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PARKScience

Integrating Research and Resource Management in the National Parks

National Park Service
U.S. Department of the Interior

Natural Resource Program Center
Office of Education and Outreach

COLLABORATIVE FOREST MONITORING

Improvements in data compatibility and reporting enable resource managers to track conditions and changes in forest health over wide regions

- CESUs at 10 years
- Interview: Glacier's Jack Potter
- Ocean and Coastal Branch update
- Invasive plants rapid survey
- Implications of airborne contaminants

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From the Editor

I am thrilled to publish a case study about a resource inventory and condition assessment of desert springs at Saguaro National Park. The authors credit the first edition of *Park Science* with inspiration for this work. Published in 1980, this inaugural issue highlighted the intensive 11-day gathering of researchers and resource managers to "take the pulse" of a wilderness drainage lying mostly within Olympic National Park. Three years later the pulse model was adopted at Sequoia–Kings Canyon national parks, where it was repeated in 1994 to illuminate resource changes over that period. I was lucky to be a participant in the second Sequoia pulse study, covering the story as the new editor of *Park Science*. I know how stimulating the pulse approach can be on account of its daily surveys, nightly group progress reports, and the opportunities for professional growth through meaningful collaboration and fieldwork. The Saguaro pulse study, as the authors note in this issue, continues to invigorate and inform the park science and resource management program. I am gratified to trace continuity in these articles, which show how good ideas can spark applications for other areas, a primary purpose of *Park Science*.

Jon Jarvis's recent confirmation as 18th director of the National Park Service signals to me the value of continuity for leadership. Though several directors have come from within the Service, Mr. Jarvis is the first of these with a biology background and extensive resource management experience. In 1996 we ran an article that tracked the career development of NPS Natural Resource Trainee Program alumni and featured a group photograph (above) of the first class in 1982. Fifth from the right in the bottom row is our new director, then a trainee from Crater Lake National Park. Each time Mr. Jarvis's career has evolved to a new position of leadership, I have taken pride that "one of us" was moving up. While he brings many important characteristics to his new job, I am especially pleased that his broad understanding of park issues and the role of science in their resolution is squarely among them.

Finally, the recent Ken Burns/Dayton Duncan television series *The National Parks: America's Best Idea* amplified for me the tremendous advances we have made in park stewardship informed by science since the earliest days of the National Park Service. We should not forget that our work to understand, manage, and protect the enduring qualities of national parks is a great service to Americans and generations yet to come.

—Jeff Selleck

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NPS/JOY MARBURGER

MATTHEW S. BERG

USGS/DON CAMPBELL

ON THE COVER

Eastern deciduous and northern hardwood forests are the focus of resource managers who are developing a forest vegetation monitoring and reporting framework that facilitates data compatibility and sharing. Discussed on pages 76–80, this collaboration enables managers to observe forest conditions and long-term change in forest health over a broad region of the Northeast. Photo: Fredericksburg and Spotsylvania National Military Park.

NPS/JIM COMISKEY

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NPS/JIM COMISKEY

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FUTURE ISSUES

Winter 2009–2010
January. Theme issue: Soundscapes research and management in the National Park System.

Spring 2010
May. Accepting articles, news, updates, and photographs. Contributor's deadline: 15 December 2009.

Fall 2010
November. Accepting proposals, articles, news, updates, and photographs. Contributor's deadline: 15 May 2010.

Visit http://www.nature.nps.gov/ParkScience/ for author guidelines or contact the editor at jeff_selleck@nps.gov or 303-969-2147 to discuss proposals for upcoming issues.

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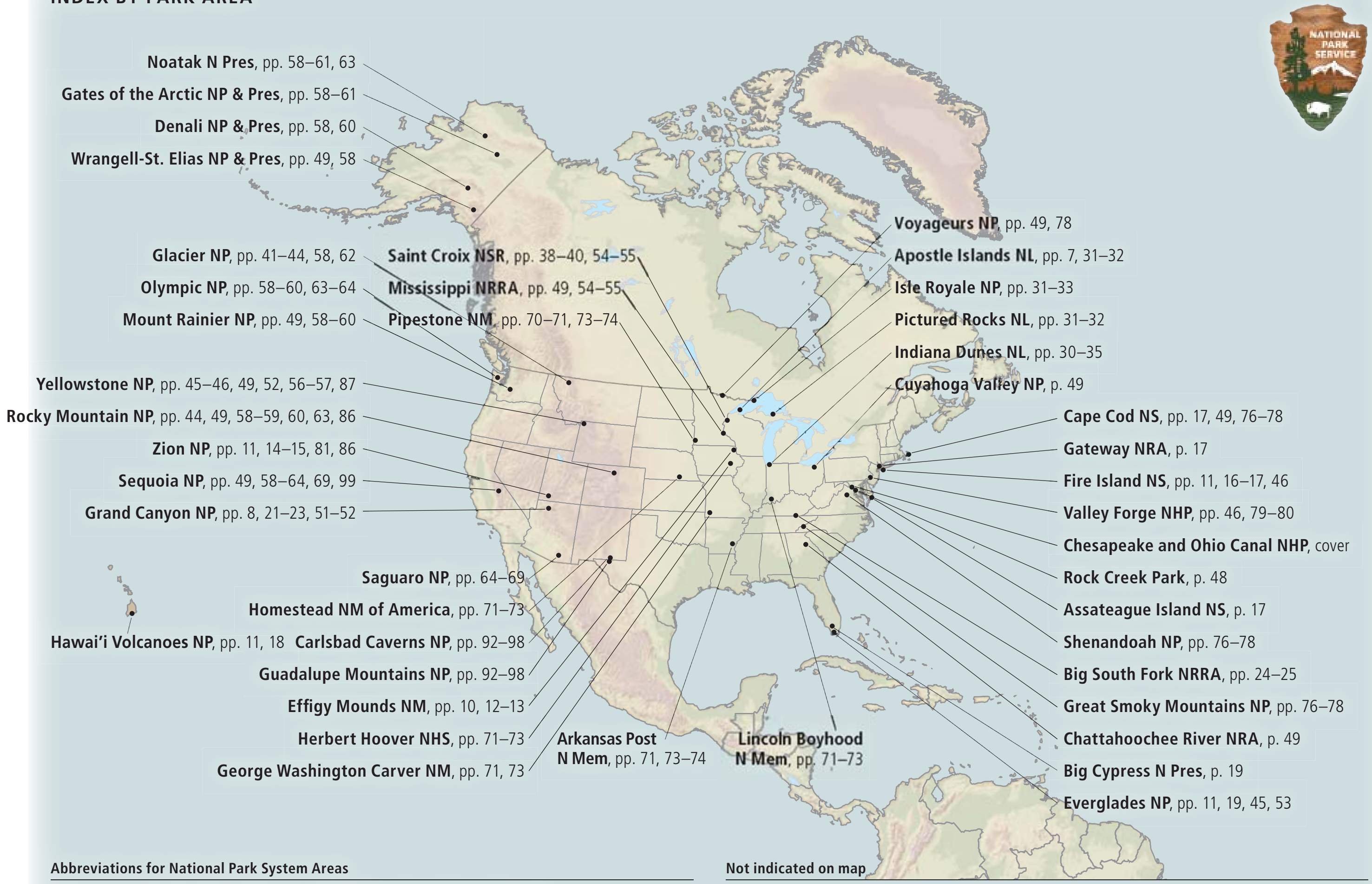

Abbreviations for National Park System Areas

NHP	National Historical Park	**NP & Pres**	National Park and Preserve
NHS	National Historic Site	**N Pres**	National Preserve
NL	National Lakeshore	**NRA**	National Recreation Area
NM	National Monument	**NRRA**	National River and Recreation Area
N Mem	National Memorial	**NS**	National Seashore
NP	National Park	**NST**	National Scenic Trail

Not indicated on map

PARKScience (CONT'D FROM PAGE 2)

Park Science is a research and resource management bulletin of the U.S. National Park Service. It reports the implications of recent and ongoing natural and social science and related cultural research for park planning, management, and policy. It is published twice a year in spring and fall with occasional supplementary or thematic issues that explore a topic in depth. It serves a broad audience of national park and protected area managers and scientists and provides public outreach. It is funded by the Associate Director for Natural Resource Stewardship and Science through the Natural Resource Preservation Program.

Articles are field-oriented accounts of applied research and resource management topics that are presented in nontechnical language. They translate scientific findings into usable knowledge for park planning and the development of sound management practices for natural resources and visitor enjoyment. The editor and board review content for clarity, completeness, usefulness, scientific and technical soundness, and relevance to NPS policy.

Article inquiries, submissions, and comments should be directed to the editor by e-mail; hard-copy materials should be forwarded to the editorial office. Letters addressing scientific or factual content are welcome and may be edited for length, clarity, and tone.

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Printed on recycled paper.

20 Years Ago in Park Science

Cave mapping

WIND CAVE NATIONAL PARK . . . IS an intricate, multilevel maze of underground passages of incredible dimension. . . . Making proper management decisions invariably comes down to knowing precisely what resources are located in each area of the cave. For this reason, cave maps have always been invaluable tools for the cave manager. [However], it is difficult to portray three-dimensional relationships of these passages on a two-dimensional piece of paper. . . . Concerned that the map should more accurately portray the relationship between the cave and the overlying surface features and developments, the management at Wind Cave decided that a redrafting of the map was necessary. . . . It was immediately apparent that a computer would be necessary. . . .

Just as a word processor is used to manipulate words, sentences, and paragraphs CAD [computer aided design] software is designed to manipulate lines, arcs, circles, and the drawings which contain them. . . . No longer did we have to worry about the map being unreadable in vertically complex sections of the cave. By placing each survey station on a layer based on its elevation, we could "turn off" layers in complex areas of the cave to zoom in on the area we were interested in. Layers could be created to portray surface topography, surface developments, and vegetation types overlying the cave, providing visual clues to the links between surface and subsurface worlds. . . . With a little programming, we have unleashed the real power of the digitized map. . . . The information age is just beginning at Wind Cave National Park.

Reference

Nepstad, J. 1989. CAD applications at Wind Cave NP. Park Science 9(4):6–7.

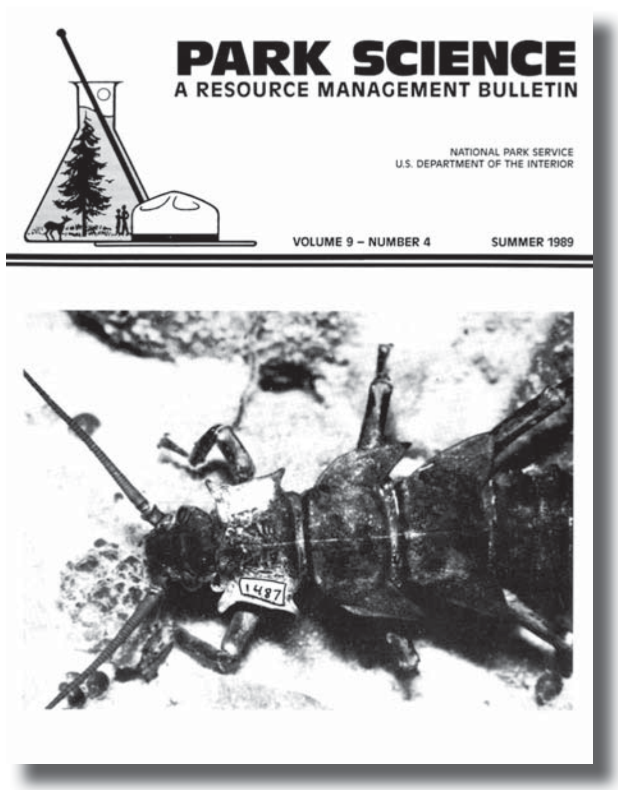
"Vignettes of primitive America" revisited

IN A REPORT ENTITLED *NATIONAL parks: From vignettes to a global view*, [an independent commission] called for "action on an unprecedented scale" to apply ecosystem management concepts to the parks, bring about a "quantum leap in both the quantity and quality of research" in the parks, achieve a higher degree of professionalization within the NPS, and adopt an expanded NPS educational mission to nurture "a conservation ethic among all segments of society, including those traditionally underrepresented in park constituencies, in order to lead the nation toward an environmentally sane future. . . ."

The commission reached key conclusions . . . (1) Preserving park resources must continue to be the most important task of the Park Service . . . (2) A significant improvement of NPS research programs across all disciplines must be initiated. . . . The Park Service has only about 75 field scientists and 46 park historians for its 354 units, and research comprises only about 2 percent of the NPS operating budget. . . . (3) The NPS can no longer rely on generalist rangers for all its needs. Career ladders must be made available to resource managers so they can rise within the hierarchy along with managers with backgrounds in law enforcement and other areas. (4) The National Park System and Service have the capacity to impart conservation ethics to the American and world population, reach out to new constituencies, and explain the processes of environmental and cultural change. . . .

Reference

Simon, D. 1989. Prestigious commission urges new NPS vision. Park Science 9(4):10.



At Your Service

Rising tide

Jeffrey Cross focuses resources on marine and coastal park issues

By Jeff Selleck and Luke Carrington

"Ocean and coastal parks are diverse, amazing places, with amazing resources. Getting involved in establishing the Ocean and Coastal Resources Branch is a way for me to make a difference, to start developing a national-level program that can serve the interests of the ocean and coastal parks. We can raise the awareness of these parks and make progress on their issues. We're working across natural and cultural resource management on issues as diverse as coastal processes, coastal development, fisheries, and climate change. There is a real opportunity to work with interdisciplinary teams on significant issues."

—Jeffrey Cross

THE NATIONAL PARK SYSTEM conserves 5,100 miles (8,206 km) of coast and 3.1 million acres (1.3 million ha) of submerged lands that include beaches, coral reefs, estuaries, barrier islands, glaciers, historic forts, and shipwrecks across 26 states and territories. Yet most ocean and coastal parks lack basic habitat maps, resource inventories, and monitoring information needed to assess the condition of submerged resources. This knowledge deficit affects the ability of the National Park Service to determine the degree of risk or threat of a wide variety of environmental issues to park resources and whether change in resource condition is natural or human-caused. Recognizing that the condition of submerged resources in ocean and Great Lakes parks is deteriorating, the National Park Service published the *Ocean Park Stewardship 2007–2008 Action Plan*[1] in 2006 as a response to the 2004 *U.S. Ocean Action Plan* that called on federal agencies to increase their emphasis on ocean and coastal resources.

Thus, in 2007 the Natural Resource Program Center, Water Resources Division, established the Ocean and Coastal Resources Branch to identify and serve the needs of 74 national parks with ocean and Great Lakes resource management issues. Jeffrey Cross, the chief of this new branch, has been working diligently to develop an implementation plan to fund the branch and prioritize the work. The branch currently operates with four staff: Cross as branch chief; Eva DiDonato, marine pollution ecologist; and Jeremy Cantor, student GIS technician, all stationed in Fort Collins, Colorado; and Cliff McCreedy, marine management specialist, in Washington, D.C. The implementation plan calls for the addition of one or two central office staff (in Fort Collins and Washington), and three or four region-based staff (i.e., in regions with ocean and Great Lakes parks to be phased in beginning in fiscal year 2010). Their job will be to coordinate or provide direct technical assistance for island parks like Channel Islands and Virgin Islands, coastal parks like Acadia and Kenai Fjords, and parks on the Great Lakes, such as Apostle Islands.

Following a superintendent's steering group meeting in 2008, Cross obtained a sample of the types of needed expertise: physical oceanography (to understand sediment and pollution transport), fisheries biology (to prevent overfishing), invasive marine species (to determine threats to native species and implement control actions), coastal processes (to understand the affects of rising sea level and increasing storm intensity), coastal engineering (to manage shoreline structures), marine ecology (to assess the efficacy of marine reserves), restoration ecology (to restore damaged habitats), and remote sensing (to map submerged habitats and track changing ocean conditions). In the future, he hopes to have the resources to deploy technical specialists to geographic clusters of parks with related coastal and marine resources and management issues, similar to the manner in which the Water Resources Division deployed and manages its field staff of aquatic resource professionals. The benefit to this approach is

[1] *Ocean Park Stewardship 2007–2008 Action Plan* is published online at http://www.nature.nps.gov/water/Homepage/Ocean_Park_Stewardship.cfm.

twofold: most individual parks would not have to employ their own experts, and the experience gained in solving a problem at one park would be applicable in the other similar parks. In addition to providing technical support and coordination services, the new branch will increase policy support to parks and regions and provide for more effective public communication and education about stewardship. As Cross outlines in the implementation plan, "Connecting people to ocean parks remains the most important task ahead."

Cross sees the role of the branch as a hub in which ocean and coastal parks can address common park problems. Additionally, the branch will be the major interagency contact for addressing issues at a national level and sharing resources with other governmental agencies. "When it comes to oceans and coastal issues, the main agencies involved are NOAA, U.S. Fish and Wildlife Service, U.S. Geological Survey [USGS], Minerals Management Service, and the U.S. Army Corps of Engineers. For projects that span multiple park areas," Cross says, "our branch can represent the technical needs of the National Park Service effectively. Whether the need is for partnerships, alliances, or coalitions, we can help parks with interagency coordination."

A big project that the Ocean and Coastal Resources Branch is undertaking now is the development of benthic habitat maps for eight of the ocean and coastal parks (fig. 1). "We've partnered with USGS and NOAA and are taking the best of their technology, science, and understanding, and translating it into products that can be used by parks in planning and management decisions about resources." Ultimately, these maps could provide information about the status of fish populations, invertebrates, coastal and beach erosion, currents and sediment flow, wetlands restoration, and faults. Unlike at terrestrial parks, managers of ocean and coastal parks cannot readily observe the resources in their care. Cross explains, "Several times I saw Gary Davis, retired marine biologist and former NPS science advisor at Channel Islands National Park, make presentations at conferences. He would show maps of the parks with a lot of terrestrial details, but the water was simply solid blue. We are focusing on benthic habitat maps because the information is badly needed. The most spectacular topography and geographic features are hidden from casual view and can only be detected by surveys that are technically complex, logistically difficult, and expensive." If the branch is fully funded, the benthic habitat mapping project would be expanded beyond the eight pilot parks.

Another important focus of the branch is coordination of coastal watershed assessments. Since 2003, 29 assessments have been completed, with another 18 in progress. These surveys describe water quality, habitat condition, invasive species, extractive uses, physical impacts from resource use and coastal development, and other issues affecting ocean and coastal resource health.

The new branch receives help from the Geologic Resources Division, which also has expertise in ocean and coastal resource management. Coastal Geologist Rebecca Beavers has been coordinating the production of coastal vulnerability maps that show a park's susceptibility to erosion and other problems related to sea level rise. Julia Brunner, policy and regulatory specialist, helps parks understand NPS legislative authorities and jurisdiction, and is drafting a handbook that will provide basic guidance to improve the consistency and effectiveness of coastal resource management.

Branch chief Cross


NPS/NATURAL RESOURCE PROGRAM CENTER

Jeffrey Cross has worked with marine and coastal issues throughout his career. After obtaining his PhD in marine fisheries from the University of Washington in 1981, he worked for about 10 years as a practicing fisheries biologist. He then moved to a management position as executive director of Southern California Coastal Water Research Project, a research institute focusing on the coastal ecosystems of southern California, in 1990. Cross moved to the National Oceanic and Atmospheric Administration (NOAA) in 1996, where he worked for the National Marine Fisheries Service. After five years he left NOAA for the National Park Service, where he served as chief of Resource Management at Grand Canyon National Park. "One of the reasons I came to the National Park Service was that we do hands-on resource management in the national parks." Cross wanted to head up this new branch because, as he says, "I was frustrated with the status of fishery resources when I left NOAA. Most of the commercial and recreational fisheries were fully exploited or overexploited. The fishery science that was being produced was not always used effectively by fishery management councils to make decisions." Cross explains that one of his priorities is to avoid allowing economics to trump research for the purposes of developing sensible ocean and coastal resource protection policies for the National Park Service.

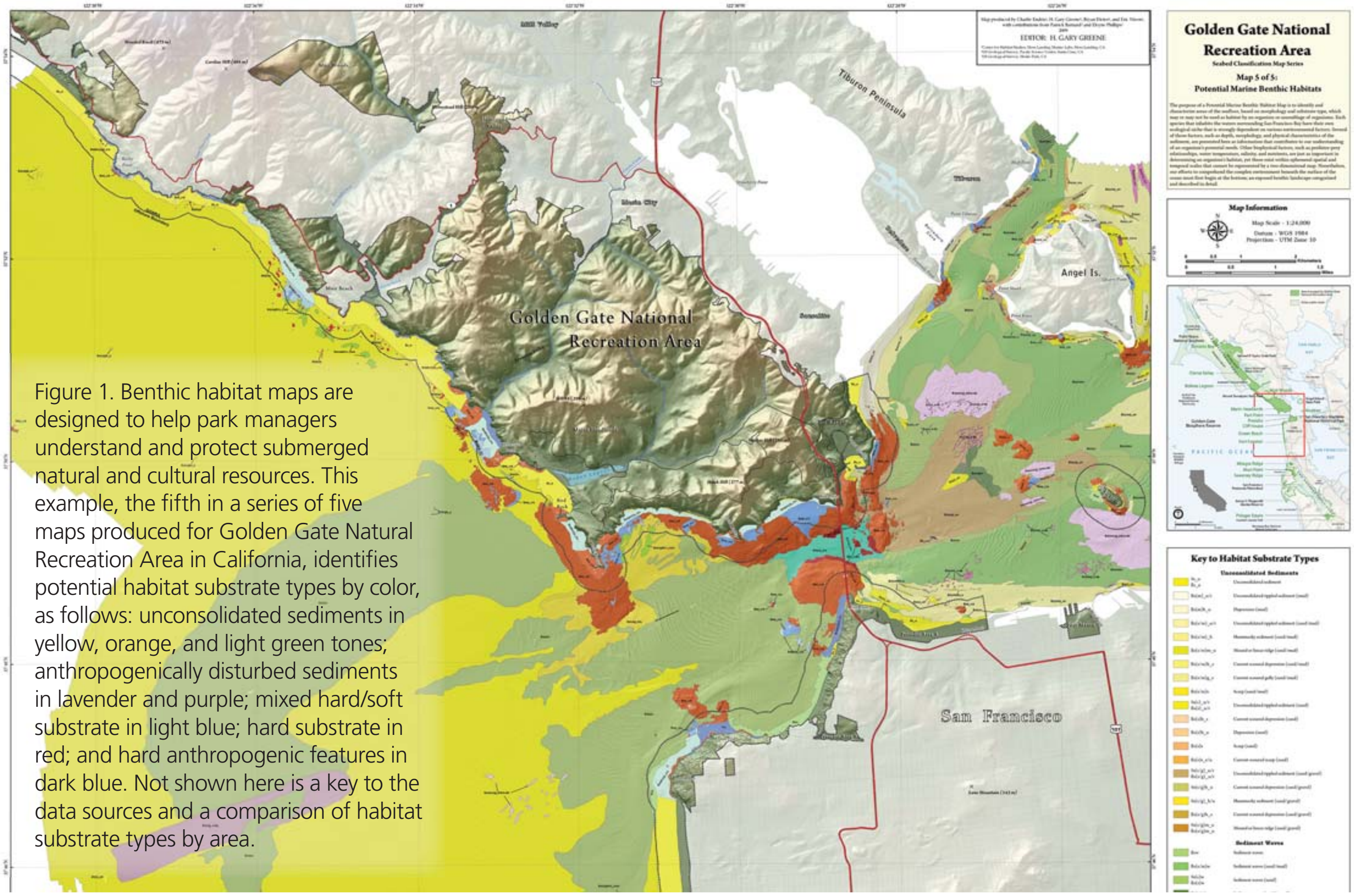


Figure 1. Benthic habitat maps are designed to help park managers understand and protect submerged natural and cultural resources. This example, the fifth in a series of five maps produced for Golden Gate Natural Recreation Area in California, identifies potential habitat substrate types by color, as follows: unconsolidated sediments in yellow, orange, and light green tones; anthropogenically disturbed sediments in lavender and purple; mixed hard/soft substrate in light blue; hard substrate in red; and hard anthropogenic features in dark blue. Not shown here is a key to the data sources and a comparison of habitat substrate types by area.

Cross and Brunner hosted a three-day workshop in Boulder, Colorado, in August 2009 for 52 NPS resource protection staff from ocean, coastal, and Great Lakes parks. The purpose of the workshop was to provide a forum to discuss ocean and coastal legal, policy, and resource management issues; NPS approaches to resource management problems; and conflicts or unresolved needs. Workshop participants identified climate change, fisheries management, invasive species, water quality, watershed management, sediment management and coastal infrastructure, and habitat and ecosystem restoration as the priority issues. Following up on the workshop, participants will frame an NPS director's order on ocean and coastal park management, propose regulatory revisions, and develop additional guidance needed by park managers. These products will help park staffs address complex submerged resource issues and will guide the development of an effective NPS ocean and coastal resource program.

Over the last 10–20 years the National Park Service has greatly expanded its capabilities for science-based management of park resources, albeit mainly terrestrial resources. Now with increasing awareness of overfishing, sea level rise, pollution, coastal erosion, and many other issues affecting our coasts, a management perspective that fully incorporates coastal and submerged natural and cultural resources is gaining strength and support. The Ocean and Coastal Resources Branch is a big step in the right direction to professionally managing and protecting these important resources. Its doors are open for business and its staff is at your service.

Contact

You can contact ***Jeffrey Cross*** *at 970-225-3547 and jeffrey_cross@nps.gov,* ***Cliff McCreedy*** *at 202-513-7164 and cliff_mccreedy@nps.gov, and* ***Eva DiDonato*** *at 970-267-7291 and eva_didonato@nps.gov.* *Park and regional staffs are encouraged to use the Solution for Technical Assistance Requests (STAR, online at http://nrpcstar) to identify needs and request technical assistance with coastal resource management issues.*

About the authors

Jeff Selleck *is the editor of* Park Science. ***Luke Carrington*** *volunteered for the Geologic Resources Division in 2009. He is a student studying journalism at the University of Wyoming.*

PS

In Focus: CESUs

Cooperative Ecosystem Studies Units at 10 years

By Thomas E. Fish

THE COOPERATIVE ECOSYSTEM STUDIES Units (CESU) network is a nationwide consortium of federal agencies, universities, conservation organizations, and other partners working together to support agency missions and informed public trust resource stewardship. The CESU network was established pursuant to the National Parks Omnibus Management Act of 1998 (16 USC 5933). A memorandum of understanding was signed in 1999 by participating federal agency administrators, establishing the CESU Council as the governing body for the CESU network, and initiating the process to competitively establish a national network of CESUs. The first four pilot CESUs were established in 1999, comprising six federal agencies and more than two dozen academic and other nonfederal partners. Now in its 10th year, the CESU network includes more than 250 partners, including 13 federal agencies, in 17 CESUs representing biogeographic regions across all 50 states and U.S. territories (see map, opposite page).

CESUs bring together scientists, resource managers, and other conservation professionals from across the biological, physical, social, cultural, and engineering fields (from anthropology to zoology) to conduct coordinated, collaborative applied projects that address natural and cultural heritage resource issues at multiple scales and in an ecosystem context. Each CESU consists of a partnership between a host university; multiple federal agencies; numerous additional academic institutions; tribal, state, and local government agencies; and nongovernmental organizations. All projects are supported by federal financial assistance awards facilitated through master cooperative agreements at each CESU. NPS project development and coordination is assisted by duty-stationed NPS scientists (CESU research coordinators) at each CESU.

Current activities at the national level include looking back over the first 10 years and looking forward to the next. At the 10-year mark, the establishment of the national network of CESUs is complete, yet the organization is still young. A 10-year program evaluation is under way across the system, aimed at capturing vital statistics for the program (e.g., project typology, partner involvement, geographic locations, outputs, outcomes) and to better understand the successes, challenges, and lessons learned from the first 10 years. Preliminary data indicate that more than 5,500 projects have been administered through the program since 1999 at a cumulative value (across all CESUs and federal agencies) of more than $350 million. Recent CESU Council discussions have focused on the utility of these vital statistics for periodic reporting, performance measurement, transparency, program visibility, outreach, and recruitment of new partners. Additional initiatives supported at the national level include a comprehensive administrative history, information resource development, multiagency climate change workshops, establishment of a national office fellowship program, and enhancement of the CESU network Web site (www.cesu.org).

It is an important and exciting time for science in the federal government, with reinvigorated support for collaboration in science-based and outcome-oriented decision making coming from the highest levels. The CESU network is well positioned to serve as a platform for supporting research, technical assistance, and capacity building that is responsive to national, regional, and local needs. The strategic plan for the CESU network is currently being revised, employing an outcome-oriented logic model approach that aligns program inputs, activities, and outputs with strategic goals linked to agency missions and relevant policy and management directives. Much of the first 10 years of the program, including its strategic goals, focused on the development of the national network. Revising the plan affords reflection and rearticulation of the strategic goals in terms of contemporary science, management, and capacity building drivers and priorities, for example, climate change adaptation, sustainability science, renewable energy, cultural and historic resource preservation, ecological restoration, connecting people to nature, ocean stewardship, green design and engineering, biological invasions and disease, and training of the next generation of conservation professionals. Developing innovative approaches that transcend disciplinary and institutional boundaries will be critical to solving the complex problems facing the sustainability of our natural and cultural heritage. The CESU network can support efforts to address existing and emerging priorities, building new usable knowledge, and engaging partners from across the palette of expertise in the CESUs.

This section of Park Science highlights a selection of CESU projects from across the network. The first article discusses the investigation and restoration of ancient cultural landscape features in Effigy Mounds National Monument in Iowa. The second article summarizes research conducted in Utah's Zion National Park that describes the cumulative effects of predator loss on terrestrial, riparian, and aquatic ecosystems. Scientists and managers in the northeastern United States explore changes in marsh elevation in relation to

NPS/CESU PROGRAM

Cooperative Ecosystem Studies Units are structured as collaborations among federal and state agencies, universities, nongovernmental organizations, and other nonfederal partners. They play a broad role in providing the research, technical assistance, and educational services necessary for management of national parks and pertinent to the missions of many other agencies. Each unit is hosted by a university and is named for the biogeographic area of service.

sea-level rise in coastal barrier island salt marshes within Fire Island National Seashore in New York. As an example of the many archaeological field school programs supported through the CESU network, the following piece details how Hawaiian high school students work alongside NPS staff and university faculty to learn archaeological field techniques and collect baseline data for Hawaii Volcanoes National Park. Next is a presentation of recent findings from research and monitoring efforts at Everglades National Park to address the increasing population of Burmese pythons that has invaded the park and surrounding areas in southern Florida. The final article provides a brief overview of the Money Generation Model, a useful economic assessment tool developed for gauging the impacts of NPS visitor spending on local and regional economies.

The CESU network sustains strong partnerships for NPS science, stewardship, and capacity building. The examples presented in this issue are intended to highlight some of the good work that NPS staff and collaborators are engaged in, yet provide just a snapshot into the true breadth and depth of efforts and outcomes supported across this unique program. The next 10 years will bring new opportunities, new partners, new challenges, and new successes as the CESU network continues to evolve.

About the author

Thomas E. Fish *is national coordinator, Cooperative Ecosystem Studies Units Network, 1849 C Street NW, Room 2723, Washington DC 20240. He can be reached at 202-208-5972 and tom_fish@nps.gov.*

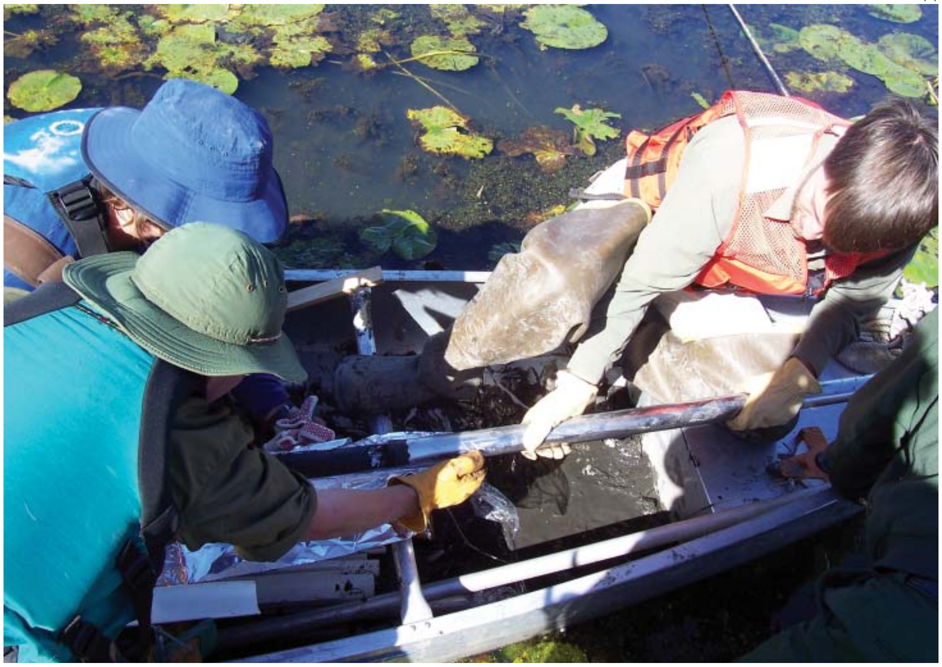
Reconstructing prehistoric ecology to restore the paleo-environment at Effigy Mounds

By Betsie Blumberg

Restoring the landscape to the conditions present when the mound builders lived here is an objective of the monument's management plans. . . . The initial challenge to carrying out these plans was learning what the landscape was like in mound builders' time.

NPS PHOTOS (2)

Figure 1 (facing page and right). A core sample provides evidence of prehistoric ecological conditions. Investigators chose a spot at the bottom of a shallow pond at Effigy Mounds National Monument to sink a core sampler. The 26-foot core reached sediment that was 9,000 years old. Investigators carefully divided the core into 2-foot sections for transport to the lab for analysis.



EFFIGY MOUNDS NATIONAL MONUment in Iowa is the site of 200 burial mounds constructed 2,500 to 750 years ago. Restoring the landscape to the conditions present when the mound builders lived here is an objective of the monument's management plans. However, the initial challenge to carrying out these plans was learning what the landscape was like in mound builders' time and how it changed over the 1,750 years when the mounds were built. When a graduate student from the University of Wisconsin–Madison requested permission to take a core sample at the monument for data for her master's thesis, the opportunity arose to retrieve some information that managers needed. The Great Lakes Northern Forests Cooperative Ecosystem Studies Unit (CESU) provided funds for the equipment and analysis of the core. Partners were the National Park Service and the University of Wisconsin–Madison.

The core was taken from the bottom of a shallow pond and extended as deep as it was possible to sink the sampler. Monument staff stood on a plywood platform fastened to two canoes and pushed the sampler into the sediment using a post driver (fig. 1), ultimately producing a core 26 feet (8 m) in length. Two-foot (60 cm) segments were extruded from the sampler, and taken to the lab for analysis of pollen (indicating vegetation type), charcoal (for carbon-14 dating and indicating fire), and grain size (indicating flooding).

The result was a sketchy profile of the environment around the pond for the last 9,000 years. Most important to the monument was the period when the mounds were constructed. The mound builders were people who practiced what is called Woodland culture. The beginning of the decline in the prairie ecosystem coincided with the appearance of Early Woodland culture (2,500 years ago). The temperature cooled, more patches of trees were present, and probably more deer appeared, which these people hunted as they adopted pottery and began the mound-building tradition. Middle Woodland people (1,900 to 1,500 years ago) experienced an environment that included mesic (well-balanced moisture supply) forest oak woodland, savanna, and prairie. The core indicates that around 1,710 years ago, the incidence of fire decreased and that there was heavy flooding around 1,600 years ago. Late Woodland people (1,500 years ago) also enjoyed a landscape of mixed prairie, savanna, and forest where they began using the bow and arrow. They were succeeded by the Oneota people, who did not build mounds.

The core suggests that the landscape around the pond at Effigy Mounds varied from prairie to mesic forest over the last 8,500 years. Rodney Rovang, natural resources manager at Effigy Mounds, reports that activity is already under way to modify today's largely mesic, but disturbed, landscape to reflect conditions present 1,000 years ago. That landscape, as the core revealed, should include mesic woodland, floodplain forest, savanna, and prairie.

For more information

Bogen, S. M., and S. C. Hotchkiss. 2007. Paleo-environmental investigations of a cultural landscape at Effigy Mounds National Monument. Report. University of Wisconsin–Madison. Accessed 2 June 2009 from http://www.cesu.umn.edu/documents/ProjectReports/UW.M/UWM_NPS_04.FinalReport.pdf.

About the author

Betsie Blumberg *is* Park Science *contributing editor.*

PS

In Focus: CESUs

Impact of a cougar decline on Zion Canyon, Zion National Park

By Betsie Blumberg

THE COUGARS OF ZION NATIONAL Park, Utah, have withdrawn from Zion Canyon, and the cottonwood forest in the canyon has declined with their departure. Further changes in biodiversity and streambed characteristics in the canyon area of the park have also taken place. Researchers William J. Ripple and Robert L. Beschta of Oregon State University studied the trophic cascade that occurred with the decline in cougar (*Puma concolor*) population (fig. 1). Their research was supported by the Colorado Plateau Cooperative Ecosystem Studies Unit (CESU). Cooperators were Oregon State University and the National Park Service.

Zion Canyon was first settled by ranchers and homesteaders in 1862. Their activities left the canyon with destabilized creek channels, little of its natural vegetation, and a very small mule deer (*Odocoileus hemionus*) population. The settlers later abandoned the canyon and in 1918, Zion National Park was established. By the late 1920s, the vegetation and the deer were returning, and the number of visitors to the park was growing. By 1934, the decline of the cougar, attributed to human traffic and activity, was noted by park staff.

Researchers Ripple and Beschta were interested in assessing ecosystem changes where cougars had become rare. To do so, they compared the age of cottonwood trees (*Populus fremontii*) and selected riparian biota in the canyon with the same landscape features in an adjacent area of the park, the North Creek drainage, where human visits are infrequent and the cougar population is stable. (According to Utah Division of Wildlife files, the park has an estimated cougar population of 17–25 animals/1,000 km^2 [386 miles^2].)

At both sites, investigators measured the diameter of cottonwood trees and took cores from trees to establish age-diameter relationships. These results were used to develop historical trends in cottonwood recruitment (seedlings that matured to trees). They also surveyed streambank conditions, channel dimensions and width:depth ratio, and hydrophytic vegetation (i.e., plants that grow in water). To assess biodiversity, they inventoried the abundance of selected indicator species of wildflowers, amphibians, reptiles, and butterflies. They determined mule deer abundance by recording hoofprints along transects, and cougar abundance by quantifying scat per linear kilometer of foot trails.

Decline of the cougar had a profound long-term effect on terrestrial and aquatic ecosystems in Zion Canyon.

In the North Creek study area, where cougar and deer continue to coexist, cottonwood trees showed continuous recruitment, with more young trees than old ones. Zion Canyon, in contrast, had few young trees and little recruitment since the 1940s, the apparent result of heavy browsing by deer after cougar were displaced from the canyon. The abundance of hydrophytic plants and wildflowers along streams was greater in the North Creek area than in the canyon, and there were more species and a greater abundance of lizards and butterflies. In Zion Canyon, where streambank erosion was 2.5 times more common than in North Creek, streambeds were wider and shallower. Fish surveys conducted since 1994 also indicated that mean densities of native fish were three times higher in streams in areas where cougars were common (North Creek) than where cougars were rare (Zion Canyon).

These observations indicate that the decline of the cougar had a profound long-term effect on terrestrial and aquatic ecosystems in Zion Canyon. The loss of the large predator resulted in greatly increased mule deer density, which increased browsing on cottonwood seedlings and other vegetation, and the forest was diminished. Heavily browsed streamside vegetation caused declines in riparian fauna and allowed streambanks to erode. Overwidened channels and non-vegetated streambanks created shallow channels of degraded fish habitat.

This study demonstrates the consequences that followed the departure of the cougars from Zion Canyon. Its findings are consistent with those assessing the impact of the removal of wolves and provide important insight to managers of parks and other natural areas where large predators have been extirpated or displaced.

