducted at Montezuma Castle National Monument. Montezuma Castle is a small park with a total area of less than 2.6 km^2 (1 mi^2), and receives approximately 800,000 visitors per year at the Castle unit alone. Almost all of this visitation is concentrated on a small section of walking trails, where rattlesnakes are occasionally spotted by visitors or park staff.

At least two rattlesnake species, the western diamondback *(Crotalus atrox)* and the black-tailed rattlesnake *(Crotalus molossus)* are residents of the monument. Prior to 1994, at least 75% of the rattlesnakes sighted at the Castle unit were relocated more than 1 km (0.6 mi) from their capture point to adjacent national forest land.

The objectives of the study are 1) to determine location of hibernacula and summer foraging areas for resident rattlesnakes; 2) to determine the daily and seasonal movement patterns of the rattlesnakes; 3) to determine the reasons for rattlesnake concentration in visitor access and housing areas; 4) to compare the movement patterns, home range size, health, behavior, and mortality of rattlesnakes that are relocated outside their normal home range to those that are not relocated; 5) to determine if relocated snakes have homing ability; and 6) to develop guidelines for rattlesnake management at Montezuma Castle National Monument.

Since August 1994, 16 adult western diamondback rattlesnakes have been captured, most from the visitor access and housing areas, and have been surgically implanted with radio-transmitters. After a 24-hour recovery period, the rattlesnakes are released at their original capture point. Their locations are recorded using radiotelemetry equipment every other day during their active period, and once a week during hibernation, to determine their seasonal movement patterns and basic natural history information.

The average home range for a rattlesnake at Montezuma Castle is 13.2 ha (32.6 ac), with males having a slightly larger home range (14.9 ha [36.8 ac]) than females (10.51 ha [25.9 ac]). Results to date indicate that there are two primary reasons for rattlesnake presence in visitor access and housing areas. Nine of the 16 tagged rattlesnakes hibernated in cliffs behind the visitor trails. In the spring and fall, rattlesnakes migrated through the trail area on their way to prime hibernation sites. In the summer, rattlesnakes likely foraged on rodents, rabbits, and birds attracted to these areas. Ten of the 16 rattlesnakes were located in the visitor access or housing areas more than 50% of the times they were tracked during their active period. These observations are supported by studies conducted at Natural Bridges National Monument (Graham 1991). As the snakes appear either to be seeking out visitor areas for foraging, or moving through the areas on a seasonal basis, relocation of rattlesnakes may be ineffective at removing them from the area over the long term.

Although radiotelemetry work showed that 10 radio-tagged rattlesnakes spent much of their time in the visitor or housing areas, including 1 snake with a home range almost exclusively contained by the visitor access area, the snakes tended to stay away from trails during the day and so were almost never seen by visitors. Although there were about 100 locations of tagged rattlesnakes in the visitor access and housing areas in 1994 and 1995, they were seen by staff or visitors only four times, implying that the threat of envenomation may be overestimated in this park unit.

To understand the effects of relocating rattlesnakes outside their normal home range, in August 1995, we conducted a relocation experiment with eight rattlesnakes. Four were randomly selected and relocated to areas 2 km (1.3 mi) east of the visitor access area concentration of den sites, and a control group of four were carried a distance of 2 km and then re-released at their most recent capture point (within their natural home range).

The average activity range of the relocated rattlesnakes (they never settled into predictable movement patterns, so home range is not appropriate) was twice as large (38.5 ha [95.2 ac]) as before relocation (16.9 ha [41.8 ac]). The ranges of the non-relocated rattlesnakes were slightly different before (11.6 ha [28.8 ac]) and after the relocation experiment (18.4 ha [45.6 ac]), but were 50% as large as those of the relocated snakes after the experiment. The relocated rattlesnakes changed hibernation locations three times as frequently as non-relocated rattlesnakes, suggesting that their initial den site selections were insufficiently insulated to sustain them over winter. There was no pattern of weight change between relocated and non-relocated rattlesnakes between midsummer 1995 and April 1996. One of the relocated rattlesnakes had returned to within 50 m (165 ft) of its original home range by 1 May 1996.

These preliminary results are supported by recent studies conducted with timber rattlesnakes *(Crotalus horridus)* in Pennsylvania, and with several desert species in Tucson urban areas, which showed that relocated rattlesnakes had much larger home ranges than their non-relocated counterparts, and had mortality rates ranging from 38% to 100%, three or more times that of non-relocated rattlesnakes (B. Johnson, pers. comm.; Reinert 1995; McNally 1995). Causes of mortality included predation, starvation, and freezing, apparently due to being in an unfamiliar area or due to selecting an inappropriate hibernation site. Relocation of snakes in Tucson, Arizona, to areas relatively close to their capture points (less than 0.5 km [0.3 mi]) resulted in a 50% return rate, while there are no confirmed returns for rattlesnakes relocated 4 km (2.5 mi) from their capture point (Perry-Richardson and Ivanyi 1992).

Although this study is still in progress, preliminary management recommendations may be made. Relocation may not be an effective management practice due to the homing and immigration potential of rattlesnakes. In addition, relocation appears to cause certain negative impacts on rattlesnake movements and behavior at Montezuma Castle National Monument, so I recommend that parks and other public areas do not relocate rattlesnakes outside their normal home range.

There are several management alternatives to relocation of rattlesnakes. Because most of the rattlesnakes seen in visitor access and housing areas in the spring and fall are making migratory movements to or from hibernation dens, these rattlesnakes should be relocated from trails and other unsafe areas to the nearest cover in the direction of their original travel (toward den sites in the fall and away from them in the winter). In the summer, rattlesnakes may be relocated just far enough to remove them from the housing or visitor access areas. Rattlesnakes may be discouraged from establishing home ranges within these areas by decreasing the number of birds and small mammals present, for example, by controlling garbage and exotic seed-producing vegetation. Rattlesnakes may also be physically prevented from entering certain areas by installation of snake-proof fencing, although care should be taken not to interfere with the animals reaching their hibernacula.

As the human population encroaches on remaining rattlesnake habitat in the Southwest, national parks and other protected areas will become increasingly important to rattlesnake survival. However, given the history of persecution of rattlesnakes, habitat protection may not be sufficient to stop the decline of rattlesnake populations. Education of the public by the NPS and other agencies of the role of rattlesnakes in natural communities and of their generally non-aggressive nature may be the most effective long-term policy for management of rattlesnakes in public areas.

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Tracking the Next Generation of Saguaros in The Cactus Forest of Saguaro National Park (Rincon Mountains District)

T. V. Orum,[1] J. D. Mihail,[2] S. M. Alcorn,[1] and N. Ferguson[3]

[1] *Department of Plant Pathology, The University of Arizona, Tucson, AZ 85721*
[2] *Department of Plant Pathology, University of Missouri, Columbia, MO*
[3] *Department of Ecology and Evolutionary Biology, The University of Arizona, Tucson AZ 85721*

In 1941, the National Park Service allocated 259 ha (640 ac) for a study of saguaro cactus *(Carnegiea gigantea)* mortality by the U.S. Forest Service. The population in 1941 was one of the densest stands of saguaros in the Sonoran Desert, but saguaro mortality and a lack of young plants was a cause of concern. The study area is located in relatively flat terrain in the northwest corner of the Rincon Mountain District of Saguaro National Park. The topography of the study area differs substantially from the rocky slopes east of the loop drive, and the population dynamics reported here may be specific to this site. The study area was divided into an 8 x 8 lattice of 64 4-ha (10-ac) plots. Each of the 12,898 saguaros in the study area was mapped, marked, and height estimated in 1.8-m (6 ft) height categories. A census of plants was conducted annually through 1945. In 1945, six plots were selected for further censuses, which have continued annually through this year. When new plants are found, they are mapped and measured for height until they reach 1.8 m (6 ft).

Most of the saguaros in the population in 1941 were 3.7–5.5 m (12–18 ft) tall. The height class frequency distribution in 1941 was 92 saguaros < 1.8 m (6 ft) tall, 190 saguaros 1.8–3.7 m (6–12 ft) tall, 457 saguaros 3.7–5.5 m (12–18 ft) tall, 343 saguaros 5.5–7.3 m (18–24 ft) tall, and 361 > 7.3 m (24 ft) tall. Only 6% of the population in 1941 was represented by plants under 1.8 m (6 ft) tall. By 1960, the percent of the population under 1.8 m (6 ft) tall was 15%, and the population as a whole had declined from 1,480 to 555 individuals. Only 25 new plants were found in the six plots between 1941 and 1960. Between 1960 and 1970, 13 new plants were found. After 1970, the number of young saguaros found in the study plots increased dramatically. Here, we report on the preliminary analysis of data collected on this new generation of saguaros in Saguaro National Park.

A total of 617 saguaros have been found since 1970, reversing the constant decline in population size that had been the pattern since 1941. During the last fifteen years, three people have spent approximately four field days each year censusing the plots. The saguaro census has included a careful search for young saguaros. Not all young saguaros in a particular cohort are found each year, but searches in successive years lead to the discovery of most (65%) surviving plants by the time they are 18 cm (7 in) tall. Ninety percent of all plants found are < 30 cm (12 in) tall when found. Very young saguaros, < 7.6 cm (3 in) in height, have been found in 16 of the last 26 years, including a block of 11 consecutive years from 1986 through 1996. The largest number (23) of these very young saguaros were found in 1987. A total of 124 saguaros < 7.6 cm (3 in) tall when found have been located since 1970.

Recruitment of saguaros is widely understood to be episodic. Only in certain years is there a combination of environmental conditions that favor the survival of newly germinated saguaros until they are large enough to be discovered. We have chosen to group young plants into cohorts based on years in which a relatively large number of very small saguaros (< 7.6 cm) were discovered. Cohort names refer to these years rather than germination dates. Plants > 7.6 cm (3 in) tall when discovered were assigned to cohorts by comparison to the heights of the young saguaros found in previous years. For example, the survivors of the 23 saguaros found in 1987 that were 0.6–7.6 cm (0.5–3 in) tall had grown to 10–18 cm (4–7 in) tall in 1991. A saguaro found for the first time in 1991 in the 10-18-cm (4–7 in) size range was assigned to the 1987 cohort, while a saguaro found in 1991 that was < 7.6 cm (3 in) tall was assigned to the 1991 cohort. In this way, we have assigned all plants discovered since 1970 to cohorts by a sequential process based on accumulated height measurements rather than estimating age from a standardized height/age curve. Since 1970, 617 young saguaros have been found and assigned to cohorts as follows: 1971: 76; 1974: 7; 1977: 68; 1981: 101; 1984: 18; 1987: 107;

1989: 25; 1991: 162; 1994: 53. In 1996, 449 (73%) of these saguaros were still alive.

A nurse plant was recorded for every young saguaro that was found. If the saguaro was not under the canopy of a larger plant, we recorded that it was in the open. Fourteen species of plants, an unknown shrub, and unidentified bunch grasses were recorded as nurse plants. Foothill paloverde *(Cercidium microphyllum)* was the most common nurse plant. Nurse plants in descending order of frequency were foothill paloverde (355), velvet mesquite *(Prosopis velutina)* (79), burroweed *(Isocoma tenuisecta)* (63), whitethorn acacia *(Acacia constricta)* (38), no nurse plant (28), creosotebush *(Larrea tridentata)* (27), desert zinnia *(Zinnia acerosa)* (13), catclaw acacia *(Acacia greggii)* (9), grass (8), desert hackberry *(Celtis pallida)* (5), paper flower *(Psilostrophe cooperi)* (5), unknown shrub (5), desert broom *(Baccharis sarothroides)* (2), gray thorn *(Ziziphus obtusifolia)* (1), and prickly pear *(Opuntia* sp.) (1). There has been a major shift in nurse plant association since 1981. For cohorts up to and including 1981, only 1% of the nurse plants were burroweed and 2% were found in the open. Paloverdes and mesquites, on the other hand, accounted for 64% and 15% of the nurse plants, respectively. For the five cohorts after 1981 (1984, 1987, 1989, 1991, and 1994), 16% of the nurse plants were burroweed and 6% of the saguaros were found in the open. Paloverdes and mesquites dropped to 46% and 10% of the nurse plants. The highest rates of mortality were found among saguaros in grass and in the open. Beyond this, to date, there are no obvious differences in mortality related to nurse plants. A number of the nurse plant species are typically shorter than 45.7 cm (18 in) tall. Since a relatively high frequency of association with small nurse plants (e.g., burroweed) has only recently been recorded, we do not yet know the long-term consequences on growth and survival of these saguaros.

This is a preliminary report of a portion of an ongoing long-term study of saguaro mortality and recruitment in the Cactus Forest portion of the Rincon Mountain District of Saguaro National Park. There are a number of questions we plan to explore with further data collection and analysis. We are interested in seeing if episodes of establishment as defined by our cohort groups correspond to weather patterns. In the long run, this will help us interpret the lack of establishment between 1940 and the mid-1960s and the temporal patterns of establishment since the mid-1960s. This post-1960 establishment of saguaros coincides with the withdrawal of grazing from the study area, which occurred in two steps during the early 1960s. In addition, widespread cutting of paloverdes and mesquites for kiln fuel and other purposes in the study area in the early 1900s probably influenced recruitment patterns at that time and may still be having an influence on the temporal patterns of paloverde population structure. Future patterns of recruitment or lack thereof can now be understood without the confounding factors of pressure from cattle grazing and wood cutting. Because we have location and mortality data on all large saguaros in the six plots, we can reconstruct the density of flowering saguaros at any time since 1942. In so doing, we can compare the spatial pattern of establishment for plants in each cohort with the spatial pattern and density of saguaros at the estimated germination years for each cohort. Is there a minimum local saguaro adult density (potential seed source) required for establishment of saguaros in a particular area? Is there a difference in growth and survival between plants in the same cohort associated with different nurse plants? In particular, how will the relatively large number of saguaros found recently in burroweed thrive in comparison with those in the same cohort found under paloverde? Noting significant paloverde mortality in the last few years, we are interested in following survival and growth of saguaros whose paloverde nurse plant dies when the saguaro is very small (<15–20 cm [6–8 in] tall). What started out as a mortality survey of a declining population of saguaros has evolved into the documentation of the establishment of a new generation, the monitoring of their growth, and relationships to nurse plants.

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Ecology of the Mexican Rosy Boa at Organ Pipe Cactus National Monument, Arizona

David A. Parizek,[1] Philip C. Rosen,[2] Cecil R. Schwalbe,[3] and Charles H. Lowe[2]

[1]*Wildlife and Fisheries Science, School of Renewable Natural Resources, The University of Arizona, Tucson, AZ 85721*
[2]*Department of Ecology and Evolutionary Biology, The University of Arizona, Tucson, AZ 85721*
[3]*U.S. Geological Survey, Cooperative Park Studies Unit, The University of Arizona, Tucson, AZ 85721*

We studied Mexican rosy boas *(Lichanura trivirgata trivirgata)* using radiotelemetry at Organ Pipe Cactus National Monument, Arizona. This taxon is listed as a sensitive species by the Arizona Game and Fish Department in response to several management concerns: 1) it has a limited geographic distribution in the United States at and near Organ Pipe Cactus, 2) local populations appear to be decimated by highway mortality, 3) it is potentially threatened by collecting for the pet trade, and 4) such collecting may involve substantial and serious habitat destruction. To address these concerns and learn more about the ecology of this sought-after snake, we conducted a study to 1) quantify habitat use and activity patterns, 2) quantify seasonal and daily profiles of body temperature, 3) determine movement distances and home range size, and 4) evaluate movement ecology in relation to potential effects of highway mortality and collecting pressure on populations of the rosy boa at the monument.

The rosy boa is a small, heavy-bodied snake that eats small rodents, birds, and probably lizards. It bears live young, born in October and November. This species is mostly nocturnal and crepuscular, but in cooler months it may be active in the daytime. It is slow-moving, apparently long-lived, and spends most of its time underground.

We tracked five radiotransmitter-implanted boas with a portable receiver (Model TR4, Telonics, Inc., Mesa, Arizona) and directional H-antenna for periods ranging from 7 to 25 months each. We used a global positioning system (GPS) to get coordinates for snake locations and a geographic information system (GIS) to map them. Captured snakes were transported to the Tucson office of James L. Jarchow, D.V.M., for transmitter implantation. Temperature-sensing transmitters (Telonics, Inc. model CHP-3P, Mesa, Arizona; Wildlife Materials, Inc. model SOPT, Carbondale, Illinois) were surgically implanted, using sterile technique, into the peritoneum of snakes anesthetized with halothane gas. The peritoneum and the skin were each sutured in a double closure. Subsequently, the radio-tracked individuals were monitored from one to seven days per week during the active seasons and one to four days per month during winter. We monitored three of these individuals for periods up to one year, and the other two for two consecutive years. Ancillary data were obtained for 27 additional Mexican rosy boas at the monument.

The five radio-tracked boas had a mean single-year home range area of 1.6 ± 0.6 (SD, N=7) ha (3.9 ± 1.4 ac) (minimum convex polygon method). This is smaller than for other vertebrate-eating snake species, especially those with similar body size. The two rosy boas we tracked for two years maintained their home range in the same general areas from year to year. This suggests that this species has relatively well-defined, stable home ranges, as opposed to transient, shifting, or varying activity ranges.

Rosy boas have been associated historically with rocky habitats by herpetologists and snake enthusiasts. We therefore expected them to use primarily rocky macro-habitats and rocks as shelters most of the time. Instead, we found that they used the relatively rock-free flats (slope < 5%) extensively and that by far the most frequently used shelters were rodent burrows.

