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PARK Science

Integrating Research and Resource Management in the National Parks

National Park Service
U.S. Department of the Interior

THREATENED CORAL AT BUCK ISLAND REEF

Monitoring captures the devastating 2005 bleaching event of the barrier reef

- Learning center goes virtual
- The *Park Science* interview: Mike Soukup
- Remembering Eric York
- Adaptive management for national parks

PARKScience

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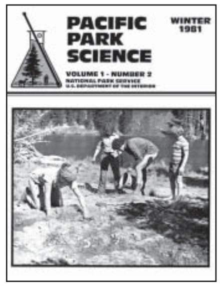
From the Editor



1981

1995

2000

2008

Colorful content

***PARK SCIENCE* HAS UNDERGONE** several redesigns since its inception in 1980, but never before have these changes embraced full color. I am excited by this opportunity to present the findings and applications of science to park management in this engaging format. This update facilitates better use of photography, maps, graphs, and other illustrations to impart relevant information. It strengthens our National Park Service identity and reflects the progression of science applications in national park management over the past few decades.

The new format also incorporates editorial improvements: magazine- and journal-style articles, such as "Science Features" and "Research Reports," within new and revised departments. Introduced in this issue, "Profile" presents interviews and career reflections of resource professionals. "20 Years Ago in *Park Science*" reprises past perspectives on NPS science and resource management, provoking reflection on progress (or inaction). "Field Moment" shares a researcher's or resource manager's personal, scientific field experience in a national park. "Tribute" recognizes the contributions of active, recently retired, or deceased resource professionals. Other departments will debut in future editions.

An important part of the redesign is making a concerted effort toward content planning. In the year ahead we will report on climate change, the integration of inventory and monitoring processes in park planning, and effective roles for Cooperative Ecosystem Studies Units. In addition to expanding our information sources within the National Park Service, we will continue to rely on guest editors to help develop theme issues. In the near future we plan to publish theme editions on soundscape management and the Canon National Park Science Scholars program.

The transition to the new format has taken more than a year, and I hope you find it worth the wait. We encourage your participation as a contributor and look forward to bringing you colorful reports of science in parks for years to come.

Jeff Selleck

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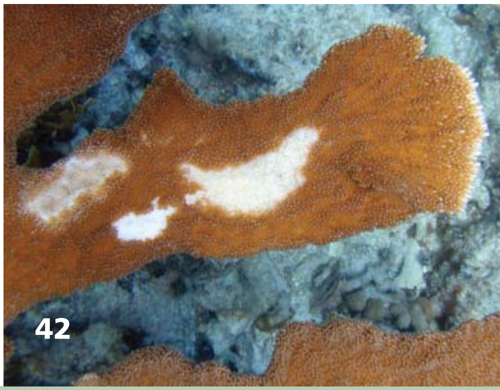

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DEPARTMENTS

SCIENCE FEATURES

CASE STUDIES

ON THE COVER

Tropical marine habitats of the U.S. Virgin Islands host reef communities such as the elkhorn coral (*Acropora palmata*) of Buck Island Reef National Monument. Elkhorn coral is one of the first coral species to be protected under the Endangered Species Act. Surveys in 2003–2004 determined the species' distribution and documented wave damage, predation, disease, and other stressors such as bleaching. Investigators continue monitoring the effects of the severe bleaching event of 2005 (see page 36).

NATIONAL PARK SERVICE/HANK TONNEMACHER

FUTURE ISSUES

Fall 2008:
Ten Years of Canon National Parks Science Scholars

Spring 2009:
Now accepting articles, news, updates, and photographs. Visit http://www.nature.nps.gov/ParkScience for author guidelines or contact the editor at jeff_selleck@nps.gov or 303-969-2147.

Contributor's deadline: 15 January 2009.