For more information

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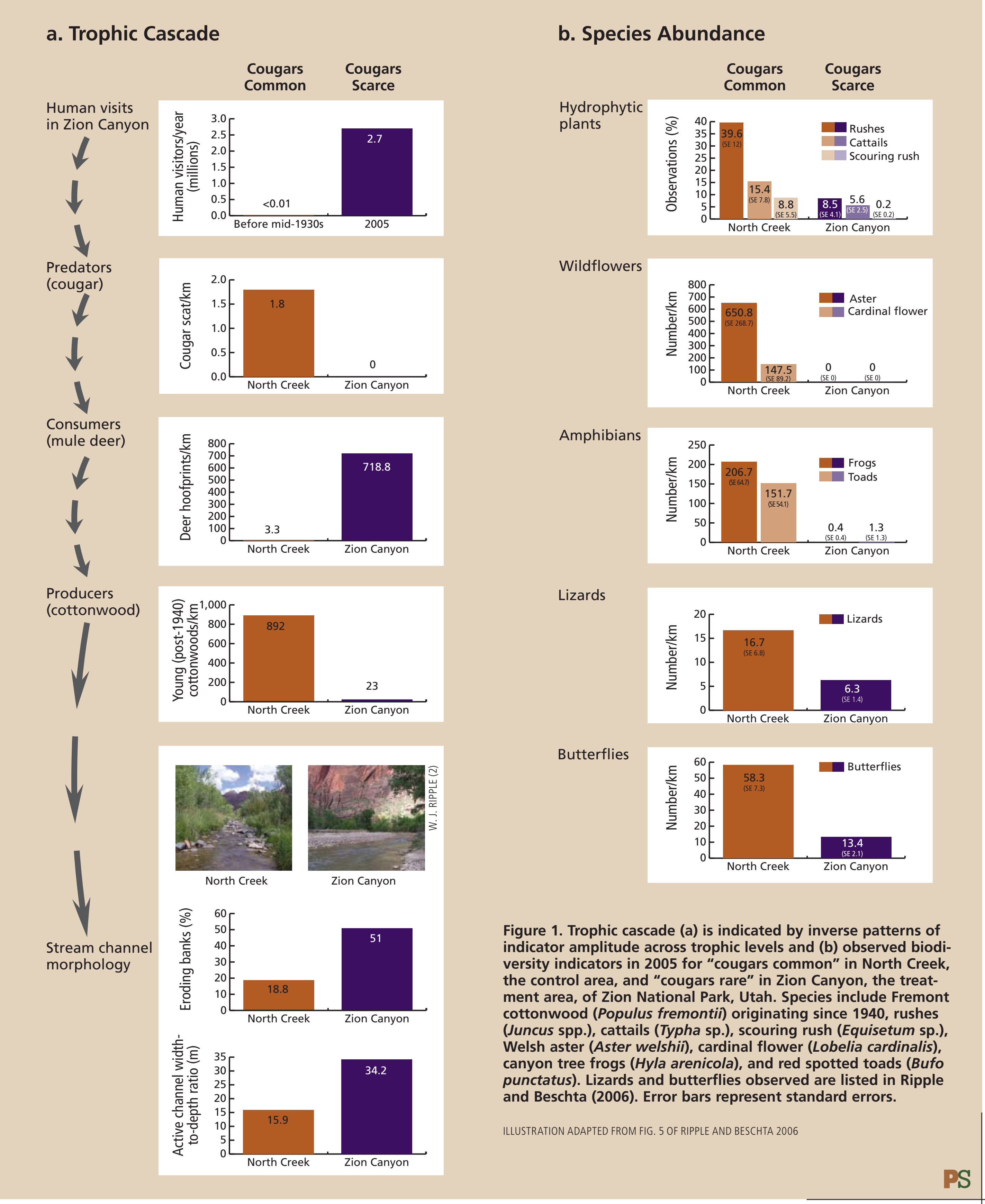


Figure 1. Trophic cascade (a) is indicated by inverse patterns of indicator amplitude across trophic levels and (b) observed biodiversity indicators in 2005 for "cougars common" in North Creek, the control area, and "cougars rare" in Zion Canyon, the treatment area, of Zion National Park, Utah. Species include Fremont cottonwood (*Populus fremontii*) originating since 1940, rushes (*Juncus* spp.), cattails (*Typha* sp.), scouring rush (*Equisetum* sp.), Welsh aster (*Aster welshii*), cardinal flower (*Lobelia cardinalis*), canyon tree frogs (*Hyla arenicola*), and red spotted toads (*Bufo punctatus*). Lizards and butterflies observed are listed in Ripple and Beschta (2006). Error bars represent standard errors.

ILLUSTRATION ADAPTED FROM FIG. 5 OF RIPPLE AND BESCHTA 2006

In Focus: CESUs

Sea-level rise, climate change, and salt-marsh development processes at Fire Island

By Betsie Blumberg

NORTH ATLANTIC COAST Cooperative Ecosystem Studies Unit (CESU) research partners have been addressing complex issues at coastal national park units for more than a decade. One of these projects, undertaken in partnership with scientists and graduate students from the University of Rhode Island and the U.S. Geological Survey focused on the salt marshes at Fire Island National Seashore. The project's objectives were to quantify marsh elevation change in relation to recent rates of sea-level rise. Under a regime of accelerated sea-level rise there is concern that marshes could become submerged, perhaps changing from vegetated meadows to mudflats and open water. It is important to understand the processes that maintain marshes.

Under a regime of accelerated sea-level rise there is concern that marshes could become submerged, perhaps changing from vegetated meadows to mudflats and open water.

Fire Island is a barrier island along the south shore of Long Island, New York. Its bay shoreline is salt marsh. When bay tides flood the marsh, sediment can accumulate, raising the surface elevation of the marsh, while buildup of marsh peat also contributes to elevation increase. At the same time, however, sediment is compacting, organic matter is decomposing, and erosion can carry away surface material, causing subsidence or elevation loss. Subsidence occurs naturally, but it can threaten the survival of the marsh if it progresses more quickly than accretion or sea-level rise.

Monitoring of three marsh areas began in 2002 and continues for the long term. To determine the status of the marsh elevation, both surface elevation and vertical accretion were measured (fig. 1). Surface elevation was measured by installing a vertical benchmark pipe through the peat and into the underlying sediment, to provide a constant reference elevation. A surface elevation table (SET) was then attached to the benchmark pipe and pins were lowered to the marsh surface (fig 2). Repeated pin measurements, twice a year, recorded changes in marsh surface elevation relative to the benchmark elevation. Vertical accretion or accumulation of material on the marsh surface was measured using small feldspar marker horizon plots, circles of feldspar spread on the surface. When cores were taken periodically from the plots, the feldspar marker clearly showed the level marked at the start of the study, and accretion was indicated by the depth of material above the marker (fig. 3).

At each site, the data indicated that vertical accretion was greater than marsh surface elevation. Although sediment accumulated on the marsh surface, measurement of the marsh surface elevation indicated that the marsh was subsiding. Furthermore, compared with local measurements of sea-level rise, the marsh surface levels were not keeping pace with sea-level rise. The hypothesis that may explain this subsidence is that as the marsh becomes wetter or less well drained, the marsh vegetation produces fewer of the roots and rhizomes that comprise the peat. Decomposition and subsidence of belowground peat appear to be outpacing the deposition of sediment on the marsh surface. More sediment delivered to the surface would balance the process.

The elevation deficit at Fire Island was small, but if it continues, Fire Island marshes are likely to become wetter; the high marsh grass species, *Spartina patens*, will be replaced by the dominant *Spartina alterniflora* and open water habitat may increase. Salt marshes associated with barrier islands often receive pulses of sediment during storms, often associated with overwash and inlet processes, but it was noted that no major storms occurred during the six-year monitoring period. A sediment pulse could relieve the elevation deficit.

Monitoring continues. The longer the duration of monitoring, the easier it is to identify trends. Findings to date suggest that long-term maintenance of barrier island salt marshes is tightly coupled with inlet and overwash processes. Further, as sea level rises, marshes often grow vertically, but also can encroach on upland areas, assuming that the landscape adjacent to the marsh is free of impediments to this landward migration (e.g., bulkheads). Dr.

Charles Roman, research coordinator for the North Atlantic Coast CESU, reports that this technology is now being applied at Cape Cod and Assateague Island national seashores and Gateway National Recreation Area to determine the relationship between sea-level rise and salt-marsh elevation. Chief of Resource Management at Fire Island Michael Bilecki says that this project has made the north side of the island, the bay side, a priority. "Before, the concern was beach erosion on the ocean side. Now we see that there are some big issues on the bay side and we are understanding relationships between barrier island processes and bayside marshes."

Final report

Roman, C., J. W. King, D. R. Cahoon, J. C. Lynch, and P. G. Appley. 2007. Evaluation of marsh development processes at Fire Island National Seashore (New York): Recent and historic perspectives. Technical Report NPS/NER/NRTR–2007/089. National Park Service, Northeast Region, Boston, Massachusetts. Accessed 2 June 2009 from http://www.nps.gov/nero/science/FINAL/FIIS_marsh/FIIS_marsh_sealevel_final_July07_v2.pdf.

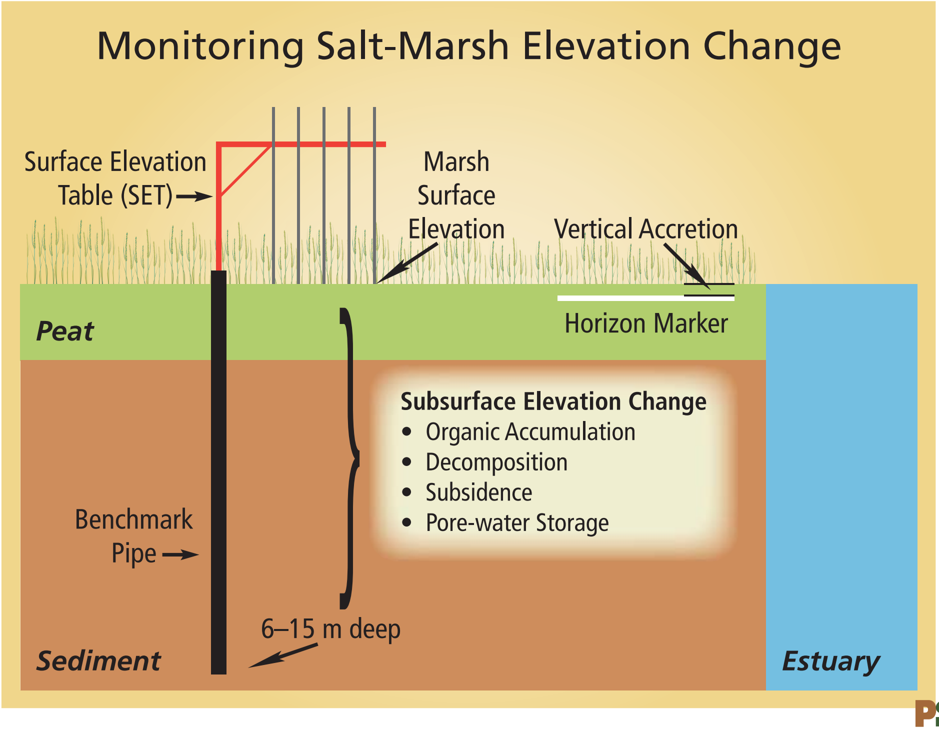
NPS PHOTO

Figure 1. Investigators examine measuring pins in the rod-type surface elevation table to discern changes in overall marsh elevation. A third scientist prepares to freeze a marsh core sample using liquid nitrogen.

NPS PHOTO

Figure 2 (right). This schematic shows the surface elevation table and feldspar horizon marker used in the study to monitor changes in the elevation of the salt marsh at Fire Island relative to changes in sea level.

Figure 3 (above). This cryo-core sample of the marsh surface horizon shows the white feldspar marker and sediment that has accumulated above it, indicating accretion of soil.



SPARTINA ALTERNIFLORA SYMBOLS COURTESY OF THE INTEGRATION AND APPLICATION NETWORK (IAN.UMCES.EDU/SYMBOLS/), UNIVERSITY OF MARYLAND CENTER FOR ENVIRONMENTAL SCIENCE

PS

In Focus: CESUs

Archaeological field school provides valuable data for Hawaii Volcanoes National Park

By Betsie Blumberg

NPS/HAWAII VOLCANOES NATIONAL PARK

High school students under the supervision of University of Hawaii at Hilo Professor Steve Lundblad (in red hat) examine basalt chips at Kilauea caldera and learn archaeological techniques that will provide information about the early Hawaiians' use and trade of lithic material.

DURING SUMMER 2007, the Hawaii–Pacific Islands Cooperative Ecosystem Studies Unit facilitated a project at Hawaii Volcanoes National Park that accomplished two goals: identifying the sources of Hawaiian stone artifacts in the park collection, and training high school students in the archaeological techniques used in this study. Partners were the National Park Service and the University of Hawaii, Hilo.

Twelve students from the Na Pua No'eau Gifted and Talented Hawaiian program spent two weeks attending an archaeological field school working with park and university staff learning basic archaeological techniques, including field description, use of Global Positioning System equipment, artifact collection, and lab analysis. The students worked in a remote part of the park on the northern edge of the Kilauea caldera. This caldera erupts explosively (at approximately 300-year intervals), spewing forth chunks of basalt, a fine-grained material that the indigenous Hawaiians chipped into tools. They would knap the basalt into rough forms at the quarries and carry off the cores to refine later, leaving behind the flakes of stone that archaeologists recognize as the debitage of an ancient workshop. In 2007, the young archaeology students located the quarry site and collected samples from several features.

The next step was to define the "signature" of the Kilauea basalt using a state-of-the-art spectrometer at the University of Hawaii. The spectrometer analyzes the stone to determine the particular set of trace elements that allow an artifact to be associated with its quarry source. The students learned how to operate this equipment and were able to analyze not only the material they had collected, but also artifacts in the park's collection. They found that some pieces in the collection came from other parts of the island of Hawaii and from other islands, just as artifacts made of the basalt from the Kilauea caldera have been found far from their source. Tracking the transport of lithic materials provides insight into the movement and trade of Hawaiian people before and during the early years of contact with Europeans. The artifacts in the park's collection are dated at about AD 1450. The Kilauea caldera quarries are dated at about AD 1650 to 1790.pAnalysis of these materials and their provenance also sheds light on the strategies used to procure lithic resources, as well as variations in tools and their distribution over time. The information gained from this project will provide Hawaii Volcanoes National Park with baseline data needed in making appropriate research decisions and in evaluating sites for the National Register of Historic Places. The experience of the students in the field school acquainted them with Hawaii's prehistory and the techniques employed to discover it. Perhaps some of them will pursue this study in the future and contribute further to our understanding of the earliest inhabitants of Hawaii.

PS

Burmese pythons in southern Florida's Everglades

By Betsie Blumberg

BURMESE PYTHONS (*Python molurus bivittatus*) are colonizing Everglades National Park and areas around the park in southern Florida (fig. 1). These snakes were probably released by pet owners when they grew too big to be pets; they reach a length of 23 feet (7 m) and a weight of almost 200 pounds (90 kg), much larger than any snakes native to Florida, which they can outcompete as predators. They threaten native ecosystems because they eat many species of birds, mammals, and reptiles, including species of concern such as the Key Largo wood rat (*Neotoma floridana smalli*) and three wading birds, the limpkin (*Aramus guarauna*), the white ibis (*Endocemus albus*), and the wood stork (*Mycteria americana*). The wild python population has been estimated to number in the thousands. Its containment is part of the restoration effort for the Florida Everglades.

A workshop of invasive-snake management experts held in 2005 identified priorities in managing the python invasion. The resulting Python Science Support Team was formed to determine the status and extent of the python population, investigate movement and habitat use, refine methods to estimate potential impacts, and capture and remove pythons. Previous experience in dealing with invasive snakes is limited. In the Pacific islands of Guam the invasive brown tree snake, and on the island of Ryuku the habu, seriously disrupted the existing ecology. Methods used to address those invasions must be modified to accommodate the characteristics of the Everglades habitat and the python.

Many institutions and agencies are participating in python research. The South Florida–Caribbean Cooperative Ecosystem Studies Unit collaborators in this project are the Critical Ecosystems Studies Initiative (CESI) Everglades–Research, U.S. Geological Survey Greater Everglades Priority Ecosystems Science, and the University of Florida. In addition to park funds, python research funding is coming from the U.S. Fish and Wildlife Service (trap development in the Florida Keys) and the South Florida Water Management District (trap development). Davidson College partnered in thermobiology research and the Smithsonian Institution partnered in feather identification for diet analysis.

Figure 1. Lynn Scarlett, former Deputy Secretary of the Interior, and Roger Hammer, Miami-Dade County naturalist, encounter a Burmese python in Everglades National Park in April 2008.

The Python Science Support Team is focusing on research using radiotelemetry, diet analysis, and thermal research. Radiotelemetry enables the team to follow the movements of snakes that have been implanted with very high-frequency radio transmitters. These implanted "Judas" snakes lead the team to other pythons that are then captured and euthanized. One Judas snake led researchers to a nest, confirming that the pythons are breeding within the park.

Thermal research involves implanted temperature-sensitive data loggers along with the radio transmitters. Temperature data recorded every 30 minutes indicate which microhabitats the snakes are using, and when they are in the water or basking in the sun. This information suggests the best times to capture the pythons. It also provides data that can be used in a model predicting the number and type of prey the snake needs to eat, because these reptiles' metabolic rate is dependent on temperature.

National Park Service personnel euthanize the snakes, and University of Florida researchers analyze the contents of their digestive tracts. The list of species that have been found in the pythons' gut includes bobcat (*Felis rufus*) and white-tailed deer (*Odocoileus virginianus*) as well as the four species of concern.

The Python Science Support Team's research is broadening understanding of the python's behavior and impact on the Everglades. This is leading to the development of methods of containment that may be applied to others areas, such as Big Cypress National Preserve and the Florida Keys, and to other invasive nonnative snakes in southern Florida, such as the boa constrictor (*Boa constrictor*).

For more information

Harvey, R. G., M. L. Brien, M. S. Cherkiss, M. Dorcas, M. Rochford, R. W. Snow, and F. J. Mazzotti. 2008. Burmese pythons in south Florida: Scientific support for invasive species management. Document WEC242. Wildlife Ecology and Conservation Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Accessed 2 June 2009 from http://edis.ifas.ufl.edu/UW286.

PS

In Focus: CESUs

Assessing economic impacts of national parks

By Thomas E. Fish

NATIONAL PARK UNITS IMPACT LOCAL economies in a variety of ways. In particular, park visitors spend money on items such as entrance fees, overnight accommodations, local attractions and tourism activities, fuel, food, beverages, entertainment, and souvenirs. Parks also contribute to local economies through employment of agency personnel; park operations and capital expenditures; by influencing park-related employment and economic development, especially in amenity and tourism support industries; and through associated local household spending. Dollars that enter the local economy are redistributed through purchase of local goods and services, residential and commercial construction, and other expenditures. Accurately estimating the economic impact a unit of the National Park System has on a community or region can be very useful for planning and management decisions at the park level as well as for local and regional planning.

The Money Generation Model (MGM) is an economic assessment tool available to national park managers to help gauge the economic impact of national park visitor spending on local economies. The MGM was developed by Dr. Ken Hornback in 1995. An updated version—MGM2—was developed in 2000 by Drs. Daniel Stynes and Dennis Probst at Michigan State University. The NPS Social Science Program has worked with Stynes's team (through the Great Lakes–Northern Forest CESU) over the past several years to incorporate additional features and refinements.

The basic equation for computing the economic impact of visitor spending is *economic impacts = number of visitors × average spending per visitor × economic multipliers* (Stynes et al. 2000). The inputs to the model include number of visitors, average spending (per visitor or party), and multipliers. According to Stynes et al. (2000), these inputs can come from a variety of sources. Visitor numbers are typically provided by the NPS Public Use Statistics Office; average spending is estimated from NPS Visitor Services Project survey data, where available. If these data are not available, generic estimates are provided for natural resource and cultural and historical park units. Several multipliers are included with the model, although customized multipliers can be used.

The MGM2 arranges visitors into eight visitor segments according to visit characteristics: local day visitors; nonlocal day visitors; visitors who stay in overnight commercial lodging (e.g., motels, cabins, lodges) within the park; visitors who stay in campgrounds within the park; backcountry camping visitors; visitors who stay in commercial lodging outside the park; those who camp outside the park; and those who stay at vacation homes with friends or relatives. Visitor spending is divided into 12 spending categories: commercial accommodations (e.g., motels, cabins, bed-and-breakfasts [B&Bs]); camping fees; restaurants and bars; groceries and take-out food/drinks; fuel; nonfuel vehicle expenses; local transportation; admission fees; clothing; sporting goods; gambling; and souvenirs and other expenses. Multipliers are assigned to each spending category to arrive at the adjusted value per dollar spent and to estimate the corresponding jobs and income for the particular park unit or region.

The MGM2 estimates "direct," "indirect," and "induced" effects of visitor spending. Direct effects relate to the direct receipt of visitor funds (e.g., paid directly to a motel or restaurant). Indirect effects reflect funds transferred from direct recipients to their associated support industries (e.g., beverage supplier). Induced effects reflect the "household spending" of funds received by direct or indirect recipients in the local economy. Economic impacts calculated by the MGM2 are reported in four key areas: sales, jobs, personal income, and value added.

The MGM2 can be applied to one park unit or a collection of units, or scaled to a larger geographic area. It has also been used to aggregate statistics across the National Park System for annual estimates of visitor spending and payroll impacts (see sidebar). The latest technical report (for

Report summarizes economic impacts of parks for 2008

In addition to individual park analyses, the 2008 MGM2 technical report (Stynes 2009) shares the following aggregate economic impacts of the National Park System:

> The National Park System received 274.9 million recreation visits in 2008. Park visitors spent $11.56 billion in local gateway regions (within roughly 50 miles of the park). Visitors staying outside the park in motels, hotels, cabins, and B&B's accounted for 55% of the total spending. Over half of the spending was for lodging and meals, 17% for gas and local transportation, 9% for groceries, and 14% for souvenirs. Local economic impacts are estimated after excluding spending by visitors from the local area (9.8% of the total). Combining local impacts across all parks yields a total impact, including direct and secondary effects, of 205,000 jobs, $4.4 billion in labor income, and $6.9 billion value added. The four economic sectors most directly affected by visitor spending are lodging, restaurants, retail trade, and amusements. Visitor spending supports over 50,000 jobs in each of the hotel and restaurant sectors, and over 23,000 jobs each in the retail trade and the amusements sectors.

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Restoration Journal

Restoring native vegetation along Hermit Road in Grand Canyon National Park

By Allyson Mathis, Kassy Theobald, Janice Busco, and Lori Makarick

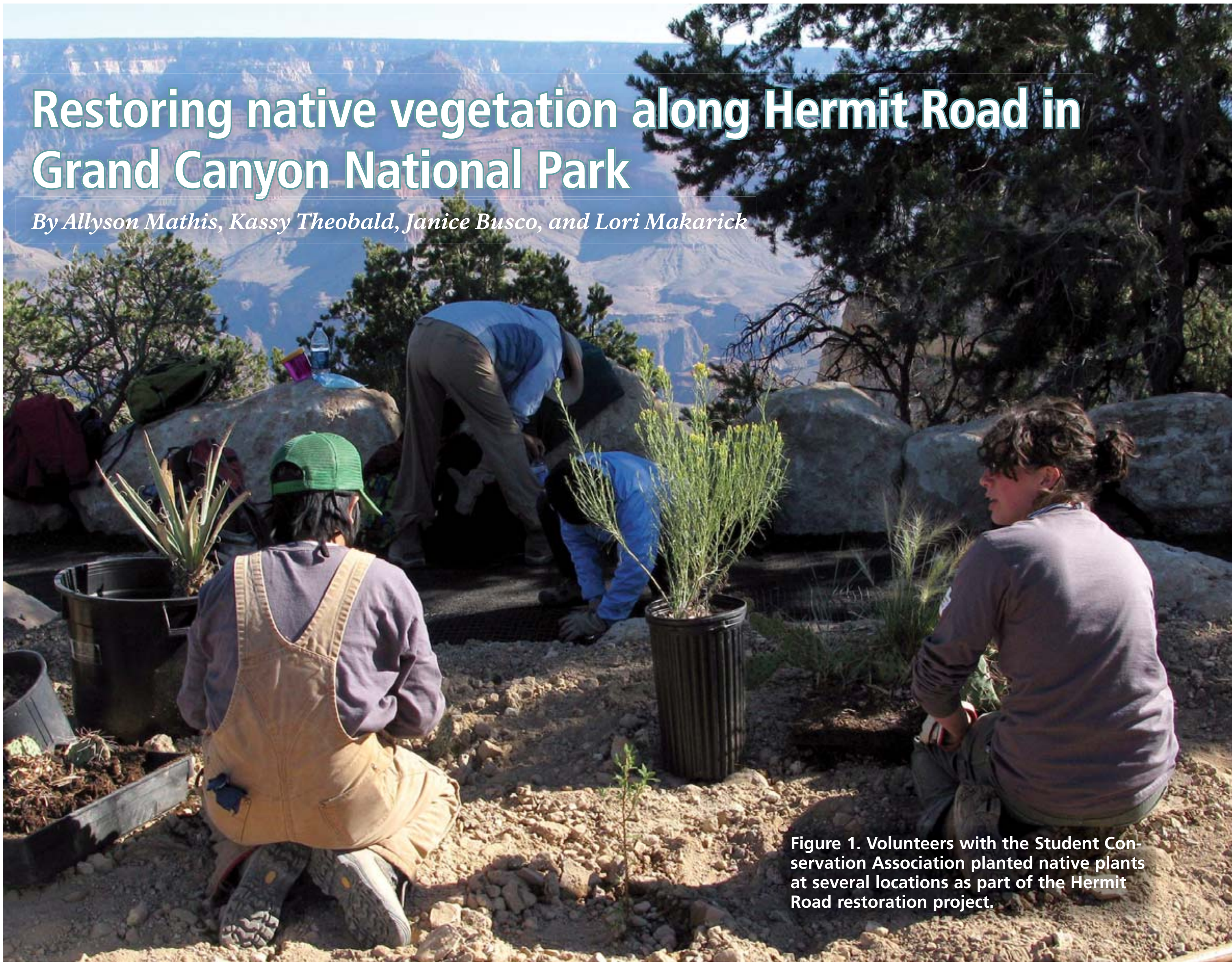

Figure 1. Volunteers with the Student Conservation Association planted native plants at several locations as part of the Hermit Road restoration project.

NPS/MICHAEL QUINN

HERMIT ROAD IN GRAND CANYON National Park (Arizona) reopened in November 2008 after a nine-month rehabilitation. The widened road and improvements to shuttle bus stops and the rim trail will enhance the public's enjoyment of this spectacular section of the South Rim. However, visitors may not realize that the Hermit Road project included one of the largest vegetation restoration and rehabilitation efforts ever undertaken at Grand Canyon National Park (figs. 1 and 2).

Hermit Road was originally constructed in 1934 and 1935 by the Bureau of Public Roads and the National Park Service. The road was designed to have a rural character, providing stunning canyon views and having native vegetation close to the roadway. No major work occurred on the road for more than 70 years, leaving it in poor condition. Over many decades, the lack of a formally defined trail along most of Hermit Road led to social trailing and trampling of native vegetation.

The Hermit Road rehabilitation project increased public safety while maintaining the roadway's historic character and protecting the park's natural and cultural resources. The vegetation restoration plan for the project had several objectives, including stabilizing road shoulders, maintaining the genetic integrity of plant species along Hermit Road, replanting impacted areas with native species, protecting rare plant species, and ensuring the long-term success of restoration areas through invasive species management and routine maintenance.

Prior to the start of construction in February 2008, Vegetation Program staff and volunteers also salvaged plants, such as Utah agave (*Agave utahensis*), banana

Figure 2. Hermit Road restoration sites, where a total of 11 acres (4.5 ha) were restored.

yucca (*Yucca baccata*), fernbush (*Chamaebatiaria millifolium*), cliffrose (*Purshia mexicana*), blue grama (*Bouteloua gracilis*), mutton-grass (*Poa fendleriana*), and Indian ricegrass (*Achnatherum hymenoides*) from construction zones and collected seeds from these and other native species to use in the restoration project (fig. 3). When road and trail construction by the contractor neared completion in early October, the restoration work stepped into high gear. A five-person Student Conservation Association Native Plant Corps Team planted the majority of the salvaged and propagated native plant species. Restoration crews planted 16,000 plants that were propagated from native seed collected in the park, and approximately 4,000 plants that were salvaged prior to the start of road and trail work. Two hundred pounds of native grass and shrub seed were spread along roadways and in other restoration project areas by the construction contractor and by park crews.

Vegetation crews devoted the majority of their efforts to replanting areas near major viewpoints, such as Powell and Mohave Points, where road or parking lot realignments increased traffic safety or conserved park resources (fig. 4). A total of 11 acres (4.5 ha) were restored. Volunteers, including the SCA Corps Team, contributed a total of 5,200 hours to the project. Monitoring of restoration areas will take place over the next 5 to 10 years to assess the success of the restoration techniques that were utilized and to inform future restoration projects.

Sentry milkvetch habitat restoration

The Hermit Road project provided park managers with an extremely rare opportunity to restore habitat for sentry milkvetch (*Astragalus cremnophylax* var. *cremnophylax*), the only listed endangered plant species in Grand Canyon National Park (fig. 4). Sentry milkvetch grows only in specialized habitat consisting of shallow limestone soils in narrow zones immediately adjacent to the canyon rim. One of the few known sentry milkvetch populations is near Maricopa Point, yet the habitat for the plant there was reduced in size by the construction of a parking lot in 1935.

NPS/MICHAEL QUINN

Figure 3. Approximately 4,000 plants were salvaged along Hermit Road prior to the beginning of construction in 2007. The salvaged plants were replanted in the fall of 2008, along with approximately 16,000 additional plants.

NPS/MICHAEL QUINN

Figure 4. Sentry milkvetch, the park's only endangered plant species, lives at Maricopa Point, where crews replanted an obliterated parking lot with native vegetation to increase habitat for the species.

Figure 5. Wire cages protect newly replanted vegetation until it is established on the former parking lot site at Maricopa Point.

As part of the Hermit Road project, the Maricopa Point parking lot was removed in order to provide additional habitat for sentry milkvetch. Much of the former parking lot has already been replanted (fig. 5), but a portion of it is the focus of an additional project specifically targeted to restoring habitat for the sentry milkvetch as part of the species recovery plan. The goal is to increase the available sentry milkvetch habitat at Maricopa Point by approximately 20%. A multifaceted project will seek to reestablish the unique habitat that these rare plants require, including growing plant companion species. Once appropriate habitat is restored, techniques for introducing sentry milkvetch will be tested and developed.

Project funding

The Hermit Road rehabilitation project was funded with park entrance fees, authorized by the Federal Lands Recreation Enhancement Act, the Alternative Transportation in Parks and Public Lands Program, and the Federal Lands Highway Program. Of $10 million devoted to the project, approximately $500,000 financed vegetation and topsoil restoration along Hermit Road. The sentry milkvetch projects will be supported by a combination of National Park Service and U.S. Fish and Wildlife Service monies, with a budget of $330,000 for the species recovery plan, of which Maricopa Point is only one component.

Additional information about the vegetation restoration project on Hermit Road is in the *Canyon Sketches* eMagazine on Grand Canyon National Park's Web site at http://www.nps.gov/grca/naturescience/cynsk-v06.htm.

About the authors

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PS

Mussels protected from horses at Big South Fork

By Steve Bakaletz and Wallace Linder

THE BIG SOUTH FORK NATIONAL RIVER and Recreation Area watershed in Tennessee and Kentucky is a national focus for major conservation efforts. The river is home to one of the most diverse freshwater assemblages of fish and mussel fauna in the United States. It harbors 31 endemic and restored mussel species, of which nine are federally listed or candidates for listing. Two of the endangered mussel species (*Epioblasma walkeri* and *Pegias fabula*) are the only known reproducing populations in North America, and therefore have global significance. The U.S. Fish and Wildlife Service listed the park's major streams and the national river as critical habitat for mussels in October 2004. One hundred twenty-eight fish species (three are endangered) also live in the Big South Fork watershed.

Degraded upstream water quality is affecting park resources, and park management has plans to address the top three contributors to aquatic resource degradation: coal extraction, acid mine drainage, and oil and gas production. But park visitor activities, notably horseback riding, are contributing to the impact by increasing erosion and stream sediment load. Big South Fork National River and Recreation Area is one of the most frequented horse-riding parks in the National Park System, with 450 miles (724 km) of trails. Horse crossings impact the stream in three primary ways: (1) direct crushing of organisms (mussels), (2) disturbance and suspension of sediments, and (3) the accumulation of horse fecal matter near the water's edge. Other trail users such as mountain bike riders, hikers, and maintenance vehicles also ford creeks. Intersections where trails and creeks cross therefore require physical improvement to allow users to enjoy the trails while protecting aquatic habitat from harm. Park staff has undertaken a project that protects the water and wildlife at crossings and reduces the risk of injury to visitors by hardening the riding surface, or tread, at those points. They have installed nine hardened crossings so far and have 250 more that need to be done.

Small and medium stream crossings

Park staff chose the method of mitigating the crossings, or fords, based on the size of the stream. For small and medium-sized streams, park staff places preformed concrete planks (each 8 feet [2.4 m] long, 16 inches [0.4 m] wide, and 6 inches [0.15 m] thick) along the crossing areas using a front-end loader and hand labor. The park biologist examines the stream prior to plank placement to ensure that no organisms will be crushed under the planks. These are placed across the creek, parallel to the bank, eliminating contact of horse hooves with the creek substrate, and level with the creek bottom so that the water will flow freely over the hardened surface. The top edge of the plank is beveled to a 45-degree angle to prevent erosion at the base of the plank. A cable runs through a hole in each plank on the upstream side and is attached to an anchor on each side of the crossing. The cable system is submerged and buried to prevent user injury.

At the streambanks, resource managers engineer approaches to the stream crossings to be durable in flood events, provide good traction, and require low maintenance. Treadways are excavated for the width of the trail; a sub-base of large rock is placed in the bottom and covered with a filter fabric blanket. Next, a layer of smaller rock is placed over it and another blanket spread on top of that. The final layer is the treadway material. In some situations where traffic is heavy, staff uses three layers of blanket to hold the sub-base material together. This last situation occurs when using interlocking concrete blocks (designed for erosion control). After the third blanket layer is put down and the treadway is as level as possible, staff places concrete blocks on top and fills in the spaces and voids with an inert material derived from burned shales called "red-dog."

These improvements make ford approaches easy to see for both humans and horses. Often when horses first notice that they must cross a creek, they become nervous and defecate. Horse manure accumulates in and near stream crossings, resulting in degradation to aquatic resources and water quality. However, trails that can be clearly identified by horses help relax the animal and reduce manure in sensitive aquatic environments. Mountain bikers and hikers are also able to cross streams more easily and with less indecision about location of the correct route. An added benefit is safer driving conditions across the creek for authorized vehicles because the hardened surface provides a smoother treadway for the tires. Life expectancy of the trail improvements is more than 50 years. All trails and fords could potentially receive this treatment, and the corresponding streams would benefit.

NPS/STEVE BAKALETZ (3)

Resource managers designed and installed trail crossings at Big South Fork for potentially heavy river flows (above) and light to medium stream flows (right and previous page). The designs increase horse and human safety, reduce animal stress, improve water quality, and protect freshwater mussels and other sensitive species.

Large-river crossings

Two of three large river crossings that exist in the park occur within a 12-mile (19 km) reach that provides habitat for endangered species, including 10 mussel species and 3 federally listed fish species. The U.S. Fish and Wildlife Service, in an informal consultation, expressed concerns about the concrete plank technique working in large rivers. Water depths at the crossings vary from 3 inches [7.5 cm] during low flow to 40 feet [12 m] during a severe flood. The power of the water flow and the debris it carries can be tremendous. Therefore, anchoring the planks would be problematic, and any failure could result in harm to the habitat. Park staff prepared a biological assessment to review alternative methods at the Station Camp crossing. The environmentally preferred alternative was to mark the corridor with native sandstone rocks that were slablike in profile.

Slabs . . . provide habitat for mussels and fish while serving as an effective method for trail delineation.

First, resource managers inspected the surface of the trail crossing for endangered species and found none. The trail substrate was composed of 2 inches (0.8 cm) of sand over solid bedrock. Native mussels avoid the large-river crossings because the sediment is not deep enough for stable burrowing in the event of high river flows. Slab rocks used to mark the trail corridor at Station Camp crossing weighed from 900 to 3,000 pounds (409–1,363 kg) and measured 3 feet (1 m) wide by 6 feet (2 m) long on average. Rocks ranged from 6 to 10 inches (0.15 to 0.26 m) thick, and 22 of them were used to mark the crossing. Workers placed rocks on each side of the 10-foot (3 m) corridor to delineate the trail. The mussel's life cycle includes a host fish to which young mussels are attached temporarily. Host fish frequently hide under slab rocks, and when the young mussels fall off the fish they remain under these rocks. The slabs therefore provide habitat for mussels and fish while serving as an effective method for trail delineation.

Improvements noted

The trail corridor is now marked with slab rocks, and trail users and horses have a clear and visible pathway. (When the river is flooded and the rocks are not visible, it is not safe to cross.) Staff has installed signs providing instructions to users to stay inside the corridor, and so far the system is working well.

Monitoring has documented a drastic reduction in the number of mussels crushed by users and decreases in horse manure at the stream approaches. Treated streams are no longer turbid because users are now crossing at the fords. This technique of stream protection is likely to work well in other parks with streams forded by visitors.

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Development of a rapid assessment tool for ecological restoration

By Ron Hiebert, Diane Larson, Kathryn Thomas, Nicole Tancreto, and Dustin Haines

MANAGERS OF PARKS AND NATURAL areas are increasingly faced with difficult decisions concerning restoration of disturbed lands. Financial and workforce resources often limit these restoration efforts, and rarely can a manager afford to address all concerns within the area of interest. With limited resources, managers and scientists have to decide which areas will be targeted for restoration and which restoration treatments to use in these areas. A broad range of approaches are used to make such decisions, from well-researched expert opinions (Cipollini et al. 2005) to gut feeling, with variable degrees of input from site visits, data collection, and data analysis used to support the decision. A standardized approach including an analytical assessment of site characteristics based on the best information available, with a written or electronic record of all the steps taken along the way, would make comparisons among a group of sites easier and lend credibility through use of common, documented criteria at all sites.

In response to these concerns, we have developed the Restoration Rapid Assessment Tool (RRAT). RRAT is based on field observations of key indicators of site degradation, stressors influencing the site, value of the site with respect to larger management objectives, likelihood of achieving the management goals, and logistical constraints to restoration. The purpose of RRAT is not to make restoration decisions or prescribe methods, but rather to ensure that a basic set of pertinent issues are considered for each site and to facilitate comparisons among sites.

Several concepts have been central to the development of RRAT. First, the management goal (also known as desired future condition) of any site under evaluation should be defined before the field evaluation begins. Second, the evaluation should be based upon readily observable indicators so as to avoid cumbersome field methods. Third, the ease with which site stressors can be ameliorated must be factored into the evaluation. Fourth, intrinsic site value must be assessed independently of current condition. Finally, logistical considerations must also be addressed. Our initial focus has been on riparian areas because they are among the most heavily impacted habitat types, and RRAT indicators reflect this focus.

User inputs

Management Goal. Before any restoration can be undertaken, the goal for that restoration must be clearly articulated (Ehrenfeld 2000). Prior to undertaking the site evaluation, the user enters the management goals as part of the site description, which ensures that they are both explicitly stated and available to whoever does the evaluation in the field. Evaluation of indicators in the field requires an understanding of the difference between the current and desired condition, as well as the impediments to achieving the desired condition. To help ensure a comprehensive statement of restoration goals, we suggest that the user become familiar with the indicators before defining the management goal.

Indicators. RRAT indicators are arranged into six modules: hydrology and landform, soil and water quality, nonnative animals, nonnative plants, native animals, and native plants. These categories, and the 40 specific indicators within them, were vetted through a series of workshops followed by field testing and refinement (Richey 2005). Hydrology, landform, and soil indicators are based largely on descriptions in Pellant et al. (2005); these and all other indicators also were formally evaluated at two workshops. Indicators were tested in 2004 at national parks throughout the United States to confirm their relationship to characteristics for which they were thought to be indicators (Richey 2005). In addition, we assessed correlations among indicators and combined those that were strongly correlated.