Rosy boas were also expected to be thermal conformers, more or less passively assuming the wide range of temperatures offered by the environment. This expectation was based on previous studies on similar species, as well as on the apparently slow, secretive life-style of this desert species. However, they maintained remarkably stable body temperatures throughout the year, and are probably fairly precise thermoregulators. They maintained low body temperatures (usually 24–29° C [75–84° F]) relative to most other desert snakes. Over the course of diel observations, we usually found that body temperatures were maintained within an even narrower range. We interpret this to reflect careful selection of the thermal characteristics of occupied microsites by this slow-moving snake. Rosy boas were active in the cool seasons, making short movements in winter, and were observed sun-basking, as well as subsurface-basking by contact with sun-warmed rocks, in the spring and fall.

Strong site fidelity was observed in all five radiotelemetered rosy boas, with up to five known visits to a specific shelter by one boa over two years of study. Had we monitored the individuals more frequently, the number of repeated visits to specific shelters by each snake would have been higher still. Rosy boas used specific features (such as burrows in sides of washes), and sometimes specific separate areas (such as rocky knolls), of their home ranges for varying purposes. The spatial ecology of this species is complex, and suggests subtle and important responses to extremes of drought and heat, as well as active mobilization and behavioral changes when opportunities exist. Our observations allow us to describe these behaviors in some detail.

Following the boas through their typical yearly movement and activity cycles illustrates how important specific habitat features can be for this species. They overwintered primarily on rocky, southerly, warmer exposures. In early spring, they used rock shelters for basking, and then moved over fairly extensive portions, but not the full extent, of their home ranges. Throughout the warm season, gently sloping and flat areas were used extensively. As spring merged into the hot, dry summer (the expected foresummer drought, prior to the monsoonal rains), boas moved to refugia in more mesic habitats (typically wash-side rodent burrows). These soil burrows in fine substrata along arroyo channels are generally the least xeric microhabitats available to snakes in this desert region. With the arrival of the monsoonal humidity and rainfall of wet summer, boas moved extensively over their entire home ranges. In fall, they moved back to rocky slopes and knolls.

The two boas (boas B3 and B4) monitored for two successive years both used the same areas of their home ranges for the same activities in the same seasonal sequence in each year. These two adult females overwintered on the same, shared, rocky knoll, and reused some of the specific microsites there in the second winter that were used in the first. In dry summer 1993, after a light rain, B4 moved away from its wash-side rodent burrow; several days later, when the habitat had again dried, it moved back to the exact burrow in which it had so recently been weathering the drought. During a particularly dry period in wet summer 1994, both B3 and B4 returned precisely to their respective dry summer 1994 refugia until rains prompted both of them to return again to the broader flat areas that they used actively during warm moist times of the monsoon season. The Mexican rosy boa is a slow but precise snake that clearly responds to the physical challenges of cold, heat, and aridity posed by its subtropical desert environment.

These ecological observations provide important insights into management concerns for this species. Rosy boas are especially susceptible to highway mortality because they are long-lived, slow crawling, and active in the cool seasons when automotive traffic at the monument is highest. Our work on site indicates that highway traffic on State Route 85 in the monument has decimated the population of the Mexican rosy boa that once occurred in habitat adjacent to the road. In the 1950s, rosy boas could be collected with some regularity on State Route 85; only a single dead rosy boa was found on State Route 85 from 1983 through 1995, in comparison to numerous rosy boas found (with much less effort) in monument areas remote from the highway from 1993 through 1995. Our movement data showing that the species is relatively sedentary, however, indicate that the highway effect probably extends no more than 1.2 km (0.75 mi) into the wilderness area, and perhaps less. The rosy boa remains abundant in remote areas of the monument, and presumably elsewhere in its geographic range. Highway mortality, where new pavement construction in previously undisturbed habitat is absent, does not pose a primary threat to the species or to subspecies populations.

There is great interest in collecting the rosy boa, including an ongoing, active poaching interest for this species in the monument. And, we have confirmed at least two cases of severe, long-lasting habitat destruction associated with past collecting activity at Organ Pipe Cactus; this type of destruction, involving the application of heavy tools to fragile rock structures, is undoubtedly continuing.

The Mexican rosy boa is a sedentary snake, living a relatively long life if undisturbed. Heavy collection pressure could substantially, though only temporarily, deplete populations. Habitat destruction, wreaked by unscrupulous and unthinking reptile collectors, causes essentially permanent damage to what our findings suggest are key features of the rosy boa's rock habitat. Taking a single important rock or wrecking a single crucial crevice could ruin a home range area for rosy boas. We recommend that collecting of this species be regulated in Arizona, and that habitat destruction by collectors be prohibited.

Acknowledgments

We were able to study the rosy boa at Organ Pipe Cactus National Monument thanks to funding from the Arizona Game and Fish Department Heritage Fund, the Southwest Parks and Monuments Association, and The University of Arizona Graduate Research Fund. We are also grateful to the staff at Organ Pipe Cactus National Monument for extensive help and cooperation in many aspects of our work there.

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Bat Monitoring at Quitobaquito Pond, Organ Pipe Cactus National Monument, Arizona

Yar Petryszyn,[1] Stephen Russ,[2] and Ami C. Pate[3]

[1]*Department of Ecology and Evolutionary Biology, The University of Arizona, Tucson, AZ 85721*
[2]*484 Lake Park Ave. #141, Oakland, CA 94610*
[3]*Organ Pipe Cactus National Monument, Route 1, Box 100, Ajo, AZ 85321*

In the southwestern portion of Organ Pipe Cactus National Monument, lying along the U.S.-Mexican border is an area called Quitobaquito. The area contains perennial springs that feed a man-made earthen pond called Quitobaquito Pond. The pond is approximately 60 x 80 m (200 x 260 ft), has an average depth of 1.5 m (4.8 ft), and a surface area of 0.26 ha (0.64 ac). It is unique in that it is one of the largest spring-fed bodies of water in the Sonoran Desert. It is used by a wide variety of wildlife, including Underwood's mastiff bat *(Eumops underwoodi)*.

Underwood's mastiff bat is considered by the U.S. Fish and Wildlife Service to be a species of special concern. Very little is known about the natural history of this bat. It occurs in only two known locations in the United States, and in small numbers at each. One location is at Quitobaquito Pond. The other is approximately 145 km (90 mi) east of Quitobaquito in the Altar Valley. Underwood's mastiff bats were monitored bimonthly at Quitobaquito Pond from April 1994 through February 1995. The following data were recorded for every bat caught: date and time of capture, species, sex, weight, and breeding condition. Numbered metal arm bands were placed on the left forearm of each Underwood's mastiff bat.

During this monitoring period, 9 of the 13 species of bats found at Organ Pipe Cactus National Monument were captured at Quitobaquito. The number of bats captured per night varied by season from 1 bat per night in the winter to approximately 100 bats per night in the summer. Forty-nine Underwood's mastiff bats and 2 western mastiff bats *(E. perotis)* were banded. Three of the 49 Underwood's mastiff bats have been recaptured. There was no apparent trauma to any bat from the arm band. The most frequently caught bat was the pocketed free-tailed bat *(Nyctinomops femorosaccus)*. Data from this bat monitoring period were compared to bat monitoring data collected a decade ago, allowing some indications of long-term trends.

Three families of bats have been recorded at Organ Pipe Cactus National Monument, representing 13 species. They are the leaf-nosed bats (Phyllostomidae), the evening bats (Vespertilionidae), and the free-tail bats (Molossidae).

There have been three species of leaf-nosed bats recorded in Organ Pipe Cactus. They are the lesser-long nosed bat *(Leptonycteris curasoae)*, the Mexican long-tongued bat *(Choeronycteris mexicana)*, and the California leaf-nosed bat *(Macrotus californicus)*. The lesser long-nosed bat and the Mexican long-tongued bat are nectar-feeding bats. The lesser long-nosed bat is federally listed as an endangered species; the state of Arizona lists it among "Wildlife of Special Concern." The third species, the California leaf-nosed bat, is an insectivorous bat. All of these bats are very good fliers with excellent maneuverability.

Six species of evening bats were recorded in Organ Pipe Cactus National Monument. They are the pallid bat, *(Antrozous pallidus)*, the big brown bat *(Eptesicus fuscus)*, the western pipistrelle *(Pipistrellus hesperus)*, the hoary bat *(Lasiuris cinereus)*, the California myotis *(Myotis californicus)*, and the cave myotis *(M. velifer)*. All of these bats are insectivorous. They are broad-winged bats and have excellent maneuverability.

There have been four species of free-tailed bats recorded in Organ Pipe Cactus. They are the pocketed free-tailed bat *(Nyctinomops femorosaccus)*, the Mexican free-tailed bat *(Tadarida brasiliensis)*, the western mastiff bat *(Eumops perotis)*, and Underwood's mastiff bat. They are all insectivorous bats. The Mexican free-tailed bat is the same bat species that is found in great numbers at Carlsbad Caverns, New Mexico, and Braken Cave, Texas.

The free-tailed bats are considered narrow-winged bats. Having narrow wings makes them very strong fliers, and they are able to fly great distances to food or water sources. But they lack the great maneuverability of broad-winged bats. To drink water they need sources with relatively large surface areas.

Mastiff bats are the largest bats in North America north of Mexico. They have a wing span of about 53 cm (21 in) and weigh approximately 65–70 g (2.4 oz). Two species of mastiff bats are found in the southwestern United States, the western mastiff bat, and the Underwood's mastiff bat. The western mastiff bat is the larger and the more common of the two. It has been captured from Texas to California. Underwood's mastiff bat is just slightly smaller and is considered to be one of the rarest and least understood bats in the United States. Its northern limits reach only into the southernmost parts of Arizona.

Little is known about this bat. They are difficult to study because they are so inaccessible. Records indicate that they are few in number. They have the ability to fly great distances to forage. They drink at water sources with large surface areas. Their narrow wings limit their ability to take off from or near the ground. Therefore, they often roost in crevices of high cliff faces, where they can drop into flight.

The first record of an Underwood's mastiff bat captured in the United States was by Baker in 1954. It was caught at an earthen water tank called Garcia's Represso, near Sasabe, Arizona. Between 1954 and 1967, bats were surveyed intermittently at Garcia's Represso. At least 48 Underwood's mastiff bats were captured during that time. This water source no longer exists.

The first known capture of an Underwood's mastiff bat at other than Garcia's Represso was by Petryszyn on 14 September 1979 at Quitobaquito. Between 1979 and 1983, Petryszyn and Cockrum surveyed bats intermittently over Quitobaquito Pond. They recorded weather conditions, date and time of capture, species, sex, breeding condition, forearm length, body weight, ectoparasites, and noteworthy observations.

Beginning in April 1994 and extending through February 1995, Petryszyn again monitored bats at Quitobaquito. Bats were surveyed every other month for two consecutive nights close to the new moon. Mist nets of 36.5 m (120 ft) in length were used to span the width of the pond. The depth of the pond necessitated the use of a small boat to set up the net and to reach the captured bats. The same parameters were measured as were measured in the 1979–83 monitoring period.

To be able to keep track of individual mastiff bats, and ultimately the total number captured, a method was needed for marking them. There are several methods available, but none is without limitations. A relatively reliable method is to use ring bands. They are similar to those used in banding birds. The bands that were used were numbered and made of aluminum. They were placed on the forearm of the bats in such a manner that they slid freely. The use of forearm bands on bats has been practiced for several decades with varying degrees of success. Some species tolerate them better than others. No information, however, is available regarding the use of forearm bands on mastiff bats.

The data for the period of 1994–95 showed that 524 individual bats were captured at Quitobaquito Pond, representing 9 species. In comparison, 13 species have been recorded at Organ Pipe Cactus National Monument, 28 species in Arizona, and 46 species in the continental United States.

The free-tailed bats were the most prevalent bats captured, representing 92% of the total captures. One might be able to predict that the free-tails would use Quitobaquito in large numbers out of their necessity to drink from water sources with large surface areas.

The most frequently captured bat was the pocketed free-tailed bat with a total of 405 captures, 77% of the sample. Females accounted for 72% of the sample, and 28% were males. They were present year-round. Their seasonal activity profile showed low activity in the winter and the greatest activity in the late summer (August); probably due to the influx of their young.

The second-most recorded bat was the Underwood's mastiff bat. Forty-nine individuals were captured and banded, representing 9% of the total number of bats. Females of this species were also more abundant than males, 63% and 37%, respectively. They were present year-round. Their seasonal activity profile showed low activity in winter and the greatest activity in early summer (May–June). It could be reasoned that a larger number of mastiff bats would be captured in late summer due to the influx of their young, as occurred with the pocketed free-tailed bats, but that did not occur.

The Mexican free-tailed bats accounted for 5% of the total bats captured. All were caught during spring or fall. It is probable that they were migrating through the area and breeding elsewhere. Two western mastiff bats were captured, one female and male. Both were banded and released. The evening bats represented 7% of the total bats captured. This was a low number compared to their numbers at other water sources in the monument. Neither of the two myotis bats were captured during this period. However, they have been recorded using Quitobaquito Pond, which brought the total number of bat species recorded at Quitobaquito to 11.

The leaf-nosed bats represented 1% of the total bats captured. The only leaf-nosed bats captured were the insectivorous California leaf-nosed bats. No nectar-feeding bats were captured during this period. Nectar-feeding bats have not been recorded at Quitobaquito. But, it is very possible that they could use the area from time to time, particularly during migration.

The collective seasonal activity of bats at Quitobaquito showed very low activity in winter and high use in summer. As few as 1 bat per night was captured in the winter months and more than 100 bats per night were captured in the summer months. The low winter activity can be explained by the colder night temperatures and the decreased food supply.

One of the most exciting things about these data is that we had data from more than a decade ago with which to compare. Comparing the 1979–83 data with the 1994–95 data, respectively, showed the following: 1) free-tailed bats were the most common family captured at Quitobaquito (78% and 92%), 2) evening bats dropped by the same percent that the free-tails increased (-14% and +14%), 3) leaf-nosed bats remained the same (1% and 1%), 4) pocketed free-tailed bats were still the most common species (63% and 77%), and 5) Underwood's mastiff bat percentage dropped (14% and 9%).

If the collective seasonal activity profiles of the bats of Quitobaquito are compared, they are almost identical. If the collective seasonal activity profiles of the pocketed free-tail bat or the Underwood's mastiff bat are compared with a decade ago, they are almost identical. The same is true if the times of capture of each species are compared to a decade ago; they are almost identical. The data are beginning to reveal behavior patterns of species.

Long-term monitoring can be very effective. Comparing data from two or more periods allows us to look for apparent trends in bat populations. In this case, the two periods, a decade apart, look very similar. We have the ability to look closer and see the subtle changes and trends within and between species. In this case, we don't yet know what these fluctuations mean. We need to continue to monitor bats at Quitobaquito Pond and to analyze the data. But, one day soon, we will be able to see and understand the big picture and what these subtle changes signify. When we can do that, we will have a meaningful tool.

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Lessons from Long-term Monitoring of Saguaro Populations in the Sonoran Desert

Elizabeth A Pierson and Raymond Turner

U.S. Geological Survey, Desert Laboratory, 1675 West Anklam Road, Tucson, AZ 85745

Long-term monitoring spanning multiple decades and a broad geographic range is often necessary to detect the population dynamics of long-lived species across their distributional ranges. We have determined the site-specific age structure of saguaro populations on multiple dates since 1959 at 10 sites across the northern portion of the saguaro's range. Comparisons of saguaro regeneration trends from site to site and census demonstrate the age structures of populations even within the Tucson basin (ca. 1,950 km^2, or 750 mi^2) have varied considerably both spatially and temporally. Although rare, extreme climatic events such as the decadal droughts of the 1890s and the 1950s can produce synchronous troughs in recruitment regionally, other factors, including land use, biotic interactions, and microclimate, apparently have contributed to site-specific differences in age structure. Our data demonstrate that large fluctuations in saguaro demography occur at rates that can only be tracked by long-term monitoring; multiple plots provide the spatial resolution to discriminate the influence of regional climate versus local factors in driving these trends.

Development of Geographic Information Systems to Support Cultural and Natural Resource Management Activities at Organ Pipe Cactus National Monument

Thomas N. Potter,[1] D. Phillip Guertin,[1] Michael R. Kunzmann,[3] and James J. Barnett[1]

[1]Organ Pipe Cactus National Monument, Route 1, Box 100, Ajo, AZ 85321
[2]Advanced Resource Technology Group, School of Renewable Natural Resources, The University of Arizona, Tucson, AZ 85721
[3]U.S. Geological Survey, Cooperative Park Studies Unit, The University of Arizona, Tucson, AZ 85721

A cooperative program was initiated in 1991 between Organ Pipe Cactus National Monument, the Advanced Resource Technology Program at The University of Arizona, and the Cooperative Park Studies Unit to develop geographic information system (GIS) capabilities at the monument. The GIS program began with development of basic layers for topography, transportation, cultural features, soils, vegetation, and geology. Currently, GIS-related technology supports many cultural and natural resource management activities. These applications include 1) development of a GIS database for archeological resources in the monument; 2) development of a desert tortoise *(Gopherus agassizii)* database and an associated habitat map; 3) GIS theme for data collected during night-sky brightness monitoring; 4) the use of global positioning systems (GPS) to map ecological monitoring program (EMP) sites, revegetation sites, bighorn sheep *(Ovis canadensis)* survey locations, ferruginous pygmy-owl *(Glaucidium brasilianum)* locations, abandoned mining lands, wildfire locations, and boundary fences. The scope of the cooperative effort is being expanded to address basic ecological questions and regional environmental problems. (POSTER)

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Multi-park Participation in Historic Preservation Projects at Organ Pipe Cactus National Monument

James Rancier,[1] David Yubeta,[2] and James J. Barnett[3]

[1]*National Park Service, Southern Arizona Group, Park Central Mall, 3115 North 3rd Ave. #101, Phoenix, AZ 85013*
[2]*Tumacacori National Historical Park, P.O. Box 67, Tumacacori, AZ 85460*
[3]*Organ Pipe Cactus National Monument, Route 1, Box 100, Ajo, AZ 85321*

In recent years, Organ Pipe Cactus National Monument hosted several inter-park sharing projects involving historic preservation personnel from a number of National Park Service units in Arizona. These projects provided a mechanism in which the host park and those participating from other areas benefited from a multi-park approach to historic preservation of historic structures, ruins and features. Planning, funding sources, and results of projects will be reviewed and open to discussion. Work at the important historic sites at Dos Lomitas (a.k.a. Blankenship) Ranch, Gachado Line Camp, Victoria Mine, and Jose Sestier's Grave Site at Quitobaquito was accomplished.