PARK SCIENCE ONLINE

www.nature.nps.gov/ParkScience/

- Expanded interview with Mike Soukup
- Meetings of interest
- Full tabular data and additional illustrations
- Key word searching
- Complete catalog of back issues
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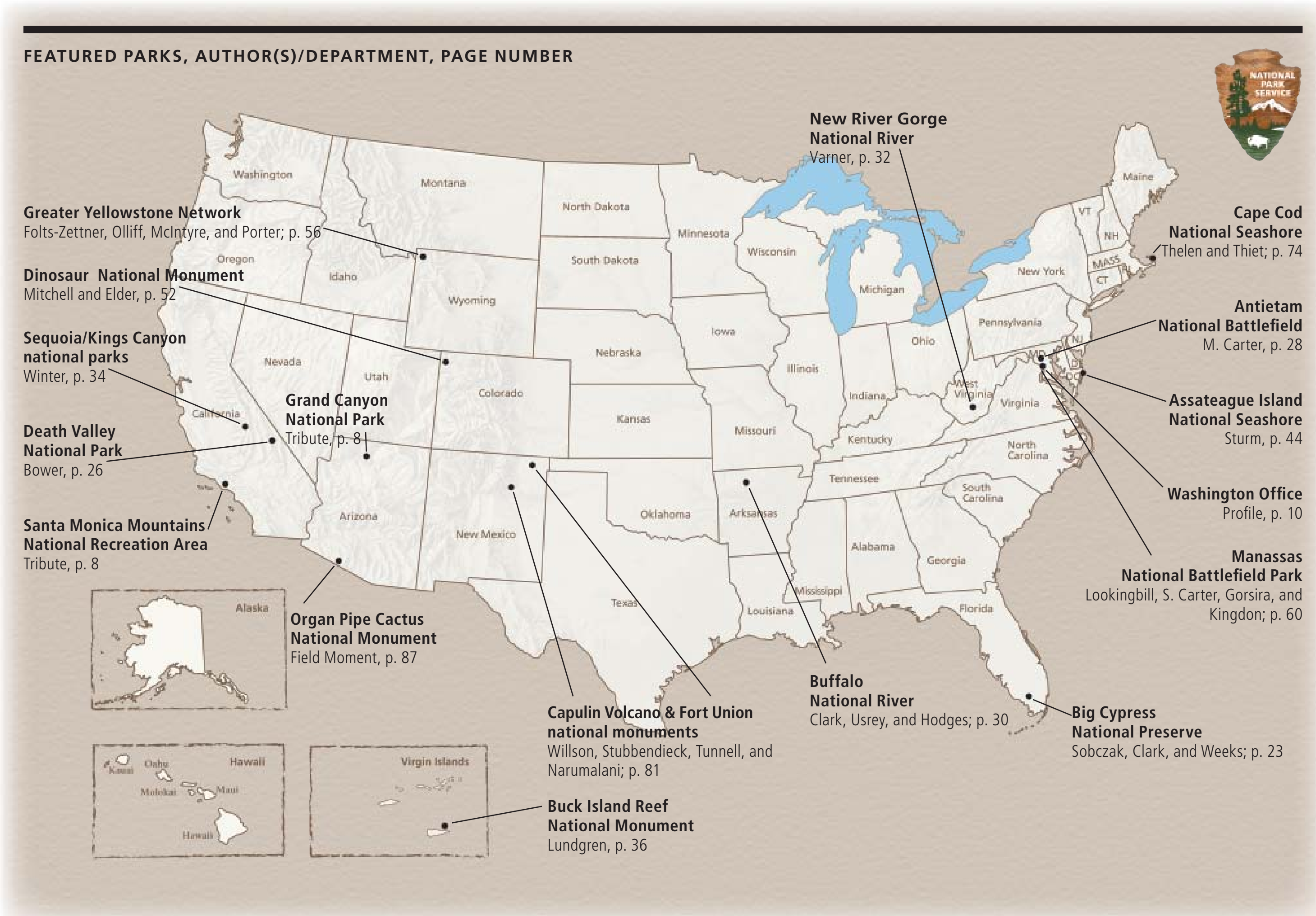
RESEARCH REPORTS

In This Issue



MASTHEAD (CONT'D FROM PAGE 2)

Park Science is a research and resource management bulletin of the U.S. National Park Service. It serves a broad audience of national park and protected area managers and scientists and provides public outreach. Published three times annually in the spring, summer, and fall/winter, *Park Science* reports the implications of recent and ongoing natural and social science and related cultural research for park planning, management, and policy. Thematic issues that explore a topic in depth are published occasionally. 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. The publication is funded by the Associate Director for Natural Resource Stewardship and Science through the Natural Resource Preservation Program.

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.