Indicators are scored in two ways. First, the departure of current condition of the site from "natural" is scored with respect to an indicator; then, the departure of the desired condition from current condition is scored with respect to the same indicator. Although "natural" is a subjective concept, we believe it is a useful point of comparison when several sites are being assessed. For example, a severely degraded site with a modest management goal could be judged as readily restorable, much as a more pristine site might be restored to a nearly natural condition. However, by comparing each site with a "natural" standard, the two sites are more clearly differentiated.

Stressor Removal Effort. After scoring the indicators, the user selects from a list of 40 stressors that require amelioration in the course of restoration. The user also is asked to estimate the amount of effort needed to remove the stressor, ranging from "easy," through "difficult," to "impossible." Stressors rated impossible to remove are highlighted in the output but do not contribute to the stressor removal index (defined on the next page).

Table 1. Index formulations for the Restoration Rapid Assessment Tool

Index	Range of values	User inputs	Formulation
Convergence (C)	0–100 (from least to most similar to natural or management goal)	Indicator Departure from Natural (IDN), a direct rating by user; 100 = no departure from natural, 75 = low, 50 = moderate, 25 = high, 0 = severe, don't know/NA = index omitted.	(IDN1 + IDN2 + IDN3 + … IDN*n*) / *n*
Stressor Removal Potential (SR)	0–100	A listing of stressors is compiled for each instance when IDN – IFG (Indicator Future Goal) >2; the user rates the difficulty of removal for each stressor (Easy, Moderate, or Difficult).	SR = (1 – ((1 – (0.85) ^ ([*n* Easy] * 0.2)) + (1 – (0.80) ^ ([*n* Moderate] * 0.5)) + (1 – (0.75) ^ ([*n* difficult] * 0.8))) * 100
Ecological Restoration Potential	0–100	None—composite metric	(C + SR) / 2
Restoration Logistics (RL)	0–100 (least feasible to most feasible logistically)	Disturbance size (DS) Site accessibility (SA) Wilderness (W)	(DS + SA + W) / 3
Ease of Restoration	0–100 (0 = hardest to restore, 100 = easiest to restore)	None—composite metric	(C + SR + RL) / 3
Gain for Effort	0–100 plus 9,999; 0 is least gain for effort, 100 is most gain for effort. 9,999 reported when SR + RL = 200.	None—composite metric	C / (200 – (SR + RL))
Site Value	0–100	Future site value (SVf): A direct rating by user; 100 = extremely valuable, 75 = highly, 5 = moderately, 25 = minimally, 0 = not, don't know/NA = index omitted.	(SVf1 + SVf2 … + SVf*n*) / *n*

Note: n is the sample size.

Site Value. Reasons for wishing to restore a site are inherently subjective; we therefore separate the intrinsic value of a site from more objective indicators of its condition. The site value categories in RRAT include animal and plant community diversity, the presence of habitat for threatened or endangered species, recreation or aesthetic values, emblematic features, landscape rarity or importance, and cultural or historic values. The user assigns each a score as if the site were restored to the management goal, rather than based on the site's current condition.

Logistical Considerations. The size of the area to be restored, its distance from a road, and whether or not it is within a designated wilderness are used to assess the logistical difficulty of restoring the site.

Indexes

We developed seven indexes to provide both a site profile and a basis for comparison among sites being considered for ecological restoration. The indexes emphasize simple averages, ratios, and other easily understood functions (table 1). We standardized the values of the indexes so that higher numbers always signify a more favorable condition for restoration than lower numbers. The reliability of the assessment is greatest when most indicators are evaluated. Users should consult with experts or others who are familiar with a site under consideration to determine values for as many indicators as possible.

Of the indexes related to ecological site condition, two are calculated directly from user input: *Convergence* and *Stressor Removal Potential*. *Convergence* refers to the degree to which indicators approach either a natural condition or a management goal. *Stressor Removal Potential* depends upon both the number of stressors that require removal and how difficult they are to remove. Because we assumed that overall difficulty would increase at a faster rate for stressors that were more difficult to remove, the change in stressor removal potential has a steeper slope for more difficult-to-remove stressors than for those that are more easily removed. *Ecological Restoration Potential* is a composite variable calculated as the mean of *Convergence* and *Stressor Removal Potential*.

Two indexes directly involve the physical difficulty in conducting restoration activities at a site. *Restoration Logistics* takes into account size, accessibility, and whether or not the site is within a designated wilderness area, which may restrict the kinds of equipment that

The purpose of RRAT is not to make restoration decisions or prescribe methods, but rather to ensure that a basic set of pertinent issues are considered for each site and to facilitate comparisons among sites.

can be used. *Ease of Restoration* is a simple average of *Convergence*, *Stressor Removal Potential*, and *Restoration Logistics*.

Gain for Effort is the ratio of *Convergence* to the sum of *Restoration Logistics* and *Stressor Removal Potential*. It provides a measure of the functional change needed to restore a site to either a natural condition or management goal for the amount of effort that would need to be expended.

To calculate *Site Value*, a numerical value is assigned to the categorical user input. Management goals may pertain to only one aspect of site value, so users must consider the score for *Site Value* with respect to their goals for the site.

Interpretive output

The *Site Profile* pertains to a single site and includes complete interpretive information for all seven indexes as well as tabular description of site value ratings, stressors that require removal and their associated difficulty ratings, and warnings related to stressors that are impossible to remove and the number of unknowns in the assessment.

In each *Site Profile*, a table lists the aspects of *Site Value* that the user evaluated and the categorical values assigned to each. A second table lists the user-selected *Stressors* that affect the site and the effort required to remove them. Any stressor deemed impossible to remove by the user is highlighted in red type and a warning advises users to carefully evaluate their ability to achieve their management goal if the stressor cannot be removed. A third table is included only if *Unknown* is selected for more than two indicators. This table lists the indicators for which *Unknown* was selected and a warning advises users to investigate the indicator(s) so that an appropriate response can be made.

A second form of output is a *Site Comparison* report. This report consists of index scores for a group of sites within one user-defined management group (see sidebar). For each group of sites selected, two reports are produced. One is based on comparison with natural conditions, the other on comparison with the management goal for each site. These reports lack the tabular and interpretive output contained in the *Site Profiles* but provide output scores sorted in various ways to facilitate comparison as well as graphic displays of the selected sites on four axes: *Ease of Restoration*, *Ecological Restoration Potential*, *Restoration Logistics*, and *Site Value* (see sidebar).

RRAT and its users' manual (Hiebert et al. 2009) can be downloaded from http://www.npwrc.usgs.gov/resource/methods/rrat/index.htm. The users' manual provides full definitions for each of the indicators and stressors, definitions for each of the seven output indexes, and details on the technical aspects of conducting an assessment. RRAT is formatted in a Microsoft Access database application programmed with Visual Basic. We encourage reviewers and users to provide comments to the first author so the tool can be made more efficient and effective.

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CASE EXAMPLE

Application of RRAT to a watershed on Santa Cruz Island

WITH THE REMOVAL OF ITS REMAINING FERAL PIGS IN 2007, Santa Cruz Island, part of Channel Islands National Park, California, finally was freed of all introduced grazers. Now park staff wants to know where active restoration is needed and how to set priorities that will result in the greatest ecological gains for their efforts. They have adopted a watershed approach for the application of RRAT, the Restoration Rapid Assessment Tool.

This case example is a preliminary application or RRAT at three disturbed sites in one watershed on Santa Cruz Island (see photo). For each potential restoration site the assessor first described the site's assumed natural state and then set a realistic management goal for success. (In setting management goals the assessor may consider such limitations to complete restoration as the inability to remove stressors.) Table 1 illustrates that the effort to restore these sites to natural condition may not be possible; however, realizing management goals may indeed be feasible.

Table 2 facilitates comparison of the potential restoration sites based on four RRAT index values. Scores for *Restoration Logistics* (site size, distance from road, and status as wilderness) are the most varied, indicating that the "disturbed wetland" site would be the easiest to restore. Since this site has the same potential *Site Value* scores as "lower reach," and scores for *Restoration Logistics* and *Site Value* scores for all three sites are the same for natural condition and management goals, "disturbed wetland" is likely to yield the greatest benefit for effort. Additionally, the scores for *Ease of Restoration* and *Ecological Restoration Potential* are high for all sites, indicating this watershed is likely to rank high compared to other watersheds on the island. An additional 50 potential restoration sites were assessed this summer in multiple watersheds on Santa Rosa Island, also part of Channel Islands National Park, and will be added to the information shared with park staff for setting watershed restoration priorities.

NPS/CHANNEL ISLANDS NATIONAL PARK

Managers at Channel Islands National Park are investigating the feasibility of restoring areas of Santa Cruz Island where the last nonnative grazing animals were removed in 2007. Scorpion Ranch, shown here, was the initial study area and compared three potential restoration sites within one watershed.

Table 1. Gain for effort to restore Santa Cruz Island sites

Site*	Gain for effort: Restoration to natural condition	Gain for effort: Restoration to management goal
Disturbed Wetland	2.13	4.60
Lower Reach	1.52	2.89
Upper Reach	1.08	2.24

*All potential restoration sites are at Scorpion Ranch (see photo).

Table 2. Restoration potential of Santa Cruz Island sites

	Restoration Logistics		Site Value		Ease of Restoration		Ecological Restoration Potential	
Site*	Natural condition	Mgmt. goal	Natural condition	Mgmt. goal	Natural condition	Mgmt. goal	Natural condition	Mgmt. goal
Disturbed Wetland	80	80	53	53	75	93	66	99
Lower Reach	67	67	53	53	73	88	71	99
Upper Reach	57	57	47	47	68	85	69	99

Note: Index values are standardized so that higher numbers always signify a more favorable condition for restoration than lower numbers.

*All potential restoration sites are at Scorpion Ranch (see photo).

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Exploring the influence of genetic diversity on pitcher plant restoration in Indiana Dunes National Lakeshore

By Jennifer M. Karberg, Joy Marburger, and Margaret R. Gale

Figure 1. The northern pitcher plant traps prey in its tubelike pitcher structure where a suite of microorganisms digests prey and extracts nutrients needed for plant growth.

CARNIVOROUS PLANTS OBTAIN NUTRIENTS needed for growth through the breakdown of insects, microbes, and small amphibians. The most widely distributed carnivorous plant in North America is the northern pitcher plant (*Sarracenia purpurea* L., fig. 1), whose range stretches from northern Canada to the midwestern United States, and along the eastern U.S. coast south to the Gulf of Mexico. This species lives primarily in isolated, low-nutrient sphagnum moss bog and poor fen wetlands (fig. 2). Though individual populations are large, typically containing more than 100 plants, the species is in decline because of the loss of its specialized wetland habitat. The wetlands that host the northern pitcher plant are in a perilous position, often drained for development, mined for Sphagnum for the horticultural trade, or degraded by inputs of road salt and lawn and agricultural fertilizer runoff. Additionally, carnivorous plant enthusiasts prize this species and threaten population survival through overcollection. As habitat and populations of the northern pitcher plant become increasingly rare, state and federal agencies are showing greater interest in conserving habitat and restoring plant populations.

Indiana Dunes National Lakeshore protects one of the few remaining populations of northern pitcher plant in the state (NatureServe 2007) (fig. 3). This population, located at the Indiana Dunes Pinhook Bog property, is isolated within an extensively developed landscape along the southern rim of Lake Michigan east of Gary, Indiana. Consequently, the national lakeshore has experienced declining populations of the northern pitcher plant. Scientifically informed management to restore this species is crucial to its survival in this and other fragmented ecosystems. Planning and implementing successful restoration of plant populations requires knowledge about how the plant functions ecologically,

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Figure 2. Though widespread in North America, the northern pitcher plant faces threats from loss and fragmentation of its specialized habitat: low-nutrient bog and poor fen wetlands. Indiana Dunes populations are genetically intermediate between the isolated island population of Isle Royale and the continuously interbreeding mainland populations of Apostle Islands and Pictured Rocks.

how it reproduces, what environmental qualities it requires, and how populations relate to each other genetically. Reestablishment of the pollination services provided by bees in Pinhook Bog will sustain the reproductive potential and genetic resilience of pitcher plants (Dixon 2009).

Importance of genetics in restoration planning

Sphagnum bog and fen wetlands south of Canada are typically isolated, separating populations of the northern pitcher plant both physically and by distance. This can lead to interesting conservation issues regarding the genetic relationships among different pitcher plant populations. One of the key questions ecologists have tried to answer is how fragmentation or isolation in the landscape affects genetic variation and gene flow of plant populations of a particular species. Wright (1969) developed the island model of migration among populations, which is frequently applied to landscape islands or fragmented natural areas such as the habitat of the northern pitcher plant. He hypothesized that within populations of a species, two important genetic forces function between isolated or island populations: (1) gene flow originating from outside populations that maintain genetic relatedness between populations either through pollen or seed exchange, and (2) genetic drift occurring within populations that create more genetically different subpopulations (Allendorf and Luikart 2007). The more geographically isolated a population becomes, the less gene flow will occur between populations, increasing genetic drift and potentially creating genetically distinct populations (Kimura and Weiss 1964; Allendorf and Luikart 2007). Essentially, the amount of divergence between two populations is a balance between gene flow homogenizing the populations and genetic drift differentiating the populations. The more isolated the populations, the less balanced these processes are, thus leading to increased genetic divergence.

Effects of genetic isolation within populations complicate habitat and plant species restoration planning. Isolated populations experiencing genetic drift and increased inbreeding can become locally adapted to a particular site (Hufford and Mazer 2003; Allendorf and Luikart 2007). Using seed or plants from distant populations that are planted with locally adapted populations to restore new sites could lead to reduced fitness in offspring from crosses between the locally adapted and distant populations in the restoration site (Hufford and Mazer 2003). Careful consideration and understanding of the genetic relatedness of populations become important in restoration when considering supplementing plant populations with outside seed sources.

Consider these two examples of how genetic understanding can aid ecosystem management:

- Imagine many populations of a plant species where pollen and seeds are continually being exchanged among the populations. These pollen and seeds represent gene flow among the populations, and the more gene flow that occurs, the more similar the populations become to each other genetically. Where some event has reduced, destroyed, or removed a plant population from a site, managers can potentially restore the population by collecting and reintroducing

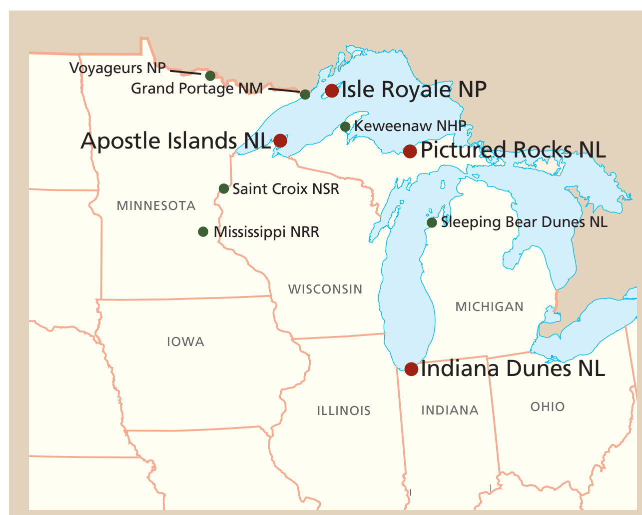

Figure 3. This study assessed the population genetics of pitcher plants in four national park units of the Great Lakes region shown by the red dots: Isle Royale National Park and Indiana Dunes, Pictured Rocks, and Apostle Islands national lakeshores. The main goal of the study was to determine if abundant populations of pitcher plants in some parks could be used to supplement decreasing populations at Indiana Dunes National Lakeshore without compromising local population genetics or reducing successful local adaptations.

The amount of divergence between two populations is a balance between gene flow homogenizing the populations and genetic drift differentiating the populations.

seeds from any of the surrounding populations because all of the populations are genetically similar. Consideration of restoration sites may thus focus on those with similar ecological conditions, rather than the genetic component.

- In the second scenario, many populations of a plant species are still spread across the landscape, but one population is isolated on an island in a lake. This population is so isolated by distance from other populations that very little seed or pollen exchange occurs between the island and the mainland; therefore, gene flow is very low for this population. As gene flow is reduced, populations can begin to become genetically different from each other, and this is an illustration of genetic drift. If the island population requires reintroduction, managers need to carefully consider where to select seeds to restore this population. Introducing seed from outside sources could lead to the loss of the local plants' genetic uniqueness, and potentially decrease the success of restoration attempts.

Fortunately, populations of northern pitcher plant are still fairly abundant in other national park units within the western Great Lakes region. We wished to assess whether some of these populations could serve as potential seed sources for restoration of this plant species within Indiana Dunes National Lakeshore. The northern pitcher plant has continuously exhibited low genetic diversity within and among populations throughout the eastern United States (Godt and Hamrick 1996; Schnell 2002; Karberg and Gale 2006). This means that throughout its range the plant has consistently displayed low genetic differences between individuals and between populations regardless of distance between populations. This would indicate that most populations are genetically similar and seed sources for restoration could be plentiful.

We wished to examine differences in genetic variation between the Pinhook Bog population located within Indiana Dunes National Lakeshore and three other national park units in the western Great Lakes area—Isle Royale National Park (Michigan), Apostle Islands National Lakeshore (Wisconsin), and Pictured Rocks National Lakeshore (Michigan)—to determine the possibility of using seed from regional sources for restoration at Indiana Dunes (see fig. 3).

Genetic analysis of the western Great Lakes populations

We collected plant leaves for molecular genetic analysis to determine the genetic relatedness of populations at each of the four sampled national parks: Apostle Islands, Indiana Dunes, Isle Royale, and Pictured Rocks. The analysis indicated a strong degree of clonal growth, created by asexual reproduction, evidenced by moderate within-population genetic diversity (Nei's gene diversity = 0.3770 ± 0.1289). Clonal species tend to have lower overall genetic diversity within a population because of their nonsexual reproductive methods. The northern pitcher plant has often been hypothesized as being clonal (Schwaegerle and Schaal 1979). This moderate amount of genetic diversity was examined using an analysis of molecular variance (AMOVA) to see how much variation exists within individual populations and how much exists between or among populations at different locations. The total variation explained by genetic differences between populations located in each park ($F_{ST} = 0.2688$, $p < 0.0001$) indicates that 26.88% of the observed genetic diversity was accounted for by population variation. In essence, our sampled populations are 26.88% genetically different from each other. To determine what this means in terms of how the individual populations are related to each other, a visual analysis of the genetic dissimilarity of populations is necessary. Genetic distance or genetic dissimilarity of populations can be graphically represented with a dendrogram or diagram tree that illustrates how closely related populations are genetically. An examination of the visual patterns of genetic distance between populations revealed genetic differences that distinguished Indiana Dunes and Isle Royale populations from the other two parks (fig. 4). This dendrogram graphically represents genetic distance between individual populations and illustrates that Isle Royale populations, segregated on a separate branch of the dendrogram, have the greatest genetic distance from the other park populations. Apostle Islands and Pictured Rocks populations are closely intermixed and not well separated by genetic distance. Indiana Dunes populations are genetically intermediate between the isolated island population of Isle Royale and the continuously interbreeding mainland populations of Apostle Islands and Pictured Rocks.

Natural and landscape island populations

The two populations of the northern pitcher plant that exhibited the most genetic differentiation from the other populations are both fairly isolated populations: the natural island population of Isle Royale National Park is isolated within Lake Superior, and the landscape island population of Indiana Dunes National Lakeshore is isolated within a highly human-altered, fragmented landscape. The genetic differentiation of these two populations as compared to mainland populations found in a non-fragmented landscape can potentially be explained by habitat isolation. The natural island population (Isle Royale) is located on an isolated island within Lake Superior that has lacked a physical connection to the mainland since the last glaciation (Dorr and Eschman 1970; Huber 1983). Northern pitcher plant seeds are not believed to be consumed by birds or mammals, which would facilitate distribution over water, but rather typically disperse close to the parent plant (Ellison and Parker 2002). The barrier of large stretches of open water may likely be the reason for genetic differentiation of the northern pitcher plant populations on Isle Royale since the water barrier reduces the possibility of gene flow and increases population inbreeding and genetic drift, making the population more genetically distinct from mainland populations.

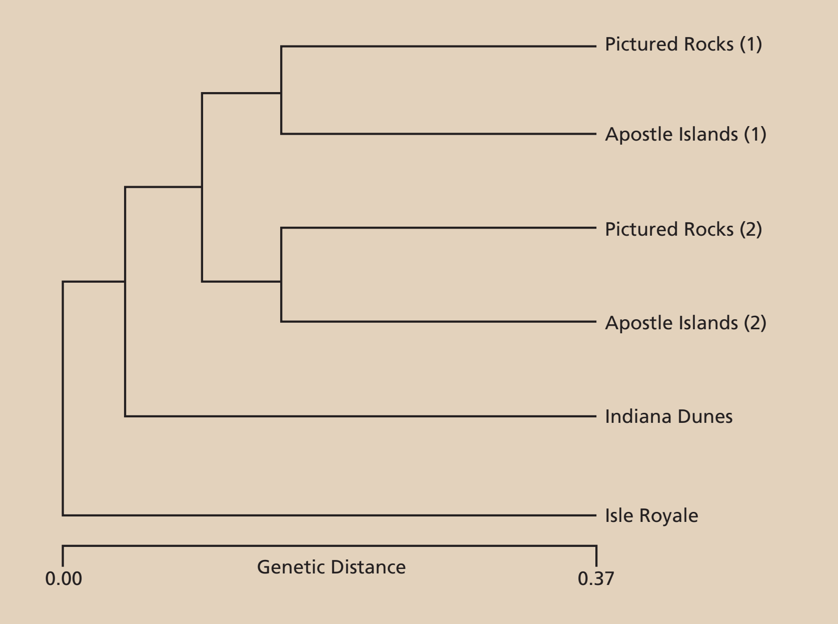

Figure 4. This dendrogram illustrates the genetic distance between the six sampled populations of northern pitcher plant. The Isle Royale and Indiana Dunes branches are separated from the other two parks, indicating unique genetic patterns in these populations. The more distant or separate the branch, the more genetically distant the populations.

In evaluating the results of our genetic analysis, which differentiated the landscape island population of Indiana Dunes from other intact populations, we think that larger expanses of fragmented landscape may also provide a sufficient barrier, reducing gene flow to the Indiana Dunes population. The two nearest populations of the northern pitcher plant to Indiana Dunes are located 45 miles (73 km) and 96 miles (154 km) away from the study site (NatureServe 2007). Hypothetically, 45 miles (73 km) of fragmented landscape may represent the outer bounds of a fragmentation threshold for this plant, beyond which genetic differentiation among populations increases as gene flow proportionally decreases.

The mechanism for genetic differentiation of the landscape island population may be related to gene flow and distance, with Indiana Dunes receiving little gene flow from outside populations because of distance, thus increasing the action of genetic drift. Pollinators of the northern pitcher plant include two bee species, *Bombus affinis* and *Augochlorella aurata*, and one fly species, *Flecherimyia fletcheri* (Ne'eman et al. 2006). Observations suggest that specific pollinators are limited at the Indiana Dunes site (A. Molumby, University of Illinois–Chicago, personal observation). Research has shown that wild bee pollinations are limited by habitat isolation; increased distance from suitable habitat leads to decreased bee visitations (Steffan-Dewenter and Tscharntke 1999). This factor of limited pollen dispersal contributes to the landscape isolation of populations within both of the sampled "island" populations.

Indiana Dunes northern pitcher plant populations show a degree of genetic isolation from other national park populations. This is a plant species that has historically shown a low degree of genetic variation, so even small amounts of genetic differentiation could be significant. Understanding how populations with this degree of isolation would respond to restoration through introduction of outside seed sources or plants is not yet fully understood. The accepted general standard among restoration ecologists is to utilize seeds or vegetative plant material

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Figure 5. Investigators are growing pitcher plants from seed in greenhouse conditions at Indiana Dunes for wetland restoration. These seedlings take 3 to 5 years to reach maturity, which may not be desirable for restoration plans.

collected within a 50-square-mile (12,950 hectares) area immediately surrounding the restoration site. However, this generalization is anecdotal and needs to be examined scientifically, given what we have learned about clonality and genetic differentiation due to geographical isolation in the northern pitcher plant. To examine restoration possibilities at Indiana Dunes, a common garden experiment could be undertaken to examine responses of plants and seeds from all four national parks planted side by side in a single site (fig. 5). Examining the growth responses and interbreeding fitness of plants from these different populations on one substrate type would help determine whether observed genetic differences are ecologically significant.

Lessons for restoration

The northern pitcher plant has historically exhibited low genetic variability, with populations very genetically similar to each other often across great distances. However, this study did document appreciable genetic differentiation between isolated, island populations and mainland populations. Currently, northern pitcher plant populations in Indiana Dunes show some genetic distinction from other mainland populations. Genetic isolation caused by artificial geographic barriers, such as urban and agricultural development, limits cross-pollination and thus possibly reduces genetic variation in the Pinhook Bog population. A decrease in pollinator populations may also be contributing to limited gene flow. Previous researchers have noted that the habitat for bumblebees, the natural pollinators of the pitcher plant, is lacking in Pinhook Bog (A. Molumby, University of Illinois–Chicago, personal communication). Another factor contributing to decline of the pitcher plant populations is the expansion of highbush blueberries (*Vaccinium corymbosum*) in the bog. The pitcher plant is shade-intolerant and thus plant growth is limited because of shading effects of blueberry plants. (Mystery surrounds the origin of blueberry plants in Pinhook Bog. Anecdotal evidence suggests that a previous property owner planted them for agriculture prior to authorization of the national lakeshore in 1966.) The major question is: Is this amount of genetic differentiation or genetic identity observed in the Indiana Dunes populations enough to preclude the use of outside seed sources for restoration of declined northern pitcher plant populations? This study alone is not enough to conclusively predict the results of introducing outside genetic sources but the differences are large enough to argue for caution and further exploration before using outside sources. The northern pitcher plant has consistently shown smaller amounts of genetic diversity across its range. It's a clonal plant, which typically reduces genetic diversity within a species, and yet significant differences were still detected between Indiana Dunes populations and populations in other parks. Before outside introduction, a common garden study should be conducted to determine the influence of local genetics versus local environment on northern pitcher plant ecology.

In the meantime, what are the options to restore pitcher plant populations in Indiana Dunes National Lakeshore? One is to improve habitat conditions for pitcher plant establishment. Managers have begun removing blueberry plants to create more open habitat suitable to the northern pitcher plant. To hasten restoration at Pinhook Bog, managers can attempt to increase seed set through hand pollination, promoting local seed production. Transplanting vegetative clones can also be conducted within the bog. Introduction of associated bee pollinators and their required habitat is also recommended. Indiana Dunes pitcher plant populations do show some degree of genetic isolation from the other national park populations, and the consequences of using outside plants and seeds to supplement restoration efforts are questionable. More research, especially using common garden experiments, is needed to determine if introduced plants from other regions of the Great Lakes can successfully reproduce without reducing the genetic integrity of northern pitcher plant populations in Indiana Dunes. The results from plants grown from clones would be faster than from seed-derived plants, which would not be available for 3 to 5 years, given the slow maturation from seed establishment to adult plants of this species (fig. 5). In the meantime, increasing habitat quality and facilitating seed set of native populations may be the best way to restore pitcher plant populations today at Indiana Dunes.

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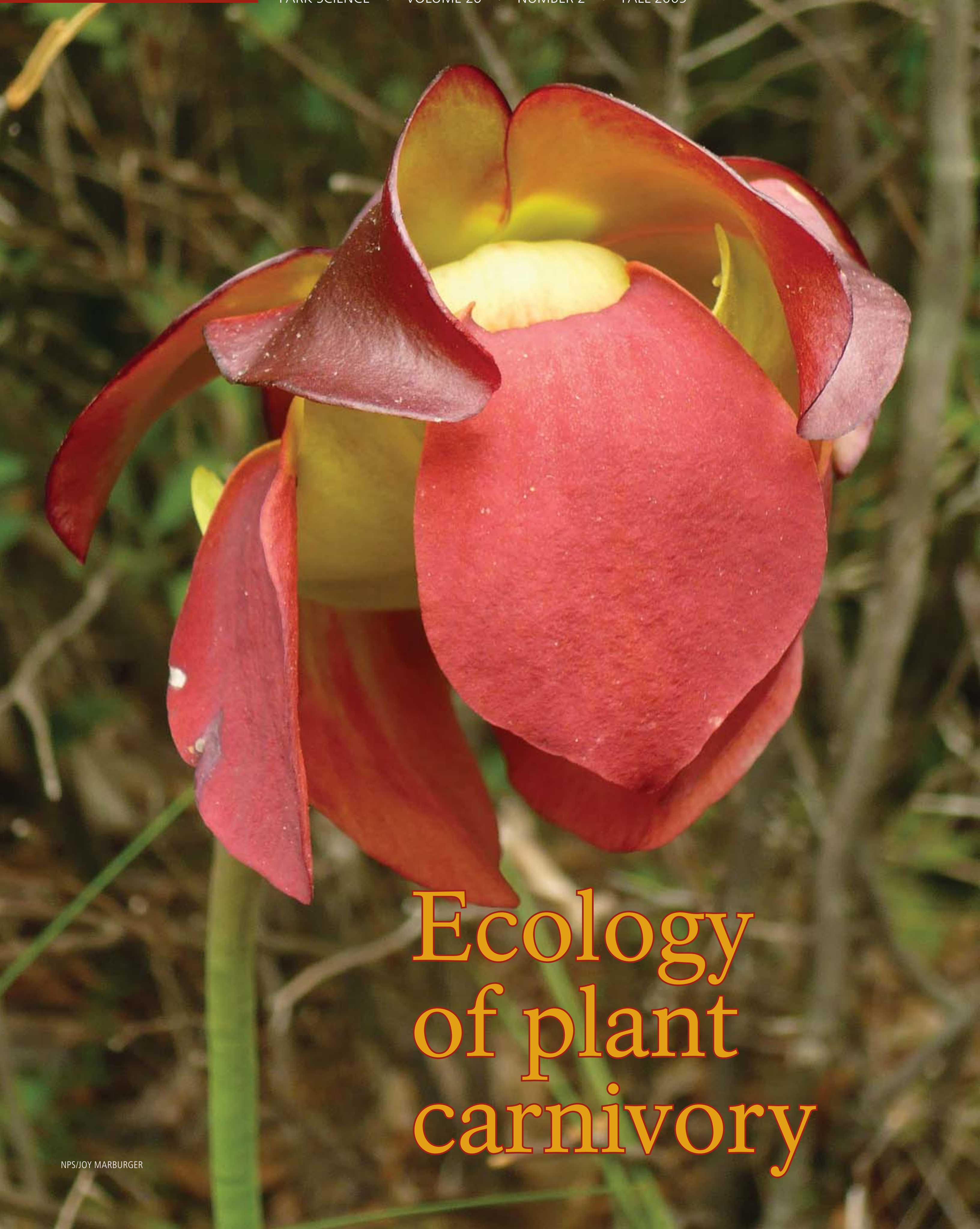

Ecology of plant carnivory

NPS/JOY MARBURGER

BY JENNIFER KARBERG AND JOY MARBURGER

THE PLANT KINGDOM HOSTS A VARIETY OF particularly adapted species, each with unique responses to the stresses of its habitat. For example, wetland plants growing in standing water can pump oxygen from the atmosphere down to feed their air-starved roots. Epiphytes (aerial plants living in forest canopies with no root system) gather rainfall in cupped leaves and extract nutrients from falling leaves, rainwater, and their host plants. Within the world of unique plant adaptations, one of the most intriguing is carnivory.

Carnivorous plants have fascinated researchers and the general public since the time that Charles Darwin first described their behavior in 1875 (Darwin, C. 1908. Insectivorous plants. Revised by Francis Darwin. John Murray, London, UK). Those who have seen the original movie version of the *Little Shop of Horrors* starring Jack Nicholson, or the musical version with Rick Moranis, can appreciate the human fascination with the macabre associated with carnivorous plants.

Carnivorous plants inhabit extremely low-nutrient ecosystems. Metabolic growth in these plants is hypothesized to be limited primarily by low concentrations of nitrogen and phosphorus. Consequently, carnivorous plants consume insects, spiders, and small amphibians to gain nutrients necessary for growth and reproduction.

With more than 600 species in 12 genera, carnivorous plants have evolved a variety of clever trapping mechanisms. Prey may fall or be sucked into pools of digestive enzymes, stick to droplets of goo, get snapped by fast-moving leaves, or be forced toward a digestive organ by inward-pointing hairs. These adaptations have allowed carnivorous plants to colonize and thrive in nutrient-poor ecosystems throughout the world.

The most common style of plant carnivory in North America is practiced by the pitcher plant. The leaves of these plants are modified into pitchers or hollow cups with a closed bottom, facilitating the collection of rainwater and potential prey (see photos). The pitcher structure acts as a passive form of carnivory, luring insects into a trap designed to capture them within the pitcher structure. The lip of each pitcher contains sweet-smelling nectaries that attract insects, which then land on the slippery plant leaf, fall into the pitcher and are prevented from climbing out by downward-facing hairs on the inside pitcher wall. In some pitcher plant species, the plants secrete digestive juices to break down prey; in others a suite of bacteria and microorganisms in the fluid digests prey and releases nutrients available for plant uptake. The plant absorbs the nutrients, particularly nitrogen and phosphorus, through the leaf wall, and transports them throughout the plant to where they are most needed.

Another interesting adaptation of the pitcher plant is its ability to modify leaves depending on the availability of nutrients. When nutrients are high, pitcher leaves are altered to perform more photosynthesis; when nutrients are low, pitcher leaves increase their carnivorous effort.

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Despite its colorful and showy flowers, the northern pitcher plant may rely on asexual reproduction for a large part of its reproductive effort, according to molecular genetics. Pollen and seed dispersal between populations can often be limited by the plant's isolated habitat. Lack of sexual reproduction further segregates the species and can possibly reduce genetic diversity in the population and increase genetic differences between isolated populations.

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Tubelike modified leaves trap prey through backward-pointed hairs that prevent escape. Digestion of prey occurs through bacterial enzymes and enzymes secreted by the plant to extract nutrients needed for plant growth.

Students to the rescue of freshwater mussels at St. Croix National Scenic Riverway

By Jean Van Tatenhove

MATTHEW S. BERG

Students catch potential mussel host fish on the St. Croix River.

AS I LISTENED TO THE PRESENTATION, I had to keep reminding myself that these were high school students. The room full of biologists, teachers, students, and community members of Solon Springs, Wisconsin, are engaged as Aimee, a junior at Grantsburg High School, describes the life cycle of a freshwater mussel. Senior Ben takes over and describes the methods used to conduct a freshwater mussel survey on the upper St. Croix River. The Friends of the St. Croix Headwaters and Macalester College in St. Paul, Minnesota, funded the project.

Nearly 30 biology students conducted qualitative and quantitative surveys last summer. Then eight research biology students analyzed the data and produced a complete research paper with quality GIS maps, graphs, and diagrams describing their results. They were now presenting their findings in a PowerPoint format to their funding sponsors. The students worked hard—several earned a certificate in scuba diving in order to conduct the research. They moved several tons of river sediment searching for mussels and quantifying sediment composition.

Their teacher, Matt Berg, was disappointed that all the research students were not able to attend this presentation because of basketball games. "They really nailed this presentation when we were at Macalester. I didn't have to say a word. We missed Tyler tonight—he is the statistician of the group." When I asked Matt how he got high school students to do such professional presentations, he said, "They don't know they're not supposed to be able to."

Unlikely partners

Matt and his students have been working on the St. Croix River since 2002, conducting studies on freshwater mussels and dragonflies for the National Park Service (NPS), the University of Minnesota, Macalester College, the Wisconsin and Minnesota

MATTHEW S. BERG

Students and Research Fellow Mark Hove (far right) pose with a seine net.

departments of natural resources, and the U.S. Fish and Wildlife Service as part of their research biology class. So how did high school students come to work with these organizations?

As the new high school biology teacher in Grantsburg, Wisconsin, a town of 1,369 people, Matt Berg contacted riverway staff in 2001 to let them know he had a great interest in getting students involved in area resources. He wanted his students to understand that they live in a very special place and should get involved in its protection.

Mark Hove, research fellow at Macalester College and the University of Minnesota, contacted riverway staff in 2002 with an idea for helping a highly endangered group of organisms: freshwater mussels. "I had some straightforward projects and not enough people power to get the science done quickly." He wondered if he could get a team of trained help to triple the output of his research.

St. Croix National Scenic Riverway is home to—and in some cases, the last stronghold for—40 species of freshwater mussels. Mussels have a remarkable life cycle that includes a short period of time when they attach to the gills or fins of fish, using nutrients from the fish blood to grow their internal organs. Some mussels can utilize a wide variety of fish as hosts, but some require specific species. Host fish for several state and federally protected mussels in the river were unknown—essential information required in managing their recovery.

Riverway education staff met with Mark Hove to identify his research needs and what volunteer possibilities could fulfill his request. As Mark was describing his work, I thought high school students would best accomplish his tasks. I called Matt Berg, who was able to join the meeting, and we all began brainstorming. We quickly determined that Grantsburg High School students would come to the research rescue. Students would also become aware of the importance and plight of freshwater mussels in a river very near to them.

Mussels and more

The first study was titled "Fish Host Suitability Assessment of the WI/MN State Endangered Snuffbox Mussel (*Epioblasma triquetra*) from the St. Croix River." Students, along with Matt and Mark, captured potential host fish from the St. Croix River and separated them into species-specific tanks in the classroom. The students siphoned the tank bottoms to capture any glochidia (mussel babies) that fell from the fish over the next few weeks. As glochidia were identified, suitable host fish were recorded.

Both Mark and Matt were concerned about data quality. Matt worked out some classroom techniques. "We have a checklist of things. We save a raw data set just in case. I have the students work in pairs. If the two students come up with differing answers, they have to tell me why. I have student project managers. We involve other school staff such as math teachers to check formulas." Mark says that the transparency of research papers naturally allows others to review the work.

Once the high school operation was established and word started getting out, researchers began contacting the school and proposing projects. After a brief stint as an NPS seasonal biotech, Matt started his own company to handle the research grants and employ past students home from college for the summer. He also learned the National Park Service research permit system. Projects are already under way for this summer: a continuation of the mussel survey on the upper St. Croix, a river survey for

MATTHEW S. BERG

Students snorkel at the confluence of a tributary.

exotic aquatic macrophytes, and a proposal for an aquatic macroinvertebrate survey. At least 10 new student scuba divers have just been certified.

Master motivators

I wondered how the partners got teenagers really interested in mussels. When you listen to Mark describe his work, it is hard not to get excited. Enthusiasm is contagious. He tells me a story about the federally endangered winged mapleleaf mussel. "I knew these channel cats had to be host fish, but we couldn't catch one with glochidia attached. So we decided to have a fishing tournament. The grandfather of one student ended up catching the only cat with winged mapleleaf glochidia, but it was enough to confirm outside the lab that channel catfish are a host fish. Adding the field information made the study more realistic."

I witness Matt giving a student some well-deserved respect. He tells me as the student is listening, "Aimee is the map expert. I taught her everything I know and now I go to her with questions." She is beaming. I am thinking about how he just gave her a big dose of motivation. Teacher and student just finished an online GIS class together through the University of Montana. Recognizing the students' work goes a long way.

Park resource managers appreciate the information that these students contribute. Robin Maercklein, resource manager at St. Croix National Scenic Riverway, uses the survey data generated from several student studies when working on compliance documents such as environmental assessments and impact statements. "Even if the information is just in the back of my mind, their studies help me to identify mussel-sensitive areas when the park management is in planning mode. The student work is regularly incorporated into population ranges for each species of mussel, especially on the upper portion of the Riverway."

As a riverway educator, I am confronted every day by headlines about how teenagers are consumed by technology and how they don't interact with nature anymore. I hear people lamenting the absence of the next generation of scientists. I see answers in the model this group provides.

Engaging the next generation

Parks are overwhelmed with inventory and monitoring needs and understaffed with people to conduct the projects. Many monitoring protocols are in place and easily replicated. The National Park Service 2008 Director's Report states that "reaching out to the next generation to engage their intellect . . . to inspire their leadership in caring for the environment" is a goal. By providing quality teacher training and supervision, high school students could come to the rescue again, providing ways of multiplying research output. Everyone I interviewed for this article listed student engagement as the number one benefit of the work conducted with students of Mark Hove and Matt Berg. Students list the opportunity to work on real science as motivation.