Between Desert and Sea: Identifying Hohokam Populations And Settlement Patterns in Western Papagueria

Adrianne Rankin

56 CES/CEVN, 13970 W. Lightning St., Luke Air Force Base, AZ 85309

Archeologists from the Western Archeological and Conservation Center conducted a parkwide survey in Organ Pipe Cactus National Monument between 1989 and 1994. Approximately 3,641 ha (9,000 ac) were surveyed, and 200 archeological sites, spanning the range of time from Early Archaic (ca. 8000 B.C.) hunter and gatherers to Historic (ca. A.D. 1900) Hia C'ed O'odham were recorded. Data from Hohokam period sites (ca. A.D. 300 to 1450) are used to reexamine the culture boundary identified by Ezell's work in the early 1950s. Our survey data indicate greater use of the area by Hohokam during the Classic period (A.D. 1150 to 1400) and a previously unrecognized settlement pattern of large reservoir-based villages strategically located along the trails between the desert and the Sea of Cortez (Gulf of California).

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The Role of Our National Parks Inventory and Monitoring Program: Are We Learning What We Need to Know?

Len Robbins[1] and William L. Halvorson[2]

[1]7610 Upper Applegate Road, Jacksonville, OR 97530
[2]U.S. Geological Survey, Cooperative Park Studies Unit, 125 Biological Sciences East, The University of Arizona, Tucson, AZ 85721

Collecting field data for the purposes of natural resource monitoring in our National Park System has been the primary focus of National Park Service (NPS) Inventory and Monitoring (I&M) programs. The transformation of raw data to usable information, and the final dissemination of that information to policy makers in concise and easy-to-understand terms, is usually accomplished with great difficulty, if at all. To address these problems, today's resource managers must balance the capabilities provided by limited research budgets with the often disparate interests of the end-users of the data. Such end-users often consist of park visitors, policy makers, and commercial entities such as the fishing and tourist industries.

To examine the problem in more concrete terms, the I&M program at Channel Islands National Park is being evaluated as an example of long-term environmental monitoring in the National Park Service. One concern associated with these types of programs is whether they are meeting their stated objectives. The purpose of this current study is therefore to determine how program managers can assess the desired effectiveness of their resource monitoring programs. This study presents one approach for performing such an assessment. This presentation is based upon master's thesis work conducted at the The University of Arizona, which is part of ongoing research to be completed in the fall of 1996.

The Channel Islands National Park I&M program is unique in several ways: 1) it has been in existence for nearly 15 years (one of the longest-running programs of its kind in NPS); 2) it includes information on 12 categories of environmental monitoring, addressing a broad range of terrestrial, intertidal, and aquatic zones; and 3) the data collected from the I&M program help guide not only park resource managers but also play a critical role in interagency policy formation governing commercial fisheries and tourism along the southern California coast. These factors make Channel Islands an excellent case study to track the processes of data collection, data management, and information dissemination throughout the scientific community, as well as through state and federal agencies (including the commercial interests they must either work with or regulate).

This presentation provides an overview of data interpretation and management studies currently in progress on some of the field monitoring data. One of the 12 monitoring categories will be discussed as a specific case study. Kelp forest data are presented as an example of aquatic zone monitoring in the park. This offers challenging insights into the problems facing today's resource managers, who must regularly use interdisciplinary approaches for problem solving to provide relevant and useful information to both agencies and private interests that count on such information to establish realistic and achievable ecosystem management objectives.

To initially assess the output goals of the program, interviews were conducted with a majority of the individuals who work on the program at Channel Islands National Park. It was determined that there was a common thread in the concerns and issues the resource monitors had regarding the output and usefulness of the data they were collecting in the field. The decision was then made to implement a Delphi Survey to more specifically delineate the issues, and to provide a ranking of those issues in relation to each other.

The Delphi Survey consisted of three phases. In the first phase, participants were asked to provide a list of criteria for output from the monitoring program. The responses were then grouped with regard to content and category, and similar responses were combined to eliminate overlap in any output goal category. In the second phase of the survey, the participants reviewed the list of goals that they developed, and were asked to rank the categories of goals by means of a scoring system. Once this was completed, the scores were tallied, and mean scores determined for each output criteria. The criteria with the highest mean score were considered the most important program output goals. In the third phase of the survey (currently in progress), the participants will be given the tallied results for the whole group, and will be asked to review their individual responses in light of the group's overall responses. They will then have the opportunity to revise their individual scores if they so desire. The first two phases of the Delphi Survey have been completed for this project and are discussed in more detail below. Although the third-phase results are not currently available, information collected from the first two phases provides a clear indication of the critical output criteria for the park's inventory and monitoring program.

In the first phase of the survey, the respondents developed a list of criteria that included 12 distinct output goals for the I&M program. Once the list of viable criteria was developed, the respondents then ranked the criteria as described above. Of the 12 output criteria identified by the survey participants, the top 4 in order of importance included 1) determines population dynamics, 2) identifies problem indicators (environmental influences, invader species, etc.), 3) indicates system health, and 4) provides comparative analysis. These output goals can be linked directly to accurately detecting trends in population dynamics of the survey population. The survey results indicate that tracking population dynamics seems to be of paramount importance to the resource monitors as outputs of the I&M program. It is that determination that serves as a basis for further analysis.

The next step in this evaluation included reviewing kelp forest field data to determine if the program can provide sufficient data to achieve the goals as outlined by the survey participants. Analysis of the kelp forest monitoring data was accomplished using the software program MONITOR, a simple and easy-to-use DOS/PC-based program developed by James Gibbs of Yale University. The MONITOR program was specifically designed to evaluate the statistical power of population monitoring programs, and includes review of the monitoring programs with respect to 1) number of plots monitored, 2) magnitude of plots monitored, 3) count variation, 4) plot weighing schemes, 5) duration of monitoring, 6) interval of monitoring, 7) magnitude and nature of ongoing population trends, and 8) the significance level associated with trend detection, as well as several other factors. The MONITOR program is available free of charge on the Internet, web address: ftp://ftp.im.nbs.gov/pub/software/monitor.

To provide a benchmark for data analysis, the output from the MONITOR program was compared to a previous data evaluation report completed in December 1994. The data from the kelp forest monitoring program was reviewed by Ecometrics, an environmental consulting firm specializing in statistical analysis of field data and monitoring programs. In the Ecometrics report, we are given numerous indicators of the usefulness of the data sets analyzed. Parts of that assessment are compared to the results of the MONITOR analysis, and the similarities and differences between the two evaluations are explored. Preliminary analysis of the data using the MONITOR program compared favorably with the Ecometrics report in calculating levels of power to estimate population trends for the kelp *Macrocystis pyrifera*.

The usefulness and limitations of the PC program were reviewed regarding regression analysis, trend variations, and trend coverage. The program's applicability to NPS I&M programs was demonstrated as a tool for resource managers in determining the power of their respective monitoring programs. The MONITOR program, as stated earlier, functions on stand-alone PCs, requires no previous software training, and can easily be operated by resource monitors/mangers in field offices without the support of more complex and costly computer systems. The MONITOR program can play a very cost-effective role in testing the statistical usefulness of new monitoring programs, as well as help managers modify existing programs to better meet their informational needs.

Through identifying the desired output goals of the I&M program at Channel Islands National Park in the Delphi Survey, and by applying statistical analyses (e.g., the MONITOR program) of the collected monitoring data, one can assess the effectiveness of the park's I&M program. This effort serves as an example of how managers can perform program evaluations quickly and cost-effectively, thereby enabling them to modify their programs as needed and allowing them to achieve their program output goals.

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Landscape Patterns in Lizard Ecology Revealed by Line-transect Monitoring Methodology at Organ Pipe Cactus National Monument, Arizona

P. C. Rosen[1] and C. W. Conner[2]

[1]*Department of Ecology and Evolutionary Biology, The University of Arizona, Tucson, AZ 85721*
[2]*Resource Management Division, Organ Pipe Cactus National Monument, Route 1, Box 100, Ajo, AZ 85321*

We designed and implemented a lizard transect monitoring protocol as part of the Ecological Monitoring Program (EMP) at Organ Pipe Cactus National Monument. The methodology is well-suited to desert lizard study, where a landscapewide view is of interest, and when pitfall trap methods are undesirable. Beginning in 1989, we established yearly lizard monitoring using 25 transects on 15 sites, later increased to 31 transects at 18 sites, representative of the monument's varied landscape. Transects were run once per season (spring, summer) at selected core sites (less frequently at other sites), and scored for the daily maximum of observed lizard activity. Although lizard reproduction was tied to precipitation, survivorship was seemingly related to predator abundance and activity. Predator populations also expanded in the wake of good rains, with strong sustained increases documented for most species of endotherms that feed on lizards. Our results suggest that, in this Sonoran Desert study area, lizard population responses are not a simple, direct consequence of rainfall and food availability.

The EMP at Organ Pipe Cactus was established under the Sensitive Ecosystems Program, with study design and research commencing in August 1987. Monitoring protocols were developed for a host of animal groups as well as for climate and vegetation at a series of sites representative of the monument's varied landscape. The primary objective of this study was to develop a more thorough inventory of monument biota, and to establish a continuing monitoring program to track the health or functioning of the ecosystem. The herpetology project, conducted by Charles H. Lowe and Philip C. Rosen (Rosen and Lowe 1996) established a monitoring protocol for diurnal lizards, with the most abundant taxa, whiptail lizards (western whiptail, *Cnemidophorus tigris*; canyon spotted whiptail, *C. burti*), as the primary "index," or "indicator," species. The lizard line-transect methodology was turned over to the Resource Management Divison at the monument for implementation starting in 1991, following extensive interaction between Rosen and monument Biological Science Technician Charles Conner. This report briefly describes the method and summarizes results for the first seven years of monitoring.

The lizard line-transect method is based on permanently established study lines marked with metal-tagged rebar at origin, terminus, and at 50-m (164 ft) intervals along the transect course. Transects are 100–300 m (328–985 ft) long. Starting early on warm, clear mornings during seasonal maxima of lizard activity (mid-April to late May for spring; July–August, dependent on onset of rainfall, for summer), each transect is walked along the midline repeatedly over the course of diurnal heating of the environment. During each transit across the transect, all lizards observed within 7.5 m (25 ft) on either side of the line are recorded. For each species, activity is initially low, increasing as optimal environmental temperatures are reached, and decreasing again as temperature preferenda or tolerances are exceeded. A "peak value" is thus recorded for each species on the transect on a given day. The peak value is simply the greatest number of individuals recorded during a single transit across the transect. This value, converted to "lizards/100 m," is the estimator for lizard abundance. Detailed conditions governing actions of the transect worker are spelled out in a formal monitoring protocol document that is available to interested parties.

Climate during the study was monitored at a series of automated weather stations at several EMP sites, and supplemented by a series of Forester rain gauges that were read by hand. The study period, 1987–95, included much of the hottest weather on record for the desert Southwest, including all-time high temperatures in June 1990. A preceding period, 1977–84, was one of exceptionally strong rainfall, both winter and summer. The years 1985–88 were of average rainfall, but were followed by a marked drought from November 1988 to 5 July 1990. Subsequent to the drought-breaking strong summer rains of 1990, winter rainfall has been strong in all but one of the years, as a consequence of a strong, persistent El Niño-Southern Oscillation event. During this period, summer rains were average or somewhat below average;

yearly rainfall was thus generally above average.

The change in overall lizard abundance showed a direct positive relationship to rainfall in the preceding season. In general, lizard abundance declined during the drought of 1989–90, increased steeply in response to drought-breaking rains in summer 1990, and immediately following strong winter rains, and then levelled off and declined, starting especially during the very wet spring of 1993. The estimates for lizard abundance increased to a maximum of slightly less than three times the drought minimum. Despite the strong rains, and in spite of evidence for successful reproduction by lizards throughout much of the time span, lizard populations in 1994–95 were generally equal to or less than those observed in 1989. Understanding a paradox of this kind poses a fundamental problem for the interpretation of biological monitoring data.

Individual species showed distinctive patterns of population response. The whiptails generally followed the pattern described for lizards overall. However, they showed the largest fluctuations, as well as the highest population levels throughout the study period, in floodplain habitat on the valley floor. Their observed populations were least dense in rock habitat, and intermediate on bajadas. The side-blotched lizard *(Uta stansburiana)* showed a markedly divergent population pattern. Its abundance oscillated from minima during the winter–spring reproductive season to maxima in summer, with large numbers of subadults observed. Nonetheless, year-to-year trends were apparent within the context of this oscillation: side-blotched lizards increased during the drought and decreased during the wettest period. The species was most abundant in the rocks, and much less abundant in valley floor floodplains, especially so during the whiptail lizard population boom. Side-blotched lizards were, in short, abundant when and where whiptails were not; it is possible that predation by whiptails may directly affect this small lizard.

Other lizard species frequently observed on the transects were the tree lizard *(Urosaurus ornatus)*, the spiny lizards *(Sceloporus magister, S. clarkii)*, and the zebra-tailed lizard *(Callisaurus draconoides)*. All three showed increases in spring 1991 to spring 1993 and decreased subsequently to lowered abundances. The tree lizard, which reproduces during the summer rains, reached its lowest observed population levels in 1995, apparently in part because the strongest rains in preceding years were winter rains. In summary, none of the individual species showed perfect correlations of population to rainfall—population growth was strongest just after the drought, and failed to increase substantially thereafter, even in response to strong winter rains and modest summer rains.

We obtained a complete data set on predators observed by a single observer (Rosen) during herpetological work in the monument in 1987–95. For endothermic predators, including coyotes *(Canis latrans)*, foxes, buteos, owls, and the roadrunner *(Geococcyx californianus)*, American kestrel *(Falco sparverius)*, and loggerhead shrike *(Lanius ludovicianus)*, there was a marked decline in observed abundance during 1988–90 to about 0.5 observed per day, followed by a steady increase to a plateau of about 1.7 per day in 1993–95. Species showing especially marked increases included roadrunners, shrikes, coyotes, and buteos (redtailed and Harris hawks, *Buteo jamaicensis, Parabuteo unicinctus*), all of which are known to feed on lizards frequently. In 1993, we observed three instances of kestrels carrying adult lizards in a single day. We offer the hypothesis that various predators play a major role in setting lizard population levels.

It has rarely been possible to sustain studies of lizard population ecology for several years, such as we already have in connection with the EMP. Further, no published study of lizard ecology has presented as thorough an accounting of the fluctuation of predation pressure as is possible in this work. This is a pattern repeated frequently in ecology—the sustainability needed to understand population and community processes has rarely been possible in vertebrate studies. Many classic studies have relied on vertebrates harvested by humans for their pelts or as food. Therefore, in addition to presenting this early stage of our study as an example of a successful monitoring protocol, we offer it as a formal program for a synergy between basic research and applied monitoring, as follows:

1. Observe the ecosystem empirically.
2. Form hypotheses about causes and forces underlying the observed patterns.
3. Test these hypotheses about causes of population fluctuations against:
    a. accumulating monitoring data, and,
    b. observed details of population dynamic processes (such as growth, reproduction, age structure, and incidence of mortality).

The application of this research program can offer assistance in interpretation of monitoring results, in the applied sense, as well as permitting the coexistence of ecosystems research at a level not heretofore possible with wild vertebrate species.

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Ecology and Management of the Sonoran Mud Turtle at Quitobaquito Springs, Organ Pipe Cactus National Monument, Arizona

P. C. Rosen and C. H. Lowe

Department of Ecology and Evolutionary Biology, The University of Arizona, Tucson, AZ 85721

The Sonoran mud turtle *(Kinosternon sonoriense)* population at Quitobaquito was studied using primarily mark-recapture methods during 1982–95. During the 1980s, an apparently ongoing decline reached a minimum estimated at 68 individuals in 1989. Juvenile survivorship was apparently low, and there was little recruitment into the adult population. In addition, dead turtles were recorded on 22 occasions at Quitobaquito. Chemical analysis revealed no "smoking gun" toxicant, although some suspect concentrations were observed. Storage lipids were low, consistent with a resource limitation hypothesis. It appeared that competition with desert pupfish *(Cyprinodon macularius eremus)* may have been responsible for nutritional deficiency in the turtles, leading to some of the observed mortality. Juvenile habitat for turtles was created through management action in winter 1989–90. Subsequent sampling revealed a marked increase in the juvenile population, and a generalized population increase to an estimated 134 individuals in 1993. A life table analysis also projected an increasing population, and identified varying juvenile survivorship as the key parameter influencing population trajectory in the Quitobaquito population.

The Sonoran mud turtle occurs at a southwestern, arid-range margin at Quitobaquito oasis, Organ Pipe Cactus National Monument, where it shares the only refuge for the endangered Quitobaquito desert pupfish. The mud turtle is represented as a local subspecies *(K. s. longifemorale)*, occurring only in the adjacent Río Sonoyta, Mexico. Herpetologists have studied mud turtles at least as far back as 1955, when a pair of yellow mud turtles *(K. flavescens)* was collected there, the only record of that species in the Río Sonoyta valley. Lowe first visited the site in the early 1950s, when turtles were probably significantly more abundant than at present.