Facts and views expressed in *Park Science* are the responsibility of the authors and do not necessarily reflect opinions or policies of the National Park Service. Mention of trade names or commercial products does not constitute an endorsement or recommendation by the National Park Service.

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Thelen, B. A., and R. K. Thiet. 2008. Cultivating connection: Incorporating meaningful citizen science into Cape Cod National Seashore's estuarine research and monitoring programs. Park Science 25(1):74–80.

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Comments and Corrections

Subscriptions updated

WE RECEIVED MANY COMMENTS about *Park Science* as a result of our request in January to confirm and update your subscription. I appreciate the feedback, both on the content of the publication and on the subscriptions, which indicated where we could reduce hard-copy waste. (We now have nearly 350 readers who prefer to be notified when the online edition is posted than to receive the print edition.) Decreasing waste is certainly important, but if you neglected to update your subscription and want to receive either the hard copy or e-mail notification in the future please take a minute to subscribe online at www.nature.nps.gov/ParkScience; click "Subscribe," and choose how you'd like to receive the publication.

Following are some of the comments from our recent inquiry:

- Thanks for making this publication easy to subscribe to.
- This is a very popular publication and we use it for many things.
- *Park Science* is read by many rangers, volunteers, and park partners.
- What a valuable, professional publication!
- I would like to share *Park Science* with new employees who may not have subscribed at the time of publication.
- Hard to read light brown print on white background.
- Love *Park Science*. We would like to receive additional copies, as we hand them out to international visitors.
- If I can have full access on the Web site, I do not need to receive a paper copy.
- Subscribing by e-mail seems very sensible, efficient, and quick. I very much appreciate the material in *Park Science*.
- I'll try e-mail notification. Thanks for mentioning that option.
- Thanks for the opportunity to subscribe online. Saves money and space.
- Discontinue hard copy; e-mail copy is sufficient.
- We would accept an online version and save some trees. Thanks.
- The print edition is beautiful, but I'm happy to save paper with an electronic subscription. Your new *Park Science* Web site looks great!
- I like the hard copy! Thanks for keeping this as an option.
- The information is good!
- Great articles!
- Wonderful publication with outstanding valuable information! Thanks for the service.
- Keep up the good work and excellent quality of these publications.

Thanks again for your input.

—Editor

Corrections

TABLE

Park Science 24(2):62–66. Peterjohn, B., B. Eick, and B. Blumberg. 2007. Native grasses: Contributors to historical landscapes and grassland-bird habitat in the Northeast.

We listed three grassland bird species under the incorrect park unit (i.e., Antietam) in table 1 on page 66. Savannah sparrow (9) and bobolink (74) should be under Gettysburg; Henslow's sparrow (1) should be under Manassas. The number of birds reported for the estimated populations (in parentheses here) was correct.

■ ■ ■

TABLE

Park Science 24(2):72–77. Hammitt, W. E., L. K. Machnik, E. D. Rodgers, and B. A. Wright. 2007. Workforce succession and training needs among National Park Service program managers.

The final line of data presented in table 2 on page 76 was incomplete. It should have read as follows:

Table 2. Significant differences in competency preparation among GS grade levels

No.	Competency description	Grade Level Average Ratings GS-12	GS-13	GS-14+
33	Ability to effectively compete for funding through large-scale partnerships that may include diverse/opposing viewpoints.	4.64[a]	5.00	5.49[b]

PS

20 years ago in Park Science

Climate change

ON FEB. 10, 1988, INTERIOR DEPUTY Undersecretary Becky Norton Dunlap appointed a 12-person Departmental Working Group on Climate Change (DWGCC) . . . to look into potential impacts of climate change on [Department of the Interior] bureaus and to come up with short[-] and long[-]term options as possible responses and mitigation measures. . . . In the face of such possibilities [i.e., certain animal and plant communities being stressed beyond their abilities to survive], the NPS science program must ask itself if the inventory and monitoring guidelines now under consideration will give the baseline information needed against which to measure future climate-induced changes. In other words, are we ready to do our part in assessing the natural responses that seem to be taking place? And as we find the answers, can we set up [an] intra-System strategy for dealing with these changes?

Reference

Matthews, J. 1988. Editorial. Park Science 8(3):2.