I am able to observe the benefits firsthand, as Aimee is my daughter. She is not unique in her response to this research experience. Many other Grantsburg students share her newfound interest. They are the faces of the next generation of environmental leaders, scientists, and riverway stewards.

About the author

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Profile

Jack Potter: Glacier National Park's veteran of resource management

By the editor and associate editor

COURTESY OF JACK POTTER

Jack Potter, chief of Science and Resource Management, Glacier National Park, Montana.

Editor's note: Resource managers who stay in one national park for their entire career, building and refining their knowledge of the place, exercising judgment, sharing insights, and defending park values are a rare thing in the National Park Service. Thus, we explore the long-tenured career of Jack Potter in Glacier National Park, Montana, as a way to learn from his experience, help preserve institutional memory, and celebrate his special contribution to the National Park Service.

***Park Science:* You have gone from busboy to chief of Science and Resource Management. Tell us about your 40-year "ride" at Glacier.**

Jack Potter: During my first year in Glacier I distinctly remember people listing their home as "Woodstock Nation" at our self-registration trailhead boxes and thinking, "Now where was that?" and "What was that supposed to mean?" During those early years, I really hadn't considered a career in the National Park Service. It was more place driven—I wanted to work in Glacier. After seven years as a seasonal maintenance worker and work leader, I wanted a more permanent job and I was able to get a subject-to-furlough position as district trails supervisor at St. Mary for the Hudson Bay District on the east side of Glacier. I have been very fortunate to be able to broaden my working experience and move upward in the ranks, especially in Glacier.

What is your college background?

JP: I was a political science graduate from Colgate University, but I decided to switch directions and got a forestry degree from the University of Montana. I have taken additional coursework from Colorado State University and attended a University of Washington continuing education field camp. I was not part of any particular intake program—I guess just working here in Glacier was my intake.

What is your most memorable "natural resource" experience?

JP: Seeing a huge, black-colored grizzly bear chase a smaller grizzly from the partially buried carcass of a large bull elk, and excavate and feed on it. Somewhere in those 25,000+ miles of hiking, climbing, riding, skiing, and snowshoeing and many days of camping are numerous diamonds, and the wonder has not diminished for me.

What is your most memorable "cultural resource" experience?

JP: I couldn't pinpoint one thing, but I have been very fortunate to have worked with the local Indian nations. I can't say everything has always gone smoothly, but cultural diversity in northwestern Montana is largely defined by American Indians/First Nations, and working in this setting has been very rewarding. I will say that holding an exquisite spear point, formed from a black and green rock that a visitor found, was really amazing. We returned the point to the area from which it was taken at the request of the Salish and Kootenai elders.

COURTESY OF JACK POTTER

Potter is the winner of numerous awards, including the 2003 Intermountain Regional Director's Award for Resource Management and the 2007 Department of the Interior Superior Service Award. He is credited with strengthening the park's management team with his "in-depth knowledge" of Glacier and the National Park Service mission and objectives, and is recognized as being committed to the "highest principles of leadership and integrity."

What issues have you been tracking over your entire 40-year career?

JP: I have been most intimately involved with trying to balance recreational use with resource protection. I have tried to incorporate my scientifically informed perspective into several planning efforts, such as our Backcountry and Wilderness Management Plan, Commercial Services Management Plan, and the General Management Plan. These plans address everything from trail maintenance and campground locations to management of wildlife-human conflicts and restoration of degraded areas.

What projects, programs, and practices will be your legacy?

JP: Resource protection has been a constant effort, with some problems that came and went and others that persist. I would say at least for the relatively short term, the General Management Plan, the Commercial Services Plan, and the Backcountry and Wilderness Plan and wilderness proposal have put some ideas into policy. There are many other efforts relating to fire and other issues that may also add up. Our Resource Management Plan was good for the time [i.e., 1994, updated in 1998], but it needs to be updated into a Resource Stewardship Plan.

What are some examples of how science has informed or changed park practices?

JP: This is a huge list ranging from recreation ecology to individual species management—grizzly bears, bighorn sheep, native fish, and more. U.S. Geological Survey [USGS] researcher Kate Kendall's monumental grizzly bear baseline research gave us valuable information about population numbers and distribution. Also from USGS, Kim Keating's research on bighorn sheep gave us a wealth of new information about the population, habitat use, and external issues.

Several researchers have contributed important and alarming information about native bull trout and westslope cutthroat trout that is moving us toward adaptive management to protect these species. The climate change information, particularly the revelations about glacial mass, hydrologic changes, and possibly landscape effects by Dan Fagre and his colleagues, has caused the greatest challenge for management as we try to downscale effects, understand vulnerabilities, identify stressors, and adapt management.

Tell us more about the state of the glaciers and when you first noticed them getting smaller.

JP: Dr. Dan Fagre of the USGS has been documenting the change in glacier coverage since 1991, utilizing his effective comparative photography, among other methods. Having been close to or on many of those glaciers, I began observing this retreat more than a decade ago, influenced by Dan's work. The most graphic evidence for me was Grinnell Glacier, which I have visited numerous times and watched as the ice retreated from familiar landmarks. The emergence of a new meltwater lake, where there was formerly a lobe of the glacier, was particularly graphic.

We are still catching up on how to talk to the public about this and other climate change–induced phenomena and need to formulate an adaptive management strategy. There is really nothing we can do for the glaciers, although we have had suggestions for insulating tarps and other materials. I was also fortunate to have Dr. Leigh Welling as the first director of the Crown of the Continent Research Learning Center, who really pushed awareness of this issue in Glacier before she became the Natural Resource Program Center lead for climate change.

What other changes in natural resources have you observed?

JP: When I first came to Glacier the common phrase was "the asbestos forest," which referred to our forests that did not burn very often. People warned, "Don't count on firefighting to make any money here." That reality changed with the Red Bench Fire of 1988, which ushered in a new wave of fires influenced by large fuel buildups and severe fire weather. This culminated for me in 2003 when numerous large fires raged, forcing evacuation of park headquarters. Four Type 1 teams [used

NATIONAL PARK SERVICE/DOUG MCMAINS

The four tribes that make up the Blackfoot Confederacy hold an annual conference and encampment in Glacier National Park to discuss tribal relations and contemporary issues facing the tribes. The eastern part of the park near St. Mary is on ancestral Blackfoot lands. Little Chief Mountain is in the background.

to suppress large fires] were operating in or near the park, and smoke and haze lingered for months. The Red Eagle Fire of 2006 probably marked the shift to a parkwide change in fire behavior, where fire previously had generally been limited to areas west of the Continental Divide but now burned throughout the park.

Another sad thing for me has been the devastation of our whitebark pine forests by white pine blister rust. Whole drainages now are full of skeleton trees and Clark's nutcrackers are getting very scarce. Unlike the regeneration after fires or the mountain pine beetle epidemic in the 1970s, some of these forested areas remain barren. The current run of at least five different insect infestations, along with several other pathogens, has transformed large areas of the park. What the forest composition will be in the future is unknown.

Cultural diversity in northwestern Montana is largely defined by American Indians/First Nations, and working in this setting has been very rewarding.

Lastly, the hydrologic cycle has been altered so greatly that it is hard to predict what will come next. Late fall rains and floods, early runoff, reduced snowfall, drastically reduced late-season streamflows are a real challenge to our native fisheries.

Glacier is designated an international peace park and world heritage site. How has working with Waterton staff influenced your perspective on the U.S. National Park Service?

JP: It has been extremely rewarding both for the personal contacts and friendships and for the wonderful reality check from another point of view on everything from management of wildlife and resource monitoring to interpretation. While Parks Canada and the U.S. National Park Service are alike in many ways, we look at many issues from different perspectives that reflect agency culture, individual training, and societal values. We can learn from each other and the result will be better for both.

Spending your entire career in the same park is a rare NPS experience. Will current or future resource managers have more or less of an opportunity to stay in their "park of choice"?

JP: I know of a few managers who have spent or are spending a significant amount of time in a particular place. The advantages are a relatively longer frame of reference for park resources and issues balanced with the need for new ideas and solutions to problems.

I'm not sure what the future will hold, but I feel strongly that our intake/career ladder system discourages many good people because it is not a consistent, merit-based, predictable system. Budgetary realities and time-sensitive needs for expertise make it difficult to sustain an intern program or create intake positions. For example, if I only have two wildlife biologists and a host of pressing issues, I will opt for a full performance–level position if one becomes open.

What changes have you seen in your day-to-day job as a resource manager?

JP: Partly because of my long history here and partly because of the nature of the issues, a significant portion of my time is spent on larger, often political issues rather than just those that may just affect our natural and cultural resources.

What advice can you provide to future resource managers based on your experience?

JP: You will need to constantly adapt to changing knowledge and challenges. You cannot escape politics at all levels—local, regional, and for Glacier even national—so you must know how to work in that reality. You cannot escape making unpopular choices and compromises but you have to keep the big picture in mind. For example, you may have to eliminate a problem grizzly bear, as we had to do this year, because it may be best for managing the population as a whole.

What issues will Glacier face in the next 5 to 10 years?

JP: We have probably only reached a temporary lull in the rapid growth of Flathead County. As area population grows and park visitation from all sources potentially increases, conversion of wildlife habitat and disruption of connectivity corridors and increased noise, light, and traffic will continue to affect park-related resources. Since we did not address a carrying capacity or system of limits of acceptable change for increased park visitation scenarios in our General Management Plan, we are left with limitations generally dictated by facilities. Also, the impacts of noise will continue to draw visitor complaints primarily directed toward scenic helicopter overflights and motorcycles with after market exhaust modifications. Other issues include land use change on all boundaries, fisheries, unexplained disappearance of fisher and porcupine, and increases in exotic species or diseases projected against the background of climate change.

The benefits we have received from the Cooperative Ecosystem Studies Unit [CESU] hosted by the University of Montana, and particularly the outstanding director Dr. Kathy Tonnessen, totally changed our ability to attract and carry out research.

The ongoing issue with mineral development in the British Columbia headwaters of the Flathead River continues to be a concern. I think the recent IUCN/World Heritage review mission went very well. This was in response to a petition to have Waterton-Glacier designated a "world heritage site in danger" because of several mining initiatives in the Flathead River Basin in British Columbia. We were able to demonstrate the incompatibility of mining in this area with the world heritage site. How this will affect the long-range plans of the British Columbian government remains to be seen; however, the mission's report to the World Heritage Committee, due next June, will certainly make a strong case for additional protection even if the site is not listed as in danger.

What do you see as the most important issues facing the National Park Service over the next several decades?

JP: Certainly climate change and the implications for hydrology, habitats, and individual species will be with us for a long time. I hope we will put into place some adaptive strategies that will mitigate those effects somewhat. Grizzly bear conservation will also continue to be a challenge as the local human population increases, habitat disappears, connectivity is disrupted, and climate change potentially influences food availability and the species' earlier emergence from hibernation.

How did the Natural Resource Challenge initiative earlier this decade change the ways you do business at Glacier?

JP: We filled our benchmark professional resource management positions and were able to host the Crown of the Continent Research Learning Center, which has been a great benefit to us. The biggest disappointment was having the base budget increases indicated by RMAP [Resource Management Assessment Program] stop the year before Glacier was to receive a substantial funding increase. The benefits we have received from the Cooperative Ecosystem Studies Unit [CESU] hosted by the University of Montana, and particularly the outstanding director Dr. Kathy Tonnessen, totally changed our ability to attract and carry out research. Also, establishment of the Rocky Mountain Inventory and Monitoring Network has enabled us to break out of reactionary mode and work toward long-term ecological monitoring. For Glacier, sharing the expertise of the CESU and network staffs has been extremely important. I see them as part-time members and partners of our staff, and I hope they feel that way also.

What are your plans for retirement?

JP: My wife and I are planning to retire in the Flathead Valley, probably within the next two years. I would love to travel and take longer trips to Alaska, Canada—particularly the Nahanni River—other national parks, Australia and New Zealand, and the Southwest, and spend more time hiking, floating, and camping. I am also very interested in the recently announced NPS emeritus program and have many other volunteer projects in mind.

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Information Crossfile

Synopses of selected publications relevant to natural resource management

SUMMARIES

Conservation of rare or little-known species: Biological, social, and economic considerations

AS PART OF THE NORTHWEST FOREST PLAN (1994), federal agencies in the Pacific Northwest were tasked with inventorying and conserving an estimated 300 exceedingly rare or poorly understood species, whose status was possibly imperiled. This group encompassed little-known species such as arthropods, fungi, and mollusks, which are often buried in substrate or hidden in the forest floor. Given the difficulty in detecting rare species, the lack of scientific understanding of little-known species, and the inherent extinction risks, conservation planning and management seemed overwhelming. Furthermore, planning and implementation occurred in an environment of significant uncertainty and political controversy (Raphael and Molina 2007). Facing this challenge, in 2003 the USDA Forest Service, U.S. Geological Survey, U.S. Fish and Wildlife Service, Bureau of Land Management, Oregon State University, The Nature Conservancy, and the Society for Conservation Biology sponsored a symposium, "Innovations in Species Conservation," where participants grappled with a variety of questions:

- What are some alternative approaches to conservation of rare and little-known species? What are the goals of these approaches, and what is the likelihood they will be successful?
- How do different groups of constituents in society feel about these approaches?
- What are the economic implications?
- What are the legal and policy requirements associated with different conservation approaches?
- What constraints are imposed on land managers and natural resource use by the various approaches?

Conservation of rare or little-known species: Biological, social, and economic considerations is the outcome of this symposium. The book thoroughly discusses "species rarity," provides definitions and attributes of little-known species, and addresses special considerations for studying and managing such species. By using case examples of successful and failed applications of conservation practices at both species and system levels, the authors emphasize practical considerations—including social values and economic costs and benefits—that land managers face in developing and implementing conservation strategies. Martin G. Raphael, Randy Molina, and 10 other contributing authors discuss approaches to conservation planning, identify the main assumptions and point out the strengths and weaknesses of each approach for rare or little-known species, and ultimately supply a thorough scientific evaluation of management options for conserving rare or little-known species in terrestrial environments. The authors highlight legal, biological, sociological, political, administrative, and economic considerations for evaluating conservation strategies. The topics covered help resource managers determine which strategy or combination of strategies will best meet their goals and objectives. Although no fixed or easy answers exist, the book suggests an overall procedure for selecting management approaches. Perhaps most importantly, the book guides readers in how to reach the ultimate goal of long-term buy-in and commitment of a devised strategy for conserving rare or little-known species.

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—Katie KellerLynn
Associate Editor

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Managing protected areas as surrounding land use changes

TWO COMPLEMENTARY JOURNAL ARTICLES explore management of protected areas in a world of changing land use. To show ways in which land use in surrounding areas can influence protected areas, the authors draw upon case studies that include the Greater Yellowstone Ecosystem (Yukon, Canada, to western United States), Clakmul Biosphere Reserve (southern Yucatán Peninsula), and Wolong Nature Reserve (Sichuan, China). The first article, Hansen and DeFries (2007), introduces a synthetic framework for predicting the effects of changes in surrounding land use on protected areas. The framework consists of a comprehensive set of ecological mechanisms for assessing the vulnerability of protected areas to land use. These mechanisms are effective size of the ecosystem, flow zones of ecological processes (e.g., natural disturbances), crucial habitats (e.g., seasonal migrations and population "source" areas), and proximity to humans (e.g., exposure to hunting, poaching, exotic species, and disease).

The central thesis of this article and DeFries et al. (2007) is that protected areas are often part of larger ecosystems, for example,

SUMMARIES (CONT'D)

the greater Yellowstone, Everglades, and Serengeti ecosystems. A classic North American example of this thesis showed that the needs of grizzly bears could not be met solely within the borders of Yellowstone National Park (e.g., Craighead 1979). Another tenet of the thesis is that land use change in the unprotected portion of the ecosystem may rescale the ecosystem, leading to changes in ecological functioning and biodiversity within the protected area.

The second article, DeFries et al. (2007), serves as a follow-up to Hansen and DeFries (2007) and proposes scientifically based management alternatives for striking a balance between surrounding land use and protected areas. The authors point out that "the historical view of protected areas as islands isolated from surrounding areas and neighboring communities is superseded by the reality that effective management in and around protected areas must account for human use of natural resources." Their approach is to identify small loss–big gain opportunities that maintain ecological functioning of the protected area ("big gain") and result in minimal negative consequences for human land use and well-being ("small loss"). They propose three factors—management objectives, biophysical setting, and socioeconomic setting—and related questions to help identify such management opportunities: Which attributes of biodiversity are of greatest concern? What is the spatial extent of interactions among protected areas and their surroundings? What are the conflicts between biodiversity and land use in and around the protected area? According to the authors, the challenge to developing scientifically based, regional land use management approaches "pertains to both the development community to incorporate ecological principles in land management and the ecological community to consider growing human needs for ecosystem services in management recommendations."

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—Katie KellerLynn

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Framing problems to understand stakeholders, reduce conflict, and find solutions

OFTEN, FRAMING THE PROBLEM IS THE PROBLEM. Leong et al. (2007) proposes a conceptual model that helps resource managers determine whether their "frame"—filter or lens through which people interpret and process information—on a particular issue jibes with other stakeholders. The particular issue presented in the article is management of white-tailed deer (*Odocoileus virginianus*) at Fire Island National Seashore (New York) and Valley Forge National Historical Park (Pennsylvania), but managers could apply the model to other species in other contexts. The model illustrates the variety of ways a group of stakeholders can define a complex issue. For instance, if the overarching issue is deer abundance and a citizen frames the issues to be about reducing the incidence of people feeding deer (as a solution to deer abundance), but a resource manager frames the issue to be about immunocontraception and sets up bait stations to attract deer for inoculations, then the citizen may see the management solution as exacerbating the problem, not solving it.

Additionally, the authors point out that the considerations of stakeholders are generally broader than the problem frames typically considered by NPS managers. Knowing what these citizens' frames are will help managers gauge responses. For example, results of this study showed that stakeholders concerned about specific impacts (e.g., deer-vehicle collisions, spread of disease or parasites, or loss of ornamental landscaping) often desired faster results from a management action than stakeholders who were concerned about broad ecological effects (e.g., habitat alteration or changes in deer population dynamics).

The model also illustrates the relationships among different frames and their levels: anthropogenic activities (level I) result in broad ecological effects (level II), causing events or interactions between deer and people or resources (level III), some of which lead to habituation of deer to anthropogenic activities (level IV), amplifying perceptions of specific impacts (level V) (fig. 1). For example, if citizens have identified changes in deer behavior (a level IV frame) as the problem, but managers have identified vegetation damage (a level II frame) as the problem, then "they may apply different metrics of success to the same management action, resulting in incompatible opinions about whether or not a management action 'works,' thereby posing the risk of decreasing agency credibility, eroding relationships, and ultimately increasing conflict."

Being at different levels in the system, however, does not necessarily equate to failure. If stakeholders and managers recognize differences, they may be able to find solutions. The authors con-

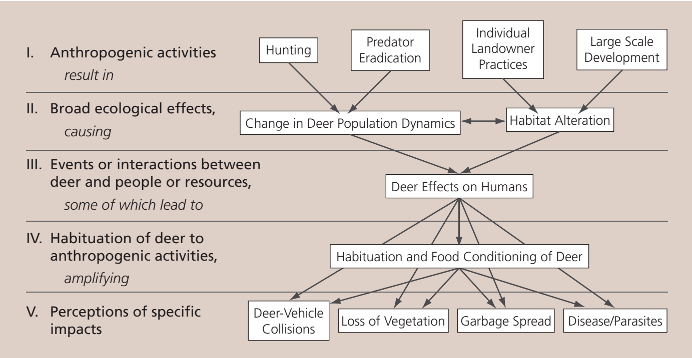

Figure 1. Elements of messy deer problems in and around northeastern U.S. NPS units, as collectively described by local community residents. DERIVED FROM LEONG ET AL. 2007, P. 69

tend that "a more robust view of the problem may be achieved by synthesizing multiple problem frames." Furthermore, restricting attention to an established management frame "misses opportunities to identify creative solutions outside agency jurisdiction."

Leong et al. (2007) provides a conceptual model for identifying frames of stakeholders (citizens and managers), which the authors admit is a starting point. Although future research and managers must take this model and develop a tool that facilitates constructive dialogue among stakeholders, Leong et al. (2007) provide a frame for taking this step.

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—Katie KellerLynn

The considerations of stakeholders are generally broader than the problem frames typically considered by NPS managers.

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Glyphosate and other pesticides in vernal pools and streams in parks

HERBICIDES CONTAINING GLYPHOSATE are used in more than 130 countries on more than 100 crops (Monsanto 2009). Part of the reason for their popularity is the perception that glyphosate is an "environmentally benign" herbicide (Giesy et al. 2000; Duke and Powles 2008) that has low toxicity and little mobility or persistence in the environment. Recent studies, however, suggest that glyphosate is more mobile and occurs more widely in the environment than was previously thought (Battaglin et al. 2005; Baker et al. 2006; Kolpin et al. 2006; Scribner et al. 2007; Battaglin et al. 2008).

Glyphosate is a nonselective contact herbicide that kills plants by inhibiting synthesis of aromatic amino acids needed for protein formation. Glyphosate is the most commonly used pesticide for agriculture, and the second most commonly used pesticide for "home and garden" and "commercial and industrial" uses in the United States (Kiely et al. 2004). Glyphosate use in the United States has increased dramatically in recent years as a result of its use on soybean, cotton, and corn crops that have been genetically modified to tolerate it. In national parks and national wildlife refuges (parks), glyphosate has been recommended for control of some noxious or nonindigenous plant species in select settings. Deleterious effects on the development and survival of amphibians have been observed at various levels of exposure to commercial glyphosate formulations, in some cases at concentrations of 1,000 µg/L or less (Cauble and Wagner 2005; Edginton et al. 2004; Howe et al. 2004; Relyea 2005; Dinehart et al. 2009). Most of these studies indicate that commercial glyphosate formulations are more toxic than pure glyphosate due to the effects of the surfactants used (Howe et al. 2004: Bringolf et al. 2007). However, surfactant concentrations were not measured in this study (Battaglin et al. 2008) or any of the other studies referenced.

Vernal pools are sensitive environments that provide critical habitats for many species, including amphibians. In 2005 and 2006, water samples were collected from vernal pools and adjacent flowing waters in parks in Iowa, Washington, D.C., and Maryland, prior to and just after the local use of glyphosate (Battaglin et al. 2008). At each site there was a treatment pool (with adjacent glyphosate use), a control pool (with no glyphosate use nearby), and a flowing stream (with multiple potential glyphosate sources). In addition, a park in Wyoming was a study control with no reported glyphosate use nearby. Results indicate that vernal pools and adjacent streams can be contaminated by the use of herbicides within parks to control weeds in cropped areas or to kill noxious or nonindigenous plants. Contamination also originates from pesticide use occurring outside park boundaries (Battaglin

SUMMARIES (CONT'D)

et al. 2008). Glyphosate was detected in 31 of 76 samples with a maximum concentration of 328 µg/L, measured in a sample collected from a vernal pool in Rock Creek Park, Washington, D.C. That sample was collected seven days after glyphosate was applied by backpack sprayer in the area near the site to control lesser celandine (*Ranunculus ficaria*) and one day after approximately 3 cm of rain fell at the site. Glyphosate was not the only pesticide found; 27 other pesticides or pesticide degradation products, including atrazine, triclopyr, and 2,4-D, were detected at concentrations ranging from less than 0.01 to more than 10 µg/L. The results of this study provide a baseline of information on the occurrence of glyphosate and other pesticides in selected national parks and wildlife refuges that is relevant to studies of the ecology, hydrology, and biology of water-related habitats at those sites.

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ARTICLE

Discovering contaminants of emerging concern

CONTAMINANTS ARE UBIQUITOUS. According to Battaglin and Kolpin (2009), "the environmental occurrence of trace organic compounds such as pharmaceuticals, personal care products, pesticides, and hormones, and their potential adverse effects on aquatic and terrestrial life and on human health is an issue that concerns not only scientists and engineers, but also the general public." Investigations are detecting such trace organic compounds with increasing frequency in the environment on a global scale (Halling-Sørensen et al. 1998; Kolpin et al. 2002; Ashton et al. 2004; Moldovan 2006; Gulkowska et al. 2007). Contaminants of emerging concern include endocrine disrupting compounds (Emerging Contaminants Workgroup 2008). Such contaminants occur in treated Las Vegas sewage effluent upstream of Lake Mead National Recreation Area (Nevada). More surprising, perhaps, is the documented occurrence of these contaminants in the remote alpine lakes of national parks such as Glacier, Mount Rainier, and Rocky Mountain in Montana, Washington, and Colorado respectively (Landers et al. 2008); findings of this recent EPA report on airborne contaminants are summarized in this issue (see pages 58–63). Furthermore, an NPS natural resource report by Rebecca A. Landewe summarizes the occurrence of chemical contaminants throughout the National Park System. Landewe (2008) reviews what is currently known about "new or existing compounds with emerging concern," in particular endocrine disrupting compounds. These compounds have come under intense scrutiny in recent years because, when present during key life cycle stages even in miniscule amounts, they can have significant effects on the reproduction, growth, and development of organisms.

Landewe (2008) documents contamination by National Park Service (NPS) region: The snowpack of Yellowstone National Park (Intermountain Region) contains the by-products of fossil-fuel combustion, including toluene—a potential endocrine disruptor. The waters of Chattahoochee River National Recreation Area (Southeast Region) contain a cocktail of organic wastewater contaminants, 13 of which are endocrine disruptors. In the Midwest Region, estrogenic compounds from wastewater treatment facilities are present in Mississippi National River and Recreation Area. Potential endocrine-active compounds from detergents and other household and industrial products occur in more than 74 miles (119 km) of the Cuyahoga River, which flows through Cuyahoga Valley National Park. In a study in Voyageurs National Park, half of the sampled fish contained perfluorinated compounds, which are used in grease-resistant food packaging, stain-resistant fabrics, and nonstick cookware, for example. In the Northeast Region, residential septic systems leak groundwater contaminated with estrogenic compounds at Cape Cod National Seashore.

Salmon contaminated with PCBs (polychlorinated biphenyls) and DDE (dichlorodiphenyldichloroethylene) spawn and die in the Copper River upstream of Wrangell–St. Elias National Park and Preserve (Alaska Region), introducing potential endocrine disrupters into an otherwise mostly pristine freshwater food web. PCBs are persistent organic pollutants that bioaccumulate in animals, and DDE is a potentially potent endocrine disruptor that results from the breakdown of the synthetic pesticide DDT (dichlorodiphenyltrichloroethane). In the Pacific West Region, insecticides such as chlorpyrifos, diazinon, and parathion in montane lakes in Sequoia National Park illustrate the far-flung impacts of atmospherically transported contaminants.

Much data on wildlife come from fish and other species hunted for food. Fish are among the aquatic species of concern for endocrine disrupting contaminants because they are immersed in water and take up contaminants through both skin and gills. In the 1990s, studies began to document the phenomenon of vitellogenin (VTG) production in male fish (e.g., Purdom et al. 1994; Harries et al. 1996; Lye et al. 1997, 1998); VTG is an egg yolk precursor protein synthesized in response to estrogen or xenoestrogenic (estrogen-mimicking) compounds. In natural systems, VTG is typically only produced by females. Intersexuality, the presence of both male and female reproductive structures in the same animal, is another common biomarker (alongside elevated VTG) of xenoestrogen exposure in fish. Investigators of the Western Airborne Contaminants Assessment Project (WACAP) documented the presence of intersex fish with the finding of some male fish with both female oocytes and male testes at Rocky Mountain and Glacier national parks, and elevated VTG in some male fish at Rocky Mountain, Glacier, and Mount Rainier national parks. Although WACAP scientists are still investigating the cause-and-effect relationship, these changes are indicative of a chemical effect possibly resulting from endocrine disrupting contaminants such as the insecticides dieldrin and DDT (Landers et al. 2008; Schwindt et al. 2009; also see Flanagan on pages 58–63 of this issue).

Concern over contaminants increases when reproductive disorders pass to subsequent generations; for example, laboratory studies have concluded that deficits in sperm production can be transgenerational (Lyons 2008). However, data about the effects of endocrine disrupting contaminants on populations are comparatively few (Geschwind et al. 1999), though a recent study suggests that one outcome may be population collapse (Kidd et al. 2008).

ARTICLE (CONT'D)

At present many researchers, including WACAP investigators and NPS Water Resources Division scientists, are trying to decipher the full meaning of these new findings by asking pertinent questions, such as which contaminants are posing threats, what are the pathways for these contaminants, where are contaminants accumulating (areal extent and by elevation), what are the most useful indicators of contaminants, and what are the effects of contaminants at the population level? New findings, unanswered questions, and the health of wildlife and human populations provide plenty of rationale for continuing these studies in national parks and elsewhere.

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— Katie KellerLynn

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BOOK REVIEWS

A rough yet provocative guide to climate change

"WHETHER YOU'RE ALARMED, skeptical or simply curious about climate change, this book will help you sort through the many facets of this sprawling issue," states the introduction to *The rough guide to climate change* by Robert Henson. A meteorologist and journalist by training, Henson has been reporting on climate change for nearly 20 years as a freelancer and for the National Center for Atmospheric Research in Boulder, Colorado. First published in 2006, *The rough guide to climate change* is in its second (2008) edition.

Written for a general audience, the book is organized into five parts. First, "The Basics" explains greenhouse gases and how climate change works. Second, "The Symptoms" shows how climate change is already affecting life on Earth and how these changes may play out in the future. This section may help resource managers elucidate what changes may occur on park lands and waters and put currently identified changes into context. Of interest to managers may be Henson's succinct explanation of why certain species are vulnerable to climate change—the so-called canaries of climate change (e.g., amphibians, reptiles, butterflies, and certain species of mice). Also managers in the Gulf Coast Network may find the chapter about hurricanes and other storms particularly pertinent. Third, "The Science" describes the global warm-up: what's measured, who is measuring, how they're measuring, and what various time scales show. Fourth, "Debates and Solutions" provides a history of the global-warming debate and its media coverage, as well as a discussion of solutions that include political agreements, cleaner energy sources, household and travel tips for reducing one's carbon footprint, and geoengineering schemes (i.e., global-scale attempts to reshape Earth's atmosphere). This section also addresses common arguments and counterarguments, which resource managers may find useful in preparing funding proposals. Perhaps tongue in cheek, Henson sums up the extremes of these arguments as follows:

> The atmosphere isn't warming; and if it is, then it's due to natural variation; and even if it's not due to natural variation, then the amount of warming is insignificant; and if it becomes significant, then the benefits outweigh the problems; and even if they don't, technology will come to the rescue; and even if it doesn't, we shouldn't wreck the economy to fix the problem when many parts of the science are uncertain.

Henson responds to each of these points scientifically. Resource managers may find his responses useful when preparing public presentations or addressing skeptics of climate change in an audience. Finally, Part 5 lists books and Web sites that have global warming as a focus.

The rough guide to climate change is well researched and presents logical discussions that guide readers through the complexities of climate change. Though lighthearted in its title and approach, this little book is provocative, making readers think about climate change in new ways. Perhaps the result of climate change will not be a disastrous end, but simply a more mundane planet as coral reefs glow with less brilliance, and common, robust species (e.g., deer) proliferate. It is provocative because it makes readers think, "Is this what I want? Is this an acceptable outcome?"

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— Katie KellerLynn

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Stepping into the wind with California condors

"OH MY GOD," the gray-haired woman standing at my side exclaimed. That's the most beautiful thing I've ever seen!" This from someone who moments before blurted, "Those are the ugliest birds I've ever seen." Like this woman, readers of Sophie A. H. Osborn's 2007 book, *Condors in canyon country: The return of the California condor to the Grand Canyon region*, are suddenly captivated by condor flight. The book chronicles the historical decline of the California condor (*Gymnogyps californianus*) and the efforts to save it. It focuses on the Grand Canyon of Arizona but follows events in California because the Arizona birds "owe their history and their fates to [these condors] and to those who struggled to keep the California birds from extinction" (Osborn, p. 3).

Words like "stunning" describe the photo of an adult condor peering through its flight feathers, "amazing" for the picture of a hatchling condor emerging from its egg, and "majestic" for the condor portrait on the book's final page. Readers could be satisfied simply perusing the book's photos and captions but are enticed by chapter topics such as natural history, condors in the past, captivity and reintroductions, condor behavior, survival of condors, and wild condors.

With so few condors remaining and so carefully watched, these birds become individuals with distinctive personalities. Condors are playful, curious, and intelligent. According to Osborn, "the need for scavengers to evaluate their situation and make a variety of adaptive decisions that will allow them to feed safely, compete with other scavengers, and avoid predators every time they encounter a new carcass likely explains why much of scavenger

BOOK REVIEWS (CONT'D)

behavior appears to be learned rather than innate" (Osborn, p. 64).

But learning by doing can be problematic for many juvenile condors who are not equipped to survive in the wild without guidance. Every story in the book may have a silver lining, but every silver lining seems to have a cloud: Readers are amused by the descriptions of condor play, which ultimately contributes to motor and sensory development, but frustrated by their selection of toys (i.e., trash), which they ingest and ultimately regurgitate to their young. Their natural curiosity and intelligence makes them extremely interesting but can equate to life-threatening "bad behavior," often making hazing an integral part of wildlife management. The condors' attraction to activity, commotion, and crowds, which perhaps resemble herds or congregating animals where births and deaths (i.e., available food) occur, makes Grand Canyon's South Rim the most reliable place on Earth to see California condor in the wild, but also puts the birds in proximity to potentially dangerous situations that may defeat their safe return to the wild.

As the book jacket states, *Condors in canyon country* is "a must-read for anyone passionate about endangered species and what humankind can do to save them." The book takes a subtly scientific approach and addresses many scientific inquiries: Did condors have a continuous presence in the Grand Canyon between the Pleistocene Epoch and historic times? What are the causes of decline? How do scientists maximize the genetic diversity remaining in an extremely small population for successful breeding? What is the significance of double- and triple-clutching? What technologies are the most appropriate for tracking condors? What factors inhibit the survival of condors in the wild? So caught up in hoping for the survival of "a creature so utterly captivating, so highly treasured, so nearly lost" (Osborn, p. 2), readers may not realize that their scientific questions are being answered.

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— Katie KellerLynn

■ ■ ■

Yellowstone's rebirth by fire

THROUGH INTERPRETIVE PROSE AND LAVISH PHOTOGRAPHS, *Yellowstone's rebirth by fire: Rising from the ashes of the 1988 wildfires* revisits the "awesome and bewildering summer that compelled people to look at the element of fire in a new way" (Reinhart 2008, p. 12). The book reveals the "burning legacy" of Yellowstone through chapters on the history of fire in the park, the meteorological and political climate of summer 1988, a timeline of the "biggest days" of that year's fire season, personal stories of people who experienced the fires, and an inspirational conclusion that rekindles old memories and inspires new confidence in a changing landscape. In the book, Research Ecologist Don Despain says, "the amount and breadth of . . . research was the most important outcome of the 1988 Yellowstone fires" (p. 88). Although the author certainly recognizes the significance of the opportunity for research, the book, unfortunately, does not live up to the expectations touted in the promotional materials—"exploring the science behind the burning questions of 1988." Scientists flocked to Yellowstone National Park to study fire during this rare opportunity of such large proportions; they conducted more than 250 scientific investigations of fire and its effects. Although the scientific counterpoints made in the "Myths and Science: Toward a New Yellowstone" chapter demystify many 1988 predictions and assumptions, perhaps Reinhart's next book will truly explore and probe the science of "rebirth by fire" by also relating these scientific and scientists' stories.

Reference

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— Katie KellerLynn

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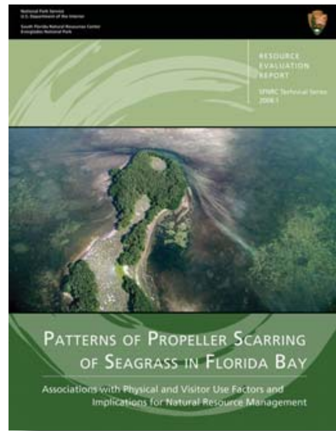
NPS IN PRINT

Patterns of propeller scarring of seagrass in Florida Bay

NATURAL RESOURCE MANAGERS OFTEN STRUGGLE to obtain accurate estimates of damage caused by recreational activities in national parks. Understanding the factors that affect recreational impacts is an important step in the development of management plans that seek to reduce impacts on natural resources. In Florida Bay, Everglades National Park, hundreds of thousands of acres of submerged wilderness are visited by recreational boaters that come from the park's primary access in Flamingo and various entry points throughout the Florida Keys. Although the principal environmental stressors on Florida Bay are related to watershed management, recreational boat use also has resulted in damage to benthic resources. Identification of propeller-scarred seagrass beds has been a critical data need of park managers and the public in the development of the park general management plan and for natural resource management. To learn more about seagrass scarring by motorboat propellers and potential ways to address this problem, scientists at Everglades National Park mapped and geostatistically analyzed seagrass damage in Florida Bay.

This study (South Florida Natural Resources Center 2008) found that seagrass scarring in Florida Bay is widespread, with dense areas occurring in shallow depths, near all navigational channels, and around sites that are most heavily visited, such as shorelines. Scientists identified substantially more scarring in this study than in a previous statewide study conducted in 1995, and scarring is increasing at specific sites in Florida Bay. In light of the worsening problem, the study concludes that new management strategies are needed to protect seagrass beds as part of an ecosystem approach to managing Florida Bay. Several options for minimizing propeller-caused damage are available to managers: education programs, improved navigational aids, pole/troll zones, idle and speed zones, limiting access of particular motorized watercraft, and area-specific seasonal access limits or closures.



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South Florida Natural Resources Center (SFNRC). 2008. Patterns of propeller scarring of seagrass in Florida Bay: Associations with visitor use factors and implications for natural resource management. Resource Evaluation Report. SFNRC Technical Series 2008:1. National Park Service, Everglades National Park, Homestead, Florida, USA. Available at http://www.nps.gov/ever/naturescience/technicalreports.htm.

—David E. Hallac,[1] Jimi Sadle,[2] Leonard Pearlstine,[3] and Fred Herling[4]

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3 Landscape ecologist

4 Lead planner

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NPS PHOTO/LORI OBERHOFER

NPS IN PRINT (CONT'D)

Reading the tale of two rivers: Historical analysis in support of river park management

Note: Aspects of this article were adapted from Engstrom (2009), an introduction to "The recent environmental history of the upper Mississippi River," a special issue of the *Journal of Paleolimnology* (fig. 1).

Figure 1. Cover of the special issue of the *Journal of Paleolimnology*, published in May 2009. The issue examines the environmental history of the Mississippi and St. Croix rivers in the vicinity of Mississippi National River and Recreation Area (Minnesota) and St. Croix National Scenic Riverway (Wisconsin).

MOST OF THE WORLD'S GREAT RIVERS have been substantially altered by centuries of land use conversion, urbanization, and hydrological modification, and North America's greatest river, the Mississippi, is no exception. Some 1,765 river miles (2,840 km) upstream of the Gulf of Mexico lies the confluence of two contrasting tributaries that in many ways epitomize these alterations (fig. 2). One is the main stem of the Mississippi itself, an often turbid and nutrient-rich waterway draining half the state of Minnesota. The Mississippi National River and Recreation Area protects a 72-mile (116 km) reach of this tributary, integrating water from northern forests, vast agricultural landscapes, and the twin cities of Minneapolis and St. Paul. The other is the St. Croix River, which drains largely forested parts of eastern Minnesota and northwestern Wisconsin. One of the eight original rivers protected under the 1968 Wild and Scenic Rivers Act, the St. Croix is often cited as a pristine example of a northern temperate river.

The challenges of managing riverine parks are well recognized. Large, complex watersheds with diverse land uses, multiple pollution sources, and overlapping jurisdictions are common. Determining management goals for national park units in these settings can be difficult, and is often complicated by a lack of information on baseline or reference water quality conditions. In this respect the Mississippi National River and Recreation Area and the St. Croix National Scenic Riverway are at a relative advantage. Long-term water quality monitoring records spanning three decades are available for both park units. Additionally, by fortunate "accident" of geologic history, both the upper Mississippi and the St. Croix rivers possess natural riverine impoundments (Lakes Pepin and St. Croix, respectively), which preserve in their sediments a historical record of changing land use and water quality.