Management of Quitobaquito waters has posed a series of challenges from the late 1950s, leading to a deepening of the pond by bulldozer, and elimination of shallow-water habitat in 1959. Park Naturalist Scotty Steenbergh subsequently reported an impression of marked reduction in the number of turtles, at the time of a second draining and refurbishing of the pond, this one in 1969 to remove introduced minnows. Fred Gehlbach and Arthur Hulse independently studied Sonoran mud turtles at Quitobaquito in the early 1970s, and both reported observing moderate turtle abundance. Gehlbach estimated the population to number somewhere in the neighborhood of 143 individuals. By 1982, it appeared that the mud turtle population was in decline, and a mark-recapture study was initiated by National Park Service (NPS) researchers Peter Bennett and Mike Kunzmann, and turned over to Rosen in 1983–85 in conjunction with his comparative life history study of the species. Rosen's final report to NPS concluded that there were about 108 individuals present, and that population instability and decline was indicated by population structure. It was recommended that additional juvenile habitat be created.

Other herpetologists trapped and observed mud turtles at Quitobaquito during the early 1980s, including John Iverson and his associates. It was discovered that amateur reptile-fanciers had also visited the site, without permission, and collected at least 2 turtles as pets. Turtles were also reportedly removed *en masse* as pets during the 1969 pond draining. Under the Sensitive Ecosystems Program (now the Ecological Monitoring Program) at Organ Pipe Cactus National Monument, a recensus of the population was conducted in 1989. This census confirmed continuing population decline by continued failure of recruits to survive to maturity, despite the presence of numerous hatchlings and small juveniles in most population samples.

Rosen observed that juveniles of this species, as in many other turtle species, select heavily vegetated, often shallow areas where they may find high productivity and, especially, cover from predators. Many predators, ranging from the size of the belted kingfisher *(Megaceryle alcyon)* to the great blue heron *(Ardea herodias)*, are capable of eating mud turtles up to at least age two years. These and other potential predators were observed with great frequency at Quitobaquito, as well as at certain other desert waters, posing an apparent risk to juveniles in the absence of suitable shallow water and cover at Quitobaquito.

In the winter of 1989–90, the NPS created and improved habitat for juvenile mud turtles, in part for the turtles and also for the benefit of the pupfish, although the pupfish were and remain thriving at population levels of about 5,000 individuals (15,000/ha; 37,000/ac). Water from the spring sources, previously piped over 150 m (490 ft), was put into a concrete channel molded to resemble desert ciénega streams, such as Tule Creek, Yavapai County, Arizona, that are known to support a large number of Sonoran mud turtles. This newly constructed channel rapidly developed a complex vegetation structure of submergent, emergent, and bankside vegetation that appeared suitable for juvenile turtles. Large numbers of pupfish were observed in the channel, also apparently thriving.

With continued NPS support and added funding from the Arizona Game and Fish Department Heritage Fund, an intensive recensus was conducted during 1993 by the authors, and supplemental data were systematically and opportunistically collected by monument resource management personnel during 1990–95. This continued censusing led to refined population estimates, a life table for the population, and evidence of enhanced juvenile survival. Our estimates indicate about 134 individuals in the population in 1993, up from a minimum estimated at 68 in 1989. Large numbers of hatchling and juvenile turtles were recorded in the channel, and for the first time since 1982, successful entry of recruits into the adult population was recorded. The proportion of juveniles in the population was higher than at any prior time during our study. Recruitment had previously varied from year to year at Quitobaquito, as may be expected for an aquatic turtle at an arid, hot range margin, so we must interpret the evidence for population recovery with caution. However, the currently observed trend suggests that population recovery may be underway. Further population censuses are required to confirm or deny this trend.

The life table was constructed using the best available estimates for all of the relevant parameters (survivorship, clutch size and frequency, age at maturity, sex ratio at hatching). The result yielded a generation time of 12 years, and net replacement rate R_0 = 1.6, indicating a population growing at the rate of 60% per generation. Sensitivity analysis of the life table, employing parameter variation in the ranges indicated by the observed variability and uncertainty of the various estimates tended to confirm a stable, and probably growing, population. The strongest negative effect on R_0 was caused by varying juvenile survivorship to mimic conditions observed in the mid-1980s.

All told, during our 14 years of study, sampling was conducted for a total of 74 days of trapping, totaling 1,099 trap-days with hoop nets plus 470 trap-days with modified minnow traps used for hatchlings and juveniles. Additional records were obtained by hand capture, visual observation, reports from other field personnel, and radiotelemetry, for a total of 560 turtle records, including 273 recaptures of marked turtles. Specific values for life history of the turtles are as follows: annual adult female survivorship at Quitobaquito was estimated at 85.5%, somewhat below most previous reports for this species. Male survivorship was higher at about 90%, and the sex ratio was nearly 2:1 in favor of males, with the survivorship difference possibly explaining most of this imbalance. Juvenile survivorship was lower, increasing gradually to adult levels. Egg survivorship appeared to be high and was estimated at 85–90%; eggs of this species are known to hatch about a year after laying, and have embryonic diapause. Sex determination depends upon incubation temperatures at a critical period (it is likely that females are produced by warm temperatures in the spring prior to hatching). This might also contribute to the sex ratio anomaly. Clutch size averaged 4.0 eggs (n=3 clutches observed). Clutch frequency was estimated at 1.5 clutches/year/female, which is rather low for this species. Females first produce a clutch at just under six years of age. Males mature at age four years, probably as a function of size rather than age. Growth is moderate in early life, and slows abruptly at maturity.

A substantial number of mud turtle carcasses (n = 22) were recovered at Quitobaquito during the study period, many of which displayed no sign of injury. Chemical analysis was conducted in collaboration with, and utilizing funding from, the U.S. Fish and Wildlife Service. Water and sediment quality analyses for Quitobaquito, and chemical composition of 8 turtle carcasses that were recovered relatively fresh, yielded no convincing evidence to sustain an ecotoxicological hypothesis involving organochlorine pesticides or heavy metals. Low levels of DDT metabolites were confirmed in 4 of the carcasses, and certain elemental metals were present at elevated levels. Present data on turtles in general are insufficient to evaluate the potential intoxicant effects of the observed elemental levels. Furthermore, the organochlorine results must be regarded with care, since the storage lipids (fat pads), where such potentially toxic residues would reside, were scarce in the turtles, making detection difficult, while not necessarily reducing the potential for harm. Water and sediment had modestly elevated arsenic levels, but the carcasses did not contain arsenic concentrations likely to be toxic. We should remain vigilant about possible contamination or natural toxicity at Quitobaquito. The carcasses all had remarkably low levels of stored fat, and it appears that the turtles are undernourished, and are feeding heavily on plants, a non-preferred food. Sonoran mud turtles are inefficient at capturing fishes, although they show strong preference for fish as food when it becomes available.

Aquatic invertebrate availability as food for mud turtles at Quitobaquito was apparently in short supply. There are experimental data in the literature showing that the density of pupfish at Quitobaquito would be expected to have a marked depressant effect on aquatic invertebrate density. We have comparative data from a series of Sonoran mud turtle populations in Arizona strongly indicative of food resource limitation on growth rate and reproductive output. Thus, it appears that the great success of the desert pupfish at Quitobaquito results in depressed food availability for the turtles, and thereby may contribute to the unusual mortality observed. Since pupfish are indigenous, and may well have reached such high densities here and elsewhere prior to their widespread extirpation, the observed turtle mortality at Quitobaquito may be a relatively natural, rather than strictly anthropogenic, phenomenon. Competition between fish and turtles has not previously been reported, although it is probably both frequent and important.

Recommendations are for 1) research and monitoring to confirm or revise the observed population trends and life history trait estimates, 2) more detailed study of nesting in another desert population of the Sonoran mud turtle, 3) vigilance against the appearance of vertebrate mortality or chemical toxicity at Quitobaquito, and 4) international collaboration in a study of the Río Sonoyta mud turtle in Río Sonoyta, Sonora.

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Vegetation Change at Montezuma Castle National Monument

Peter G. Rowlands

U.S. Geological Survey, Mountain Ecosystem Section, PO. Box 5614, Northern Arizona University, Flagstaff, AZ 86011

Montezuma Castle National Monument is a small (341 ha, or 842 ac) National Park Service unit located in central Arizona below the Mogollon Rim. The monument proper, a 20-room cliff dwelling, was established in 1906 under the authority of the Antiquities Act. In 1937, lands directly adjacent were added. Prior to this, these adjacent lands were heavily grazed and farmed, especially in the mesquite-studded floodplain of Beaver Creek, which bisects the unit. Other developments within the unit related to park operations have also created areas where the vegetation has been disturbed and the surface soil either removed or severely altered. These have included the removal, in 1981–82, of a small primary sewage treatment facility and its replacement with a new one in a different location and the removal and rehabilitation, in 1975, of the original entrance road. As a result, there is an opportunity here to observe the patterns of vegetational change and development after disturbance and especially the role played by nonnative plant species. Change in mesquite bottomlands and adjacent areas over almost 50 years was documented by means of repeat ground photography. Vegetation recovery on the abandoned entrance road was documented through a quantitative vegetation field study involving adjacent comparison sites. Implications for park management are discussed.

Plant Community Response after Fire in the Sonoran Desert

Susan Rutman

Organ Pipe Cactus National Monument, Route 1, Box 100, Ajo, AZ 85321

In 1983, the Gachado West fire burned 12 ha (30 ac) of a *Larrea tridentata-Atriplex polycarpa-Atriplex linearis* stand near the southern boundary of Organ Pipe Cactus National Monument. Permanent photo-points were established immediately after the fire. Photos have been taken from these points at least annually since 1983. In 1995, plant density and percent cover were measured along permanent transects within the burned area and in adjacent unburned vegetation. Plant density and percent cover dropped substantially after the fire. Survival of *Atriplex polycarpa* varied throughout the site; in places the species was lost completely, while in other places skipped or resprouted plants are common. Recruitment of *A. polycarpa* has been highest near reproductive female plants and also has been affected by site micro-topography. Percent fire mortality of *A. linearis* was very high, but recruitment has been relatively fast where seed sources are present. Some plants of *Larrea tridentata* survived and resprouted in areas where fire intensity was not high. Recruitment of this species has been slow and episodic. Recovery of all species was affected by past land uses. The different rates of recovery of each species indicate that restoration of community structure, function, and diversity will take many decades or centuries, if it is even possible. The effect of historic human use on fire hazard, fire behavior, and future fire frequency are discussed.

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Topics, Tips, and Techniques: The Role of Interpretation in Preventing Destruction of Cultural Resources on Federal Lands

Jan Ryan

Tonto National Monument, HC02, Box 4602, Roosevelt, AZ 85545

Introduction

In October 1979, Congress passed the Archaeological Resources Protection Act (ARPA). The intent was to reduce the destruction of cultural resources on federal lands across the country. However, merely having a law on the books proved inadequate. Though several cases were brought to trial under ARPA, which provided far stiffer penalties than the outdated Antiquities Act of 1906, looting and vandalism continued. It became clear that a tool with more power in the long run would have to be employed: education.

In 1988, ARPA was amended to toughen it. A provision was added, directing each federal land manager to establish a program to increase public awareness of the significance of archeological resources located on public lands and the need to protect them. This provision was the catalyst for development of a project that I began in 1990, with support provided by the Division of Park Historic Preservation, in the former Western Regional Office of the National Park Service.

Research Design

Beginning with a Scope of Work statement, I outlined the current legislation affecting cultural resource protection, the need for public awareness and involvement, a project proposal, and the subsequent benefits of the project. Over a period of four months, I contacted hundreds of personnel from land management agencies (National Park Service, Bureau of Land Management, U.S. Forest Service, U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, and state and local parks), museums, and educational institutions for whom cultural resource protection and interpretation/education were a primary role in their jobs. Via telephone and personal interviews and a four-page questionnaire, I received responses to the following questions:

1. What cultural resource protection problems is your area experiencing?
2. What specific interpretive strategies and techniques are you using to combat the problems?
3. What other ideas do you have for interpretation of cultural resource preservation?

I received over 100 responses to the questions, many with multiple ideas and further networks of helpful contributors. From this information, I compiled the final product of the research effort: a handbook of ideas for field interpreters to use in developing programs, exhibits, special events, publications, and the like. The book, titled *Preventing Cultural Resources Destruction: Taking Action Through Interpretation*, was published by the National Park Service in 1992 and distributed servicewide, as well as to those who participated in the research.

The book begins with a brief history of archeological protection in the United States. Ideas are proposed for discouraging vandalistic behavior, for promoting understanding by other cultures, for assisting with enforcement, and for establishing site monitoring programs. One section explains the ARPA exclusion to the Freedom of Information Act, which states that site information may not be made available to the public when doing so might lead to its destruction. The heart of the handbook presents dozens of innovative and field-tested interpretive methods of preventing cultural resource loss due to vandalism and looting. Following is a sampling.

Special Events

Many states sponsor a special "Archeology Week," "Historic Preservation Month," or similar program. Public education is the focus, providing an opportunity to offer special tours, exhibits, demonstrations, film festivals, and lectures. State and county fairs and other special events such as "National Park Week" also give a chance to enlighten the public about preservation issues.

Interpretive Talks

Resource protection messages are desirable in interpretive presentations. A program focused entirely on cultural resource protection needs to avoid becoming a heavy-handed lecture. But, delivered with just the right dose of fact and feeling, the impact can be phenomenal and the long-term benefit measurable. Walks, talks, tours, demonstrations, and participatory activities can all aim toward instilling a sense of stewardship in visitors.

Possibilities for off-site presentations are limitless: schools; service organizations like Lion's Club, Kiwanis, Rotary, Optimist, YMCA, and YWCA; youth groups such as Campfire, Boy Scouts, Girl Scouts, 4-H; amateur archeological or historical societies and re-enactment groups; outdoor organizations such as 4-wheel-drive enthusiasts and shooting clubs; church and synagog groups; Parent Teacher Associations and other education-oriented affiliates; recreational vehicle parks and retirement centers; local chapters of the Sierra Club, Audubon Society, and other environmental organizations. All of these and more welcome outside speakers and would enjoy a program about cultural resource protection. Interpreters can sign up for a community speaker's bureau; organizations frequently contact the bureau for programs. Interpreters are also encouraged to join some of these organizations to become better aware of area issues and concerns.

The Media

Opportunities exist to inform the public about cultural resource degradation and possible solutions via news media: small town newspapers frequently need news fillers and are appreciative if someone else can write them; many parks produce a visitor newspaper that could feature a section about cultural resource degradation; talented writers can approach larger regional and national markets with articles; local radio or television talk shows might be interested in a segment; sometimes a spokesperson, well-known either nationally or locally, will donate time to be featured in a public service announcement.

Education Programs

Successful education programs about archeology and cultural resource protection abound nationwide, and more are being developed. Videos, slide programs, activity booklets, teacher's guides, and whole curricula are available. *Preventing Cultural Resources Destruction* details several; consulting various state and federal agencies, institutions, schools, archeological societies, and museums will reveal even more.

Educational programs range from pre-school to senior citizens. Some are classroom oriented; others involve field work. All encourage participation.

Signing

Often signs are the only method of communicating with the public, especially in remote areas where no personnel can be regularly stationed. Text, imagery, and overall content need to be carefully designed to avoid harsh warnings or a long list of "don'ts" that tend to irritate the public. Interpretive messages explaining the need for treading lightly in cultural sites should accompany the regulatory wording. Examples of sensitively written signs are illustrated in *Preventing Cultural Resources Destruction.* Enlisting the help of affiliated Native Americans or other cultural descendants can add extra emphasis and power to the message.

Simple signs warning visitors of situations that have nothing to do with the resource being protected often work as deterrents. Most people will gladly avoid an area signed for abundance of poison ivy, rattlesnakes, or other hazards.

Temporary signs or posters can be installed in bulletin boards at campgrounds, picnic areas, or visitor centers. Messages about preservation have been successfully placed in restrooms as well. Additionally, any time the agency is performing what appears to the public to be destructive work at or near a cultural site, a temporary sign to explain the situation is essential.

Exhibits

Temporary displays can be created to occupy wall or floor space. Several parks have installed exhibits using artifacts, tools, and other evidence seized from site looting, with a message to help halt this behavior. Showing the destruction of objects and loss of their aesthetic and scientific value can have quite an impact on visitors.

Popular with both children and adults are "Please Touch" boxes or tables. Cultural items (uncatalogued items without provenance) can be displayed for visitors to pick up, observe, and learn about their usage. To discourage visitors from collecting on their own, a short message should accompany the display.

Off-site temporary displays are often welcomed at local banks, chambers of commerce, libraries, and other public buildings.

Brochures and Site Bulletins

Dozens of brochures, produced by federal, state, and local agencies, and various institutions and archeology societies, are available for distribution to visitors. These are generic handouts, often in full color on slick stock, promoting cultural resource protection. Many parks have developed site-specific bulletins addressing the issue. Examples are given in *Preventing Cultural Resources Destruction.* One area developed a site bulletin explaining how to care for family heirlooms, with a message that preserving these pieces of the past is important for both privately and publicly owned objects. Interpreters with a bit of imagination and creativity can design excellent handouts; distribution can be far beyond the visitor center desk, such as local tourist centers, other area attractions, chambers of commerce, and local businesses that cater to park visitors.

Sales Items

Cooperating associations frequently sell reproduction items such as war period insignia, belt buckles, bullets, toys, tools, petroglyphs, projectile points, and pottery. Buyers need to be extremely careful that these items are truly replicas and not originals, and labels should be developed both for the display and for the individually packaged unit that indicate the item is a replica.

Modern objects, such as Native American pottery or rugs, should also be clearly labelled as contemporary, not historic or prehistoric. Visitors should never have the impression we are selling objects collected from cultural sites.

Many books that appear to be merely identification guides to cultural objects do in fact encourage collection by identifying locations and giving current values. During the review process for cooperating association sales, these books need to be eliminated as potential sales items.

To the extent possible, concession operations should also be monitored to ensure they are not selling original historic or prehistoric items, that they are correctly labelling the sales items, and that sales literature is not promoting collection.