Communicating research findings

THE RESULTS [OF AN INFORMAL questionnaire to all NPS scientists involved in fish and wildlife research] indicate that [78% of] NPS researchers place a great importance on publications. This was evident in the written comments attached to many questionnaires. Several individuals pointed to the need for an NPS technical report series as an outlet, particularly for management-oriented publications. The high interest in publications struck me as somewhat ironic because the reviews I have done of NPS scientific literature . . . have shown a low portion (< 20%) of NPS research winds up in professional journals. . . . These responses seem to indicate that more than any other factor, the NPS natural science program could be greatly improved by better communication between scientists and managers. This is not a new problem. It was voiced time and again in interviews I have conducted with retired NPS biologists in the course of my research.

Reference

Wright, R. G. 1988. Improving the NPS science program: A rejoinder. Park Science 8(3):4.

Tribute

A biologist's biologist: Remembering Eric York 1970–2007

Erik York

NPS/EMILY GARDING

Editor's Note: This memorial was contributed by many of Eric York's colleagues and friends throughout the National Park Service.

WITH THE PASSING OF ERIC YORK ON 2 November 2007, Grand Canyon National Park and the National Park Service lost an extremely talented and dedicated wildlife biologist. More importantly, the mountain lions, carnivores, and other wildlife he studied lost one of their most knowledgeable and devoted human allies and advocates. Eric's work, in fact his life, centered on his passion for wildlife, the outdoors, and grand landscapes of our national parks and other wildlands.

Eric worked at Grand Canyon National Park in Arizona as a wildlife biologist studying carnivore movement patterns from July 2006 until his death, and previously as a contract biologist starting in 2003. He also worked for Santa Monica Mountains National Recreation Area in California and Lake Clark National Park and Preserve in Alaska, in addition to his work for the Biological Resources Discipline of the U.S. Geological Survey and the University of California–Davis Wildlife Health Center on mountain lions and other large carnivores, specializing in live-capture techniques.

Grand Canyon lion study

Beginning in 2003, the National Park Service participated in a radiotelemetry study of mountain lions within the Grand Canyon ecosystem to complement existing studies using remote cameras, track surveys, and scat and hair collection. Eric's skill in trapping techniques and his compassion in handling captured cats were key to the successful implementation of the telemetry program that allowed collection of specific information about lion predation habits, reproductive activity, and other behaviors.

Objectives of the study include determining behavior patterns of lions that use human-populated areas; determining the impact of park infrastructure, such as roads, on lion behavior; and analyzing the effects of management of adjacent public lands on lion populations in order to develop management and conservation strategies. Research to date showed that although collared cats use sites surrounding Grand Canyon's developed areas, no significant lion/human interactions have occurred. In fact, Eric's work demonstrated instead that humans have a serious impact on lions. During the study, the only confirmed mortalities of collared lions were caused by humans: two were killed by vehicle collisions on park roads and two by legal hunting outside the park.

An additional component of Eric's work for Grand Canyon's Division of Science and Resource Management was his active collaboration with interpretive staff for outreach and education about his research on lions in the park. This outreach, via ranger programs, site bulletins, and the Grand Canyon Web site (e.g., http://www.nps.gov/grca/naturescience/200710mtlionkit.htm), reached thousands of visitors each year.

Santa Monica Mountains carnivore study

Eric worked at Santa Monica Mountains National Recreation Area for more than 10 years. He came to the park in 1995 after finishing his master's thesis on fisher ecology in Massachusetts. It was his first trip west of the Mississippi River and brought him to a new challenge: capturing and radio-collaring bobcats and coyotes in a complex urban landscape outside Los Angeles. This research is perhaps the longest-running continuous radio-tracking study of bobcats, and resulted in many important findings and publications about the ecology, behavior, and conservation of carnivores in urban areas. Eric was critical in the establishment of the carnivore study from 1995 to 1998 and continued to assist with animal capture work through 2006. From the beginning, he was interested in studying mountain lions in the Santa Monica Mountains, where they had not been studied before and are perhaps the ultimate challenge for conservation in urban areas. Eric worked full-time in the Santa Monica Mountains from early 2002 through 2003 to begin a project using GPS radio collars in the study of mountain lion ecology and behavior in the park. He caught his first mountain lion in July 2002. The lion research project continues to provide critical information about how these animals move about, hunt, reproduce, and die in an urban landscape. Eric leaves an incredible legacy of important biological findings, colleagues trained and projects begun, and good friends made and kept.