A recent special issue of the *Journal of Paleolimnology* (published online at http://www.springerlink.com/content/100294/; print version volume 41, number 4, May 2009) is devoted to a collection of studies that describe the recent environmental history of these two river impoundments and provide an important context for current water quality management decisions. Blumentritt et al. (2009) summarize the glacial-fluvial origin of Lakes Pepin and St. Croix and their postglacial history. The remaining papers pick up the story near the onset of Euro-American settlement in the early 19th century, quantifying historical nutrient, sediment, and trace metal loading (Balogh et al. 2009; Engstrom et al. 2009; Lafrancois et al. 2009; Triplett et al. 2009), exploring likely drivers of major water quality changes (Edlund et al. 2009a; Mulla and Sekely 2009), and characterizing biological outcomes of these changes (Edlund et al. 2009b).

Collectively, this body of work shows that both lakes (and both park units) have changed substantially since Euro-American settlement. The paleolimnological studies (fig. 3), corroborated by long-term monitoring records, clarified the magnitude of water quality changes in the upper Mississippi River and provided clear evidence that the St. Croix is not immune to the effects of land conversion and population growth. Engstrom et al. (2009) found that sediment loading to Lake Pepin had increased by an order of magnitude since Euro-American settlement and that phosphorus loading had increased sevenfold. Similarly, Triplett et al. (2009) found that phosphorus loading to Lake St. Croix had increased

COURTESY OF DAVID MORRISON, MINNESOTA POLLUTION CONTROL AGENCY

Figure 2. The relatively clear waters of the St. Croix River (draining largely forested lands) join the sediment-laden waters of the upper Mississippi River (draining agricultural and urban lands) within the boundaries of the Mississippi National River and Recreation Area and Lower St. Croix National Scenic Riverway at Prescott, Wisconsin.

COURTESY OF DAN ENGSTROM, ST. CROIX WATERSHED RESEARCH STATION

Figure 3. Mark Edlund and Laura Triplett collect a sediment core from Lake St. Croix, St. Croix National Scenic Riverway. Sediment samples provided historical evidence for change in water quality in the lake since Euro-American settlement in the region.

fourfold since the mid-1900s, coincident with major shifts in diatom species assemblages and productivity (Edlund et al. 2009a).

These findings have greatly improved managers' understanding of baseline water quality conditions in both rivers and formed the basis for ongoing nutrient and sediment management activities. Plans for mitigating water quality impairments (known as total maximum daily loads, or TMDLs) are under way for Lakes Pepin and St. Croix and rely heavily on this group of studies. In the case of Lake St. Croix, an interagency watershed planning team, chaired by staff from St. Croix National Scenic Riverway, used results from Edlund et al. (2009a, b), Lafrancois et al. (2009), and Triplett et al. (2009) directly to develop biologically based numeric nutrient goals for Lake St. Croix. Together these studies represent a scientific advancement in the application of paleolimnological methods to large river systems. Just as importantly, they serve as an example of how effective cooperation among scientists and agency managers can lead to sound watershed stewardship and ultimately the protection of park aquatic resources.

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—Brenda Moraska Lafrancois[1] and Daniel R. Engstrom[2]

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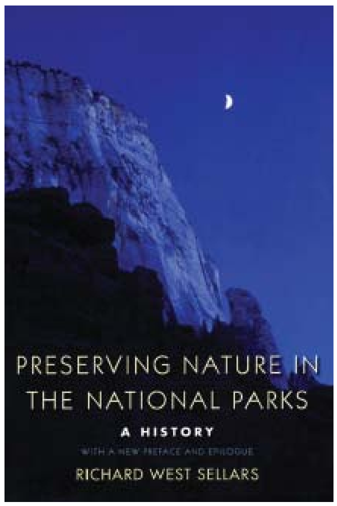
[2] Science Museum of Minnesota, St. Croix Watershed Research Station. Phone: 651-433-5953, ext. 11; e-mail: dengstrom@smm.org. Address: Same address as for Lafrancois.

NPS IN PRINT (CONT'D)

Preserving nature, round two

RICHARD WEST SELLARS'S INFLUENTIAL 1997 BOOK *Preserving nature in the national parks: A history* has been reissued. Called "a landmark in NPS historical treatises" by Robert C. Pavlik of the Yosemite Association, the new edition is updated with a new preface and epilogue that extend the story from the 1995 NPS reorganization, where it had ended, through the January 2009 change in presidential administration.

As most *Park Science* readers will remember, *Preserving nature* traces the clash of values between traditional scenery-and-tourism management and emerging ecological management concepts in America's national parks. In the epilogue of the new edition, retired NPS historian Sellars contrasts shortsighted and long-term management of national parks.



COURTESY OF YALE UNIVERSITY PRESS

Sellars analyzes a variety of resource concerns, policies, and initiatives that were in favor only for a brief time owing to the changing and sometimes contradictory influences of "a presidential administration, a new Congress, the tenure of [an NPS] director or secretary of the interior," and others. He then describes the development and impact of the Natural Resource Challenge on national park management, concluding that although "it never achieved the funding and staffing levels needed for ecologically sound management of a national park system totaling more than eighty-four million acres, the Service has institutionalized a robust natural resource management program." Finally, Sellars assesses the Challenge as "a farsighted program of proven quality, but one that needs political and bureaucratic stability and steadfast support to survive and remain effective." The epilogue reminds us that perpetuating the Challenge or "some future similarly aggressive science-based endeavor depends most fundamentally on how much the American public values preserved national parks—landscapes kept intact both scenically and ecologically to the extent possible."

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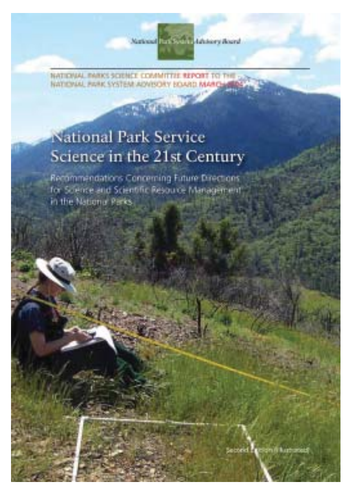
Science policy recommendations reissued in illustrated volume

YOU MAY HAVE MISSED PUBLICATION of *National Park Service Science in the 21st century* when it first appeared online only as a plain-looking PDF document in March 2004. This brief report of the National Parks Science Committee to the National Park System Advisory Board has been reissued as a full-color, small-format (i.e., 7 × 10 inch) booklet that serves as a handsome companion to the 2001 advisory board report *Rethinking the national parks for the 21st century*. Limited quantities are available in print, and the PDF version is available for downloading (see below).

This second edition, 42-page booklet retains the original text but features 20 color photographs and captions that illustrate the main themes of the report: (1) managing natural systems in the 21st century, (2) a review of the Natural Resource Challenge, and as the subtitle states (3) future directions for science and resource management in the national parks. Additionally, main points are excerpted in large-type display quotes throughout the volume. It is a relatively quick and worthwhile read at 7,600 words.

Contributors to the report are Sylvia A. Earle (National Geographic Society), Robert S. Chandler (NPS, retired), Larry Madin (Woods Hole Oceanographic Institute), Shirley M. Malcom (American Association for the Advancement of Science), Gary Paul Nabhan (Center for Sustainable Environments, Northern Arizona University), Peter Raven (Missouri Botanical Gardens), and Edward O. Wilson (Harvard University).

The illustrated, print edition is available upon request from Jeff Selleck (jeff_selleck@nps.gov) while supplies last. Additionally, the PDF is available for downloading in two formats: one for screen viewing and e-mailing (http://www.nature.nps.gov/scienceresearch/ScienceCommitteeReport2ndEdition.pdf) and a higher-quality version for printing on a color office printer (http://www.nature.nps.gov/scienceresearch/ScienceCommitteeReport2ndEdition_office_printer.pdf).



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Vital signs report evaluates natural resource conditions in Yellowstone

Though healthy, Yellowstone National Park faces challenges from environmental changes taking place inside and outside park boundaries, according to the *Superintendent's 2008 report on natural resource vital signs*, published recently. This report reviews research and data on more than two dozen indicators selected to monitor the condition of park natural resources. It cites progress with grizzly bear conservation, but indicates greater effort is needed to reverse the decline in cutthroat trout and trumpeter swan populations. It also raises concerns about how air pollution from outside the park may be changing native plant habitat inside the park. Yellowstone staff welcomes feedback on the report, which is published online at http://www.GreaterYellowstoneScience.org/.

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Isotope analysis aids monitoring of estuarine nitrogen

Bannon and Roman (2008) investigate the practicality of stable nitrogen (N) isotope analysis in monitoring salt-marsh ecosystems for changes in wastewater inputs. Different nitrogen sources are generally associated with different ranges of nitrogen-15 concentrations; therefore, analysis of N isotope ratios in plant and animal tissues reveals the relative contributions of nitrogen from the atmosphere and from human populations (e.g., sewer overflows and effluent from treated sewage and storm sewers).

The investigators sampled saltmarsh cordgrass (*Spartina alterniflora*), sea lettuce macroalgae (*Ulva lactuca*),mummichog killifish (*Fundulus heteroclitus*), and ribbed marsh mussel (*Geukensia demissa*) in marshes of Cape Cod National Seashore (Massachusetts), Fire Island National Seashore (New York), and Gateway National Recreation Area (New York). Their goal was to identify which species are the most sensitive indicators of anthropogenic N and to evaluate the feasibility of incorporating stable N isotope sampling into long-term monitoring programs.

The study found that the mussel and fish species—consumers—"might be better indicators of nutrient source" than the plant species. It also found that human population, as opposed to residential development from land use data, is a better predictor of nitrogen derived from wastewater because most anthropogenic N in the study came from wastewater.

The investigators were also interested in determining the necessary sample sizes of each organism to detect significant changes in anthropogenic N loading over time. They found that 10 samples of cordgrass are needed to detect a change of one part per thousand in anthropogenic nitrogen. For sea lettuce the sample size jumps to 66, but would reveal changes of ½ part per thousand. Only 9 or 10 samples of the killifish and mussel species would be needed to detect this same change.

The authors conclude with recommendations for incorporating this sampling and analysis technique into monitoring programs, stressing a balance between "the ability to detect change and the time, cost, and effort required for sample collection and analysis." They suggest the best blend for characterizing an entire marsh-dominated estuarine system is to sample a small number of killifish and a larger number of cordgrass.

Reference

Bannon, R. O., and C. T. Roman. 2008. Using stable isotopes to monitor anthropogenic nitrogen inputs to estuaries. Ecological Applications 18(1):22–30.

"MGM2" CONT'D FROM PAGE 20

2008) is available online and includes summaries of economic impacts for 356 park units and the national aggregate analysis.

Managers from national park units have indicated that the MGM2 has utility not only as an assessment tool but also as a public relations tool, useful for engaging local communities and elected officials and decision makers (e.g., mayors, county commissioners, planners) as verification of the impact of NPS facilities and programs in relation to the local economy. They have also indicated that repeated applications of the MGM2 can be useful for comparing economic impact data over time and to gauge changes in relation to particular management actions or policies. Results from the MGM2 can also be used to inform future program planning and additional economic studies relevant to NPS presence in the community.

For more information

Money Generation Model Web site
http://web4.msue.msu.edu/mgm2/default.htm

***Daniel Stynes**, Professor Emeritus, Department of Community, Agriculture, Recreation, and Resource Studies, Michigan State University. E-mail: stynes@msu.edu / www.msu.edu/~stynes/*

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State of Science

Contaminants study provides window onto airborne toxic impacts in western U.S. and Alaska national parks

Results and implications of the Western Airborne Contaminants Assessment Project

By Colleen Flanagan

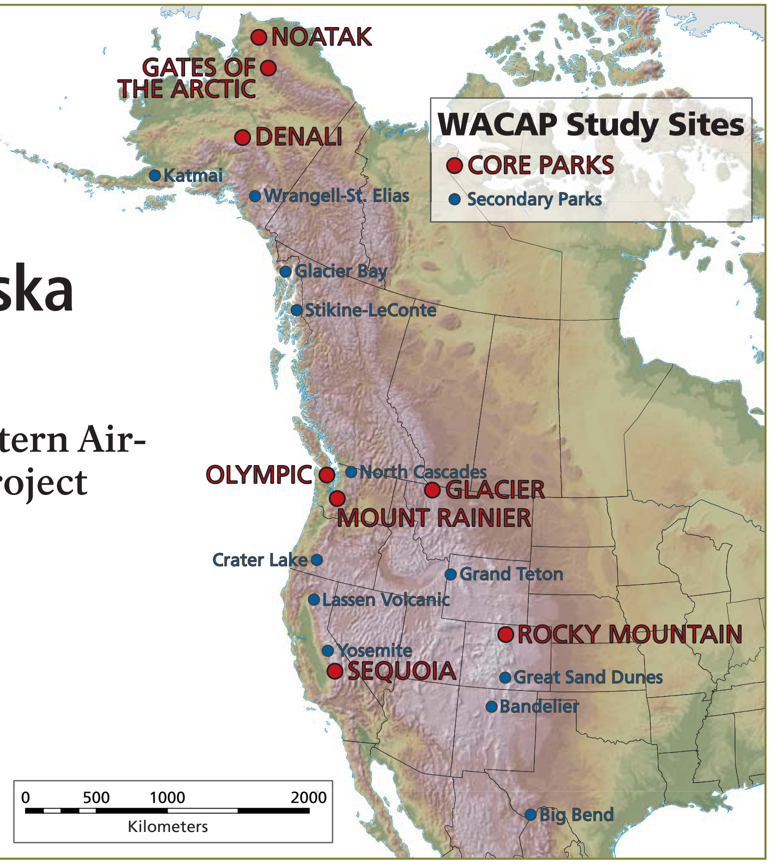

Figure 1. Sampling locations for the Western Airborne Contaminants Assessment Project. All sites are administered by the National Park Service except for Stikine-LeConte Wilderness (Tongass National Forest, Alaska), which is managed by the USDA Forest Service.

TRANSPORT AND DEPOSITION OF atmospheric contaminants have been recognized as a possible threat to aquatic and terrestrial ecosystems for several decades. Studies in the 1970s and 1980s on air quality and acidic precipitation first demonstrated the concept of long-range transport of airborne contaminants in the United States. Numerous other airborne contaminant threats to ecosystems and humans that depend upon them were subsequently identified. The presence of contaminants in remote Arctic ecosystems with no local or watershed sources of contaminants confirmed the risk of long-range atmospheric transport. High-elevation and high-latitude areas were identified as areas of particular peril due to the tendency of contaminants, such as some pesticides, to migrate to colder alpine and Arctic areas and deposit with the annual snowpack.

Given the above concerns, as well as the persistence and toxicity of these contaminants in the environment, the bioaccumulative properties of many compounds that magnify concentrations at higher levels of the food chain, and federal legislation that requires protection of the natural parks in perpetuity, the National Park Service (NPS) conducted the multiagency Western Airborne Contaminants Assessment Project (WACAP) from 2002 to 2007 to determine the risk from airborne toxic compounds to national park ecosystems and food webs. Concentration of contaminants in air, snow, water, lake sediment, lichen, conifer needles, and fish was determined from sampling two sites/lakes in eight core park units: Denali National Park and Preserve (Alaska), Gates of the Arctic National Park and Preserve (Alaska), Glacier National Park (Montana), Mount Rainier National Park (Washington), Noatak National Preserve (Alaska), Olympic National Park (Washington), Rocky Mountain National Park (Colorado), and Sequoia and Kings Canyon National Parks (California). More limited assessments focusing on vegetation and air were conducted in 12 secondary parks (fig. 1).

Airborne contaminants detected

Released in spring 2008, the WACAP study (Landers et al. 2008) indicated that numerous airborne contaminants, including mercury and pesticides, were detected at measurable levels in ecosystems at 20 western U.S. and Alaskan national parks from the Arctic to the Mexican border. The study provides an initial indication of the scale and distribution of contami-


USGS/DON CAMPBELL

WACAP investigators make their way into park backcountry at Sequoia and Kings Canyon national parks in midwinter to collect snow samples for airborne contaminant analysis.

The study provides an initial indication of the scale and distribution of contaminants across a wide geographic area.

nants across a wide geographic area. Key findings from the study indicate that out of more than 100 organic contaminants tested, 70 were found at detectable levels. Though concentrations of most of these contaminants were below levels of concern, others appear to be accumulating in sensitive resources such as fish. For some contaminants, high concentrations in fish exceeded fish-eating wildlife or human health consumption thresholds developed by the U.S. Environmental Protection Agency (EPA) and others.

The three contaminants found in park ecosystems of highest concern for human and wildlife health were:

1. Mercury—a heavy metal emitted through processes such as burning coal for electricity, known to cause neurological and reproductive impairment;

2. Dieldrin—an acutely toxic insecticide banned from use in the United States since 1987, known to decrease the effectiveness of the immune system and reduce reproductive success; and

3. DDT—an insecticide banned in the United States since 1972 that also impacts the reproductive system.

Mercury levels in fish at Alaska's Noatak National Preserve were a cause of great concern as the average concentration in fish was above the EPA human health threshold for consumption. Gates of the Arctic, Olympic, Mount Rainier, and Sequoia national parks each also had some individual fish that exceeded the threshold.[1] Investigators also assessed the risk to fish-eating wildlife and found that mercury concentrations in fish at all eight core parks exceeded health thresholds suggested for birds. Mercury concentrations were also above health thresholds for some fish-eating mammals at some parks (fig. 2, next page).

Dieldrin concentrations in some individual fish exceeded the health threshold for recreational[2] fishermen at Rocky Mountain, Sequoia, and Glacier national parks. All core national parks except Olympic contained some fish with dieldrin concentrations that exceeded health thresholds for subsistence fish consumption. Average DDT concentrations in fish exceeded the human risk threshold for subsistence fishers and the bird health threshold at Sequoia and Glacier national parks (fig. 3, next page).

Researchers also found some individual "intersex" trout (i.e., male fish testes contained oocytes, a female reproductive structure) at Rocky Mountain and Glacier national parks. Some male fish also exhibited underdeveloped testes and elevated levels of the estrogen-responsive protein vitellogenin, and some fish had reproductive structures sufficiently altered such that reproduction may be unlikely. Elevated vitellogenin levels and intersexuality in fish are common biomarkers used as evidence of response to exposure to certain contaminants (e.g., dieldrin and DDT) that mimic the hormone estrogen. The weight of evidence for reproductive disruption in these national park ecosystems is substantial, but because the sample size was small, WACAP established neither the extent of the problem nor the correlation between fish reproductive effects and contaminant concentrations.

Additionally, current-use pesticides and other compounds, such as the commonly used flame retardant coating for fabric PBDE, were detected in fish and sediment at all eight core parks. According to sediment records, particularly at Rocky Mountain and Mount Rainier national parks, these compounds are increasing at rapid rates over time but concentrations in fish did not exceed human or wildlife health consumption thresholds. Exposure to PBDEs may affect liver, thyroid, and neurobehavioral development.

This research suggests that the contaminants found in WACAP are carried in air masses from sources that are both local and as far away as Europe and Asia. The presence of some contaminants in snow is

[1] The EPA and other agencies define the contaminant health threshold for mercury for 70 kg (154 lb) adults who consume 2.3 eight-ounce fillets of these fish per month for a lifetime.

[2] Because different populations of humans consume fish at different rates, contaminant health thresholds for dieldrin and DDT are different for recreational and subsistence fishing. The values are calculated for 70 kg (154 lb) adults. For recreational fishing, it is assumed that 2.3 eight-ounce fillets are consumed every month for a lifetime; for subsistence fishing, it is assumed that 19 eight-ounce meals of whole fish are consumed every month. Based on these estimated amounts of fish consumed, the contaminant health thresholds for dieldrin and DDT are concentrations of exposure that would raise the risk of cancer above 1:100,000.

State of Science

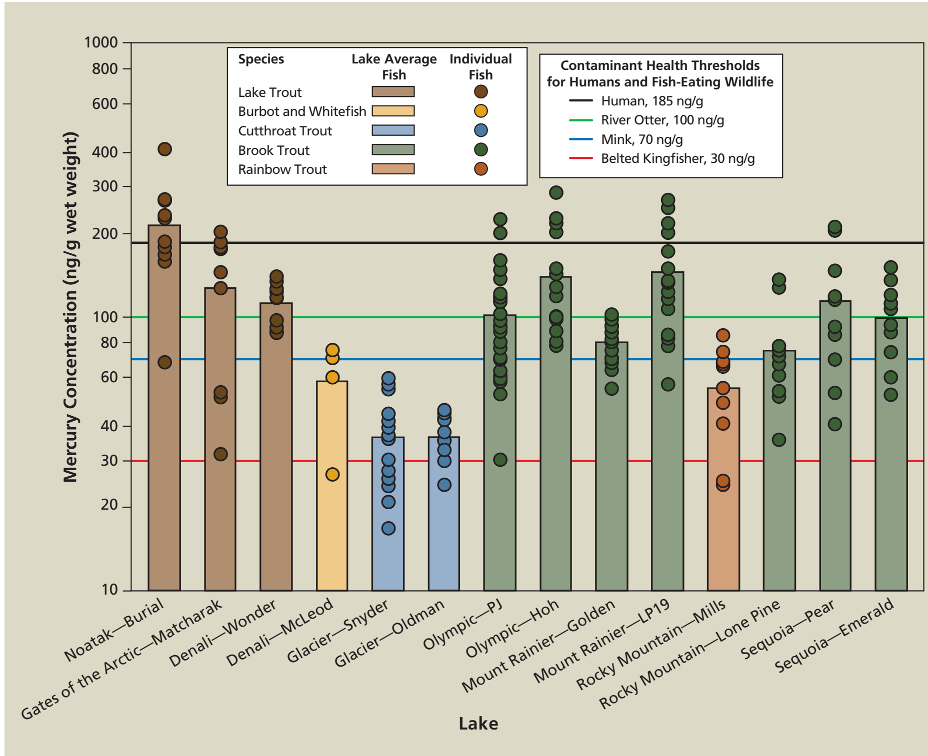

Figure 2. This graph shows the concentrations of mercury in fish, as compared to human and fish-eating wildlife contaminant health thresholds. Fish whole-body total mercury averages (bars) and individual fish (circles) are based on wet weight from all WACAP park lakes and contaminant health thresholds for human and piscivorous wildlife fish consumption. The average mercury concentration in fish sampled at Noatak exceeded the human consumption threshold, while some fish at Gates of the Arctic, Olympic, Mount Rainier (LP19), and Sequoia (Pear) also exceeded the human consumption threshold. The average mercury concentration in fish in all lakes sampled at all parks exceeded the kingfisher health threshold, and the average mercury concentration at Noatak, Gates of the Arctic, Denali (Wonder), Olympic (PJ and Hoh), Mount Rainier (LP19), and Sequoia (Pear) exceeded all wildlife (otter, mink, and kingfisher) thresholds. Data are plotted on a $\log_{10}$ scale.

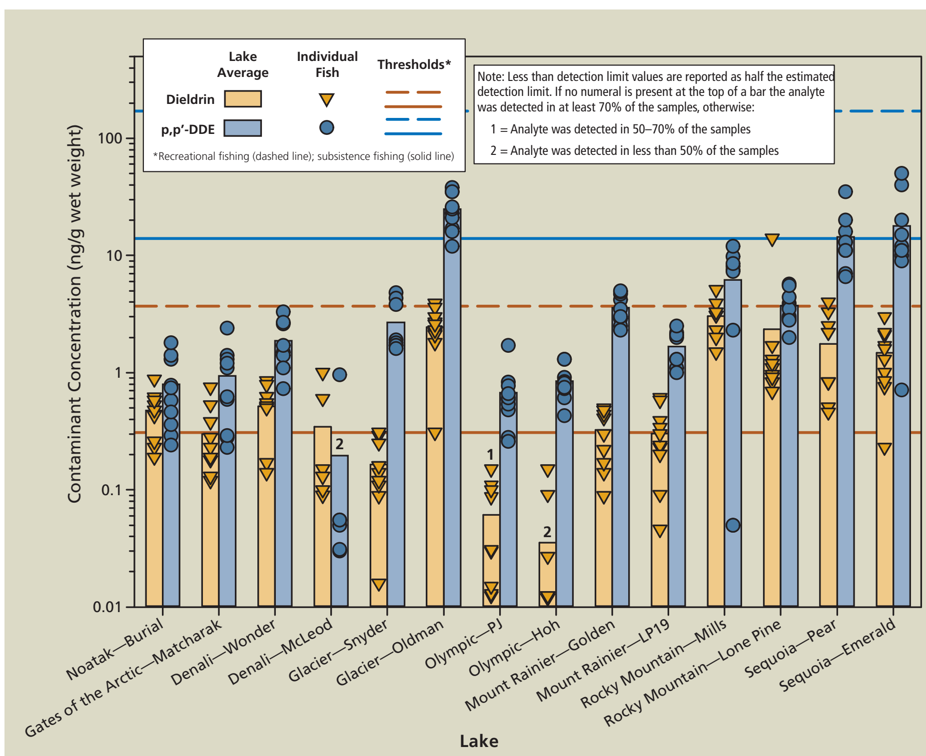

Figure 3. This graph shows the concentrations of historic-use pesticides (dieldrin and p,p'-DDE, a by-product of DDT most commonly found in fish) in fish, as compared with human thresholds for recreational and subsistence fishing. Symbols represent concentrations in individual fish and the bars denote lake averages. Some fish from Glacier, Rocky Mountain, and Sequoia exceeded contaminant health thresholds for dieldrin for recreational fishing. The average concentration of dieldrin in fish from Noatak, Denali, Glacier (Oldman), Mount Rainier (Golden), Rocky Mountain, and Sequoia, and some fish from Gates of the Arctic and Mount Rainier (LP19), exceeded contaminant health thresholds for subsistence fishing. The average concentration of p,p'-DDE in fish from Glacier (Oldman) and Sequoia exceeded contaminant health thresholds for subsistence fishing. Exceedances imply that human lifetime consumption may increase risk of developing cancer by more than 1 in 100,000. Data are plotted on a $\log_{10}$ scale.

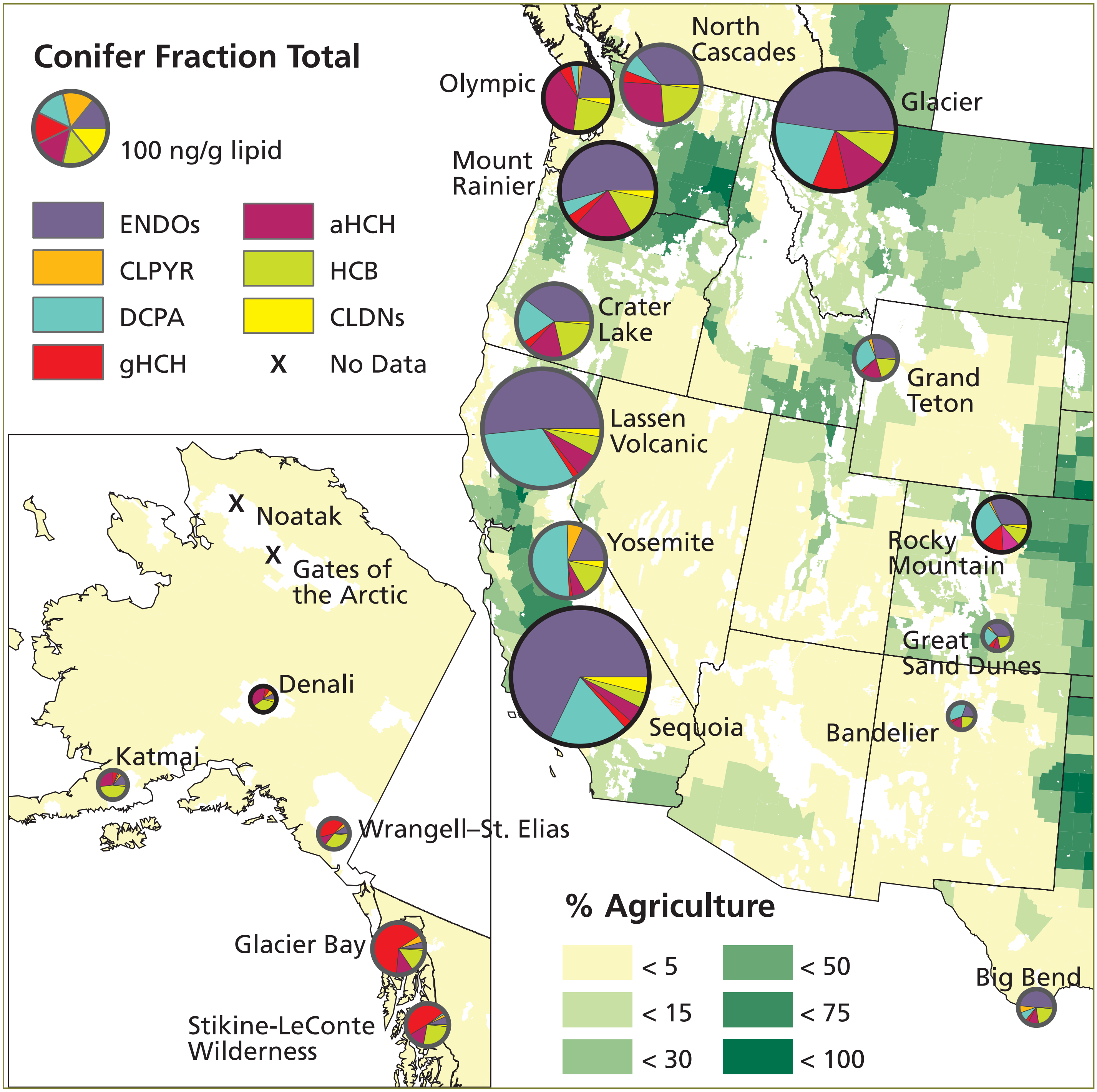

Figure 4. This illustration depicts pesticide concentrations (ng/g lipid) in conifer needles from core and secondary WACAP parks as compared to agricultural intensity. Circle area is proportional to total pesticide concentration. Light to dark green shading indicates increasing agricultural intensity. White shading indicates national forests or parks. Current-use pesticides endosulfan and dacthal dominate pesticide concentrations in parks in the conterminous United States, where most agriculture occurs. Historic-use pesticides comprise a relatively large fraction of the total pesticide concentration in Alaska, although the total pesticide concentrations are lower. Conifers were not present in Noatak and Gates of the Arctic. Circles outlined in black represent the core study parks. Pesticide groups include the current-use pesticides endosulfans (ENDOs), chlorpyrifos (CLPYR), dacthal (DCPA), and lindane (gHCH), and historic-use pesticides a-HCH, HCB, and chlordanes (CLDNs).

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well correlated with the proximity of each park to agricultural areas, identifying these areas as probable major sources of some pesticides that end up in park ecosystems (fig. 4, previous page). Concentrations of industrial contaminants (e.g., mercury and combustion by-products such as PAHes) were also highest in parks where local and regional point sources produce these contaminants. For example, at Glacier National Park, where PAH concentrations in vegetation, snow, and sediments were one to two orders of magnitude greater than at any other site, source "fingerprints" strongly suggest influence from a nearby aluminum smelter.

Unexpected findings

Project researchers initially hypothesized that a majority of contaminants found in western national parks would originate from eastern Europe and Asia and travel across the Pacific Ocean to the western United States. While this study provided evidence that this phenomenon does occur, particularly in Alaskan parks, analysis of snow concentration data showed that contaminant contributions from trans-Pacific sources were small in most WACAP parks compared with contributions from other sources closer to parks.

Additionally, given fish consumption advisories on major waterways and commercial fisheries throughout the conterminous United States and Alaska, it is well known that toxins found in fish can threaten human health. However, it was not expected that concentrations would exceed human and wildlife risk thresholds in the national parks, ironically celebrated as some of the most pristine ecosystems in the United States.

Implications of results

Prior to the Western Airborne Contaminants Assessment Project, scant published evidence of regional or long-range atmospheric sources of toxic pollutants reaching remote western park ecosystems existed. Further, even less was known about the potential impacts of contaminants in these ecosystems. Dr. Dixon Landers of the U.S. Environmental Protection Agency, the project's lead scientist, indicated that "WACAP findings add considerably to the state of the science concerning contaminant distribution and effects in remote ecosystems of the western United States and Alaska."

Study results have been widely shared with federal, state, and local agencies, as well as stakeholders. These efforts have resulted in follow-up research and exploration of cause-and-effect relationships between contaminant concentrations and impacts in ecosystems. Study findings may also be relevant to areas outside of national parks. In an effort to facilitate communication and to foster research and monitoring initiatives on toxins in the environment, Glacier National Park hosted an interagency, post-WACAP contaminants workshop for the state of Montana in spring 2008. Sequoia, Yosemite, and Lassen Volcanic national parks followed by hosting a Sierra Nevada–Southern Cascades Contaminants Workshop in spring 2009. These workshops resulted in increased awareness, research and monitoring plans, public outreach and educational efforts, and collaborative partnerships with state and federal agencies expressing interest in furthering research on contaminants. Additionally, an ongoing follow-up study is investigating the extent of reproductive disruption in fish across western and Alaskan national parks via fish tissue analyses of biological effects and chemical concentrations. The implications of WACAP findings are also being considered in numerous venues, including a National Academy of Sciences review panel on the international transport of air pollutants, the Stockholm Convention on Persistent Organic Pollutants, the NPS Office of Public Health, and the U.S. Environmental Protection Agency.

Methods developed by WACAP scientists also furthered the science. Identification of new field and analytical lab techniques allowed detection of very low concentrations of organic compounds in snow, lake water, and sediment. Moreover, a new computer program allowed quantification of the severity of tissue damage from mercury in fish livers and spleens. Such scientific breakthroughs were subsequently published in peer-reviewed journals for application by other research teams.

In addition to the release of the final project report, a database containing all the

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WACAP by the numbers	
Study sites	28
National park areas studied	19
Partnering agencies/institutions	21
Researchers involved	29
Duration (years)	6
Field days	± 238
Scholarly research articles published	10 (and more anticipated)
Media outlets that reported WACAP findings	>200
Contaminants identified that are of highest concern	3
Approximate cost to NPS and cooperators	$6 million
Funding sources (within NPS)	13
Boats purchased	1
Pounds of dry ice used	1,500
Pounds of snow collected	10,000
Cups of coffee consumed	± 9,047
Debilitating knee injuries	1

physical, chemical, and biological data collected in the study will be made available on NPS and EPA Web sites later in 2009. These data can then be used by managers and scientists worldwide to conduct future comparisons with other studies.

A wake-up call

Whether amidst frozen tundra at Noatak, temperate rainforest at Olympic, or alpine environs at Rocky Mountain, the preserved remoteness of national parks unfortunately does not indicate these areas are as pristine as once thought. Findings convey a cautionary message that increases awareness and illustrates the potential deleterious consequences of toxic air contaminants upon natural resources legally mandated to remain unimpaired. "The results are very sobering and we hope the information contributes to science-based decisions on the regional and global use of pesticides," said Craig C. Axtell, superintendent at Sequoia and Kings Canyon national parks. WACAP was designed as a screening-level assessment that has provided a window onto contaminants of concern in respective parks and regions. The results not only offer impetus for more in-depth studies but also shed light on the risk to national park resources, cultivating future efforts to coordinate with regulatory entities that may identify strategies to reduce contaminant loads from U.S. and international sources.

Acknowledgments and further information

WACAP was funded primarily by the National Park Service and coordinated by the Air Resources Division staff in Lakewood, Colorado. Other participating institutions included the U.S. Environmental Protection Agency, U.S. Geological Survey, USDA Forest Service, Oregon State University, and the University of Washington. National park resource managers worked with scientists from the collaborating agencies to plan and conduct the study. The report, fact sheet, publications, and more can be accessed at http://www.nature.nps.gov/air/Studies/air_toxics/wacap.cfm.

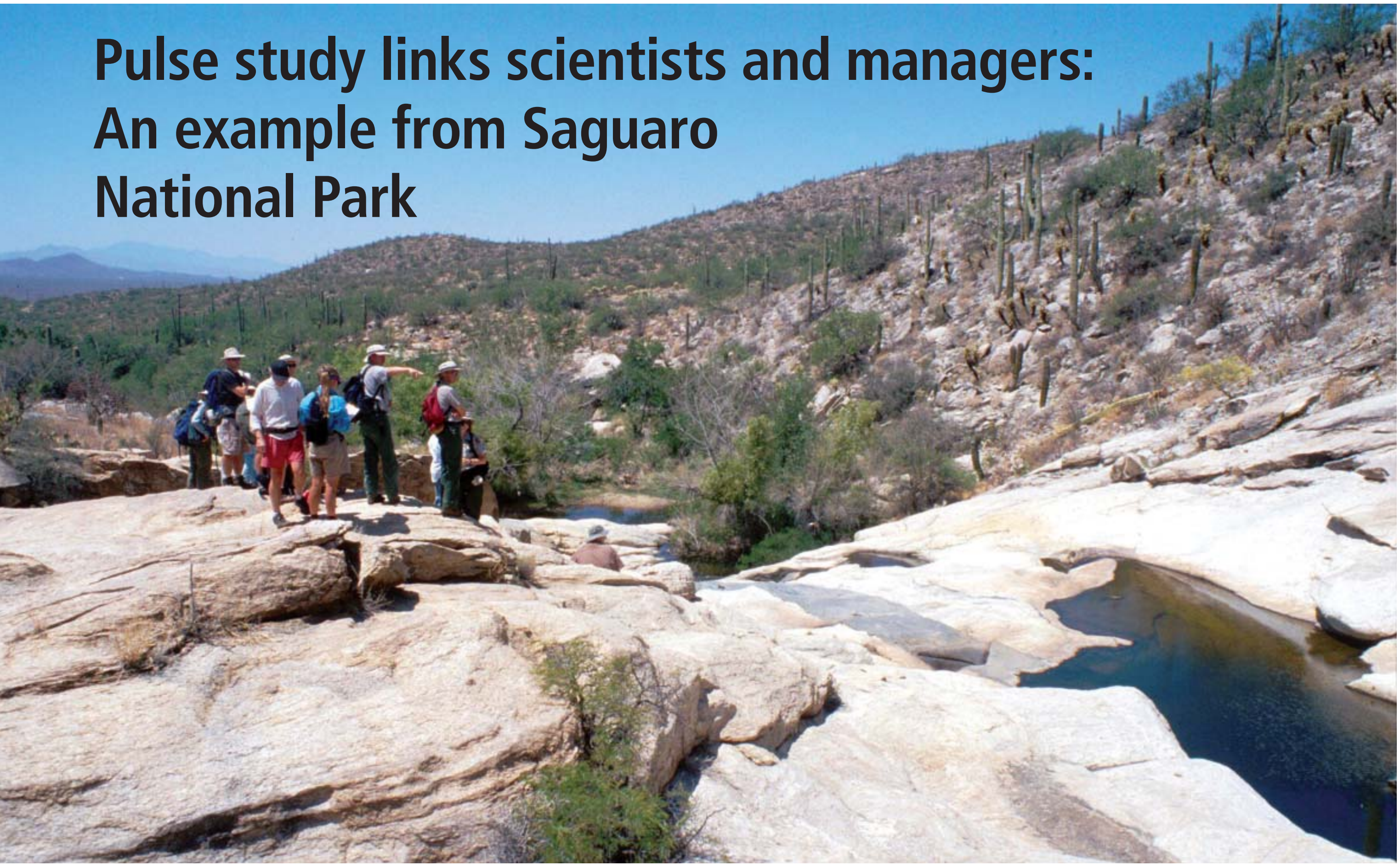
WACAP citation

Landers, D. H., S. L. Simonich, D. A. Jaffe, L. H. Geiser, D. H. Campbell, A. R. Schwindt, C. B. Schreck, M. L. Kent, W. D. Hafner, H. E. Taylor, K. J. Hageman, S. Usenko, L. K. Ackerman, J. E. Schrlau, N. L. Rose, T. F. Blett, and M. M. Erway. 2008. The fate, transport, and ecological impacts of airborne contaminants in western national parks (USA). EPA/600/R-07/138. U.S. Environmental Protection Agency, Office of Research and Development, NHEERL, Western Ecology Division, Corvallis, Oregon.

About the author

Colleen Flanagan *(colleen_flanagan@nps.gov) is an ecologist with the National Park Service Air Resources Division (ARD) in Lakewood, Colorado. Formerly at Rocky Mountain National Park, she joined the Air Resources Division in 2007. Under the leadership of WACAP project coordinator Tamara Blett (NPS-ARD), a contributing correspondent to this story, she continues to explore science and policy avenues for WACAP outreach and follow-up studies.*

Case Study



TAYLOR EDWARDS

Pulse study links scientists and managers: An example from Saguaro National Park

By Don E. Swann, Margaret W. Weesner, Sarah Craighead, and Larry L. Norris

Figure 1. The desert oasis of the Madrona pools in Saguaro National Park was the site of a pulse study in May 2003. The dynamic pulse process provides immediate results and mountains of data for park planning and decision making.