Children

The opinions and values developed during childhood will remain throughout life. Therefore, interpreters should pay special attention to encouraging cultural resource stewardship at an early age.

Hundreds of children's programs and interpretive tools have been developed for K–12; many correspond to existing school curricula. Some are brief activities to be performed while visiting the site; others involve intensive off-site time commitments. Though preservation messages will probably be lost on younger children, participatory activities involving history and prehistory can captivate them and prepare them for future activities that are more preservation-oriented. Games, songs, playing with replica toys and tools, and making baskets or pottery are memorable ways for children to enjoy the park or to learn in the classroom setting. As they mature, children can be introduced to more complex issues and ideas. Many examples of education programs are listed in *Preventing Cultural Resources Destruction.* Some are available to purchase; others are free for use.

Activity booklets can be developed for children to use on site, often accompanying a Junior Ranger Program. Most of these programs emphasize natural history, but a cultural component could be added, or the entire program could focus on cultural aspects. Children like rewards, so a badge, pin, patch, or certificate of completion is desirable to give out upon completion of the booklet or set of activities.

Many museums have special children's exhibits, which can be an effective tool for gaining understanding and appreciation of cultural resources. They should be activity-oriented and destruction-proof. Interpreters should visit area museums to see what is being done with children's exhibits.

Training

Though training on cultural resource protection is limited, courses are available periodically through the NPS or other agencies. When on-site training is given to seasonals or new employees, cultural resource protection should be addressed. It is essential to educate our own employees, especially those who will be dealing with activities that could affect cultural sites. The maintenance staff should all be trained in how to detect sites and what to do when they encounter sites during disruptive maintenance activities. All employees should be instructed in how to deal with visitors who find sites or bring in artifacts.

Conclusion

Cultural resource destruction has escalated in the latter half of the 20th century. Laws and penalties alone do not eradicate the problem. Only through long-term educational commitments can we expect to change the attitudes and values of the public, so that they can understand and appreciate our rich cultural heritage, and become stewards in helping to preserve it.

This paper very briefly describes the contents and purpose of the handbook *Preventing Cultural Resources Destruction: Taking Action Through Interpretation.* Far more detail, descriptions, and examples are given in the book itself. Although copies of the original (1992) printing are no longer available, a new printing with revisions is to be accomplished in fiscal year 1996. For more information, or to be placed on a list to receive a copy, contact Jan Ryan, Tonto National Monument, HC02, Box 4602, Roosevelt, AZ, 85545; call (520) 467-2241; or cc:mail to Jan Ryan at NP-SOAR.

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Ecology of Feral and Africanized Honey Bees in Organ Pipe Cactus National Monument

Justin O. Schmidt and John F. Edwards

U.S. Department of Agriculture, Agricultural Research Service, Carl Hayden Bee Research Center, 2000 E. Allen Road, Tucson, AZ 85719

Tropical and subtropical ecosystems rest on a foundation of floral pollinators. Without pollinators, such as bees, wasps, moths, flies, beetles, birds, bats, and butterflies, and the multitude of special relationships between these pollinators and plants, modern plant communities could not exist. Rather, they probably would resemble those simple prehistoric communities present many millions of years ago (Buchmann and Nabhan 1996). Plant communities and pollinators have evolved over the years to the point that many species of plants are entirely dependent on pollinators; and virtually all pollinators need flowers for survival. Any major disturbance of either the plant community or the pollinators can result in a decline, perhaps catastrophically, of the other group, with a possible cascading effect reaching to the animals dependent upon the plants directly for food, or indirectly by supporting prey.

Pollinators can be classified into two broad general categories: specialists and generalists. Specialists are adapted in structure, behavior, and periods of activity to exploit efficiently one, or a few, species of flowering plants. Often a plant is also highly dependent on its specialist pollinators to be fertilized and set seed. Generalist pollinators visit a wide variety of flowers and usually are not dependent on any one species for their success. Generalist pollinators, like specialists, typically pollinate the flowers they visit, but they usually are not as efficient as specialists, and sometimes simply rob the floral nectar without pollinating the flower.

Honey bees *(Apis mellifera)* are the ultimate of generalist pollinators. In a sense, they are the "pollen pigs" or "honey hogs" of the pollinator world. They efficiently exploit much of the floral resources, sometimes to the serious detriment of other pollinators, and can even affect the density and diversity of plant species in the environment (Matheson et al. 1996; Sugden et al. 1996). Honey bees are native to Africa and Western Eurasia. Historically, Organ Pipe Cactus National Monument was a complex of subtropical thorn-scrub and other communities that was pollinated primarily by specialist pollinators. Honey bees first arrived in the environment a few hundred years ago with colonizing Europeans, who brought with them their honey bees. These bees escaped and became feral throughout most of the New World, including southern Arizona. The effect of these feral European honey bees on the monument is unknown because they arrived before any floral surveys were conducted. There is also uncertainty about their impact because European honey bees do not seem to develop populous and abundant colonies in the harsh climate of the monument. In 1956, a new population of vigorous tropically adapted honey bees, called Africanized honey bees, were brought into Brazil, and began moving northward (Goncalves 1974). Africanized bees arrived in Texas in 1990 (Sugden and Williams 1990; Rubink et al. 1996) and were expected shortly thereafter in Arizona, including Organ Pipe Cactus National Monument. These bees are much more vigorous competitors in tropical climates than their feral European cousins and might adapt better to the climate of Organ Pipe Cactus. If such a postulation is correct, arriving Africanized bees could potentially damage the plant and animal communities of the monument by outcompeting native specialist pollinators and causing their serious decline or extinction (Sugden et al. 1996). This might induce a cascade with the loss of specialist plants in the monument.

The purpose of this long-range investigation was to determine the density and reproductive biology of feral European honey bees in the monument over a variety of climatic conditions ranging from very wet to very dry years and to compare the biology of the feral honey bees in the monument with that of Africanized bees after their arrival. A further goal of this study was to provide a window to view the phenomenon of population replacement as Africanized bees moved into the area and possibly replaced the existing feral European population. The final goal was to determine if the densities of Africanized bees would increase sufficiently to potentially disrupt the current plant-pollinator relationships and adversely affect some species in the monument.

Feral bee populations were surveyed using swarm traps baited with synthetic Nasonov pheromone (Schmidt et al. 1989). The swarm traps were cavities constructed of wood pulp and designed to simulate hollow trees. Nasonov pheromone is used by honey bees during reproductive or absconding swarming and, in the case of swarm traps, served to attract swarms in the area into the trap (Schmidt 1993). From 1988 through 1994, fifty swarm traps, each placed in the partial shade of a tree at a height of 1–3 m above ground, were positioned in locations along the Puerto Blanco drive, including near Quitobaquito Springs, the Senita Basin road, the Ajo Mountain drive, and around the residential and sewage treatment pond areas. Thirty traps were placed in xeric areas that contained no permanent or temporary water, 12 were placed in riparian areas that were near water and contained more lush vegetation, and 8 were placed around residential areas that were xeric in terms of plant community, but contained man-made sources of water and nest sites. The traps were checked several times a year, typically in winter before the normal swarming season commenced, and later in the summer after the main swarming season. During each survey, traps were checked for the presence or absence of bees as determined by opening the swarm trap and for the presence of honey comb, which was scored as evidence of a swarm that had inhabited the trap but had died or absconded. Fresh pheromone lures were also placed in the traps during the surveys. Starting in 1993, samples of bees from each attracted swarm were collected in alcohol and later analyzed morphometrically according to the methods of Daly and Balling (1978) to determine if they were Africanized or European.

Some traps were lost or destroyed between surveys. The final number of recovered traps were 50 in 1988, 1990, and 1994; 49 in 1991 and 1993; 47 in 1989; and 46 in 1992. These small reductions in numbers had little overall effect on the results, other than to change some percentage values in the data. Only European bees existed in the monument until 1994, when Africanized bees arrived. Overall, the number of swarms generated was highly dependent upon the yearly rainfall pattern. Years were categorized as severe drought (<40% normal rainfall, 1990); dry (<80% normal rainfall, 1989); normal (80–120% normal rainfall, 1988, 1994); wet (>120% normal rainfall, 1993); very wet (>140% normal rainfall, 1991); and extremely wet (>160% normal rainfall, 1992). During the normal-to-dry years of 1988–90, insufficient floral resources were available in most areas for good reproduction by European bees. Only 19 swarms were attracted during those three years for an average trap attractancy rate of 13%. However, within the different habitats dramatic differences were observed: 16 swarms (44% occupancy) were in traps in riparian areas, whereas only 2 were in traps in xeric areas (2% occupancy) and 1 was in a residential area (4% occupancy). These results indicate that during normal and dry years feral European bees are under such stress that only those colonies in riparian areas are able to obtain sufficient floral resources to grow and reproduce by swarming. Thus, the riparian areas are somewhat shielded from the effects of rainfall and act as refugia for the bees.

During the wet years of 1991–93, the feral European bee population exhibited a dramatically different swarming pattern. During these years, a total of 87 swarms were attracted, including 26 in riparian areas (72% occupancy), 51 in xeric areas (56% occupancy), and 10 in residential areas (42% occupancy). The occupancy rates for the different areas were not significantly different (chi-squared test). Evidently, during these years, enough floral resources were available in all areas for resident feral colonies to expand in population and to reproduce. The advantage of being in a riparian area all but disappeared. Comparisons between dry-normal years and wet years revealed several interesting differences: 1) overall swarming was dramatically reduced during dry-normal years (19 vs 87 swarms); 2) swarming essentially ceased during dry-normal years in xeric and residential areas (3 vs 61, $P < .001$, chi-squared test); 3) swarming did not significantly decrease in riparian areas during dry-normal years (16 vs 26, $P = ns$).

During 1994, the last year of the study, 10 swarms were attracted to traps in riparian areas (83% occupancy), 19 to traps in xeric areas (63% occupancy) and 7 to traps in residential areas (88% occupancy). This year received normal rainfall, but followed three wet years. This was also the first year Africanized bees were detected in the monument. The swarming pattern appeared more like that of a wet year than a dry-normal year. Possible reasons for this are 1) the previous years provided sufficiently abundant resources that some carryover occurred; and 2) Africanized bees are capable of swarming more efficiently during normal-to-poor periods than European bees. Unfortunately, because we were requested to terminate the research in late 1994, we were unable to determine the relative importance of the factors. We were able to document during 1994 some information relating to the pattern of migration of Africanized bees into the monument. Overall, 38% of the swarms were Africanized during 1994, with incidences of 30% January through April, 36% May through June, and 100% (only two samples) after that. By habitat the percent of Africanization was riparian, 33%; xeric, 41%; and residential, 22%. These results indicate that Africanized bees moved into virtually all parts of the monument almost simultaneously and that Africanized bees appeared to exhibit little habitat preference during at least this phase of their movement. We do not know whether established Africanized bee colonies will exhibit ecological patterns similar to those of feral European bees, or whether they will be able to permanently exploit xeric areas more effectively. Another possibility is that Africanized bees will be less fit to live in xeric areas, or in the monument as a whole, than European bees and that those colonies migrating in will die during the hot summers and long flower-poor winters. If so, we might be observing a phenomenon in which Africanized bees migrate into the monument each year, mainly to die, but are replaced by further migrants.

In conclusion, feral European honey bees maintained a permanent population within all areas of Organ Pipe Cactus National Monument and adopted an ecological strategy that can be described as cryptic survivors. During poor years, these cryptic survivors were mostly inactive; during good years, they explosively reproduced, and their activity was seen throughout the areas of the monument. We cannot characterize the Africanized population in any detail at this point and do not know if they are simply migrants coming into the monument, where they will likely have poor survival, or whether they can establish viable reproductive populations there.

The questions relating to the impact of honey bees and their effects on pollinator and plant communities in the monument cannot be answered directly from the results of this investigation. It appeared that feral European honey bees might not have had a severe impact on native pollinators because their populations, especially their foraging populations, were low during the harsh dry-to-normal years. In the xeric areas, we often could not detect even a single forager at flowers, or even at water sources (unpublished observations). Thus, they likely were not serious competitors for native pollinators during these times. During wet years, there likely were enough floral resources that all pollinators—honey bees and native pollinators alike—had excess floral resources available. The story with Africanized bees might be different. We do not know if Africanized bees will be able to establish much larger populations than the feral European bees, and if these populations will be able to be active during the dry years and seasons during the year. If they are populous and active, they might well outcompete native pollinators during critical resource times and drive the latter to low populations or extinction. Another possible scenario is that the Africanized bees, though unable to permanently survive in the monument might continually move there and, while in the process of dying, deplete the resources enough to impact the native pollinators. Since this "migration and dying" process could be ongoing, it could act as a continual selection pressure against native pollinators. Unfortunately, the effects of Africanized bees on the native pollinators in Organ Pipe Cactus likely will not be determined soon, and the discussion above must remain as speculation.

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National Park Resources and Urban Growth: The Effects of Urban Land Uses along the Boundaries of Saguaro National Park

William W. Shaw

School of Renewable Natural Resources, The University of Arizona, Tucson, AZ 85721

The boundaries of parks and reserves are imperfect barriers to the movements of people and wild animals. For this reason, park managers must consider and anticipate changes in adjacent and nearby land uses in terms of their implications for park resources. This presentation consolidates a series of recent studies that addressed the effects of urbanization on the wildlife resources of Saguaro National Park with several additional studies exploring the distribution and habitat values of different landscapes in metropolitan Tucson. Together, these studies provide the foundation for coordination among city, county, and National Park Service administrators in the interest of conserving wildlife resources within the park and throughout the metropolitan environment.

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Paleoclimatology of Southern Arizona from Image Analysis of Tree Rings of Conifers of Mica Mountain, Saguaro National Park

Paul R. Sheppard

Laboratory of Tree-Ring Research, The University of Arizona, Tucson, AZ 85721

For the primary objective of studying past climate of southern Arizona, I dendrochronologically analyzed ring growth of ponderosa pine *(Pinus ponderosa)* growing on Mica Mountain of the Rincon Wilderness, Saguaro National Park. I used reflected-light image analysis to measure several tree-ring variables for each annual ring (Sheppard and Graumlich 1996; Sheppard et al. 1996). From this large matrix of tree-ring variables as possible indicators of climate, I developed a climate-tree growth model that uses both ring-brightness and ring-width variables to reconstruct summer (July–October) precipitation for southern Arizona, confirming past research that used ring density to reconstruct summer precipitation (Park 1990; Park and Telewski 1992).

The climate tree-growth model accounts for 31% of variation in the modern meteorological record, largely because of having ring density variables as predictors in addition to ring width. The relationship is weak for the period 1930–50. This was a time when summer precipitation for southern Arizona was spatially heterogeneous, probably because of below-average tropical storm activity (Smith 1986; Webb and Betancourt 1992).

Reconstructed July–October precipitation exhibits strong low-frequency variation overlaid with strong high-frequency variation. This high year-to-year precipitation variability with long-term departures is a typical precipitation pattern for semiarid regions (Durrenberger and Wood 1979; Brazel 1985). An independent verification of one feature of the reconstruction from this study is the regional die-off of cattle during an unusually persistent drought, including the summer drought of 1890–92 (Bahre 1991). The July–October precipitation reconstruction has low values for those years, an extended period of drought that is unusual relative to the strong pattern of high-frequency variation for the rest of the series.

A prominent feature of the reconstruction is a period of below-average July–October precipitation for 1850–90. Questions remain about the validity of this feature as reconstructed using tree-rings, and independent verification of below-average precipitation for that time is still needed.

A larger question remains as to whether this reconstruction truly reflects July–October precipitation, or if it also reflects annual or winter–spring precipitation, which is more commonly reconstructed from semiarid Southwest tree-ring sites (e.g., Brazel et al. 1978; Meko and Graybill 1995). Most past dendrochronological research in this region has reconstructed precipitation using only total ring width, which, in this study, is the source of the below-average reconstructed values for 1850–90. However, by itself, Mica Mountain ponderosa pine total ring width does not relate to any typical monthly or seasonal climate variable, including winter precipitation, strongly enough to warrant reconstruction (Graybill and Rose 1989).

This project has a secondary objective of investigating various strategies for overcoming extraneous wood color variation, (i.e., color variation of wood that occurs after rings are formed and therefore has no relationship to environmental conditions at the time of ring formation). The most notable type of extraneous color is the heartwood-sapwood color change commonly seen in ponderosa pine. This extraneous color variation is statistical noise when using reflected-light image analysis to measure tree-rings. Either the extraneous color must be chemically removed from the wood itself, or the effects of extraneous color must be statistically removed from the data.

To remove extraneous color variation from the wood itself, I tried inorganic bleaching (Leavitt and Danzer 1993) and organic extraction (Part et al. 1992) of sample cores. To remove the effects of extraneous color from the data, I autoregressively modeled (Cook 1985) all persistence characteristics from the data. To date, each of these strategies has drawbacks for overcoming extraneous wood color variation (Sheppard 1995). Bleaching removed the heartwood-sapwood color variation, but it also removed most of the important brightness signal from the rings.

Extraction removed resins from the wood, but resin does not cause the heartwood-sapwood color change, which remained in the wood after extraction.

Autoregressive modeling effectively removed the effects of the heartwood-sapwood boundary from the data while leaving the ring brightness signal. However, autoregressive modeling cannot distinguish between extraneous persistence (related to heartwood-sapwood) from environmentally related persistence (e.g., decadal trends in climate). Thus, this strategy may remove information relevant to paleoenvironmental conditions that we wish to reconstruct and study using tree rings. The problems posed by extraneous wood color variation for reflected-light image analysis remain to be solved satisfactorily.