THE VERY FIRST ISSUE OF *PARK Science* featured a story on a "pulse study" at the Hoh River drainage in Olympic National Park in Washington (Anonymous 1980). Inspired by this example and similar studies in Sequoia and Kings Canyon national parks in 1982 and 1994 (Matthews 1983, 1994), Saguaro National Park sponsored a pulse study of the Madrona Ranger Station area ("Madrona") in May 2003. Although it has been an important site for park (backcountry) operations for years, park managers knew little about Madrona's natural or cultural history and resources. Pulse studies vary, but basically they bring together scientists and managers to "take the pulse"; that is, quickly assess the ecological health of an ecosystem or area. Pulse studies originated with University of Washington professor and U.S. Forest Service ecologist Jerry Franklin, who believed passionately that science is essential for managing natural areas but requires scientists who can think outside of their narrow disciplines, and managers who take the time to listen and understand. Franklin would invite scientists from a range of disciplines to join managers for intensive field-based studies. Participants worked and camped together, sharing ideas around the campfire at night. Superintendent Boyd Evison lauded the pulse study at Sequoia and Kings Canyon national parks for providing the kind of interdisciplinary information "that most parks unfortunately seem to have little hope of obtaining" (Matthews 1994, p. 5).

Madrona is a lush desert oasis of spring-fed pools far from the park's popular cactus forest (fig. 1). The Madrona Ranger Station had been the longtime base camp for Saguaro National Park's backcountry operation but was abandoned around 1999 because of environmental and health hazards associated with the deteriorating facility. Public access had been limited for decades, but potential changes in management and visitor use, and rapid development outside park boundaries, raised concerns about the site's future. Park staff had heard about pulse studies and thought that this model might be a cost-effective—and quick—way to gather information that would be useful for making decisions about the site.

Table 1. Madrona pulse study participants

Participant	Expertise/Discipline	Affiliation
Emma Benenati	Aquatic ecology	Northern Arizona University [NAU]
Kevin Bonine	Herpetology	University of Arizona [UA]
Alice Boyle	Ornithology	UA
Courtney Conway	Ornithology	UA
Taylor Edwards	Science coordinator	UA
Danielle Foster	Plant ecology	National Park Service [NPS]
Vicki Gempko	Plant ecology	NPS
Randy Gimblett	Social science	UA
Floyd Gray	Geologist	U.S. Geological Survey [USGS]
Kevin Harper	Cultural resources	NPS
Mark Holden	Plant ecology	NPS
Donna King	Plant ecology	NPS
Natasha Kline	Ornithology	NPS
Meg Koppen	Chef	N/A
Meg Quinn	Botany	Independent
Todd Nelson	Site coordinator	NPS
Larry Norris	Workshop moderator	Desert Southwest Cooperative Ecosystem Studies Unit
Bruce Perger	History	NPS volunteer
Cecil Schwalbe	Herpetology	USGS
Joseph Shannon	Aquatic ecology	NAU
Chris Sharpe	Social science	UA
Bill Shaw	Workshop moderator	UA
Ronnie Sidner	Mammalogy	UA
Don Swann	Mammalogy	NPS
Meg Weesner	Social science	NPS

KEVIN BONINE

Figure 2. During the pulse study, participants conducted surveys of plants and herpetofauna. Here Ranger John Williams (Saguaro National Park) photographs a variable sand snake (*Chilomeniscus stramineus*).

The Madrona pulse study—2003

Saguaro National Park's Madrona pulse study took place during a warm spring week in May 2003. Scientists from many disciplines and organizations participated. Biologists, ecologists, geologists, social scientists, and cultural resource specialists, as well as NPS resource management specialists, comprised the group (table 1). The Western National Parks Association ($7,500) and Friends of Saguaro National Park ($10,000) funded the study, with additional support from the Community Foundation of Southern Arizona and Earth Friends Wildlife Fund.

The Madrona pulse study started with field trips to the Romero pools in the Santa Catalina District of the Coronado National Forest, and Brown Canyon in the Buenos Aires National Wildlife Refuge. Both sites have perennial desert streams similar to Madrona's, but they offer different issues and management strategies that helped place Madrona in its larger ecological and management context.

At Madrona, as in previous pulse studies, scientists and managers worked side by side all week in the field. Days began with bird surveys at dawn and checking mammal traps before breakfast. Mornings were spent on herpetofaunal and plant surveys (fig. 2), water quality measurements, sampling for aquatic invertebrates, and examining trails and the park boundary nearby. At night, participants searched for frogs and checked mist nets for bats (fig. 3, next page). During delicious meals (provided by sponsors and cooked by master field chef Meg Koppen), Meg Weesner (see table 1) led talks about the day's research findings and how they might inform management issues at Madrona. Participants studied and learned together, and engaged in spirited discussions about the importance of desert waters, the potential impacts of recreation, the future of the ranger station, and many other topics throughout the cool evenings and unseasonably hot days.

The last two days of the pulse study were distinguished from most others in that staff from every division of the park, as well as members of the Friends of Saguaro National Park and other organizations, arrived at Madrona to participate in an outdoor workshop. In sessions moderated by research coordinator Larry Norris and University of Arizona wildlife professor Bill Shaw (see table 1), each scientist presented his or her week's findings. Additional speakers included Julia Fonseca, a hydrologist from Pima County, Arizona, and Pat Haddad, NPS manager of the mule-packing program. Most importantly, the workshop included opportunities for park staff to work in the field with scientists and share information about Madrona's history and cultural resources.

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Figure 3. As part of the pulse study, participants set mist nets over the Madrona pools to inventory bats.

ERIC STITT

Figure 4. An important result of the pulse study was an understanding of the regional significance of the robust population of lowland leopard frogs near the Madrona Ranger Station.

As with other pulse studies, the participants left Madrona with as many questions as they had answered: What were the dynamics of water volume and water quality in the pools? How many visitors used the site? How was wildlife activity changing over time? How large was the threat from exotic species? Nonetheless, participating scientists concluded that the Madrona pools were rich in ecological and cultural resources. In the weeklong study, investigators observed more than 50 species of birds and 153 species of plants; they also documented a large, stable population of lowland leopard frog (*Rana yavaipensis*)—a species of special concern (fig. 4). Moreover, the scientists confirmed that the pools were fed by bedrock springs in an unusual geologic setting, that is, a metamorphic core complex adjacent to the Catalina detachment fault. Such complexes are a newly recognized, hotly debated geologic phenomenon of basin-and-range crustal extension, shearing, and faulting. Another overarching conclusion of the researchers was that the Madrona pools are probably the least impacted aquatic resource of their kind in the Tucson area due to low levels of historic diversions and current recreation.

Research and monitoring at Madrona since the pulse study

Soon after the study ended, Saguaro National Park published a technical report with chapters by participating scientists (Edwards and Swann 2003) and an illustrated executive summary for lay readers. The report identifies a series of data gaps and recommends further research and monitoring. In the six years since publication, the park has followed up with studies and monitoring, which address some of these gaps.

Hydrological research and monitoring

In the same year as the pulse study, park volunteers Mike Chehoski and Chuck Perger began regular monitoring of water levels in Chimenea Creek and nearby Rincon Creek. During one of the most severe droughts on record, from 2005 to 2006, many of the pools went dry, but the largest pool retained more than 300 ft^3 (8.5 m^3) of water (fig. 5; Swann et al. 2008). Recognizing that the greatest data gap at the Madrona pools was information about water resources, park staff applied for technical assistance from the NPS Water Resources Division, Water Rights Branch. In 2005, NPS hydrologists Chris Gable and Colleen Filippone helped park staff map the topography of the Madrona pools (fig. 6), installed a staff gauge, and established datums at the site.

A grant from the Western National Parks Association has allowed continued water monitoring at Madrona and tracking of sediment levels in pools throughout the park. Results of sediment studies indicate that the Madrona pools have low (<25%) levels of sediment, in contrast to stream-fed pools where sediment input following wildfires larger than 5,000 acres (2,024 ha) has inundated habitat of leopard frogs and other aquatic life. Parker (2006) found that high volumes of sediment delivered from hillslopes to canyon headwaters greatly impacted leopard frog habitat following the 2003 Helen's II Fire in an area where most fires had been suppressed for many years. In contrast, fire management activities in the watershed above Madrona, including prescribed fire and wildland

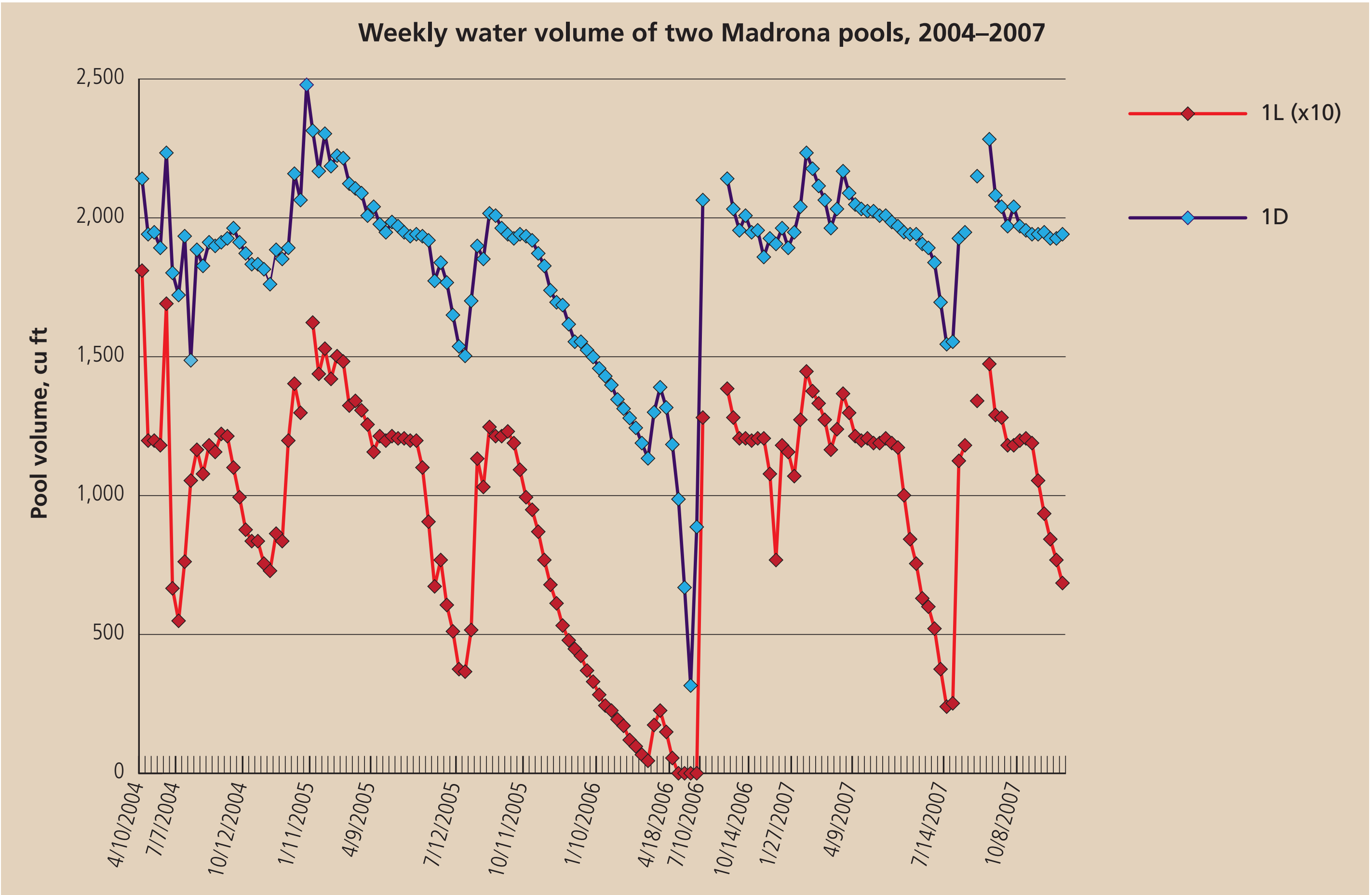

Figure 5. The pulse study was the impetus for weekly monitoring of water volume and quality of the Madrona pools. This graph shows 2004–2007 results from two pools (1L and 1D). Volume of pool 1L is multiplied by 10 for illustration purposes.

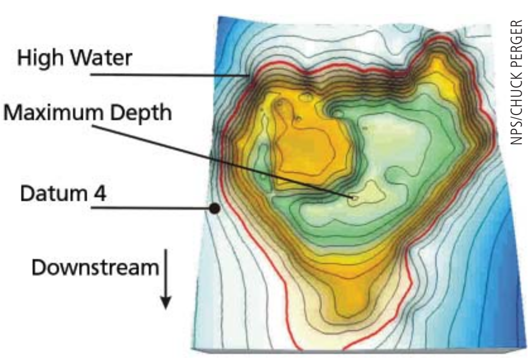

Figure 6. In addition to water volume and quality, water resource data include the topography of the Madrona pools. This topographic map details the bedrock contours of pool 1E. The contour interval is 0.5 ft (0.15 m), and the maximum depth (deepest point) is 5.1 ft (1.6 m). "Datum 4" is the elevation benchmark used for estimating pool volume. Flow is to the south (bottom of map).

fire use, may have important long-term benefits for pool habitat.

Since 2003, park staff has also cooperated with scientists from the U.S. Geological Survey (USGS) and the University of Arizona to study water quality in the pools. A graduate-student project examined the relationship between recreational use and water quality, and USGS scientists have begun baseline monitoring of heavy metals and other water quality parameters.

Wildlife monitoring

To learn more about aquatic wildlife and provide a control area to support an NPS water rights application on nearby Rincon Creek, the NPS Water Resources Division and Western National Parks Association provided additional funding to study Sonora mud turtles (*Kinosternon sonoriense*) and amphibians at Madrona. This study confirmed the importance of the Madrona pools for aquatic species. During the 2005–2006 drought, leopard frogs and canyon treefrogs (*Hyla arenicolor*) disappeared, and many mud turtles died along Rincon Creek when it went completely dry for nearly a year; however, most frogs and turtles survived in the Madrona pools (Stitt et al. 2008).

In addition, using infrared-triggered wildlife cameras that volunteers check weekly, park staff has continued to monitor mammals. After six years of surveillance, the number of medium and large mammal species detected at Madrona has risen to 20, including species of management interest such as mountain lion (*Puma*

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concolor) and white-nosed coati (*Nasua narica*; fig. 7).

Restoration and visitor use monitoring

In 2004 and 2005, Saguaro National Park received two grants from the Department of the Interior, Cooperative Conservation Initiative, for studies at Madrona. One of the grants was for restoration and the other was for applied visitor research; both projects were outcomes of the pulse study. Park managers installed trail counters to determine visitation patterns over time and have proposed their continued use in the park's general management plan as a method for long-term monitoring and management of visitor use of the pools. Working with the nonprofit Rincon Institute, neighbors, and volunteers, park managers have restored several social trails and the abandoned stable area to native vegetation by seeding native perennials and grasses such as brittlebush (*Encelia farinosa*) and cane bluestem (*Bothriochloa barinoides*), and planting shrubs such as white-thorn acacia (*Acacia constricta*) and blue paloverde (*Parkinsonia florida*). Volunteers have also removed exotic species such as wild oat (*Avena fatuas*), tamarisk (*Tamarix ramosissima*), and African buffelgrass (*Pennisetum ciliare*).

Management implications

General management and trail plans

The major driver of the pulse study was the need to gather information for the park's general management plan. The concern was how to appropriately manage and plan for a sensitive resource site that is also the location of obsolete housing and support facilities. The pulse study helped confirm for managers that not only does the site have unique resources but also that it had received a high degree of protection by on-site rangers. Alternatives in the general management plan recognize the educational and scientific value of the Madrona pools. The approved plan calls for

NPS

Figure 7. Six years of infrared-triggered camera data, acquired since the pulse study, show that many rarely seen species frequent Madrona. This photograph captures a visit by a white-nosed coati.

visitor use to be highly regulated to protect sensitive resources. Staff housing and new corrals, if developed, are to be located so that impacts on the site's most sensitive resources are minimized.

In 2005, park managers began developing a new trails plan. The pulse study noted that Madrona would become a primary destination if a rerouting of the Arizona Trail ran through the area as proposed. Furthermore, heavy recreational use would adversely affect natural and cultural values. As a result, the trails plan calls for the Arizona Trail to connect to the Manning Camp Trail through a scenic area west of the site rather than through Madrona itself.

Other benefits

The Madrona pulse study benefited Saguaro National Park in ways not anticipated in 2003. For example, more detailed information from this one site has helped park managers better understand threats to aquatic resources throughout the park, especially at Rincon Creek, and played an important role in conservation of lowland leopard frog in the Tucson area. For the past six years, park staff has worked in partnership with the Arizona Game and Fish Department and several nongovernmental organizations to raise lowland leopard frogs in backyard ponds for potential translocations in areas where this species no longer occurs. Tadpoles from Madrona have spawned frog populations elsewhere in the Rincon Valley.

An unexpected benefit of the pulse study was a renewed appreciation for the park's history and the cultural values of wilderness. One of the more spirited discussions during the pulse study workshop was about mule packing. Mules had carried the gear of generations of seasonal wildland firefighters to the park's high-elevation fire base camp at the historic Manning Cabin, but prior to the pulse study the program's future was uncertain. The pulse study reinvigorated the packing program and led to a celebration in 2005 of the Manning Cabin's 100th anniversary, which brought back many old-timers who had lived, worked, and packed in the park's wilderness areas. While mules and historic cabins were not part of the goals of the pulse study, having people from different viewpoints sit down together and talk about these issues resulted in significant, though unanticipated, outcomes.

Implications for other parks

The results and follow-up studies over the past six years show that pulse studies are a very useful, though underutilized, tool for bridging the gap that commonly develops between how scientists and managers view public lands. The NPS Omnibus Management Act of 1998 directed the National Park Service to integrate scientific knowledge into management decisions. The jobs of decision makers are made much easier, and the decisions are better, when the science is relevant, readily available, and clearly communicated (Lewis 2007).

Traditional "science for management" projects are often expensive and take years to finish. Furthermore, scientists and managers often perceive problems differently. In contrast, pulse studies are inexpensive and rapid, and place park staff and scientists in direct contact with each other (Weesner 2006). They also help to focus any follow-up research. These studies seem to be ideally suited for site-specific resource issues that demand information in a short time but are complex enough to require a range of expertise. Although pulse studies did not originally include cultural resource specialists and social scientists, their participation greatly improved the process and results of the Madrona pulse study. Even when the issues appear to be primarily ecological, cultural resource and social science expertise results in unexpected benefits.

The disadvantage of pulse studies compared with research projects is, of course, that their brevity rarely results in a full understanding of the system. But this disadvantage is offset by the benefit of having many experts discussing issues together in a focused way—something that rarely happens under usual conditions. Participants can gather an amazing amount of data, which is immediately peer-reviewed in the field and around the campfire. Pulse studies also can get the attention and interest of park management in ways that reports and conferences often do not. Interaction during the pulse study can focus the work of scientists on the practical issues and concerns of the managers, so that the latter may see that the scientists are producing worthwhile and useful products. Also, interaction during the pulse study can have a positive influence on follow-up research and monitoring.

The major costs for the Madrona pulse study were salaries. Most academic and governmental scientists donated their time, but junior scientists (usually graduate students) received a stipend upon completion of their final report. Park funds covered salaries of NPS staff. "The pulse payoff for the park," said Sequoia and Kings Canyon national parks ecologist Annie Esperanza in a 1994 interview in *Park Science*, "is the short-term labor force it affords us, the collection of a mountain of data, the stimulation and excitement of the participants who work in this important place. . . . The long-term payoff is the way it helps us keep long-term research alive here" (Matthews 1994, p. 6). Like Esperanza, Saguaro National Park staff appreciated the excitement the Madrona pulse study generated. This excitement has carried over for six years, and in ways not originally anticipated.

Pulse studies … bring together scientists and managers to … quickly assess the ecological health of an ecosystem or area.

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About the authors

Participants completed a long list of logistical tips to make pulse studies proceed more smoothly. Contact the author, ***Don E. Swann****, for a copy of this list. Swann is a biologist at Saguaro National Park, Tucson, Arizona. He can be reached at don_swann@nps.gov or 520-733-5177.* ***Margaret W. Weesner*** *is chief of science and resource management at Saguaro National Park, Tucson, Arizona. She can be reached at meg_weesner@nps.gov or 520-733-5170.* ***Sarah Craighead*** *is superintendent at Death Valley National Park, Death Valley, California. She can be reached at sarah_craighead@nps.gov or 760-786-3240.* ***Larry L. Norris*** *is NPS southwest research coordinator for the Desert Southwest Cooperative Ecosystem Studies Unit at the University of Arizona, Tucson, Arizona. He can be reached at lnorris@ag.arizona.edu or 520-621-7998.*

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Research Reports

A rapid, invasive plant survey method for national park units with a cultural resource focus

By Craig C. Young and Jennifer L. Haack

INVASIVE PLANT MANAGEMENT PLANNING IN NATIONAL parks can be categorized in three stages: inventory/survey, monitoring, and management (Rew et al. 2006). Inventories or surveys document the presence and may roughly describe the relative abundance of invasive plants in natural areas. The flexibility and broad spatial extent associated with inventories are often required for effective early detection of small invasive plant populations (Carpenter et al. 2002). Monitoring, by contrast, provides unbiased, statistically powerful, and cost-effective approaches to detect change in invasive plant abundance or distribution (Gibbs et al. 1998). While inventories often focus on extensive spatial scales, monitoring focuses only as broadly as necessary to provide reasonably precise variable estimates given the expected spatio-temporal variability. Inventories and monitoring are intended to plan or assess invasive plant management.

A comprehensive map of invasive plants occupying a national park would fully meet inventory and monitoring needs. From a monitoring standpoint, maps with reasonably small minimum mapping units reproduced accurately over time would detect changes in the abundance and spread of invasive plants. Combined with information on the controls applied to specific groups of invasive plants, maps could also be used to assess management effectiveness. Widespread interest in weed mapping reflects the potential benefit of such maps and the availability of global positioning system (GPS) technology (NAWMA 2002).

Despite notable advantages, comprehensive mapping of invasive plants in national parks poses several challenges. Mapping with small minimum units can often be accomplished only over small areas. As map unit size increases, mapping becomes more efficient, but increases the difficulty of detecting change in perimeters and presumably increases error in plant detection and estimation of abundance within the perimeter. Furthermore, comprehensively mapping invasive plants on a large landscape is generally cost-prohibitive (Stohlgren 2007). With this challenge in mind, we developed and tested a simple, rapid survey method intended to simultaneously inventory, monitor, and map invasive plants in national parks with a cultural resource focus (Young et al. 2007).

Figure 1. Pipestone National Monument, Minnesota, is one of six national park units in the Midwest that was the subject of surveys to establish a protocol for monitoring high-priority invasive plants.

Survey methods

Six national park units served as the sites for this study in 2006 (figs. 1 and 2, and table 1). Each park, administered by the NPS Midwest Regional Office and located in the Heartland Inventory and Monitoring Network in the central United States, was established for the interpretation of American history and encompasses 750 acres (304 ha) or less. The park landscapes consist of forests or prairies in three ecoregional provinces (Bailey 1998; table 1). With the exception of some native prairie remnants at Pipestone National Monument (Minnesota), most prairies in these parks have been restored from abandoned agricultural lands. The forests in the six parks reflect succession following agricultural clearing, logging, and planting.

We developed lists of target invasive plants for each park based on our review of 15 available lists (appendix A). During review, we designated a subset of high-priority invasive plants as the focus of our sampling based on one of three criteria. Each plant given a high invasive rank ("H" in Morse et al. 2004) and all plants on the New Invasive Plants in the Midwest list (MIPN 2006) were marked as a high priority. Finally, invasive plants repeatedly identified on multiple lists were subjectively designated as high priorities. The ranking resulted in a list of 126 high-priority invasive plants (referred to collectively as HPIPs) that the USDA Plants database (2007) designated as occurring in that park's respective state (see appendix A).

Figure 2. The Heartland Inventory and Monitoring Network tested the efficacy of the invasive exotic plant survey method for cultural resource–focused parks in six national park units in the central United States: Arkansas Post National Memorial, George Washington Carver National Monument, Herbert Hoover National Historic Site, Homestead National Monument of America, Lincoln Boyhood National Memorial, and Pipestone National Monument.

We limited the invasive plant survey in each park to terrestrial habitat in a relatively natural condition; this area constituted the reference frame. We divided reference frames into sampling units termed "search units," with 2 acres (0.8 ha) as the target size (fig. 3A, next page; table 1). Search units varied in size, however, because of each park's shape and management unit boundaries.

Using a GPS unit, observers made three equidistant passes in an east-to-west direction through search units in the parks (fig. 4, next page). On each pass, we identified HPIPs in each search unit within a 3 to 12 m (9.8 to 39.4 ft) belt. Observers visually documented plants in the widest belt possible given site conditions (e.g., height of grass, density of woody species). We introduced variation in belt width to maximize capture of plant occurrences, while allowing adjustment for conditions where surveying wider transects was not feasible. We assigned a cover class category to each HPIP in each search unit using the following foliar cover scale:

0 = 0
1 = 0.1–0.9 m^2 (1.1–9.7 ft^2)
2 = 1.0–9.9 m^2 (10.8–106.6 ft^2)
3 = 10.0–49.9 m^2 (107.6–537.1 ft^2)
4 = 50.0–99.9 m^2 (538.2–1,075.3 ft^2)
5 = 100.0–499.9 m^2 (1,076.4–5,380.9 ft^2)
6 = 500.0–999.9 m^2 (5,382.0–10,762.8 ft^2)
7 = 1,000.0–4,999.9 m^2 (10,763.9–53,818.5 ft^2)

Table 1. Midwestern cultural resource–focused national parks sampled for invasive plants, 2007

National park unit	State	Ecoregion (Bailey 1998)	Park size (acres/ha)	Reference frame size (acres/ha)	Number of search units	Mean search unit size (acres/ha)	Percentage of park sampled (min./max.)
Arkansas Post National Memorial	Ark.	Lower Riverine Mississippi Forest Province	758 (307)	339.3 (137.3)	169	2.01 (0.81)	10.0 39.9
George Washington Carver National Monument	Mo.	Eastern Broadleaf Forest (Continental) Province	210 (85)	188.4 (76.2)	97	1.94 (0.79)	10.2 40.6
Herbert Hoover National Historic Site	Iowa	Prairie Parkland (Temperate) Province	187 (76)	83.7 (33.9)	50	1.67 (0.68)	10.9 43.7
Homestead National Monument of America	Neb.	Prairie Parkland (Temperate) Province	195 (79)	163.9 (66.3)	82	2.00 (0.81)	10.0 40.1
Lincoln Boyhood National Memorial	Ind.	Eastern Broadleaf Forest (Continental) Province	200 (81)	153.6 (62.2)	77	2.00 (0.81)	10.0 40.1
Pipestone National Monument	Minn.	Prairie Parkland (Temperate) Province	282 (114)	270.3 (109.4)	114	2.37 (0.96)	9.2 36.8

Note: The minimum and maximum park percentage sampled indicates the potential range of the park that was surveyed given the variability in transect belt widths.

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Figure 3. (A) Exotic plant search units at Herbert Hoover National Historic Site, Iowa. Numbers identify individual units. (B) Cover of *Bromus inermis* Leyss. (smooth brome) at Hoover. Numbers represent plant cover: 1 = 0.1–0.9 m^2 (1.1–9.7 ft^2), 2 = 1.0–9.9 m^2 (10.8–106.6 ft^2), 3 = 10.0–49.9 m^2 (107.6–537.1 ft^2), 4 = 50.0–99.9 m^2 (538.2–1,075.3 ft^2), 5 = 100.0–499.9 m^2 (1,076.4–5,380.9 ft^2), 6 = 500.0–999.9 m^2 (5,382.0–10,762.8 ft^2).

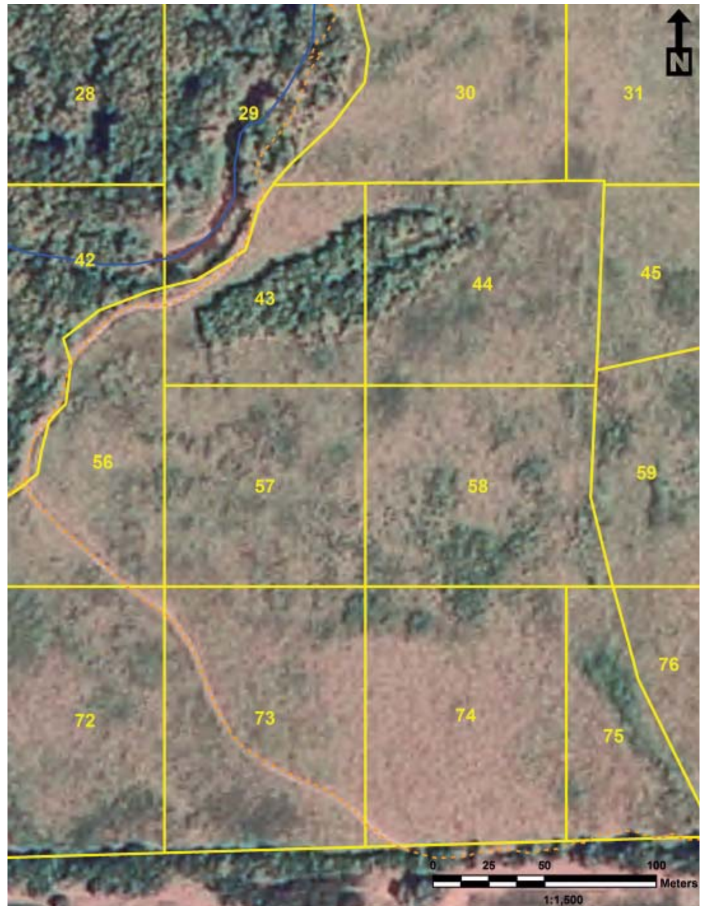

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Figure 4. Orthorectified image of invasive plant search units at Homestead National Monument of America, Nebraska. The image is used for navigation with the GeoXT global positioning system.

To summarize HPIP abundance, we calculated a cover range for each HPIP in each park (see appendix B for an example calculation). To calculate the minimum end of the range, we summed the lower endpoints associated with the cover class values assigned to an HPIP (Kelrick 2001) and then divided by the reference frame fraction observed assuming the widest possible survey belt, 12 m (39.4 ft). We calculated the observed reference frame fraction as follows:

$$\text{fraction of reference frame observed} = \frac{\text{transect length} \times \text{number of transects} \times \text{belt width}}{\text{reference frame area}}$$

We calculated transect lengths for each park using the mean sample unit size and assuming square search units. Maximum cover was calculated similarly, using the upper endpoints of the cover values in each search unit, and assumed that a 3 m (9.8 ft) belt was surveyed. We then summed high and low estimates across species, respectively, to estimate the range of total HPIP cover for each park, as well as across all six parks.

Survey results

In the six parks encompassing approximately 1,832 acres (741.4 ha), observers surveyed 589 search units in reference frames covering 1,199.2 acres (485.3 ha) (table 1). Based on the reference frame fractions observed, observers surveyed at least 9.2–10.9% and no more than 36.8–43.7% of park reference frames (table 1). Surveys at the six parks required approximately 29 person-days.

During the surveys, we identified 53 HPIPs and estimated total HPIP cover at between 165.1 acres (66.8 ha) and 1,988.8 acres (804.8 ha) in the six parks. From this estimate, the best-case scenario indicated that HPIPs cover at least 13.8% of the reference frames in these parks. The worst-case scenario suggested that HPIPs cover up to 165.8% of the reference frames. This clear overestimate (in excess of 100%) is a weakness of the survey method that resulted from the wide cover classes and variable belt widths used to estimate plant cover. This overestimation problem is exacerbated in parks with one or more frequently encountered, abundant HPIPs. For example, the maximum cover estimate for Lincoln Boyhood National Memorial (Indiana), which generally hosts HPIPs with low cover, accounted for 31.5% of the reference frame area (table 2). However, the extensive cover of smooth brome (*Bromus inermis*) (fig. 5) and reed canarygrass (*Phalaris* *arundinacea*) in Pipestone National Monument led to an estimate of maximum HPIP cover as 455.9% of the reference frame.

A relatively small number of highly abundant species accounted for the majority of HPIP cover within and among parks (table 2). Observers identified as few as 9 HPIPs in Homestead National Monument of America (Nebraska) and as many as 29 HPIPs in Lincoln Boyhood National Memorial (table 2). In each park, most HPIPs (55.6–82.8%) occupied less than 2 acres (0.8 ha) (table 2). On the other hand, relatively few species (0.0–27.8%) in each park covered more than a maximum of 25 acres (10.1 ha). Across all six parks, the combined cover of 58.5% of HPIPs was less than 2 acres (0.8 ha), and 75.5% of species occupied a maximum of 10 acres (4.0 ha). Maximum cover estimates indicated that only 11.3% of HPIPs potentially occupy more than 100 acres (40.5 ha or 8.3% of reference frame) across all six parks. Of these six species, Japanese honeysuckle (*Lonicera japonica*), sweetclover (*Melilotus officinalis*), reed canarygrass, and trifoliate orange (*Poncirus trifoliata*) occupy at least 10 acres (4.0 ha), while smooth brome and bluegrass (*Poa compressa/pratensis*) occupy at least 43 acres (17.4 ha).

Figure 5. Smooth brome (*Bromus inermis*) is one of the two most abundant invasive plants found in the six national parks included in the study.

Table 2. Invasive plant cover in six midwestern cultural resource–focused national parks, 2007

Abundance categories		Percentage of high-priority invasive plants in each park‡					
Minimum cover* acres (ha)	Maximum cover* acres (ha)	ARPO† (15 plants)	GWCA† (21 plants)	HEHO† (21 plants)	HOME† (9 plants)	LIBO† (29 plants)	PIPE† (18 plants)
> 0.1 (> 0.04)	< 2.0 (< 0.8)	66.7	57.1	71.4	55.6	82.8	55.6
0.1 – 0.4 (0.04 – 0.2)	1.0 – 5.0 (0.4 – 2.0)	6.7	14.3	14.3	11.1	6.9	5.6
0.3 – 0.8 (0.1 – 0.3)	5.0 – 10.0 (2.0 – 4.1)	13.3	9.5	4.8	0.0	3.4	5.6
0.5 – 2.0 (0.2 – 0.8)	10.0 – 25.0 (4.1 – 10.1)	6.7	9.5	0.0	22.2	6.9	5.6
1.5 – 4.0 (0.6 – 1.6)	25.0 – 50.0 (10.1 – 20.2)	0.0	4.8	4.8	0.0	0.0	11.1
4.0 – 10.0 (1.6 – 4.1)	50.0 – 100.0 (20.2 – 40.5)	0.0	4.8	0.0	11.1	0.0	5.6
10.0 – 25.0 (4.1 – 10.1)	100.0 – 250.0 (40.5 – 101.2)	6.7	0.0	4.8	0.0	0.0	0.0
35.0 – 45.0 (14.2 – 18.2)	400.0 – 650.0 (161.9 – 263.1)	0.0	0.0	0.0	0.0	0.0	11.1
Parkwide cover range		**Acres (ha)**					
Minimum cover estimate		20.5 (8.3)	15.6 (6.3)	23.7 (9.6)	8.3 (3.4)	3.4 (1.4)	93.6 (37.9)
Maximum cover estimate		182.0 (73.7)	177.4 (71.8)	246.2 (99.6)	102.4 (41.4)	48.4 (19.6)	1,232.2 (498.7)

*The minimum and maximum cover values are each presented as ranges that constitute the low and high ends of abundance categories.

†The percentage of high-priority invasive plant species in the national park unit falling within the abundance category ranges (min. and max. values) is presented.

‡ARPO = Arkansas Post National Memorial, GWCA = George Washington Carver National Monument, HEHO = Herbert Hoover National Historic Site, HOME = Homestead National Monument of America, LIBO = Lincoln Boyhood National Memorial, and PIPE = Pipestone National Monument.

A relatively small number of highly abundant species accounted for the majority of high-priority invasive plant cover within and among parks.

Evaluation of the survey method

The survey method covered a relatively high proportion of park reference frames and identified 42% of the invasive plant species of management concern. Though the probability of HPIP detection and accuracy of cover estimates in smaller quadrats (i.e., rectangular plots) is likely higher than in the long belt transects sampled here, sampling just 10% of park reference frames would require sampling 4,850 100 m^2 (1,076.4 ft^2) quadrats. The variable belt widths also increased plant detection by adapting to site conditions. In instances where the sampling area needs to be maximized to detect incipient HPIP populations, the survey method presumably requires substantially less sampling effort per unit area than quadrat-based methods.

In addition to identifying HPIPs, the survey method mapped plant locations within search units. In this respect, the method essentially predetermined the minimum mapping unit and delineation rules. Assuming that each species encountered in a search unit in this study represents only a single mapped cluster of plants (or polygon), a mapping approach would require delineating 2,365 polygons. The 2-acre (0.8 ha) search units appeared to be sufficient for planning invasive plant management actions and finding invasive plants for treatment. Managers must keep in mind that search units are not completely searched and may contain invasive plants not found during surveys. Search units, however, also provided a way to document locations where HPIPs were not found. Such areas may constitute park tracts free from invasive plants. More exhaustive follow-up surveys may be conducted in these search units as needed.

The abundance estimates can be evaluated from two perspectives: (1) suitability as a point-in-time estimate and (2) ability to detect change over time. As point-in-time estimates, the cover estimates appeared sufficiently precise to guide invasive plant management planning despite wide range variations. For example, sow thistle (*Sonchus arvensis*) occupies between 6.7×10^{-5} and 2.4×10^{-3} acres (2.7×10^{-5} and 9.7×10^{-4} ha, respectively), while smooth brome occupies between 37.7 and 469.0 acres (15.3 and 189.8 ha, respectively) at Pipestone National Monument. Despite these wide ranges, smooth brome has clearly invaded the park much more extensively than sow thistle. The wide abundance ranges posed some limitations on the survey's effectiveness in detecting change in abundance over time. Under the most extreme scenario (all actual cover values at the low end of the assigned cover class), change would be detected for 4.4%, 33.6%, 24.8%, and 37.2% of HPIPs following three, four, five, and six doubling periods (i.e., the time required for a population to increase by 100%), respectively. Without comparisons from plot sampling data, however, it is difficult to know if the ability of the method to detect change is reduced compared with plot sampling approaches. We note that we did not convert cover classes to midpoint values, which artificially reduces the sample variance. Rather, assuming a high ability to detect HPIPs and to accurately estimate plant cover visually, sources of sample variation due to imprecision of cover classes and variation in belt width are completely accounted for in the HPIP cover ranges. As an alternative, the semipermanent transects support analysis of the survey data as a paired-sample design. The average change in cover class may be calculated as an indicator of change in HPIP abundance in each park.

Invasive plant management planning

Based on minimum cover estimates alone, the extent of HPIP invasion at multiple and individual park scales suggests the need for a strategic management approach in culturally focused national parks. Though invasive plant management plans are inevitably site-specific, the survey provided several criteria that have already assisted National Park Service resource managers in developing management plans for Arkansas Post National Memorial (Arkansas), Pipestone National Monument, and Wilson's Creek National Battlefield (Missouri). The assessment method provides a parkwide estimate of invasive plant cover, as well as a map of the observed cover within occupied search units (fig. 3B, page 72). Assuming that success of control is more probable for small HPIP populations (Rejmanek and Pitcairn 2002), the relatively low abundance of the majority of HPIPs may give managers the opportunity to control a large number of plant species within and across these parks. Managers may also view HPIP distribution maps in relation to high-priority management areas (e.g., rare plant populations) and strategically focus on controlling only particular HPIPs in specific locations. These planning criteria may be augmented with available information on invasive plant impacts, management feasibility, and nontarget effects (Hiebert and Stubbendieck 1993; Morse et al. 2004) to improve site-based decisions.

Summary

In our opinion, this survey approach represents the simplest solution to invasive plant monitoring for many cultural resource parks. The approach can provide a starting point for more complex designs that focus on a set of more specific objectives. As designed, this method appears best suited for national parks of limited size where observers must balance multiple objectives that include identifying high-priority invasive exotic plants, focusing on natural and restored areas, ensuring good spatial coverage, detecting new plant invasions, monitoring multiple species simultaneously, and tracking changes in abundance and distribution of existing invasions.

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Appendixes A and B

Appendixes A and B are published online at http://science.nature.nps.gov/im/units/htln/library/monitoring/JournalArticles/InvasivePlants_SupplementaryInformation.doc.

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Forest vegetation monitoring in eastern parks

By Jim Comiskey, John Paul Schmit, Suzanne Sanders, Patrick Campbell, and Brian Mitchell

Figure 1. (Left to right). Forests form an important natural and cultural component within national parks. The Inventory and Monitoring Program is establishing long-term vegetation monitoring plots across the Northeast and Midwest (Acadia National Park, Maine). Standardized protocols (investigator measuring tree, Prince William Forest Park, Virginia) are allowing networks to share information and field crews from Acadia National Park in Maine to Booker T. Washington National Monument in Virginia.

FORESTS ARE THE DOMINANT ECOSYSTEM in many eastern and midwestern national parks. As such, activities to assess and promote forest health are a principal focus of park managers. A wide variety of ecosystem stressors affect forests, including, at the regional scale, atmospheric deposition and deer browse, while other stressors, such as introduced disease and climate change, are occurring globally. Numerous state, federal, and nongovernmental organizations currently monitor forests throughout the region, but most programs lack coordination that would facilitate information sharing and comparison. Within the National Park Service (NPS), such coordination is essential for effective management.

Under the guidance of the Inventory and Monitoring (I&M) Program, eastern and midwestern national parks and networks are collaborating to ensure that protocols for tracking forest health allow compatibility with one another and with the USDA Forest Service's Forest Inventory Analysis (FIA) and Forest Health Monitoring programs (fig. 1). Participants include eight I&M networks and three prototype parks. Natural resource staff at these prototype parks have established protocols and legacy data for long-term vegetation monitoring. In total, 61 national park units (23% of the parks in the I&M Program) are participating in this collaborative effort. They belong to the Appalachian Highlands, Cumberland Piedmont, Eastern Rivers and Mountains, Great Lakes, Mid-Atlantic, National Capital Region, Northeast Coastal and Barrier, and Northeast Temperate networks. Cape Cod National Seashore (Massachusetts), Great Smoky Mountains National Park (Tennessee and North Carolina), and Shenandoah National Park (Virginia) are also participating as prototypes (fig. 2, page 78).

The overarching goal of the vegetation monitoring programs is to provide a framework for monitoring long-term change over broad spatial scales of the eastern deciduous and northern hardwood forests. Within this context, field staff (1) monitor status and trends in forest structure, composition, and dynamics of canopy and understory; (2) track changes in the regeneration potential of the forest; (3) detect and monitor presence of invasive exotic plants, exotic plant diseases and pathogens, and forest pests; and (4) monitor trends in forest coarse woody debris and availability of snags.

LEFT TO RIGHT: NPS/THERESA MOORE, NPS/THOMAS PARADIS, NPS/JIM COMISKEY, NPS/CAROLYN DAVIS

History of monitoring and collaboration

Eleven parks were designated in the 1990s as models on which to base the network monitoring programs. Three of these prototypes, Cape Cod, Great Smoky Mountains, and Shenandoah, are located in the eastern United States, and have long-standing vegetation monitoring programs. The accomplishments of the prototype parks provided a model of how to monitor park natural resources. The Natural Resource Challenge funding initiative in 1998 designated 32 I&M networks, creating a framework for coordinated collection of data needed to understand and manage park ecosystems in 270 parks with significant natural resources. The first networks received funding in 2001 and initiated the process of identifying vital signs, a subset of physical, chemical, and biological elements and processes that are indicators of park ecosystem health. By 2006, seven eastern and midwestern networks had identified vital signs related to forest vegetation as being high-priority.

As the first networks began developing protocols for forest vegetation, an important objective was to have methodologies compatible with approaches used by other agencies and institutions. The Forest Service's FIA Program provided a potential model to be followed by the individual networks, though modifications would be required to meet NPS objectives. The first networks, National Capital Region and Northeast Temperate networks, adapted the FIA approach and conducted initial pilot testing in 2005. As more networks identified their vital signs, investigators appreciated the need for collaboration and for learning from the experience of the prototype parks, which had modified their protocols over time.

Over the past four years, the forest vegetation monitoring working group has expanded to include participation of eight networks and three prototype parks. It has made significant headway in standardizing metrics and field methods so that data sharing is possible. In addition, as the working group has developed protocols and conducted pilot testing, it has provided an ideal forum for the review of protocols and results. Thus, networks identifying forest monitoring as a priority later in the process were easily able to adopt these protocols.

By 2010, the regional forest monitoring program will be largely implemented, including eight networks in four national park regions covering 18 states. Sixty-one parks and three prototypes will have comparable data from more than 2,000 plots.

Monitoring methods

The I&M Program provides general guidance but individual networks have the freedom to develop their monitoring programs based on their own specific need, presenting a challenge to protocol standardization at a regional scale. Though plots may vary in size and shape, the collaborative effort has ensured a standardized approach to what is measured within the plots and how. Generally, plots are composed of a main plot area, with embedded microplots, quadrats, and transects (fig. 3, page 79). For the most part, all networks measure trees with a diameter at breast height (dbh) ≥ 4 inches (10 cm) in the main plot, smaller trees and shrubs in microplots, woody regeneration and herbs in the quadrats, and coarse woody debris along transects. Field staff assesses the condition of trees in the main plot, and notes infestation by native and exotic pests. At some parks, staff also collects soil samples outside each plot to evaluate long-term changes in soil chemistry caused by acid deposition. For the vast majority of the metrics collected, the working group has ensured a consistent approach.

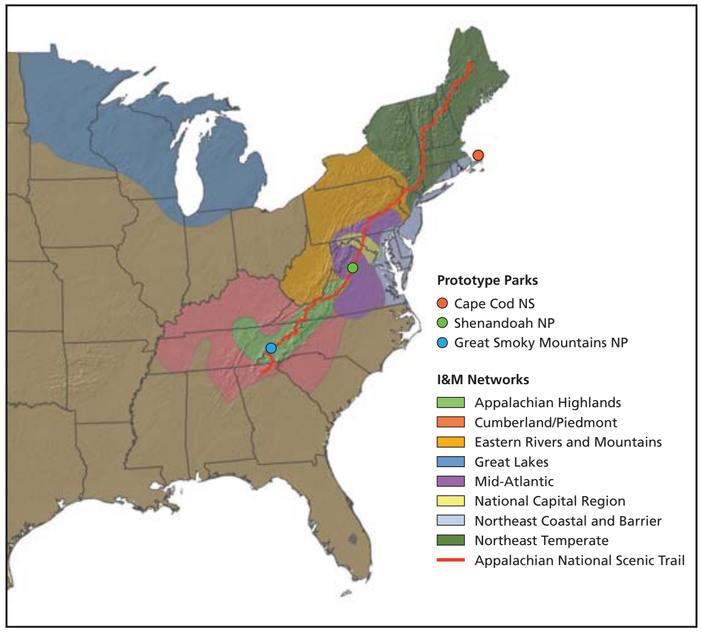

Figure 2. Parks and networks collaborating in the eastern forest vegetation monitoring initiative.

A regional coverage

By 2010, the regional forest monitoring program will be largely implemented, including eight networks in four national park regions covering 18 states. Sixty-one parks and three prototypes will have comparable data from more than 2,000 plots. Parks as far apart as Voyageurs National Park in Minnesota, Great Smoky Mountains National Park in Tennessee and North Carolina, and Acadia National Park in Maine are now monitoring forest vegetation in a comparable way. Information derived from this network is compatible with data collected by the Forest Service's FIA Program and a variety of other state and federal programs that share similar monitoring approaches.

Reporting results

The forest monitoring group is developing standardized approaches for reporting results. The goal is to ensure that data collected by the parks and networks reach resource managers and decision makers in a timely and usable fashion. Currently two similar approaches are being adopted. The Northeast Temperate Network staff is testing ecological integrity metrics (Tierney et al. 2009) and the National Capital Region Network participants are developing integrated assessment scores (Schmit et al. 2009). Both assessment methods measure the composition, structure, and function of an ecosystem compared with the system's natural or historical range of variation. Threshold values for each metric are defined, and ratings assigned, for example "good" or "significant concern," based on deviation from threshold value. For each metric, sound science supports the definition of these threshold values to ensure credible reporting. The range of ecological systems and conditions across networks means that the threshold values will likely vary throughout the region. Nevertheless, reporting the same metrics will provide a measuring stick for assessing impacts by natural or man-made agents of change as well as the effectiveness of management.

Initial Findings

A strength of the forest monitoring initiative is the ability to share information across such a wide geographic area, facilitating evaluation of trends in a variety of forest health and condition metrics. Though the program is still being implemented, and for the most part data on the status and trends of forest resources are limited, some preliminary analyses are possible. As an illustrative example, 808 plots in 40 parks belonging to five networks (Eastern Rivers and Mountains, Great Lakes, Mid-Atlantic, National Capital Region, and Northeast Temperate) and two prototypes (Cape Cod and Shenandoah) were combined to evaluate the distribution and extent of exotic plant species. There were a total of 1,557 observations of 136 exotic invasive plant species, representing an average of 1.9 exotic plant species per plot. All parks had plots with exotic plants except Allegheny Portage Railroad National Historic Site, largely due to chance and the low number of plots currently present in the park. The majority of parks had exotic species in over half of their plots (fig. 4). On average,

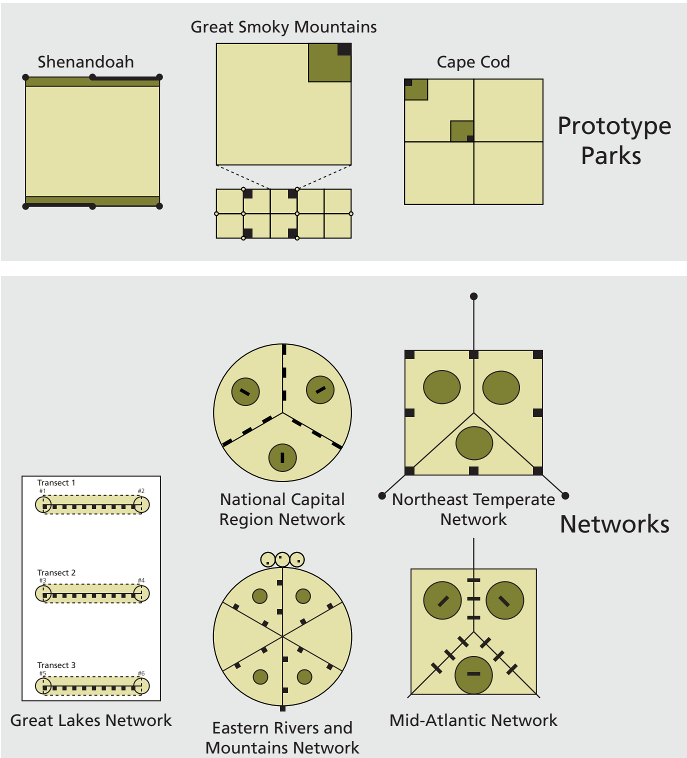

Figure 3. Plot configurations used by different parks and networks. Plots are composed of a main plot area (light olive), microplots (olive), and quadrats (black). Some of the plots also include transects (black lines).

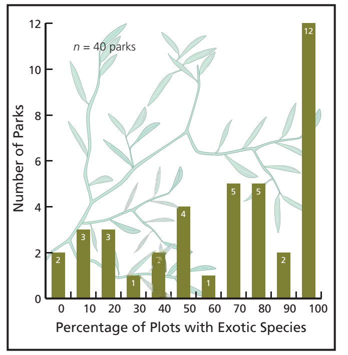

Figure 4. Percentage of plots in each park with exotic species. For example, of the 40 parks included in this analysis, two parks had plots with no exotics (0%), while 12 parks had exotics in all their plots (100%).

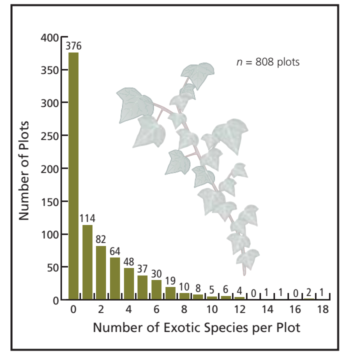

Figure 5. Number of exotic species found per plot. For example, of the 808 plots included in this analysis, 376 plots had no exotic species and 114 plots had one exotic species, while only four plots had 15 or more exotic species.

PLANT SYMBOLS COURTESY OF THE INTEGRATION AND APPLICATION NETWORK (IAN.UMCES.EDU/SYMBOLS), UNIVERSITY OF MARYLAND CENTER FOR ENVIRONMENTAL SCIENCE

there were 10.9 exotic plant species found per park. Just fewer than half the plots did not have any exotic plant species (47%), while one plot had 18 species (fig. 5). The most common exotic plant species, occurring in more than 100 plots and 20 parks, were *Alliaria petiolata* (garlic mustard) found on 159 plots in 20 parks: *Lonicera* spp. (honeysuckle), on 166 plots in 30 parks; *Microstegium vimineum* (Japanese stiltgrass), on 130 plots in 20 parks; and *Rosa multiflora* (multiflora rose), on 105 plots in 22 parks.

Integration with management

Park staff and subject matter experts prioritized the vital signs according to their importance for managing park resources, providing managers with information that will allow them to determine appropriate courses of action (Fancy et al 2009). Nevertheless, the forest vegetation monitoring program provides an overall measure of the health and condition of the forests, and not the effectiveness of management actions. For example, over time, monitoring may indicate changes in distribution and abundance of invasive exotic plant species, but does not measure how effective management efforts are; tactical monitoring aimed at evaluating management effectiveness still needs to be implemented by park staff. However, the vital signs forest vegetation monitoring will augment management-based monitoring that the parks are conducting. For example, a park that is managing deer densities to reduce overgrazing impacts on herbaceous plant communities and forest regeneration will need to monitor vegetation to evaluate understory vegetation recovery. Currently, I&M efforts are being incorporated in deer management planning at Valley Forge National Historical Park (National Park Service 2009), but the I&M forest monitoring program does not replace effectiveness monitoring conducted by the park.

Benefits of the forest monitoring group

The forest vegetation monitoring group's activities resulted in a number of benefits to participants. One advantage is the ongoing collaboration and experience sharing between prototype parks and networks. The prototypes provide a model of how long-term monitoring can be incorporated into park-based natural resource management. The three participating prototype parks have monitored forest vegetation communities for more than a decade and all three have recently redesigned their protocols. The networks

Though [vegetation monitoring] plots may vary in size and shape, the collaborative effort has ensured a standardized approach to what is measured within the plots and how.

Scientists will [likely] be attracted to our parks due to the wealth of information and data related to forest condition.

have benefited by directly incorporating those components that have strengthened the new prototype protocols. The resulting protocols can also be extended to other regions of the country, including the western portion of the United States.

The working group is also an important sounding board for new ideas and approaches. As the first networks developed draft monitoring protocols, working group participants provided reviews that helped refine the final products. The reviewers were then likely to adopt the same protocols for their own networks, thus ensuring standardization. As results emerged from pilot testing and the first year of implementation, these data were used by other networks to evaluate whether the protocols met their monitoring and sampling objectives prior to conducting their own field-based pilot tests (for example, Comiskey et al. 2009).

For monitoring to be successful, the programs need to be sustainable over the long term. Thus, cost-saving measures and building successful field teams are essential. Working group members are now employing a variety of resource-sharing options that reduce costs and increase monitoring efficiencies. One such example is a combined field team that operates in three networks to implement the forest monitoring plots from Maine to southern Virginia. The combined team further promotes standardized monitoring approaches across the networks and increases opportunities for data sharing.

This collaborative effort creates a model that can be used for developing, implementing, and sharing data from other monitoring protocols. Several participating networks are now exploring other protocols that will benefit from collaborative development. Additional information and resources are located at http://science.nature.nps.gov/im/units/midn/Forest_Monitoring_Meeting.cfm.

Future direction

Forests form an important habitat matrix for a wide variety of plants and animals in the eastern and midwestern United States. As stresses on these forests increase, the I&M Program will monitor their effects on forest composition and dynamics across latitudinal and altitudinal gradients, for example, individual responses of plant species or pest and pathogen effects in relation to climate change. Such regional analyses require continued standardization and refinement of the monitoring methods. As protocols are finalized and implemented, the focus will shift to data sharing, regional analyses, and combined reporting. Over time, it is likely that scientists will be attracted to our parks due to the wealth of information and data related to forest condition. Such intellectual investment will benefit park natural resource management.

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Prescribed fire and nonnative plant spread in Zion National Park

By Kelly Fuhrmann, Cheryl Decker, and Katie A. Johnson

PRESCRIBED FIRE IS A VALUABLE TOOL FOR MANAGING ecosystems because it promotes species diversity and productivity and reduces wildland fuels. In some communities, for example ponderosa pine, fire is critical for productivity. However, prescribed fire can also promote the spread of nonnative plant species and affect ecosystem composition, diversity, structure, and function. Land use history and climate change have contributed to the invasion of nonnative plant species into an expanding variety of ecosystems, including higher-elevation plant communities. This expansion of nonnative plants has the potential to change the fire regimes of the plant communities of which they are a part (Westerling et al. 2006). For instance, managers ignited the Clear Trap prescribed fire in a juniper-pinyon-ponderosa (*Juniperus osteosperma*, *Pinus edulis*, and *P. ponderosa*, respectively) system in Zion National Park in fall 2004 (fig. 1). Composed of the Clear Creek and Deer Trap burn units, the 4,400-acre (1,780 ha) Clear Trap fire is the largest prescribed burn undertaken to date in Zion National Park. It is also the first of several National Park Service (NPS) fire treatments in the East Zion Focus Area, a designated wildland-urban interface of high priority for protecting human life and property values at risk from wildland fire. The primary goals of this prescribed fire were to improve the defensibility of the park boundary and help restore fire to park ecosystems (NPS 2001). Though the focus of the burn was fuel reduction, in spring 2005 (the season after the burn), park natural resource managers identified another result: significant increases in nonnative plant species within the burn unit. As a result, in 2006 the vegetation program at Zion National Park enlisted the help of the NPS Northern Colorado Plateau Inventory and Monitoring Network to map the extent of nonnative plant infestations in this area.

NPS PHOTO

Figure 1. The Clear Trap prescribed fire burned approximately 4,400 acres in fall 2004. This view is representative of the mixed burn severity in ponderosa pine communities, in which the fire return interval is normally four to seven years, and in the pinyon-juniper communities, in which fire is much less frequent, with an average return of 160 years. Historically, fires in Zion National Park were suppressed.

Background

The 2005 fire management plan (NPS 2005) for the park identifies desired future conditions that are targeted through the implementation of objectives based on ecological parameters. Goals are: (1) fire processes in fire-dependent/adapted vegetation communities are managed to promote healthy and functional ecosystems; (2) vegetation succession reflects the natural range of variability under conditions that would occur under historical fire regimes; (3) fire is used as a tool to protect and enhance native vegetation communities; (4) fire program operations do not contribute to the spread of nonnative plants in Zion; and (5) resource managers develop native seed sources.

Since the Clear Trap prescribed burn in 2004, Zion National Park has experienced two of the largest wildfires in its history. In 2006 the Kolob Fire burned 10,500 acres (4,259 ha) and the Dakota Hill Fire burned 5,800 acres (2,347 ha) in 2007. Management response to these events included herbicide treatments with imazapic (Dakota Hill and Kolob) and seeding (Kolob) with native grasses and forbs such as bottlebrush squirreltail (*Elymus elymoides*), sand dropseed (*Sporobolus cryptandrus*), scarlet globemallow (*Sphaeralcea coccinea*), and Palmer penstemon (*Penstemon palmeri*) to combat the spread of nonnative plants, particularly cheatgrass (*Bromus tectorum*). The decision to apply large-scale aerial herbicides was uncharacteristic but deemed necessary to combat the dominance of cheatgrass, which increases in abundance and density after fire (Fuhrmann 2007).

Cheatgrass is aggressive in any disturbed site, without regard to aspect, moisture, or elevation (fig. 2, next page). It can successfully compete with native plant populations that have been removed as a result of a disturbance such as fire. Cheatgrass displaces native plant communities because, as a winter annual, it is able to establish earlier in the growing season, thus increasing competition and depleting soil resources until native annuals are eventually crowded out. When cheatgrass is dominant, wildfires can occur earlier in the season, when native perennials are more susceptible to injury by burning. Also, cheatgrass provides a continuous supply of fine fuel for rapid fire spread. Moreover, under appropriate moisture conditions, cheatgrass is a prolific seed producer. Over time, seed from individual plants builds into thick mats. When the grass stems are burned, only the top layer of this

NPS PHOTO

Figure 2. Cheatgrass grows aggressively in disturbed areas. Here, one year after the fire, it has infested a high-severity burn area within the Clear Trip prescribed fire.

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Figure 3. National Park Service employees Alexia Savold and Fleur Nicklen survey invasive plants as part of the Clear Trap postburn assessment.

vegetative mat is affected, leaving bottom layers of seed and mulch ready to take advantage of newly available resources (light, water, and space). This advantage sets up an annual fire return cycle that is destructive to native plant species. The result can be conversion from native shrub and perennial grasslands to annual grasslands adapted to frequent fires. This adaptation to and promotion of frequent fires are what give cheatgrass its greatest competitive advantage in ecosystems that evolved with less frequent fires. The only true competition for cheatgrass is from a healthy, abundant native plant community that prevents opportunistic sprouting by nonnatives.

Methods

We incorporated four vegetation monitoring types—gambel oak (*Quercus gambelii*), ponderosa pine–pinyon pine, Utah juniper (*Juniperus osteosperma*), and big sagebrush (*Artemesia tridentata*)—identified in the fire management handbook monitoring protocols (NPS 1992; h3) into this analysis using FEAT/FIREMON Integration (FFI) (an integration of the National Park Service's fire ecology assessment tool [FEAT] [Lutes et al. 2009; Sexton 2003] and the USDA Forest Service's Fire Effects Monitoring and Inventory System [FIREMON] [Lutes et al. 2006] database tool [Lutes et al. 2009]). Ten forest plots (20 m × 50 m [66 × 164 ft]) and one brush plot (5 m × 30 m [16 × 98 ft]) are represented. Seven of the 11 plots were in a burn conducted for the first time in this area; the remaining four were in areas burned for the second time. The combining of monitoring types may lead to higher variability in some results, such as fuel loading. This, in conjunction with small sample size, offers an explanation for the resulting standard deviation ranges.

The primary objective of mapping postburn vegetation within the Clear Trap prescribed fire was to determine the relative abundance of invasive grass species. Network staff conducted field searches at as fine a scale as required to be confident that 90 to 100% of all invasive plant infestations 0.01 acre (40 sq m) or larger within each inventory area were detected (fig. 3). Search swath widths were adjusted as needed based on variations in terrain, walking speed, associated vegetation, and target species. The locations of all target species were documented using global positioning system units with 2- to 5-meter (6.6 to 16.4 ft) accuracy. Field crews marked and dated all inventoried areas on standard United States Geological (USGS) 7.5-minute topographic maps to assist in determining project progress and thoroughness of coverage (Dewey and Andersen 2006).

Results and discussion

Data assessment in relation to project objectives must be taken in context with small sample sizes, mosaic burning patterns, and standard deviation relationships. The fuels results (fig. 4) suggest that desired reduction of fuel loads was successful. Conditions may have been drier than anticipated. We identified an increase in percentage of surface cover of native grasses and forbs (fig. 5),

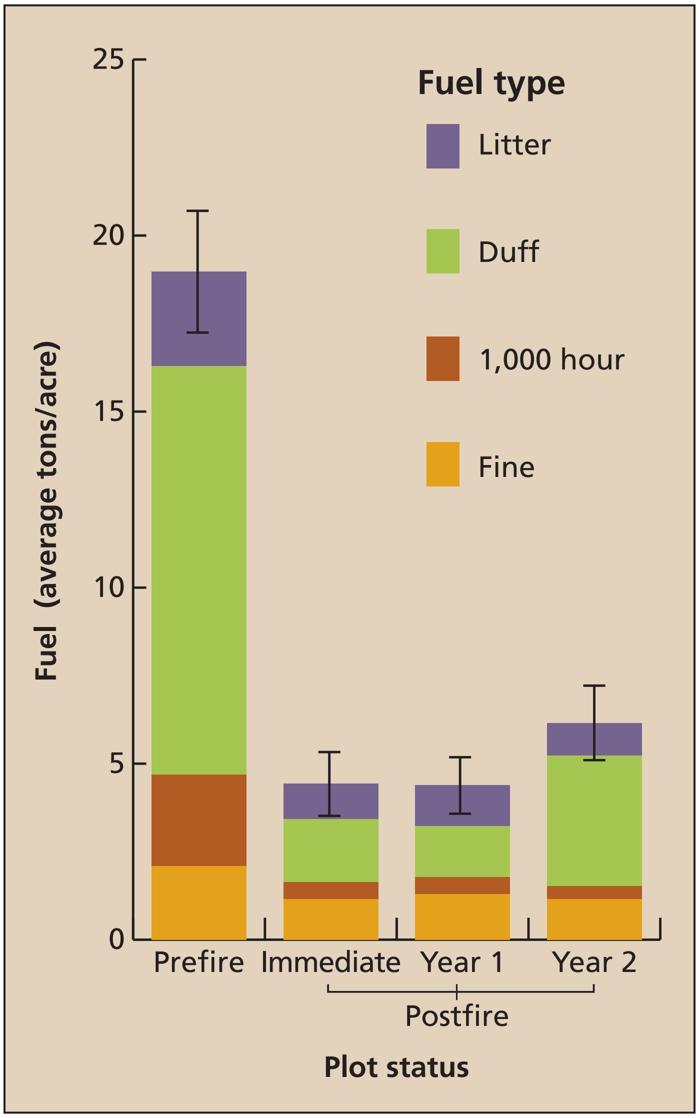

Figure 4. Total fuel loading (litter, duff, and 1,000-hour and fine fuels) within the Clear Trap fire was reduced by an average of 14.5 tons/acre (32.5 metric tons/ha) immediately after the fire. Two years later the fuel loading average has been reduced further to 6.1 tons/acre (13.7 metric tons/ha). Before the prescribed burn the average fuel load was 19 tons/acre (42.6 metric tons/ha).

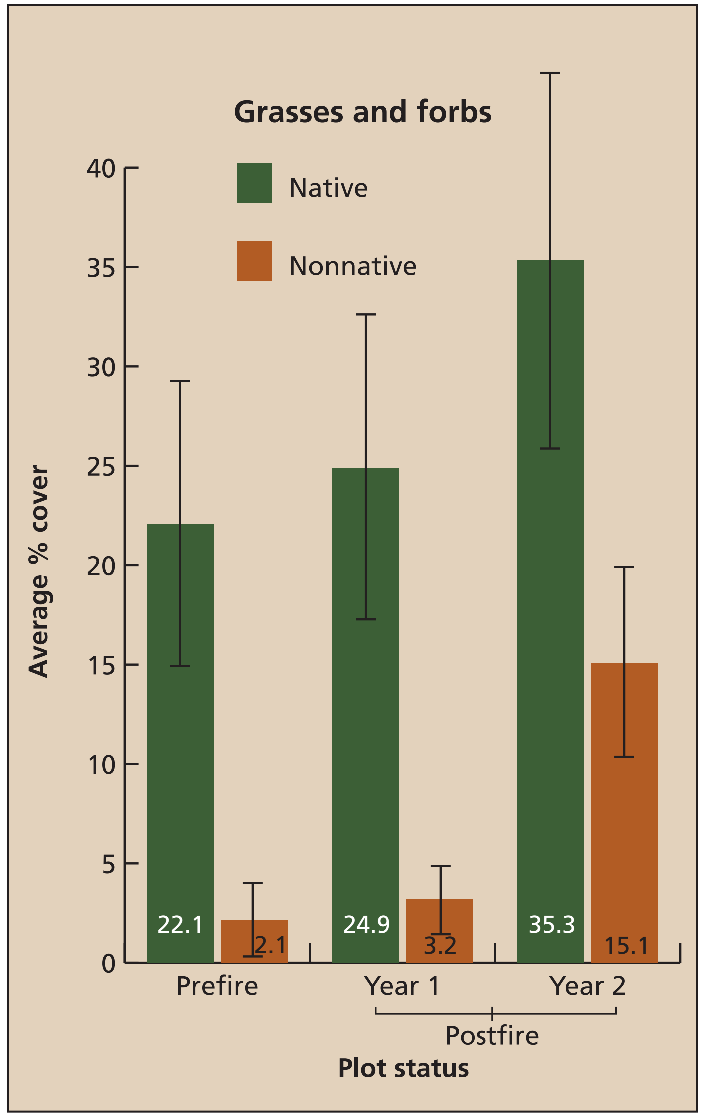

Figure 5. The percentage of native and nonnative plant species cover in the prescribed fire area also decreased two years after the burn. While native plant cover reduction met the burn plan goal (NPS 2001), nonnatives increased in quantity and extent, threatening the diversity and long-term recovery of native vegetation.

a goal that was met in the represented vegetation communities. In addition, identified increases in nonnative plant percentage of cover provide insight into a threat to native plant communities within the burn unit. This response may be partially due to an abundant snowpack in winter 2005. It may also be a result of seasonality of the burn in combination with high burn intensity in several areas where vegetation plots were located.

Survey crews recorded 413 acres (167 ha) of cheatgrass, comprising 77.2% of the acreage infested with nonnative plant species and 9% of the total area. Infestations were generally less than 0.1 acre (40.0 sq m) and consisted of dense patches scattered in open disturbed meadows or at the base of juniper trees (Dewey and Andersen 2006).

Crews found several nonnative species within the burn unit, but the most abundant target weed species was cheatgrass (table 1, next page). They found cheatgrass throughout the burn unit—in highly burned, moderately burned, and unburned areas (fig. 6, next page). It occurred more often in burned areas with minimal canopy cover. Patches ranged in size from 0.001 acre (4.0 sq m) to 5 acres (0.2 ha), but most were 0.1 acre (40.0 sq m) or smaller. In areas where burn severity was moderate to high, cheatgrass occurred in large, somewhat continuous patches. Areas that were

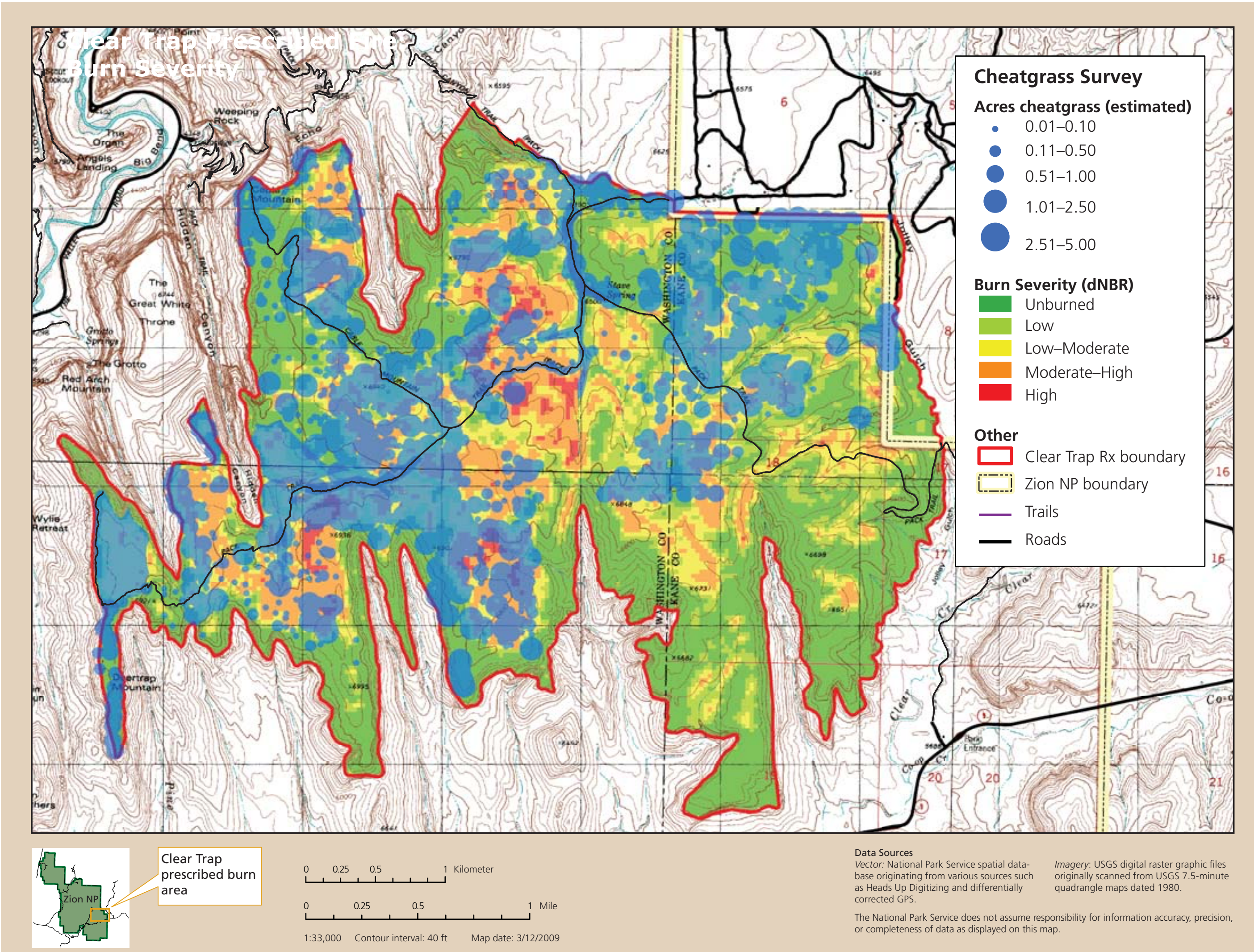

Figure 6. Clear Trap burn severity and cheatgrass survey results. The map depicts how cheatgrass locations correspond to the burn perimeter. Cheatgrass cover increased after the fire. The southeastern corner of the fire appears not to have been infested by cheatgrass. This area was not surveyed for invasives.

unburned or experienced low severity usually contained less cheatgrass. Most patches found on such sites were small—0.01 or 0.001 acre (405.0 sq m or 4.0 sq m)—and typically were located around the bases of unburned trees. This pattern suggests some kind of establishment or survival advantage associated with the microhabitat created beneath a tree's canopy, at least for cheatgrass growing under the conditions found in southern Utah (Dewey and Andersen 2006).

Table 1. Nonnative plant species infesting the Clear Trap prescribed fire, 2004

Common name	Scientific name
Ripgut brome	*Bromus diandrus*
Smooth brome	*Bromus inermis*
Downy brome	*Bromus tectorum*
Orchardgrass	*Dactylis glomerata*
Quackgrass	*Elymus repens*
Indiangrass	*Sorghastrum nutans*

Conclusions

The resulting composition of the vegetation community in the Clear Trap burn unit demonstrates the need for additional management considerations that incorporate the control of nonnative plant populations in the treatment of burned areas. Over time, different scenarios could result from this management-ignited fire disturbance. For example, if long-term dominance by invasive plant species allows for the selection of native individuals that can compete more effectively, populations may develop that are better able to coexist with invaders (Aarssen 1983; Mealor and Hild 2007). Conversely, invasive plants may come to completely dominate the invaded plant communities, changing disturbance regimes to promote the establishment of the invasive plant community (D'Antonio and Vitousek 1992; Brooks et al. 2004).

Results of this study show that an unintended conversion of fuel type or plant community composition may follow burns in juniper and ponderosa pine communities where nonnative plants such as cheatgrass live. This conversion compromised the intended goal of fuel reduction by increasing fine-fuel loading of nonnative plants. It also jeopardized native plant community composition and diversity. Future fire and resource planning should assess the benefits of using fire as a management tool in fire-adapted ecosystems susceptible to invasion by aggressive nonnative plants and provide for management needs in the pre– and post–prescribed fire environment. The invasion of nonnative cheatgrass illustrates the need to address related management issues (e.g., invasive plants) in conjunction with prescribed burning.

The following management implications (USGS 2002, p. 1) illustrate the range of variability in treatment outcomes and the additional attention necessary for controlling invasive plant infestations that may result from prescribed fire in semiarid Mojave Desert ecosystems:

- Introduction of fire where it has been suppressed often facilitates the invasion of fire-adapted invasive plants that can prevent the reestablishment of historical fire regimes.
- Fire can be used to control invasive plants if it kills adult plants, their overwintering tissues, or eliminates seed banks, but follow-up treatments are often necessary.
- Invasive species with the ability to survive fire or reestablish from long-lived seed banks should not be managed using fire in this semiarid climate.
- When targeting invasive plants for control, the potential benefits to other invasive species must always be considered.

Historical fire regimes in pinyon-juniper and ponderosa pine ecosystems that developed over thousands of years and have been shielded by elevation barriers from nonnative species invasions (such as cheatgrass) may, with climate changes, be more susceptible to invasion in modern times. This may alter the dynamics of the succession process (Miller and Tausch 2001; Allen et al. 2002) and limit biodiversity on the affected sites (Brown et al. 2007). A more thorough understanding of fire effects in juniper and ponderosa pine systems by fire managers is imperative to appropriately implement prescribed fire strategies. Nonnative plant species will continue to be a serious impediment to ecological integrity in the postfire environment. A proactive approach to postfire management of nonnative plants will be key to effectively addressing this expansive issue. Continued monitoring of fire effects within these systems and the development of weed management plans will help to improve understanding of this ecological dilemma.

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PS

Partnership behaviors, motivations, constraints, and training needs among NPS employees

By Melissa S. Weddell, Rich Fedorchak, and Brett A. Wright

AS WE PREPARE FOR THE NPS CENTENNIAL IN 2016, there has been renewed interest in developing innovative partnerships to usher in the next century of park preservation (Bomar 2007). Although some may view this partnership interest as new, the roots of forging "strategic alliances," as our first director, Stephen Mather, called them, go deep into NPS history.

More recently, Karen Wade, former director of the NPS Intermountain Region, remarked at a partnership workshop, "The parks that are doing the best are those that have figured out how to collaborate and share. . . . It is my belief that building relationships creates opportunities." Former NPS director Mary Bomar, in her 2006 nomination hearing, stated that "training for NPS personnel . . . will continue to build a culture of partnership in all fields and at all levels" (Bomar 2007). Former Secretary of the Interior Dirk Kempthorne further affirmed the commitment of the National Park Service to "sound partnership practices that are essential to the success of the centennial initiative and are accountable, efficient, and transparent" (Kempthorne 2007).

Implementing a monitoring and evaluation system to track training effectiveness and developing "an agile workforce that is capable of responding to changing organizational and personnel needs" require systematic research into issues such as employee retirement and succession (National Park Service 2003). Monitoring for potential "competency shortfalls" is logically a part of this research agenda. Therefore, the Service initiated a systematic research effort to monitor and evaluate the preparation of NPS personnel to address prescribed partnership competencies and the need for employee training and development programs. This study attempts to determine the impact of "partnership competency shortfalls" on the workforce and the ability of the Service to manage partnerships into the future. This article highlights the critical findings to enable managers to continue improving partnership training and enhance collaborative efforts.

Methods

Survey instrument

Based on a thorough review of the partnership literature and discussions with NPS managers, we developed a Web-based survey instrument. We took care to identify those variables found to influence partnership behavior in terms of both motivations and perceived constraints. Moreover, NPS staff developed an exhaustive list of employee competencies pertaining to partnerships, which our team of researchers, comprising NPS managers and university researchers, reviewed and then incorporated into the instrument.

The survey consisted of four sections, totaling 118 items. The first section contained two identical batteries of 37 competencies depicting knowledge, skills, and abilities (KSA) vis-à-vis entering

The partnership phenomenon

Partnerships have received considerable attention as a management strategy for public agencies. The political culture of fiscal constraint and "doing more with less" has led to a groundswell of interest in collaborative partnering and resource-sharing arrangements. Working in partnership increases involvement through democratic means and provides a viable approach for expanding the range of services offered, enhancing the opportunities of park visitors, and building a sense of community pride (Vaske et al. 1995; Wondolleck and Yaffee 2000; Mowen and Kerstetter 2006). Partnerships among public agencies and corporations are now an accepted mechanism to generate additional park and recreation resources that otherwise could not be provided with public funds (Mowen and Everett 2000).