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Natural-cultural Correlations at Saguaro National Park: A GIS Analysis

Joseph Svinarich

Western Archeological and Conservation Center, 1415 North 6th Avenue, Tucson, AZ 85705

Interactions between humans and their environment result in the projection of culture onto the physical environment (Sauer 1963). In interacting with the physical environment, each society leaves its unique cultural signature as a result of settlement, resource extraction, and other cultural activities (Crumley and Marquardt 1990). The advent of geographic information systems (GIS) allows archaeologists to explore these spatial relationships and interpret past human behavior (Kvamme 1990).

This study investigates the spatial distribution of prehistoric rock-art sites in the Tucson Mountain District of Saguaro National Park and defines correlations with the spatial configuration of the geology of the district. The sample used in this investigation consists of the previously surveyed areas within the Tucson Mountain District boundaries.

Previous research of prehistoric rock art in the Southwest has defined possible associations of rock-art sites and the configuration of various natural environmental variables (White 1965; Ferg 1979; Wallace 1983). Natural environmental variables that may affect the spatial distribution of rock-art sites in the study area include the rock type or geology. Wallace (1983) noted an affinity for the occurrence of rock art on andesitic boulders at Rillito Peak and the predominance of rock art occurring on granodiorites and monozogranites in the Picacho Mountains (Wallace and Holmlund 1986). However, in her study of the Saguaro National Park rock-art sites, White (1965) mentions that "the rock type did not seem to matter" in the locations of the sites.

The Tucson Mountains are comprised predominately of exposed volcanic and tilted sedimentary rocks (National Park Service 1987). A greater portion of the range is of an igneous nature, consisting of a series of intrusive formations of both granitic and porphyritic texture. Overlying the entire series of intrusive rocks and flanking it on the northern and eastern sides are a series of bedded flows of rhyolite, andesite, and tufaceous forms of both. Finally, a series of younger basalt flows is evident, especially on the eastern side of the range (Jenkins and Wilson 1920). Alluvium laps up to the foot of the Tucson Mountains and completely encircles the range, creating in effect a series of "montane islands in a sea of alluvium" (Brown 1939).

The geology layer was obtained by hand-digitizing a U.S. Geological Survey paper map of the Tucson Mountains geology (Lippman 1993). The park boundaries, rock-art sites, and survey coverage were obtained from the National Park Service in digitized format as AutoCAD files. The site location data were derived from differentially corrected field data collected using Trimble GeoExplorer GPS units. These files are accurate to within 2–5 m and were available in AutoCAD format.

Data used in this study were converted to IDRISI-compatible format for analysis. IDRISI software was used to determine if any correlations between rock-art sites and the geology of the park exist. Examination of the surface geology and the spatial distribution of prehistoric rock-art sites at the Tucson Mountain District indicates that the site distribution is not random. ($X^2 = 26.416$, df = 10, $P < 0.005$). A ratio of proportions was then used to derive ratings indicating the relative number of rock-art sites within each individual geologic type. The total number of sites recorded in the total surveyed area provided the expected proportion for comparison purposes when interpreting the variability of the different geologic rock types. The formula used to compare the individual probability of site occurrence within a rock type area consists of a ratio of proportions akin to the location quotient. $(Sites_x / Area_x) / (Sites_T / Area_T) =$ *Correlational Rating of the Rock Type*, where x represents individual geologic types and T represents the entire study sample.

Results of this study indicate that some geologic rock types may be more likely to contain prehistoric rock-art sites. Sedimentary and igneous geologic formations, with the exception of volcanic tuff, rhyolite, and quartzite formations, have higher-than-expected ratings for the occurrence of prehistoric rock-art sites. The surficial deposits such as the colluvium and alluvium surrounding the Tucson

Mountains provide a lower-than-expected rating for the occurrence of rock-art sites. These results concur with the observations of Wallace (1983) on Rillito Peak and in the Picacho Mountains (Wallace and Holmlund 1986).

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Assessing and Controlling Damage by Native Mammals to Cultural Resources at Tonto National Monument

Don E. Swann,[1] Roy C. Murray,[2] Cecil R. Schwalbe,[1,3] and William W. Shaw[1]

[1]*Wildlife and Fisheries Sciences Program, School of Renewable Natural Resources, The University of Arizona, Tucson, AZ 85721*
[2]*Arizona Game and Fish Department, 2221 W. Greenway Road, Phoenix, AZ 85023*
[3]*U.S. Geological Survey, Cooperative Park Studies Unit, The University of Arizona, Tucson, AZ 85721*

Introduction

Assessing and effectively controlling damage to cultural resources by animals is a difficult problem in national parks and monuments throughout the U.S. Southwest. At Tonto National Monument in central Arizona, cliff dwelling structures and unexcavated cultural deposits within them have been damaged extensively in recent years, apparently by native mammals. Animal burrows have exposed and damaged artifacts, weakened wall structures, and created safety problems for visitors and staff. With these concerns in mind, we conducted a two-year study in 1993–94 to determine which species were occupying and damaging both the Upper and Lower Ruin sites, and to make recommendations regarding their control. Objectives for this study were to:

1. Determine which mammal species were using the ruins, and estimate their population sizes;

2. Determine which species were most responsible for damage to the ground and walls of the Upper Ruin;

3. Suggest control measures, based on the natural history of the species identified as causing damage; and

4. Evaluate a procedure for controlling damage to the ruins by removal of target species.

Methods

To identify initially which species were obviously using the ruins, in 1993 we conducted an assessment based on identification of scat and evaluation of other sign by Yar Petryszyn of The University of Arizona Mammal Museum. To confirm presence of species and estimate population sizes, mammals were livetrapped using large (41 x 14 x 14 cm) and small (26 x 8 x 8 cm) Tomahawk traps. We trapped at both ruins in 1993 for a total of 816 trap-nights. Population sizes were estimated for the Upper Ruin by total captures and removals, and for the Lower Ruin by the Lincoln-Petersen method (Pollock et al. 1990).

To determine patterns of use by species trapped at the ruins, in 1994 we conducted visual observations on cliff chipmunks *(Eutamias dorsalis)*, and used an infrared-triggered remote photography unit (the Trailmaster) to monitor activity of animals visiting damaged rooms. We also conducted a trapping and removal experiment to measure the effect of removal of rock squirrels *(Spermophilus variegatus)*, the species determined to be causing the greatest damage. Rock squirrels were trapped using large Tomahawk traps for a total of 460 trap-nights during three periods: May–June, August, and October. Squirrels were euthanized using carbon dioxide gas (Rand 1992). We filled all animal burrows following each trapping event. Observations twice per month, and repeat photography approximately once per month, were used to monitor selected rooms to determine renewal of activity.

Results

During the 1993 season, a total of 54 individual mammals were trapped, 32 at the Upper Ruin, 21 at the Lower. The most common species captured in both ruins was the cliff chipmunk, 11 estimated at the Lower Ruin and 15 at the Upper Ruin. We estimated a total population of all mice and rat species to be 9 individuals for each ruin. Ringtails *(Bassariscus astutus)* were captured in the Upper Ruins only. Although rock squirrels (3 estimated at the Lower Ruin, 3 at the Upper) were less common than other species, based on assessment of sign, we strongly suspected that this species was causing the greatest amount of damage.

Observations and infrared-triggered photography revealed much about the usage patterns of chipmunks, rock squirrels and ringtails. During late afternoon observations, cliff chipmunks were repeatedly observed entering a rock crevice above the Lower Ruin at dusk each evening. However, none were observed or photographed digging within rooms in the ruins. Similarly, ringtails were photographed passing through damaged rooms, apparently while entering and exiting rock dens located in the rear of the Upper Ruin, but never observed digging. In contrast, rock squirrels were photographed repeatedly as they used recently excavated burrows in heavily damaged areas, confirming our assessment that this species was principally responsible for the damage.

As a result of removal trapping, 14 rock squirrels were removed from the Upper Ruin in 1994. An additional 6 squirrels were removed from the Lower Ruin. No squirrels were captured in the Lower Ruin after May 1994. Although the total number of squirrels trapped in the Upper Ruin was lower during the August and October trapping sessions, individuals were trapped in every session except one in August. Similarly, repeat photography of damaged rooms showed that damage to the Upper Ruin decreased as a result of removals, but was never eliminated; at least two rooms showed signs of renewed damage within a month after each trapping session.

Discussion

Rock squirrels were determined to be responsible for the greatest portion of the damage to the ruins at Tonto National Monument. They enter the ruins probably to seek shelter, not food, and to find friable soil, protection from poor weather, and access to morning sun. In contrast, other mammals using the ruins do not appear to be damaging cultural materials now.

Our efforts to control rock squirrels were effective in reducing both the number of squirrels and the amount of damage they caused. However, despite an intensive trapping effort, we were unable to completely eliminate squirrels or damage to rooms such as rooms 16 and 6, which contain unexcavated cultural deposits. Rock squirrels continued to enter the ruins and excavate burrows within a month of each trapping session. For this reason, we recommend trapping and removal of squirrels only as an interim and partial measure. If trapping is implemented, it is essential that it be done as part of an Integrated Pest Management (IPM) program that is well-documented and regularly evaluated (Hoddenbach 1994).

It is important to recognize that native mammals are an inherent and natural element of many prehistoric sites throughout the Southwest. Rock squirrels are common at Tonto National Monument, and have certainly inhabited the ruins for a very long time. The remote location of sites such as the Upper Ruins makes complete elimination of these mammals impossible. Physical and structural solutions, such as stabilization of walls and partial excavations, may ultimately play an important role in the long-term solution to this problem.

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The Camp at Bonita Canon: A Buffalo Soldier Camp in Chiricahua National Monument

Martyn D. Tagg

Western Archeological and Conservation Center, 1415 North 6th Avenue, Tucson, AZ 85705

In 1986, National Park Service archeologists recorded and evaluated the significance of an 1885–86 Tenth Cavalry "Buffalo Soldier" camp in Chiricahua National Monument. The soldiers in Troops E, H, and I participated in the campaign to capture the Chiricahua Apache. The project included surface artifact collection, test excavation and mapping seven features that probably were the remains of the camp, including the base of the Garfield Monument, built by the Tenth Cavalry to honor the memory of President Garfield. (POSTER)

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Recovery Efforts for Sonoran Pronghorn

Laura Thompson-Olais,[1] John J. Hervert,[2] Bob S. Henry,[2] Steven S. Henry,[1] and Mark T. Brown[2]

[1]*Cabeza Prieta National Wildlife Refuge, 1611 North 2nd Avenue, Ajo, AZ 85321*
[2]*Arizona Game and Fish Department, 9140 East County 10 ½ Street, Yuma, AZ 85365*

Introduction

The Sonoran pronghorn *(Antilocapra americana sonoriensis)* was listed as endangered in March 1967. They inhabit the southwestern United States and northwest Mexico. Arizona Game and Fish Department (AGFD) investigated population numbers, sex and age composition, and seasonal distribution from 1969 to 1982 (Phelps 1974). The department collared 10 Sonoran pronghorn in 1983 and 9 more in 1987. These collared animals were monitored until 1991 (Wright and deVos 1986; deVos and Scott 1988).

The Core Working Group (CWG) was formed in 1991, consisting of six agencies: Cabeza Prieta National Wildlife Refuge (CPNWR) as the lead recovery office, Organ Pipe Cactus National Monument, AGFD, Bureau of Land Management (BLM), Tohono O'odham Nation, and Centro Ecológico de Sonora. Luke Air Force Base (LAFB) was added in 1995 as the seventh member. The first comprehensive aerial survey and a draft update of the 1982 Recovery Plan were both accomplished in 1994 as prioritized by the CWG.

Recent Recovery Projects

Aerial surveys using the line-transect method (Burnham et al. 1980) were done in December 1992 and in February\March 1994. Population estimates of 256 and 185, respectively, were derived from the Distance program (Laake et al. 1992).

Twenty-two Sonoran pronghorn were radio-collared in 1994 to derive estimates of productivity, recruitment; and to investigate habitat use and preference, diet, and dependence on freestanding water. Observation rates of collared pronghorn will be used in a mark-recapture method in the 1997 aerial survey.

A study was completed (Cutler et. al. 1996) to investigate year-round vertebrate use of a water development on CPNWR and to assess the effects of the development on the vertebrate community. This site was created in the 1950s specifically for Sonoran pronghorn. Fox (1996) is investigating water requirements of Sonoran pronghorn by modeling the available water and nutritional content of the forage.

The 1982 Recovery Plan was revised in draft form in 1994. The final plan is due for completion by the summer of 1996 and will reflect the significant recent information learned from monitoring collared animals.

Management Issues

Organizations that the region incorporates (CPNWR, ORPI, BLM, Barry M. Goldwater Air Force Range, BMGAFR, and the Pinacate Biosphere in Mexico) are presently completing management plans to guide land managers for the next few decades. This region contains the current habitat of Sonoran pronghorn in the United States and Mexico. An umbrella regional plan has been proposed that would link these land areas in coordinated, ecosystem-based management (beyond the scope of Sonoran pronghorn).

Jurisdiction and Legal Mandates

Sonoran pronghorn range over properties of multiple land-management agencies, including USFWS, BLM, NPS, and state lands. Although USFWS is the lead agency for recovery of endangered species, all federal agencies have responsibilities under the Endangered Species Act. Each land manager must consider the Sonoran pronghorn while making land-management decisions that may affect this endangered subspecies. The 1973 Endangered Species Act takes precedence in designated wilderness areas such as CPNWR and Organ Pipe Cactus.

How do we reconcile endangered species recovery efforts with mandates such as wilderness, refuge, and monument mission purposes, multiple use of BLM lands, national defense, and ecosystem management and biodiversity? The National Environmental Protection Act (NEPA) provides the answer. This process considers alternatives, the affected environment, consequences, includes public participation, and considers pertinent laws and agency policies.

The essence of wilderness management is *doing only what is necessary and using minimum tools* so that human influence on the wilderness is substantially unnoticed (Hendee et al. 1990). For example, the use of rotary- and fixed-wing aircraft for surveys and collaring was determined to be a minimum tool due to the vastness of Sonoran pronghorn habitat (approximately 1.2 million ha or 3 million ac) and the small population size (approx. 200 animals).

Organ Pipe Cactus National Monument is experiencing significant increases in visitation that could directly affect Sonoran pronghorn. Visitor use is a significant part of the National Park Service mission and will undoubtedly continue to grow, "loving our parks to death" as has been quoted in the past.

Management of wildlife habitat is a part of BLM's multiple-use mandate as directed by the Federal Land Policy and Management Act of 1976. Cattle grazing has played a role in the history of pronghorn habitat. Cattle are no longer present on CPNWR and Organ Pipe Cactus but continue to utilize areas in other adjacent pronghorn habitats and also in Mexico.

Habitat Fragmentation

Habitat fragmentation could negatively influence population genetic diversity. Sonoran pronghorn appear to be restricted from parts of their former range by barriers such as highways, fences, and canals. Evidence has been scarce on whether Mexico's Sonoran pronghorn continue to mix with the Arizona herd. One collared pronghorn traversed the international fence from the United States to Mexico and back to the United States (Wright and deVos 1986). Recent telemetry has not shown any international crossings, even though Sonoran pronghorn were frequently observed within a few hundred meters of the international border fence.

Wildlife corridors could assist expansion of pronghorn habitat into historic areas, decrease fragmentation, and increase genetic diversity. Cabeza Prieta is investigating the creation of a wildlife corridor along 16 km (10 mi) of its southern boundary (with Mexico). Organ Pipe Cactus is evaluating accessibility to the east side of state route 85. Access to the north through developed agricultural areas to the historic Gila River corridor would involve habitat restoration and could provide vegetation and water.

Can barriers be modified to enhance the likelihood of pronghorn expansion? Within some of the range of Sonoran pronghorn, poaching may be considered a risk. Other risks associated with removing barriers near highways and canals must be assessed. Do we encourage pronghorn to use these areas by removing barriers? The risks may overcome the advantages of additional habitat due to vehicle collisions with pronghorn or poaching.

Managing human access to currently used Sonoran pronghorn habitat might necessitate seasonal closures in high visitation areas. At Cabeza Prieta and Organ Pipe Cactus, high public visitation coincides with fawning. Harassment during fawning might have a negative impact. Popular visitor areas such as Quitobaquito, Pozo Nuevo Well, or the visitor center and housing area in Organ Pipe Cactus were sites of frequent pronghorn observations in the past. There have been recent observations of Sonoran pronghorn in the Pozo Nuevo area, but pronghorn are no longer observed in the Quitobaquito and visitor center areas.

Cumulative impacts due to both habitat fragmentation and disturbance in concert with the desert environment limit the recovery of this population. The task is to look at reducing impacts and/or modifying the environment.

Subspecies Status

Subspecies status of the Sonoran pronghorn has been in question in the past. Special Report #10 by AGFD (1981) states that the subspecies designation was unwarranted and further data are needed to confirm the designation. Hoffmeister (1986) stated that the type specimen may be smaller than average for the subspecies and that the distinctiveness of *Antilocapra americana sonoriensis* remains to be ascertained.

Recent mitochondrial DNA blood analysis suggests very little difference between the Sonoran pronghorn and *Antilocapra americana mexicana* (S. Fain, pers. comm.) These two subspecies were distinguished by less than 1% mt DNA sequence divergence. Despite scientific questions of subspecies status, future protection for the Sonoran pronghorn is warranted under the Distinct Vertebrate Population Segment of the Endangered Species Act (1996).

Population Management—Water

Little is known regarding Sonoran pronghorn use of existing water developments. Reports of pronghorn not using water such as Jose Juan guzzler and charco are available (Cutler 1996), just as there are reports of pronghorn using water at HE hill (Hervert et. al. 1995). In some parts of their habitat, some Sonoran pronghorn may use water; others in different parts of the habitat may not.

The pronghorn observed drinking at HE hill may use this water because of the openness of the area, available forage, and natural appearances of the water hole. Lack of forage and the enclosed nature of Jose Juan site might be precluding pronghorn use.