For example, with the help of partners Yellowstone National Park recently designed and constructed a world-class visitor education center using a model of sustainable energy practices. In Florida, the National Park Service has established endowments and worked with educators to deliver park-based curriculum programs to reach underserved communities. The Appalachian Trail Conservancy (ATC) has been working with more than 100 partners, 40 communities, and 1,000 volunteers to raise awareness and funds to protect the Appalachian Trail (Edelen 2006). The partnership includes the U.S. Geological Survey, USDA–Forest Service, area schools, universities, and countless volunteers. The partners cooperatively monitor environmental factors and implement programs to protect critical habitats on the trail, where more than 35,000 users are active each year.

Partnerships are increasingly important in the management of public agencies, specifically parks and recreation service providers. Citizens' heightened awareness of broader social issues creates demands to find solutions to financial, human, and capital problems through alternative methods such as collaborative agreements. Through collaboration, traditional park and recreation providers are repositioning themselves to provide goods and services that address broader social missions while supporting their agencies.

into partnerships with external organizations. In the first battery, respondents were asked to rate the importance of each KSA in the conduct of their job using a seven-point rating scale ranging from (1) not important to (7) extremely important. The second battery of questions asked respondents to rate their level of preparedness to perform the same KSAs on a scale ranging from (1) unprepared to (7) fully competent. The third section included four questions about partnership experience with outside organizations, and asked respondents how many partnerships they had been involved with in the five preceding years. The fourth section asked respondents to indicate their level of agreement or disagreement with 21 statements regarding specific motivations and constraints to partnerships found in the literature (Gray 1989; Huxham 2003; Selin and Chavez 1995); the scale ranged from (1) strongly disagree to (7) strongly agree. The final section was composed of 21 questions that solicited information on agency characteristics and respondents' demographic information. The survey asked for position title, series, grade, and position description as well as number of full-time employees supervised and years of agency and federal service. Other agency-related questions concerned division, region, park classification, and number of permanent employees working at the site, along with more personal questions about gender, age, race and national origin, and education.

Data collection and response rates

The survey instrument was administered to all NPS employees (n = 18,224) via the Internet in fall 2006. We generated an e-mail list based on information in the Federal Payroll and Personnel System (FPPS). Employees received an invitation e-mail and a link to the questionnaire. They subsequently received two additional e-mails requesting completion of the survey. The invitation addressed concerns over confidentiality and Internet security and assured participants that all data would be reported only in aggregate, not individually. The survey was viewed by 7,041 employees, and a total of 5,398 usable surveys were downloaded. Out of the total population of 18,224 employees, 39% viewed the Internet survey while 29% completed it.

Data analyses

We analyzed the data by identifying the mean, frequency distribution, and standard deviation of the perceived levels of preparation and the perceived levels of importance for each of the 37 specific competencies. We then performed a gap analysis to identify "training gap scores" between preparation and importance for the agency as a whole (table 1). We identified gap scores for each individual by calculating the difference between preparation (P) and importance (I) scores for each competency. A negative gap score (P–I) indicated an area where employees felt unprepared relative to the importance of the competency. A positive gap score indicated the reverse; in this case, a respondent's perception of preparation exceeded the importance he or she assigned to a particular competency. These gap interpretations suggest areas within the NPS partnership competencies that have implications for future education and training of the NPS workforce.

Gap interpretations suggest areas within the NPS partnership competencies that have implications for future education and training of the NPS workforce.

Results and discussion

Survey respondent characteristics

Participants were divided almost equally between male (49%) and female (51%). The majority were white (83%) and had a college degree (76%). They ranged in age from 18 to 81 (average 46 years). Average number of years of NPS employment was 14, and federal employment 16 years. Respondents represented all NPS divisions, including interpretation (19.9%), administration (17.3%), facility management (15.4%), resource management (13.0%), and visitor and resource protection (12.8%). They also represented all NPS regions, centers, and the Washington office. Almost half of the respondents (49%) held a full performance–level position, while 18% held management positions, 16% supervisor positions, and 16% entry-level or developmental-level positions.

Partnership training gaps

The largest gap respondents reported was the "ability to collaborate with philanthropic and grant-making entities to leverage funds toward achieving NPS goals" (–1.32) (see table 1). Other reported gaps were understanding partnership construction requirements (–1.29); ability to establish organizational structures that nurture and manage partnerships and ensure accountability between partners and the National Park Service (–1.23); ability to effectively plan for the commitments needed to build a successful partnership (–1.15); knowledge of techniques used to resolve conflicts, grievances, and confrontations (–1.03); and ability to work effectively with the Department of the Interior's Office of the Solicitor to develop and manage agreements (–1.01).

Table 1. Partnership competencies with the greatest P–I* gaps

Competencies	Mean		
	Importance[1]	Preparation[2]	P–I Gap
Ability to collaborate with various philanthropic and grant-making entities to leverage funds toward achieving NPS goals.	4.58	3.26	–1.32
Ability to ensure that all partnership construction projects meet agency requirements.	4.50	3.21	–1.29
Knowledge of the partnership construction process.	4.36	3.13	–1.23
Ability to establish and implement organizational structures that nurture and manage partnerships and ensure accountability between partners and the NPS.	5.45	4.23	–1.22
Ability to establish and sustain viable partnerships with foundations and other non-profit organizations.	4.69	3.52	–1.17
Ability to effectively plan for the commitments needed to build a successful partnership (e.g., staff time and skills, possible financial commitments, and other resources).	5.48	4.33	–1.15
Ability to develop solutions that cut across traditional department or park boundaries, which foster Service-wide consistency and cooperation.	5.57	4.49	–1.08
Knowledge of the concepts, policies, and practices related to donations and fund-raising partnerships in the NPS.	4.25	3.19	–1.06
Knowledge of the techniques used to resolve conflicts, grievances, confrontations, and disagreements in a constructive manner.	5.18	4.15	–1.03
Ability to align and integrate efforts, core processes, activities, and resources to maximize the effectiveness of developing partnerships.	5.49	4.47	–1.02
Ability to work effectively with the Solicitor's Office to develop and manage agreements.	4.76	3.75	–1.01
Effective communication, listening, and interpersonal skills.	6.62	5.62	–1.00

**Note:* The P–I (preparation minus importance) gap is a diagnostic statistic based on the function between the importance of a competency and the preparation to perform that competency. Caution must be used in interpreting this statistic since a large gap could conceivably include a measure that is not high in importance and therefore not worthy of training resources.

[1]where 1 = strongly disagree and 7 = strongly agree.

[2]where 1 = strongly disagree and 7 = strongly agree.

Past, present, and future partnership behaviors and intent

Almost two-thirds of respondents reported that their past experiences working with partnerships were rewarding and productive (61.2%); however, another 16% reported that their experience had been difficult, frustrating, and not very productive. Almost one-quarter of respondents (23%) had no experience working with partnerships. More than 60% reported currently being engaged in one or more partnerships. The overwhelming majority of respondents indicated they intended to be involved in partnerships in the future because they believed either (1) this would be the primary way the National Park Service would conduct business (53%), or (2) this was a better way to conduct business (35%). Respondents reported being involved in an average of seven partnerships over the past five years.

Partnership attitudes

Partnership motivation statements with the highest agreement (1 = strongly disagree, and 7 = strongly agree) are presented in table 2 (next page) and include the following: partnerships give others a better understanding of my park, the National Park Service, or its mission (5.17); partnerships promote more constructive and less adversarial relationships with stakeholders (4.96); partnerships result in better coordination of policies and practices (4.76); partnerships save time and money for all partners (4.75); partnerships allow the agency to concentrate resources on areas of most critical need (4.74); and partnerships lead to better management decisions (4.73).

Partnership-constraint statements with the highest-level agreement are also summarized in table 2 and were mostly bureaucratic: the lack of reward structure for partnering (4.42); the accountability requirements for partnerships are complex and difficult to carry out (4.41); budgeting practices among stakeholders inhibit partnerships (4.27); and challenges of finding flexibility within rules and regulations for partnering (4.11).

Implications and conclusions

The National Park Service embraces a significant partnership culture. The overwhelming majority of survey respondents (87%) had past experience working with partnerships, whether frustrating or rewarding. Moreover, 60% of respondents were engaged in one or more partnerships at the time of the survey, while only 22.8% had no experience with partnerships.

Statements depicting consequential beliefs (the attitude construct) were segmented into those about motivations to partner and, in contrast, those reflecting constraints to partnerships (i.e., negative aspects of partnerships). Interesting patterns emerged. The lowest mean reported among all motivation beliefs was higher than the highest mean reported for a constraint belief. Therefore, we conclude there is a generally positive disposition toward partnerships held by NPS employees. Specifically, respondents

Descriptive findings revealed that employees generally hold positive views about partnering, yet indicated constraints of bureaucratic and organizational barriers.

Table 2. Strength of selected partnership motivations and constraints

	Percentage of Respondents per Score (7 = Strongly Agree, 1 = Strongly Disagree)							
Partnership motivations	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**Mean score**
Partnerships give others a better understanding of my site/park and the NPS and its mission.	26.1	26.9	15.5	15.0	6.6	5.7	4.2	5.17
Leaders in the NPS should promote and support partnerships as a means of accomplishing mission-oriented goals.	26.6	22.6	17.0	18.5	6.0	4.8	4.6	5.12
Partnerships result in more constructive, less adversarial attitudes among stakeholders.	18.5	25.6	19.5	19.1	8.5	5.3	3.5	4.96
Partnerships result in better coordination of policies/practices of multiple stakeholders.	13.5	20.0	22.7	27.6	8.4	4.3	3.5	4.76
Partnerships allow the pooling of resources, thus saving time and money for each partner.	16.8	20.7	19.4	23.0	8.9	6.2	5.0	4.75
Partnerships allow the agency to capitalize on the strengths of other organizations while concentrating NPS resources in the areas of most critical need.	13.4	23.6	21.6	22.2	7.7	6.4	4.9	4.74
	Percentage of Respondents per Score (7 = Strongly Agree, 1 = Strongly Disagree)							
Partnership constraints	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**Mean score**
The reward structure of this agency provides little incentive to partner with others.	13.5	15.9	15.1	29.7	11.1	9.4	5.3	4.42
As accountability requirements within the agency increase, it makes partnering with others increasingly complex and difficult.	10.0	17.5	20.3	25.3	13.9	8.3	4.7	4.41
Different budgeting processes and regulations inhibit our ability to partner.	9.5	16.7	18.2	24.9	14.0	11.2	5.6	4.27
Partnering is difficult because most organizations we would potentially collaborate with have conflicting missions, approaches, or objectives.	8.4	14.1	18.3	23.2	17.2	12.6	6.1	4.11
I am frequently challenged to find flexibility within the rules to support or participate in partnerships with other organizations.	10.3	14.2	14.8	26.8	11.9	11.8	10.1	4.08

believed that partnerships offer others a better understanding of their parks and the National Park Service while accomplishing mission-oriented goals, and that they resulted in more constructive, less adversarial attitudes among stakeholders. Conversely, the majority of constraints were organizational barriers, including lack of reward structure, increased accountability requirements within the agency, differing budget processes and regulations, and inflexible rules that were seen as disincentives to partnering. In particular, NPS employees who reported being engaged in partnerships expressed concern over requirements set forth by the Office of the Solicitor.

In conclusion, descriptive findings revealed that employees generally hold positive views about partnering, yet indicated constraints of bureaucratic and organizational barriers. This information will enable the National Park Service to target training to specific groups to increase employees' propensity to partner. A greater understanding of the partnership phenomenon may enhance park and protected area managers' ability to obtain support, services, and funds to protect resources while providing educational and visitor opportunities.

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Distribution and abundance of Barbary sheep and other ungulates in Carlsbad Caverns National Park

Implications for native bighorn sheep restoration

By Anthony Novack, Kelly Fuhrmann, Kristin Dorman-Johnson, and Scott Bartell

NATIVE DESERT BIGHORN SHEEP (*OVIS CANADENSIS*) roamed Carlsbad Caverns when it became a national monument in 1923 and seven years later when the Congress designated the area, a national park. However, in the 1940s a combination of excessive hunting, competition with other species, and diseases introduced by domestic livestock resulted in elimination of bighorn sheep from the park (New Mexico Department of Game and Fish 2003). At the same time, a private ranching operation in the Hondo Valley of New Mexico, northeast of the Guadalupe Mountains, introduced Barbary sheep (*Ammotragus lervia*), a native of arid environments in northern Africa. Animals from this ranch began escaping into the countryside in 1943. By 1950, the New Mexico Department of Game and Fish had introduced Barbary sheep into several areas of the state with the intent that this drought-resistant exotic might be a desirable substitute for New Mexico's beleaguered native bighorn sheep in areas that the desert bighorn did not inhabit or from which they had been extirpated (Ogren 1965). In 1959, Barbary sheep were first recorded in Carlsbad Caverns National Park (Laing 2003).

NPS PHOTO

Figure 1. A nonnative ungulate from northern Africa, Barbary sheep first appeared in Carlsbad Caverns National Park in 1959. The founders of the Carlsbad herd probably escaped from a private ranch in the Hondo Valley of New Mexico.

Resource managers at Carlsbad Caverns National Park suspect that the founders of the park's exotic herd were escaped sheep from the Hondo Valley ranch. In 2004, they conducted an inventory of the three species of ungulates that inhabit the park: two native—mule deer (*Odocoileus hemionus*) and collared peccary (*Pecari tajacu angulatus*), and one nonnative—Barbary sheep (figs. 1–3). A long-term goal of the National Park Service is to reestablish bighorn sheep in Carlsbad Caverns National Park and Guadalupe Mountains National Park (Texas), to the southwest of Carlsbad Caverns (fig. 4). Managers at both parks are investigating the possibility of eliminating Barbary sheep and restoring desert bighorn. Results of this survey provide a baseline from which to evaluate the removal of Barbary sheep from, and the restoration of desert bighorn sheep to, Carlsbad Caverns National Park (New Mexico Department of Game and Fish 2003).

Resource managers … suspect that the founders of the park's exotic herd were escaped sheep from the Hondo Valley ranch.

Site description

Located in the northeastern corner of the Chihuahuan Desert in southeastern New Mexico, Carlsbad Caverns National Park consists of 46,766 acres (18,926 ha) of rugged terrain along the south-east–facing Guadalupe Escarpment, which extends northeast with diminishing elevations from Guadalupe Mountains National Park. Elevations in Carlsbad Caverns National Park range from 3,596 feet (1,096 m) to 6,519 feet (1,987 m). The Guadalupe Mountains are an uplifted Permian (270–260 million years ago) limestone reef that rises from the desert lowlands. The escarpment consists of steep slopes and cliff faces that dominate the western two-thirds of the park. Canyons cut the escarpment and open onto desert flats along the escarpment face.

For this study, investigators divided the park into three landscape categories: canyon, escarpment, and ridge (fig. 5, page 95). Grasslands and shrublands occur on both ridges and the escarpment. Canyons contain a mix of habitat types. Vegetation in the canyon

NPS PHOTO

NPS PHOTO

Figures 2 and 3. Mule deer (left) are one of two native ungulates in Carlsbad Caverns National Park. Also known as javelina or pecarí, collared peccary (right) inhabit the southwestern parts of North America and live throughout South America. It is one of two native ungulate species in Carlsbad Caverns National Park.

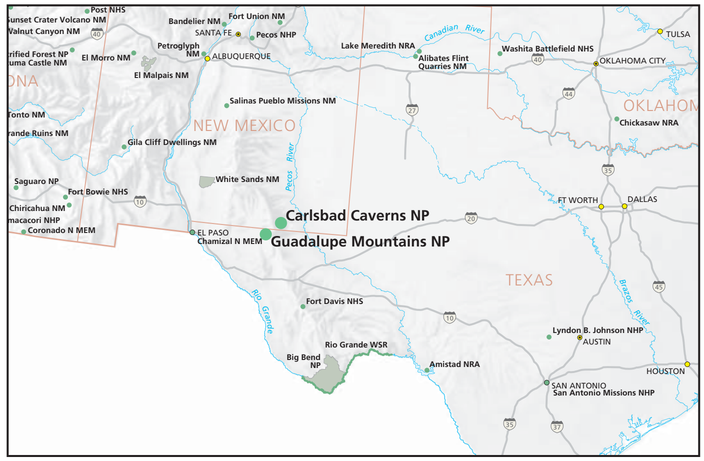


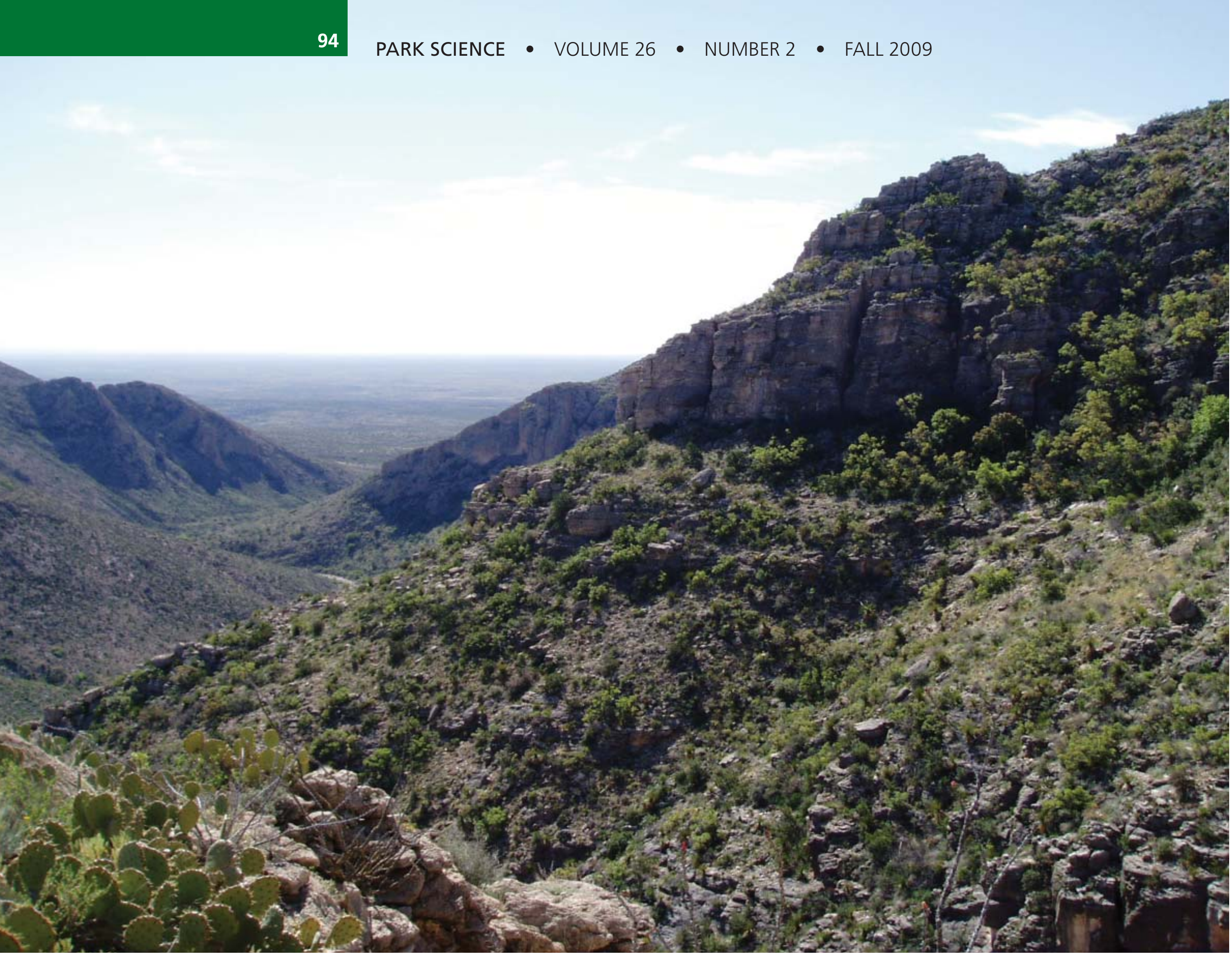
Figure 4. Carlsbad Caverns (New Mexico) and Guadalupe Mountains (Texas) national parks were once home to native bighorn sheep. The National Park Service is studying the potential for restoring this species, which has been displaced by introduced Barbary sheep.

bottoms and escarpments consists of various grasses, as well as sotol (*Dasylirion leiophyllum*), lechuguilla (*Agave lecheguilla*), pinchot juniper (*Juniperus pinchotii*), prickly pear cactus (*Opuntia* spp.), catclaw mimosa (*Mimosa aculeaticarpa* var. *biuncifera*), ocotillo (*Fouquieria splendens*), and yucca (*Yucca* spp.). Common plant species along ridges are alligator juniper (*Juniperus deppeana*), ponderosa pine (*Pinus ponderosa*), two needle pinyon (*Pinus edulis*), mountain mahogany (*Cercocarpus ledifolius*), and sandpaper oak (*Quercus pungens*). Most rainfall (14.8 inches [376.1 mm] annually) accumulates during the monsoon season between late May and early September. Temperatures range from 109°F (43°C) in summer to 1.4°F (-17°C) in winter. Water sources are rare and limited to ephemeral desert springs and seeps.

Surveys

Based on a method by Buckland et al. (2001), investigators used line transects to index densities of Barbary sheep, mule deer, and collared peccary. This type of survey is used effectively to monitor ungulates worldwide (Peres 2000; Devcharan et al. 2003; Novack et al. 2005). In Carlsbad Caverns National Park, investigators established 11 transects, ranging from 1.5 miles (2.5 km) to 1.9 miles (3.0 km) in length (fig. 6, page 96). Transects were typically located along the existing trail network. Transects were widely distributed throughout the study area to ensure adequate sampling and coverage of the three landscape categories. With sighting distances typically in excess of 0.6 mile (1 km), this sampling method is appropriate for the desert landscape of Carlsbad Caverns National Park, which is mostly devoid of large trees and dense stands of brush. Investigators surveyed each transect on average once every 6 to 10 days between 26 March 2004 and 21 September 2005. Surveys began immediately after daybreak, when one or two observers walked the transect line at 0.6–1.2 miles per hour (1–2 kph). When surveyors observed an ungulate or group of ungulates, they recorded the distance of each animal or group from the transect line; they also recorded group size and the sex and age class of individual animals (when possible). Encounter rates, measured as the number of individuals and number of groups per 100 km, were compared for each species in each landscape category (table 1, page 97). Investigators analyzed transect data using Program R (version 2.4.0) (R Development Core Team 2006) and made comparisons running separate Poisson regressions (using log transect distance as the offset) and deviance tests for each subquestion with an alpha value of 0.05 and no adjustment for multiple comparisons. These regression models treat each ungulate count as a Poisson distribution, a common assumption for non-negative integer counts that are not normally distributed. These regression models compare the encounter rate across species or across habitat type, in order to determine whether the differences are strong enough to conclude statistical significance (i.e., unlikely to have been caused by chance alone).

In addition, on 24 April 2004, four observers completed a helicopter survey to locate ungulates. The helicopter followed a predetermined area census grid that covered all landscape categories and passed over 90% of the park, excluding the visitor center and northwestern corner. The helicopter survey provided an estimate or snapshot for one species, Barbary sheep. Observers detected only groups of sheep; single individuals or pairs of animals are likely to have been missed during the helicopter survey.



Results

Observers completed surveys on a total of 297 miles (478 km) of transect lines. They observed Barbary sheep on 7 transects (table 1, page 97) with the highest encounter rates in canyons (57.14 animals/100 km [35.48/100 mi]) and escarpments (47.84 animals/100 km [29.71/100 mi]). Only 11.85 Barbary sheep per kilometer (7.36/mi) were encountered on ridges. Group size ranged from 1 to 34 individuals along these transects, with a mean group size of 7.75 animals. Based on both transect observations and the helicopter survey, observers estimated that a minimum of 40 to 50 Barbary sheep inhabit the park. Observers did not record estimates of the other ungulate species during the helicopter survey.

Mule deer occurred on 7 of 11 transects, with the highest encounter rates occurring on the escarpment transects (55.81 animals/100 km [34.66/100 mi]), and much lower encounter rates in canyons (7.79 animals/100 km [4.84/mi]) and along ridges (14.81 animals/100 km [9.20/mi]). Groups of deer ranged in size from 1 to 14 animals (mean number of animals 3.67).

Surveyors observed collared peccary on four transects; group size ranged from 1 to 22 individuals (mean group size 8.45). The largest number of peccary observations occurred on the escarpment transects (48.50 animals/100 km [30.12/mi]), especially a single transect that followed a dirt road and was open to limited traffic (Sewage Road transect; see table 1 and fig. 4).

Investigators found significant differences in the total number of Barbary sheep (deviance = 53.06, degrees of freedom [df] = 2, probability [p]$<$0.001), mule deer (deviance = 80.02, df = 2, $p<0.001$), and collared peccary (deviance = 127.03, df = 2, $p<0.001$) observed among landscape categories. These differences were constant when comparing the total observations of individuals for all species within a single habitat type (canyons: deviance = 231.2, df = 3, $p<0.001$; escarpments: deviance = 109.61, df = 3, $p<0.001$; ridges: deviance = 29.890, df = 3, $p<0.001$).

The transect data reveal that Barbary sheep, mule deer, and collared peccary are unevenly distributed throughout the park. Mule deer were concentrated on one transect of the escarpment where no Barbary sheep were observed (Sewage Road transect; see table 1 and fig. 4). Surveyors recorded fairly high numbers of Barbary sheep on the two escarpment transects where mule deer were absent (Nuevo and Midnight transects; see table 1 and fig. 4). The absence of Barbary sheep from one escarpment transect (Sewage

NPS PHOTOS (3)

Figure 5. In Carlsbad Caverns National Park, investigators conducted ungulate surveys along transects in three landscape types: canyon (facing page), ridge (left), and escarpment (above). The escarpment is an uplifted Permian-age reef. A segment of Rattlesnake Canyon served as a survey transect in the canyon landscape category. Slaughter Cave Ridge exemplifies the ridge landscape type.

Road) may indicate an inability to adapt to human disturbance; this single transect was the only one located on a road that had occasional vehicular traffic (<3 vehicles per day). By contrast, the greatest encounter rate of mule deer occurred along the Sewage Road transect. Because mule deer readily adapt to human disturbance in central Arizona, they commonly occur near roads and housing developments (Tull and Krausman 2007). Surveyors also observed collared peccary most frequently on this transect. This road is located in the only segment of the park that is dominated by desert shrubland vegetation types, including creosote bush (*Larrea tridentata*), viscid acacia (*Acacia neovernicosa*), tarbush (*Flourensia cernua*), and littleleaf sumac (*Rhus microphylla*). The shrubland provides cover and forage for animals that use the habitat.

Discussion

Resource managers at Carlsbad Caverns National Park need to analyze many factors in the planning process for removing Barbary sheep and restoring desert bighorn sheep. Barbary sheep are socially aggressive toward desert bighorn sheep, have higher reproductive rates, and can transmit diseases to bighorn sheep and mule deer (Ogren 1965, Johnston 1979, Pence 1979, Seegmiller and Simpson 1979, Simpson et al. 1979, McCarty and Bailey 1994). Although Barbary sheep survive on lower-quality forage than bighorn sheep, their diet overlaps with both desert bighorn sheep and mule deer (Krysl et al. 1979), resulting in direct competition (Simpson et al. 1978). Furthermore, given the size of Carlsbad Caverns National Park and the population estimate of a minimum of 40 Barbary sheep, the maximum potential for desert bighorn is probably lower than the threshold of 100 ± 20 animals needed to ensure a viable population (Berger 1990). Because Barbary sheep are larger than bighorns and deer, they possibly impact native vegetation more negatively; for example, Barbary sheep can stand on their hind legs to feed on the flowers of tall yuccas and rare plants that grow on vertical cliff faces.

Successful bighorn restoration would likely require connectivity with another population in the Guadalupe Mountains or periodic translocations of individuals from other populations into the Carlsbad population to maintain genetic diversity. Should a

The absence of Barbary sheep from one escarpment transect … may indicate an inability to adapt to human disturbance.

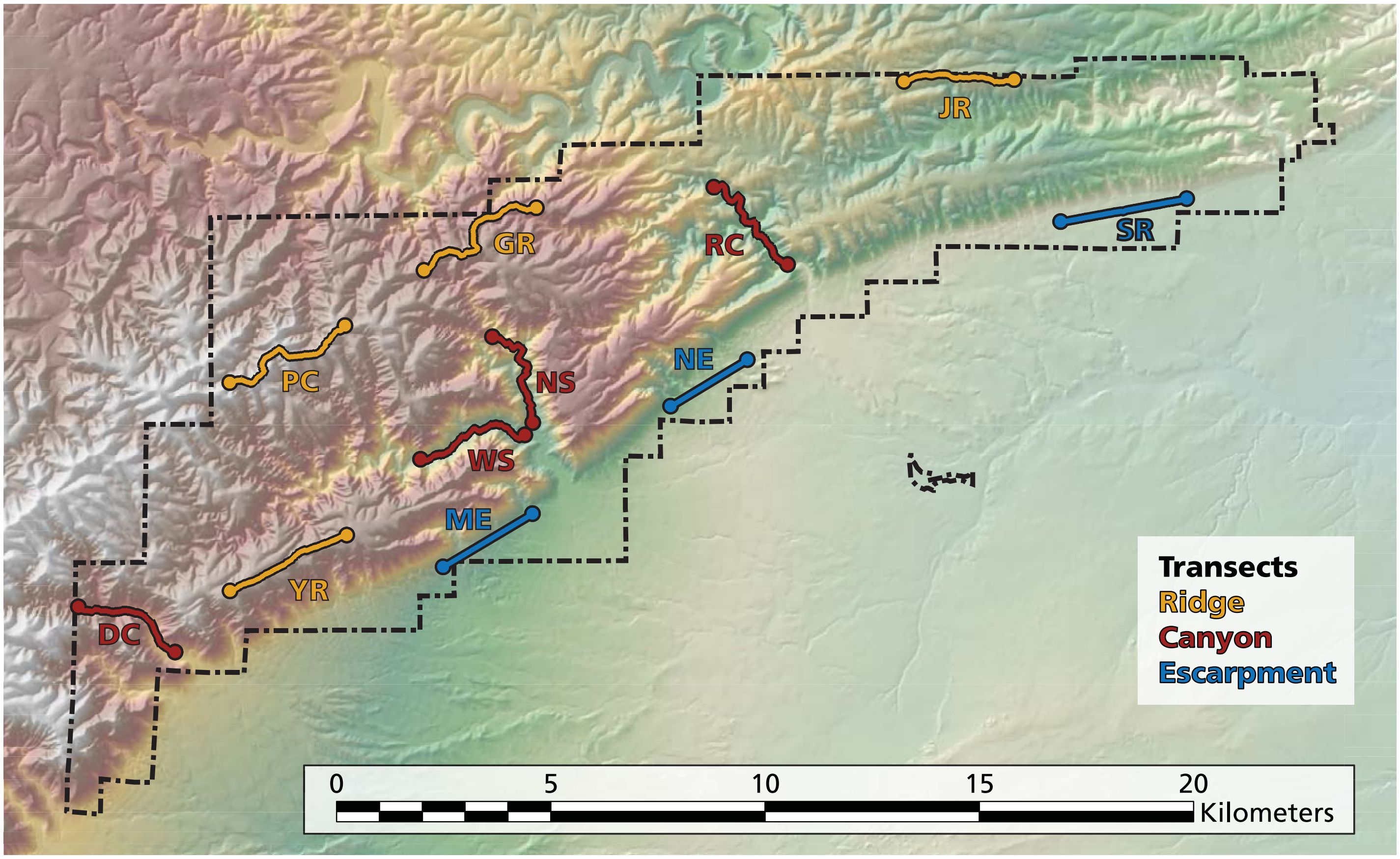


Figure 6. Investigators surveyed 11 transects for ungulates within Carlsbad Caverns National Park: Juniper Ridge = JR, Guadalupe Ridge = GR, Putnam Cabin = PC, Yucca Ridge = YR, Rattlesnake Canyon = RC, Double Canyon = DC, West Slaughter = WS, North Slaughter = NS, Nuevo Escarpment = NE, Midnight Escarpment = ME, and Sewage Road = SR.

bighorn population become established in Guadalupe Mountains National Park, that source of genetic diversity would help ensure the long-term viability of the Carlsbad Caverns National Park population.

Complete eradication of Barbary sheep from Carlsbad Caverns National Park is perhaps not possible because source populations exist in close proximity, and these sheep are able to disperse long distances (Cassinello 1998). In addition to the Barbary sheep population residing in the Guadalupe Mountains (an estimated 400–700 animals), more than 1,000 animals live within 300 miles of this area (482 km) in Presidio, Brewster, and Jeff Davis counties of western Texas (Mungall and Sheffield 1994). Preventing reinvasion by Barbary sheep would require collaboration with the New Mexico Department of Game and Fish to increase hunter harvest or extend the hunting season in the area surrounding Carlsbad Caverns National Park and the Guadalupe Mountains. Making the area a trophy hunt location may promote a reduction in numbers. Recreational hunting does not reduce Barbary sheep numbers within Carlsbad Caverns National Park because laws prohibit public hunting inside park boundaries. Furthermore, Barbary sheep may be drawn to the area during the hunting season because of the refuge it provides.

Complete eradication of Barbary sheep from Carlsbad Caverns National Park is perhaps not possible because source populations exist in close proximity, and these sheep are able to disperse long distances.

One strategy identified in New Mexico's long-range plan for desert bighorn sheep management is to eradicate nonnative species, including Barbary sheep, from suitable bighorn sheep range of Carlsbad Caverns and the Guadalupe Mountains (New Mexico

Table 1. Ungulate encounter rates per 100 kilometers in Carlsbad Caverns National Park

Transect	Kilometers surveyed	Encounter rate: Barbary sheep Individuals	Barbary sheep Groups	Mule deer Individuals	Mule deer Groups	Collared peccary Individuals	Collared peccary Groups
Juniper Ridge	50.0	0	0	26.00	6.00	4.00	2.00
Guadalupe Ridge	26.5	60.40	7.55	26.41	7.55	0	0
Putnam Cabin	29.0	0	0	0	0	0	0
Yucca Ridge	29.5	0	0	0	0	0	0
Total (ridge)	**135.0**	**11.85**	**1.48**	**14.81**	**3.70**	**1.48**	**0.74**
Nuevo Escarpment	40.0	45.00	2.50	0	0	10.00	2.50
Midnight Escarpment	41.5	132.53	7.23	0	0	0	0
Sewage Road	69.0	0	0	121.70	31.88	100.00	8.70
Total (escarpment)	**150.5**	**47.84**	**2.66**	**55.81**	**14.62**	**48.50**	**4.65**
Rattlesnake Canyon	57.5	17.39	6.96	10.43	1.74	8.70	3.48
Double Canyon	30.0	53.33	10.00	6.67	3.33	0	0
West Slaughter	57.5	113.04	17.39	10.43	5.21	0	0
North Slaughter	47.5	44.21	6.32	2.11	2.11	0	0
Total (canyon)	**192.5**	**57.14**	**9.87**	**7.79**	**3.12**	**2.56**	**1.03**
Group size range			1–34		1–14		1–22
Mean			7.75		3.67		8.45

Department of Game and Fish 2003). Removal of nonnative Barbary sheep from Carlsbad Caverns and Guadalupe Mountains national parks is in accordance with National Park Service policy and would need to be successfully accomplished before attempting any translocation of desert bighorn. Past removal efforts of Barbary sheep from the park were limited to a few animals shot between 1979 and 1993. A successful program for the removal of Barbary sheep could incorporate the "Judas" technique, which managers have used effectively to control social ungulates, such as goats, in areas of difficult topography, dense vegetation, or low density of animals (Keegan et al. 1994). Investigators capture and affix radio collars to a sample of target animals. The radio collar allows managers to quickly locate the animal when it has rejoined with conspecifics. Once a radio-collared animal is relocated, the other members of the herd can be lethally removed via aerial or ground shooting.

Conclusion

Recent anecdotal evidence from park personnel and visitors indicates that Barbary sheep numbers may be increasing. Reports of Barbary sheep from Guadalupe Mountains National Park are more frequent at the southern end of the Guadalupe Mountains. A drier climate trend over the past two years has resulted in more sightings at springs and seeps in the park. Barring some major disturbance such as wildfire, extensive hunting, or introduction of another exotic ungulate species, no major changes are expected in the status of Barbary sheep or other ungulate populations within Carlsbad Caverns National Park.

Managers at Carlsbad Caverns and Guadalupe Mountains national parks are expecting to receive funding in 2010 to begin work on planning and compliance activities for addressing the Barbary sheep issue. Removal of Barbary sheep from the Guadalupe Mountains must be a joint effort between the New Mexico Department of Game and Fish and the National Park Service. Although the feasibility of total removal is remote, reduction in numbers will improve the chances of successful bighorn sheep restoration.

Managers could reapply the census method used for this survey, if action is taken to remove Barbary sheep, to assess program effectiveness, and determine if native ungulate distribution is influenced by removal of this nonnative species.

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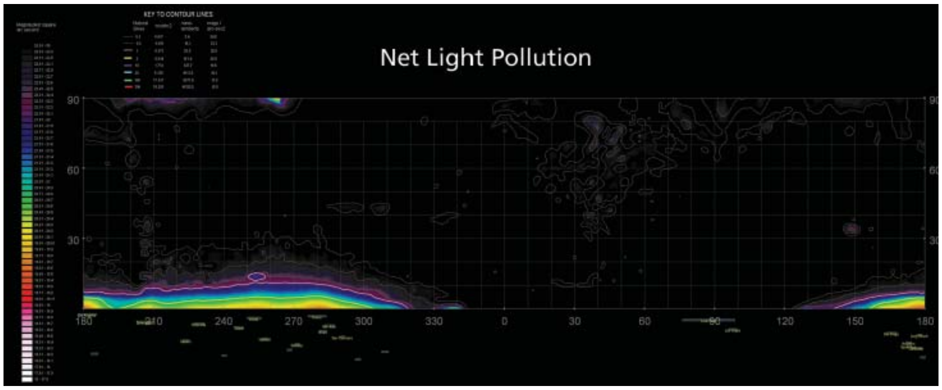
PS

Field Moment

Mt. Whitney, Sequoia National Park

22 July 2009
12:30–2:00 am



NPS/NIGHT SKY PROGRAM (3)

THESE REMARKABLE IMAGES ARE the products of Dan Duriscoe, physical scientist with the National Park Service Night Sky Program. Using specialized cameras (bottom), Duriscoe visits national parks and records data that are later analyzed to determine the quality of night skies and identify sources of light pollution. The images provide a baseline for managers striving to preserve dark night skies in national parks.

At 14,495 feet, Mt. Whitney is the highest point in the lower 48 states and an excellent place to observe the night sky. A small minority of visitors spends the night here, but they can be rewarded with a front-row seat for viewing the cosmos. "Mt. Whitney was on my short list for more than seven years," Duriscoe says, "and we were finally able to get this done in July 2009."

Shortly after midnight, Duriscoe ran through his routine of connecting the computer, aligning the telescope mount, and taking test images, things he has done hundreds of times before but that were much more difficult in the rarefied atmosphere. "Just trying to install one of the machine screws for attaching the tripod to the mount took about five minutes of fumbling," Duriscoe notes. "Once we got going . . . and the images began to show up on the computer screen, I knew it was worth the effort."

The panorama (top) is an unfiltered photo mosaic combining 60 images. You can see Mt. Langley, Kaweah Peaks, the Great Western Divide, and, of course, the familiar boulders and Smithsonian Shelter of the Mt. Whitney summit. The air glow is so bright that light pollution is hard to see. Look carefully for the cities of Fresno and Visalia (behind the shelter), a few cars on Highway 395 near Bishop (far right and far left), and the city of Las Vegas (left, beneath a large thunderstorm over the Panamint Mountains in Death Valley).

The false-color image (middle) is not a photo mosaic, but is a contour plot of more than 5,000 measurements of background

sky brightness derived from 60 images. It reveals net light pollution that is detectable by humans. (Made the same night, the mosaic and false-color image do not align with each other.) Duriscoe's analysis indicates that the vast majority of the sky was free from artificial light pollution on this night, and that Mt. Whitney remains one of the very best locations in our national parks for observing the night sky.

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