Location, design, and other wildlife uses of artificial waters could be influencing pronghorn use or nonuse. Remote sensing cameras at three artificial water sites (Papago and Little Tule guzzlers, and Antelope parabolic collector) on CPNWR in pronghorn habitat during the 1995–96 winter drought did not show pronghorn use.

The presence of water alone without forage does not insure its use. Recent data indicate that forage availability could be the most limiting factor for Sonoran pronghorn. Disturbed areas on BMGAFR such as old runways and target sites where pronghorn have been observed feeding produce forage from rain runoff that otherwise is not available. However, these areas are active target ranges, therefore experiencing different activity from the rest of pronghorn habitat.

Whether the observed water use is opportunistic behavior or required for survival has yet to be determined. A valid scientific method must be applied before conclusions can be reached regarding the use or nonuse of water developments or natural water sources available to Sonoran pronghorn.

Population Management—Predation

Telemetry has been useful in gathering information regarding threats to Sonoran pronghorn such as predation. Collars retrieved from pronghorn mortalities have shown evidence of predation and/or scavenging. Drought may have predisposed the pronghorn to predation, as they may have been in a less than fit condition. Those pronghorn mortalities that lacked signs of struggle with predators may simply be cases of scavenging after the animal died. The cause of death has been difficult to ascertain because of the lack of sufficient evidence.

During periods of drought, Sonoran pronghorn are vulnerable to predation at levels that might depress the overall population. During a three-month period (January–March), there was a 38% mortality rate of the collared population. Did the unmarked population of adults experience a similar decline? It is assumed they did. Predator control has been discussed as a tool to use for recovery efforts during times of drought. If predator control is selected as a tool for recovery for the Sonoran pronghorn, applications and locations may be varied to recognize the various agencies' policies regarding wilderness, where it comprises much of the habitat.

Population Management—Grazing

Cattle grazing has long occurred in Sonoran pronghorn habitat. Questions have arisen regarding the effects of past and present grazing on Sonoran pronghorn habitat. Cattle fencing may limit pronghorn movement. Vegetation changes over time in pronghorn habitat have not been monitored sufficiently to draw conclusions regarding the impacts of habitat changes on pronghorn population numbers. Fences have been modified for pronghorn movement between agency lands but not between the United States and Mexico. Pronghorn have been documented moving across agency boundaries, but sufficient data have not been collected regarding these movements to evaluate the effect of these fences.

A vegetation map is being pursued to examine microhabitats used by Sonoran pronghorn, such as bajadas and creosotebush/bursage communities. Information on vegetation communities and locations could assist in evaluating grazing allotment conditions and pellet analysis. Recent telemetry data suggest that specific plants such as chain fruit cholla may be an important aspect of their diet during stressful drier times of the year.

Diet analysis covering the 1995–96 drought period will play an important part in looking at Sonoran pronghorn ecology. Caution is necessary when comparing this past year with varying precipitation rates of other years. Pellet studies should take place over several years with differing precipitation patterns. In addition, diet should be sampled specifically during the last two months of pronghorn pregnancy and the first two months of lactation. If a mother does not obtain sufficient nutritious forage during this time, fawn survival is decreased (Ellis 1970; O'Gara and Yoakum 1992).

Management Implications

Many studies of large mammals cover only short time periods. These data are then extrapolated to pertain to the general life history of the animals, a practice that may not necessarily be valid. The data collected on Sonoran pronghorn over a 17-month period covered a drought in the summer and winter of 1995–96, which had not occurred during the previous several years. The mortality rate during this drought caused biologists and managers to consider possible emergency measures to address a potential population crash. Fluctuating environmental conditions in this Sonoran Desert habitat have indicated a strong need for continued research.

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The Revegetation of Red Hills Construction Sites at Saguaro National Park: A "One Hand Clapping" Approach to Revegetation

Michael K. Ward, Elizabeth S. Bellantoni, and Margaret W. Weesner

Saguaro National Park, 3693 South Old Spanish Trail, Tucson, AZ 85730

The resource management division of Saguaro National Park was charged with the task of revegetating more than an acre of Upland Sonoran Desert landscape denuded as a result of a major three-phase construction project at the Red Hills area of the Tucson Mountain District. The National Park Service's (NPS) repository of planners, architects, and engineers, known as the Denver Service Center (DSC), designed a maintenance facility (Phase I), visitor center (Phase II), and a single-family residence and administrative office (Phase III) to upgrade the existing facilities at Red Hills. Four separate primary contractors were employed over the course of the project, which occurred between the fall of 1991 and the summer of 1995. Approximately 3 ha (7 ac) of undisturbed desert were impacted.

The strategy for revegetating the Red Hills sites was based on NPS guidelines that state ". . . . wherever possible, revegetation efforts in natural zones will use seeds, cuttings, or transplants representing species and gene pools native to the ecological portion of the park in which the restoration project is occurring" (National Park Service 1988).

The challenges inherent in implementing these guidelines were plentiful. Upwards of 2,000 cacti, ocotillos *(Fouquieria splendens)*, and shrub species needed to be salvaged before the construction phases and then stored for use in the subsequent revegetation efforts. Seeds from the site needed to be gathered and then propagated in a nursery setting. Numbers of laborers were needed for the salvage and planting aspects of the project.

A memorandum of understanding was developed between Pima County Parks and Recreation (PCPR) and NPS. Pima County Parks and Recreation agreed to provide labor, seed propagation, salvaged plant care, storage at their nursery, and revegetation technical assistance in exchange for planning and design services performed by DSC at PCPR's neighboring Tucson Mountain Park. This fortuitous partnership enabled Saguaro's resource management division to proceed with the large project.

Before any ground was broken, the resource management staff conducted a species abundance and diversity census on the future construction sites. After consulting the county's experts and other local sources experienced in desert plant salvage, we determined that all cactus species and ocotillos within the work limits would be transplanted to a holding area established south of the development zone, along an old roadbed and utility corridor.

Seeds were collected from the predominant species of the site and given to PCPR to propagate in their nursery: foothill paloverde *(Cercidium microphyllum)*, whitethorn acacia *(Acacia constricta)*, fairy duster *(Calliandra eriophylla)*, jojoba *(Simmondsia chinensis)*, triangle-leaf bursage *(Ambrosia deltoidea)*, and brittlebush *(Encelia farinosa)*. Species that had a reputation for difficult propagation, specifically limberbush *(Jatropha cardiophylla)*, creosotebush *(Larrea tridentata)*, and wolfberry *(Lycium* sp.*)*, were salvaged into containers and stored and watered at the nursery. These transplants would eventually provide a more varied structural diversity on the newly revegetated areas. Seeds were also opportunistically gathered from the Red Hills vicinity from some of the more sporadically occurring species, such as trixis *(Trixis californica)*, chia *(Salvia columbariae)*, Parry's penstemon *(Penstemon parryi)*, and desert senna *(Cassia covesii)* to be broadcast along with seeds from the primary species throughout the disturbed areas.

A contract was let for the transplant of saguaros *(Carnegiea gigantea)* > 1.8 m (6 ft) in height. Division staff determined which specimens within the work limits would most likely survive a move. Five saguaros that were either too old and large or in too poor a condition to be moved were sacrificed. Forty-two saguaros were moved. Seven of these were healthy spears (without arms) ranging in size from 2.1 to 3.7 m (7 to 12 ft) that were placed together in the holding area to await a second and final transplant to a site in front of the new visitor center. Photo documentation and a notation of the general health of all of the transplants began in the winter of 1991–92 and have been ongoing biannually.

The next scenario was to be repeated before each phase of construction. Work limits were established around each construction site by DSC personnel and park resource management staff. Crews from PCPR, supplemented by a female work crew from the Pima County Detention Center, showed up with picks, shovels, caliche bars, and a backhoe. With guidance and assistance from park staff and volunteers, the crews proceeded to dig up the plants to be salvaged. Cacti and ocotillos were hauled across the street to the holding area, and shrubs were transported back to the county's nursery facility.

After the completion of the maintenance facility (Phase I) in the summer of 1992, we began our initial attempts to heal the scars in the landscape. Topsoil salvaged and stockpiled during construction had been redistributed to the sites to be revegetated. Crews from PCPR planted cacti and ocotillos from the holding area and potted trees and shrubs from the nursery. Resource management staff broadcast seeds and experimented with an excelsior groundcover to enhance seed germination.

All irrigation on the revegetation sites was designed to be temporary (two years) and to make judicious use of a limited water supply. All of the drip lines were left above ground where they could be removed easily. Fortunately, the resident mammal species were uninterested in gnawing on our spaghetti tubing. By the time we had installed a clock on the first drip line, the summer monsoon season was in force, providing adequate moisture. When the monsoons tapered off in the fall, we ran the drip lines manually during extended periods between storms. A very wet winter ensued, and only a few shrubs failed to survive the summer planting. After a year, it was no longer necessary to use the drip system for Phase I. We used the same strategy for Phase III in the fall of 1994, recycling the drip lines from Phase I, and operated the system manually in conjunction with seasonal rainfall.

The excelsior groundcover, covered with a plastic mesh netting to hold it in place, proved to be a boon for jojoba and bursage germination but a death trap for rattlesnakes. All of the netting from the existing excelsior was removed, and a loosely woven jute was used instead for groundcover and erosion control.

Our losses of nursery and salvaged specimens were offset many times over by the tremendous volume of individual species that germinated from topsoil and broadcast seeds. Any seedling that sprouted was periodically hand watered. Lessons learned in Phase I were applied to the remaining phases of the project.

Phase II construction began in January 1993. As with all construction phases, resource management staff worked hand-in-hand with the DSC project supervisors to address our landscape concerns and to monitor the contractors' ability to remain within the work limits. The quality of soil and its dispersal around the finished grade of the site was a crucial element of our project. We checked topsoil reserves to insure they were free of construction debris.

The "final" grades specified on the DSC plans for Phase II were too steep in many places to prevent erosion and often clashed with the adjacent natural contours. With help from our maintenance division, the area was regraded and soil reserves used from the leach field that had been built across the street to manage the effluvium from the new visitor center.

Phase II of the Red Hills project was finally completed almost a year behind schedule. By December 1994, we were ready to plant the most visible aspect of the entire project, the Red Hills Visitor Center. A contractor was hired to plant a medium-sized paloverde tree salvaged from the leach field and the seven saguaro spears (from the holding area) in front of the new building. Crews from PCPR, exhibiting remarkable patience given the construction delays, returned to plant shrubs, trees, cacti, and ocotillos.

At the beginning of the project, the assumption was that all irrigation design and installation for Phase II would be contracted out. The biotech hired to assist with Phase II was also experienced in the more technical aspects of irrigation installation. Our combination of corporate knowledge of the project and technical expertise allowed us to put together our own irrigation design. This enhanced our ability to flexibly adjust to scheduling quirks and gave us the means to improvise drip-line placement as necessary.

The size of the Phase II area that was to be revegetated made it impractical to irrigate manually. We set up seven separate irrigation zones run by two clocks that were hard-wired into the new visitor center. These clocks were programmed to run in the early morning hours, and usually only two zones were watered each day, each zone receiving water once a week or less often according to variegated rain and temperature conditions. It was rare to use more than 7,570 litre (2,000 gal) of water per day for irrigation even though a maximum allotment of 26,495 litre (7,000 gal) per day was available. After a year, all plants were established and currently the drip lines are run only occasionally to supplement tree growth.

The majority of the planting, seed broadcasting, and irrigation installation was completed by the end of February 1995. Ten months later the success of the revegetation effort was remarked on by a visitor who asked a park employee at the new visitor center how we were able to get the building in "around all these plants."

The reasons for our relatively rapid success with Phase II are many. One 81-year-old gentleman who had worked at the Organ Pipe Cactus National Monument nursery for the previous 10 winters chose to volunteer at Saguaro the winter of 1994–95 and was almost single-handedly responsible for the transplant of more than 200 bursage and brittlebush seedlings around the new visitor center, plants that thrived and quickly erased the bare, "newly revegetated" look. The delay in construction positioned us to plant during the most benign season possible. Consequently, losses of transplanted nursery stock and specimens from the holding area were minimal. Ample winter rains soaked the soil, and brittlebush seeds that had been broadcast in January germinated strongly in March.

The conscientious handling of vegetation from the holding area and nursery stock by PCPR personnel and adequate rainfall and supplemental irrigation applied by resource management staff attributed to the high percentage of plant survival. All cacti and ocotillos were transplanted with their original orientation toward the sun. In places where the soil was poor around the Phase II site, we imported soil from the holding area to pack around the root systems of the transplants to minimize shock.

These elements of success were present throughout all of the phases of the Red Hills revegetation efforts. Retaining continuity of dedicated field-level personnel through the length of the project helped immensely. Finally, each plant was treated with the inherent respect that those of us who cherish the planet would convey to all living things.

It's been said that luck is the residue of design. The resource management staff at Saguaro National Park can only look back over the past four years and bask in the aura of luck that seemed to surround this project. It rained when it was the best time for rain, seeds seemingly sprouted at our will, and both physical and technical assistance appeared at our doorstep as we needed it.

There is a famous Zen riddle that asks, "What is the sound of one hand clapping?" We don't pretend to know much about Zen, but a basic tenet of its philosophy describes the lack of conflict between the human element of control and the natural element of chance. A complex and ultimately happy combination of those elements that mixed luck and design, professionals and amateurs, human control and the wiles of nature, wove their way through the fabric of the Red Hills revegetation project. If you listen closely, you can hear the resource management staff clapping.

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Ecosystem Recovery From Livestock Grazing

Peter L. Warren and L. Susan Anderson

The Nature Conservancy, 300 E. University Blvd., Suite 230, Tucson, AZ 85705

Patterns of change in plant and small mammal communities at Organ Pipe Cactus National Monument were documented over a 10-year period. Vegetation and rodent community structure were analyzed on 20 permanent monitoring plots that were established in 1975–76. Photographs taken at permanent photopoints in 1988–89 were compared with photographs taken in 1975–76. In general, vegetation cover increased in all plant communities studied, although the species contributing to cover increases varied from one site to another. The cover increase is probably due to a combination of factors, especially unusually high rainfall and termination of livestock grazing. Contrary to expectation, plant species richness did not show a general increase. However, species turnover (net gain and loss of plant species) was high. Rodent densities were lower in 1988–89 than in 1975–76, and two species found in the earlier study were not captured. General patterns of relative abundance and habitat preference of the rodents remained the same.

Rehabilitating CCC-Built Picnic Structures in the Tucson Mountain District of Saguaro National Park

Margaret W. Weesner and Gregory S. Johnson

Saguaro National Park, 3693 South Old Spanish Trail, Tucson, AZ 85730

Five picnic areas in the Tucson Mountain District of Saguaro National Park were built by the Civilian Conservation Corps in 1937. Structures include picnic tables, shade ramadas, barbecue grills, and comfort stations, made of native stone, saguaro ribs, and commercial materials. In 1992, the roofs of nine picnic ramadas were replaced to improve drainage and replace rotten wood. The original historic fabric was kept wherever possible, and deteriorated materials were replaced in kind. One particularly challenging ramada was located in designated wilderness, more than a mile from the trailhead. Most materials were carried in on foot, and heavier materials were flown in by helicopter. (POSTER)

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The 1995 Archeological Survey of Casa Grande Ruins National Monument

Susan J. Wells

Western Archeological and Conservation Center, 1415 North 6th Avenue, Tucson, AZ 85705

Background

Archeologists are known for their love of old things, and sometimes the definition of old things extends to research done in the past. This is the case at Casa Grande Ruins National Monument. Western Archeological and Conservation Center archeologists resurveyed the monument in the spring of 1995. Previous information about the sites and research at the park was integrated in the survey process. Hand-held global positioning system (GPS) units were used to define the boundaries of mounds, compounds, and other features visible on the surface. Two new sites were recorded and a possible canal was identified from aerial photos.

The outcome of this project will be a report that will include a series of maps. The survey data and archival information have been integrated on large-scale topographic maps of the monument prepared for this project from aerial photos. The information collected includes the locations of sites, features, and previous archeological excavations as well as information about construction, erosion control features, and other historic and modern disturbances at the monument. It is interesting that most of the archeological sites show up as topographic features on the map.

Casa Grande Ruins has the distinction of being the first archeological site put under federal protection with a Presidential Proclamation, signed by Benjamin Harrison in 1892. Archeological sites in the park were occupied by the Hohokam culture, which occurred in central and southern Arizona between A.D. 300 and 1450. It is clear that the earliest sites identified are from the Sacaton Phase (c. A.D. 950) and the latest are from the late Classic (Civano) Period (A.D. 1300–1450). The Casa Grande itself was probably built and occupied between A.D. 1300 and 1450. In the extensive architectural study conducted by Wilcox and Shenk (1977), they suggested that the Casa Grande may have been used for both domestic and special functions such as a solar observatory.

The first written report of the Big House was in the diaries of Jesuit priest Father Kino, who visited the area in 1694 (Bolton 1948). Other accounts and descriptions are known from the 1700s and 1800s (Emory 1848; Hinton 1878; Bartlett 1894; Nentvig 1894; Karns 1954). The first archeological description was written in 1881 by Adolph Bandelier (1884, 1892). In 1890 and 1891 Cosmos Mindeleff mapped 65 ac in the vicinity of the Big House (Mindeleff 1896, 1897). Work by Fewkes between 1906 and 1908 (Fewkes 1906, 1907, 1912) and by later researchers and land managers such as Cummings (1926), Gladwin (1928), Pinkley (1921, 1935, 1936), and Hastings (1934) are reported in varying degrees of detail. Ambler (1961) summarized the findings of the archeological survey conducted in the 1950s by Leland Abel, Alden Hayes, and Sallie Van Valkenberg. Ambler also reported on Russell Hastings' excavation of AZ AA:2:61, located in the southeast corner of the monument. One of our goals is to try to figure out what each archeologist may have done at each site. There are a number of sites with evidence of excavation, including some rather large trenches that have little or no documentation on file.

The Resurvey

The resurvey was conducted in two stages. First we visited known sites and recorded information on the mounds, walled features, and surface artifacts. Site and mound boundaries and features were traced with GPS units. Buried adobe-walled features sometimes show up as lines on the ground with little or no vegetation; this has been called the brigadoon effect (Andresen 1980).

The second stage was to conduct detailed archeological survey to record the density of surface artifacts or the lack or artifacts between the archeological sites. A technique called measured transect recording was used to characterize the scatters of artifacts that exist between the actual sites. We have produced a rather detailed map of surface artifact density.

Canals

Canals built for irrigation are one of the major accomplishments of the Hohokam, who lived along the Salt and Gila rivers (Midvale 1965). A vegetation anomaly in the vacant corridor in the eastern half of the park, north of the entrance road, may be a buried canal. Another canal recorded by Midvale (and reported by Andresen 1987) in the northwest corner was confirmed by ground-penetrating radar (McGill and Sternberg 1989); this explains the different look of the sites and artifact assemblages in this area of the monument.

Other Research

Other research being conducted in and around the national monument includes extensive excavation at the Grewe Site, located one mile northeast of the Big House, to mitigate the impact of Arizona Department of Transportation projects. There is also Bayman and Shackley's (1996) study of obsidian sources for both the monument and the nearby Grewe Site, which has produced interesting results. Ceramic research being conducted in the Gila Basin is reported in a paper from this conference by David Abbott and Beth Miksa.

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Overview and Status of the National Park Service Inventory and Monitoring Program

Gary L. Williams

Natural Resource Information Division, National Park Service, 1201 Oakridge Drive, Fort Collins, CO 80525

Many units of the National Park System are being subjected to a wide variety of natural and man-induced impacts and alterations. Left unchecked, these factors could threaten the existence of many natural systems and biotic communities within the parks. To cope with these diverse changes, park managers and superintendents must have at their disposal comprehensive inventory information about the types and status of natural resources in their parks and monitoring information that provides insights into how the condition of those systems and communities are changing over time.

In fiscal year 1991, the National Park Service (NPS) initiated a servicewide Inventory and Monitoring (I&M) program with a primary mission to implement natural resource inventory and monitoring on a more programmatic basis throughout the NPS. To accomplish this mission, the servicewide program was structured around two major goals: 1) to insure that the approximately 250 natural resource park units possess at least the basic compliment of data sets needed to support managerial decision making and resource protection, and 2) to acquire the knowledge and expertise the NPS will need in the future to design and implement comprehensive, cost-effective monitoring programs at various spatial and temporal scales. This paper provides a brief summary of the current status of the NPS effort to accomplish these two programmatic goals.

Level I Inventories

The servicewide I&M program seeks to complete a set of 12 basic (Level I) natural resource data sets for each natural resource park unit. The Level I data sets includes a variety of biotic and abiotic ecosystem components and cartographic data sets needed to implement geographic information systems (GIS). The status of the five inventories currently underway is summarized as follows:

Bibliographic Databases

A major focus of the servicewide inventory effort is to maximize the utilization of existing information. By placing emphasis on collecting existing information and getting it into a format most useful to park managers, the NPS will be in a much better position to know where data deficiencies exist and what specific field inventories need to be completed to bring the parks up to a complete set of Level I data coverage. For that reason, the first major inventory effort focused upon constructing bibliographic databases for each of the natural resource parks. The databases include information on previous studies and research investigations that have been completed in the parks. Park bibliographies are being completed using a common format in Procite software to ensure compatibility with other efforts underway within the NPS. Funding has now been provided to complete a bibliography project for all 250 natural resource parks, although actual database development will proceed over the next two to three years.

Base Cartographic Data Sets

A key feature of the servicewide I&M program is to make most of the inventory information accessible through park GISs. To facilitate that goal, the program has provided funding to acquire standard U.S. Geological Service (USGS) base cartographic data sets for use in park GISs. Cartographic data sets being acquired through this effort include digital elevation models, digital line graphs, and digital orthophoto quads. Thus far, data sets have been acquired for approximately 130 parks. However, the I&M program has provide only about 50% of that funding. The remaining funding has been provided by USGS cost-sharing and the A-16 data acquisition process.

Water Quality Baseline

Consistent with the programmatic strategy of assembling existing information to identify data gaps and needed field inventories, the I&M program has entered into a cooperative effort with the NPS Water Resources Division to produce Baseline Water Quality Assessment reports for each of the natural resource park units. These reports summarize existing information stored in Environmental Protection Agency (EPA) national databases, principally STORET, and provide each park with water quality summary statistics, trend information, and insights into potential data deficiencies and situations needing management attention. To date, Baseline Water Quality Assessment reports have been completed for 60 parks. At the current rate, reports for all of the remaining park units should be completed by late 1997.

Vegetation Mapping

In 1994, the NPS entered into a cooperative effort with the National Biological Service [now USGS Biological Resources Division (BRD)] to complete a vegetation map for each natural resource park unit that would meet park needs for park management and resource protection, be consistent from park to park, and also facilitate aggregation of park vegetation information at the regional scale. The inventory is being carried out through a national contract awarded to a consortium of firms in which the Environmental Systems Research Institute (ESRI) provides overall project management and coordination and The Nature Conservancy provides field ecology expertise. Through this contact, the NPS has developed standards and protocols for the classification system, field sampling methodologies, and map accuracy assessment procedures. Adoption of the classification system by the Federal Geographic Data Committee is pending and the classification system is in use by the EPA, GAP, and the U.S. Department of the Interior Earth Cover Mapping Initiative. The classification system and mapping protocols are currently being tested in 4 pilot park units: Tuzigoot, Assateague Island, Scott's Bluff, and Great Smoky Mountains. A database summarizing existing aerial photography and related mapping data plus logistical information for the top 100 park units on the NPS priority list has been completed. Aerial photography for 22 parks has been obtained, and an additional 35 parks are projected to be flown during 1996.

In addition to the vegetation mapping inventory contract through ESRI, the I&M program is also funding vegetation mapping efforts for Alaskan parks. This effort is being managed by the NPS Alaskan Field Office in Anchorage rather than the ESRI contract because, unlike the ESRI effort which uses aerial photography technology, vegetation mapping in Alaska is being conducted using satellite imagery. The Alaskan vegetation mapping effort is only in its second year and is acquiring new satellite imagery as well as conducting pilot mapping efforts in several parks.

Soils Mapping

In 1995, the NPS began cooperative efforts with the Natural Resource Conservation Service (NRCS) to initiate soils mapping activities in a number of NPS units. Pecos National Historic Site in New Mexico served as a pilot project and helped investigators refine procedures for assessing park needs for soils information. To date, soils mapping projects have been initiated or completed in 18 park units. The most concentrated soils mapping effort initiated so far includes the Southern Arizona parks, Lake Mead National Recreation Area, and Grand Canyon National Park. Many of the contracting and administrative procedures developed in the Arizona park units are being and will continue to be used in soils mapping efforts in other park units throughout the United States.

Prototype Monitoring Programs

The tremendous variability in park ecological conditions, sizes, and management capabilities represent significant problems for any attempt to implement ecological monitoring throughout the NPS. To deal with this ecological and managerial diversity, the I&M program assigned each of the 250 natural resource park units to 1 of 10 major NPS biomes. Once that process was completed, 1 park unit from each major biome was then selected through a competitive process to represent a "prototype" or experimental monitoring program for that particular biome. To insure that the broad range of managerial situations was adequately represented in this national network of prototype monitoring programs, 3 of the prototype programs were selected as "cluster" programs, that is, a grouping of 4–6 small units, each of which lacked the full range of staff and resident expertise needed to conduct a long-range monitoring program on its own.

The prototype programs vary widely with respect to the detail in which the structure and function of the park ecosystems are monitored. They also share many common features, and this is particularity true for program components monitoring trends in species abundance, population dynamics, watershed ecology, and other indicators of environmental change. In all instances, the monitoring programs are designed to provide ecological information that will be useful in addressing questions beyond today's issues. Protocols and expertise developed by the prototype programs will be shared with sister parks occurring within similar ecological and managerial settings. Prototype programs will also serve as training centers for natural resource management personnel throughout the NPS. A brief summary of the seven prototype monitoring programs that have been initiated is provided below.

Channel Islands National Park (Pacific Coast Biome)

Channel Islands National Park, located off the coast of California, has served as a prototype monitoring program since 1992. The monitoring strategy at Channel Islands is based on the belief that organisms integrate the effects of a vast array of ecological factors, including predation, competition, and other environmental factors that are expressed in changes in population abundance, distribution, and growth and mortality rates. A conceptual model of the park's ecosystems was used to identify 15 mutually exclusive system components for monitoring. These components include invertebrate species, terrestrial vegetation, kelp forests, rocky intertidal communities, seabirds, and pinnipeds.

The Channel Islands monitoring program is fully operational. The monitoring activities and associated information management are being carried out by members of the park's natural resource management staff. The monitoring program has also hosted the I&M training course in 1994 and 1996.

Shenandoah National Park (Deciduous Forest Biome)

The prototype monitoring program at Shenandoah National Park focuses on four major components: ecosystem dynamics, population dynamics, watershed process monitoring and modeling, and landscape change monitoring. The park's monitoring efforts began in the mid-1980s when park managers needed to have a better understanding of how invasions by the nonnative gypsy moth *(Portheria dispar)* were affecting the park's forest communities. Since that time, the program has been expanded to include also air quality monitoring, water quality investigations, plus black bear *(Ursus americana)* and brook trout *(Salvelinus fontinalis)* monitoring.

Like Channel Islands, Shenandoah's program is fully operational. All research and design efforts have been completed and the monitoring efforts are integrated into the park's natural resource management program.

Great Smoky Mountains National Park (Deciduous Forest Biome)

Great Smoky Mountains National Park, which encompasses approximately 224,600 ha (550,000 ac) in the states of Tennessee and North Carolina, also entered the prototype monitoring program in 1992. Long-term monitoring in very large parks presents a special problem related to spatial scale. The monitoring program at the Great Smoky Mountains attempts to deal with these difficulties by structuring the program around a hierarchy of five spatial scales: landscape, ecosystems, watersheds, communities, and individual species. Within these spatial levels, 13 key ecosystem processes, and components identified in the park's resource management plan are being monitored. Much of the monitoring at the landscape level is focused on determining how the structure and dynamics of the park's spruce-fir forest communities are being affected by air pollution and climatic changes. At the species level, population dynamics of black bear and white-tailed deer *(Odocoileus virginianus)* are being monitored. The park's monitoring program also includes monitoring of water quality and brook trout populations.

A review of the monitoring program at Great Smoky Mountains by an interagency peer-review team during the summer of 1995 determined that research efforts associated with protocol design and development had been completed and therefore that the program should be considered to be fully operational. Based upon that decision, funding and staffing responsibility for the program transferred from the National Biological Service [USGS BRD] to the NPS in 1996.

Denali National Park (Arctic/Sub-arctic Biome)

In 1992, Denali National Park and Preserve was selected as a prototype monitoring program to evaluate a watershed approach to monitoring in large Alaskan parks. For purposes of the prototype monitoring program, the park has been divided into five major watersheds, which provide a representation of the major terrestrial habitats, aquatic systems, and climatic regimes within the park. Ecosystems based upon prevalent vegetation, from lowest to highest elevation, have been identified for study within each watershed. Vegetation community structure and dynamics, chemical and geophysical parameters, including soil characteristics and depth to permafrost, are being monitored at a series of permanent plots within the watershed. Other monitoring efforts include air and water quality, small mammals, and breeding birds.

Unlike the monitoring programs at the three parks discussed above, protocol design and development for the Denali monitoring program have not yet been fully completed. Thus, funding and support for this program is currently being provided by the USGS BRD under a cooperative arrangement between that agency and the NPS. Once protocol design and development have been completed, funding and FTE support for the Denali program will be provided by the NPS.

Great Plains Cluster (Prairies / Grasslands Biome)

The first of three "cluster" prototype monitoring programs was initiated in 1994 when the Great Plains Prairie Cluster monitoring program was funded. This monitoring program is structured around a cluster of five small prairie park units in the midwestern United States. Wilson's Creek National Battlefield in southwestern Missouri serves as the focal park for the cluster. The overall goal for the monitoring program is to develop and/or implement monitoring protocols for resources likely to be enhanced or alternatively suppressed by active management or park threats. The protocols relate to three high-priority management issues: 1) to what extent are small remnant and restored prairie ecosystems sustainable through restoration and management, 2) what are the external land-use and watershed impacts to small prairie preserves, and 3) what are the impacts of fragmentation on the biological diversity of small prairie parks. This monitoring program is still in the initial protocol design and development phase and thus funded and staffed primarily by the USGS BRD.

Virgin Islands/Florida Cluster (Tropical/Sub-tropical Biome)

A second cluster monitoring program is being initiated in 1996 in a group of three park units in the Caribbean and south Florida, Virgin Islands National Park serving as the lead park. The program, also funded and staffed by the USGS BRD, is designed to expand upon existing and prior monitoring efforts in the parks and to integrate these ongoing monitoring activities into a systematic, comprehensive program. Major focus is being placed upon monitoring for coral reefs, marine fish communities, terrestrial forests, nonnatives, and vertebrate populations.

Cape Cod National Seashore (Atlantic/Gulf Coast Biome)

A second monitoring program is being initiated in 1996 at Cape Cod National Seashore. This program, funded and staffed by the USGS BRD, will address five major coastal ecosystem components: 1) shoreline margins, 2) barrier islands/spits/dunes, 3) estuaries, 4) kettle ponds and freshwater habitats, and 5) maritime forests. Monitoring activities associated with each ecosystem component will address management questions specifically related to Cape Cod and other coastal parks.

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Stabilization of Casa Grande Ruins National Monument

David Winchester and Frank Sumrak

Casa Grande Ruins National Monument, 1100 Ruins Drive, Coolidge, AZ 85228

Casa Grande Ruins National Monument preserves the ruins of an ancient four-story structure located in the Gila River Valley. This massive building was constructed of caliche, a lime-rich desert soil, prior to A.D. 1350 by the Hohokam, a prehistoric people who farmed throughout southern Arizona from approximately A.D. 300 to 1450. For reasons unknown, the culture came to an end around A.D. 1450. Following the abandonment, years of weathering, pest infestation, and vandalism took their toll on the building, and it fell into ruins. The first attempts at stabilizing the ancient structure were initiated in 1891. Since 1918, the National Park Service has continued with stabilization efforts that will help preserve the prehistoric structure for generations of visitors yet to come. (POSTER)

Protecting the Threatened Desert Tortoise: Survey, Monitoring, and Management at Organ Pipe Cactus National Monument and Saguaro National Park

Elizabeth B. Wirt,[1] Peter Holm,[1] Natasha Kline,[2] Brent Martin,[1] Tom Potter,[3] Robert Robichaux,[2] and Tim Tibbitts[3]

[1]*Department of Ecology and Evolutionary Biology, The University of Arizona, Tucson, AZ 85721*
[2]*Saguaro National Park, Old Spanish Trail, Tucson, AZ 85730*
[3]*Organ Pipe Cactus National Monument, Route 1, Box 100, Ajo, AZ 85321*

The desert tortoise *(Gopherus agassizii)* is a threatened and sensitive species in the Southwest. As part of the National Park Service obligation to sensitive species, a multi-park desert tortoise study was funded. Two Sonoran Desert and three Mojave Desert parks are involved. To begin managing desert tortoises, we are collecting baseline data at Organ Pipe Cactus National Monument and Saguaro National Park. Surveys (50 at Organ Pipe Cactus, 30 at Saguaro) are used to establish presence and relative abundance, and monitoring plots (3 at Organ Pipe Cactus, 2 at Saguaro) are used to estimate population densities. Survey and monitoring, from August 1995 to November 1997, involve mapping tortoise locations, sign, and habitat using a global positioning system (GPS). Radio telemetry is used to gather data on habitat use of the Sonoran desert tortoise in unique habitats (N = 10 at Organ Pipe Cactus, N = 5 at Saguaro) at each park. These baseline studies will provide technical support for management objectives including geographic information systems (GIS), long-term monitoring, habitat improvement, and interpretive outreach to rangers and park visitors. (POSTER)

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Legacy in Ruins at Mission San Jose de Tumacacori, San Cayetano de Calabazas, and Los Santos Angeles de Guevavi

David Yubeta

Tumacacori National Historical Park, P.O. Box 67, Tumacacori, AZ 85640

Presidential proclamation established Tumacacori National Monument in 1908, protecting the ruins of an 18th century Spanish colonial mission, San Jose de Tumacacori. In 1990, P.L. # 101-344 added for protection and interpretation the mission ruins of San Cayetano de Calabazas and Los Santos Angeles de Guevavi to the existing monument, and Tumacacori National Historical Park was created. This poster is a chronology of those ruins in the late 19th and early 20th centuries depicting the "ravages of time" on these important cultural resources. Los Santos Angeles de Guevavi was the first mission in Arizona. Established in 1691 by Padre Eusebio Francisco Kino, mission Guevavi was first a *Cabecera* and later a *visita* of mission Tumacacori. A *visita* is a village that is visited by a priest from a *Cabecera*. It is possibly one of a few, if not the only, true Jesuit "earthen architectural only" sites in the United States. Padre Kino established the mission of San Cayetano de Tumacacori in 1691 on the east side of the Santa Cruz River. In 1757, the mission was moved to the west side of the river. Following the Jesuits' expulsion in 1769, Franciscans built the present church, San Jose de Tumacacori. It was somewhat restored in the 1930s by National Park Service custodian Frank "Boss" Pinkley, and receives approximately 2,000 person hours of stabilization and preservation annually. San Cayetano de Calabazas was established as a *visita* in 1756. The mission was later used as a ranch house by the governor of Sonora, Gandara, and afterwards as a military outpost by U.S. soldiers. (POSTER)