Pneumonic plague

In 2007, Eric was monitoring nine collared lions in and around Grand Canyon National Park, and also collecting data on bighorn sheep, black bears, bobcats, coyotes, and other species. Two of the collared female lions produced litters last summer, and Eric found the kittens, which he ear-tagged to incorporate them in the study, by using the GPS locations of their mothers. A few days prior to his death, he found the mother of one of these litters dead and recovered her body to perform a postmortem examination.

The Centers for Disease Control and Prevention (CDC) confirmed pneumonic plague as the cause of Eric's death. With the detection of the same strain of plague in the remains of the necropsied lion, the CDC concluded that Eric contracted the disease from the animal. While plague can be transmitted to humans through the bites of rodent fleas, Eric's exposure likely was through direct contact with the infected lion. Although plague is endemic in northern Arizona, cases of pneumonic plague in humans are very rare. Eric's death reminds us of the inherent hazards, including the less obvious ones, that biologists are exposed to while working to manage and conserve wildlife. It is also a reminder to think about risks and how to mitigate them. The National Park Service is developing additional guidance to assist biologists in identifying risks and the appropriate work practices and personal protective equipment to make their job safer. Taking actions to ensure that a tragedy such as Eric's death never happens again is a way that all NPS employees can honor this great man.

In memory

Eric will be remembered as a biologist's biologist, and his expertise went far beyond that of his intimate knowledge of the lions and other species he tracked at Santa Monica Mountains and Grand Canyon. During his career Eric captured and tagged 23 different species of carnivores, and he worked in many areas of the United States and the world, including Pakistan, where he researched the elusive snow leopard, and Chile. In her comments at the celebration of his life held on the canyon rim on 15 November 2007, Elaine Leslie, Eric's former supervisor, said, "Eric was much like the lions he stalked. To catch a glimpse of the elusive Eric, you needed to be up at dawn as he hurried in and out of the office to gather up his freshly charged radio, dart pistol, and other tools of the trade. By sunrise you could find him on the carcass of a freshly killed deer or elk, carefully reading the signs and placing a snare. Then off he would run—yes, run—to check his traplines."

She also said, "If you couldn't be Eric York, you at the very least wanted to hang out with him in the field and absorb every ounce of skill the man had to offer." Those who learned from Eric—be they NPS wildlife biologists, interpreters and educators, researchers in Chile and Pakistan, or his family and friends—will remember Eric by continuing his research and by sharing his passion for big cats, wildlife, and wild places.

"If you couldn't be Eric York, you at the very least wanted to hang out with him in the field and absorb every ounce of skill the man had to offer."

—Elaine Leslie

Eric York was a native of Shelburne, Massachusetts. He earned a Bachelor of Science in Wildlife Management from the University of Maine, and a Master of Science in Wildlife Conservation from the University of Massachusetts.

Cards, letters, and condolences may be sent to Eric's parents, Tony and Launie York, 180 S. Shelburne Road, Shelburne, MA 01370. Donations can be made in Eric's name to (1) The Grand Canyon Association, attn: Brad Wallis, P.O. Box 399, Grand Canyon, AZ 86023, www.grandcanyon.org; (2) Felidae Conservation Fund, 14 Cove Road, Belvedere, CA 94920, www.felidaefund.org; and (3) The Wildlands Fund, Division of Massachusetts Fish and Wildlife, attn: Julie, 1 Rabbit Hill Road, Westboro, MA 01581.

Profile

Associate Director Mike Soukup with his wife and children.

NPS/RICK LEWIS

Legacy of an intellectual leader

By the editor

After serving for 12 years as associate director of Natural Resource Stewardship and Science, Mike Soukup retired from the National Park Service in November 2007. During his tenure he led the National Park Service through a period of tremendous growth in its applied science programs. Through the Natural Resource Challenge initiative he helped obtain broad support and funding for the addition of important scientific capabilities. This included building a national network for inventory and monitoring that is fundamental to understanding the condition of park resources. His involvement in a wide variety of management issues has helped the National Park Service become a leader in conservation science. He argued persuasively for science as the basis for sound park management decisions, and engaged world-class scientists and NPS managers in the discussion of advancing National Park Service science in the 21st century. To help park managers meet their research needs and to increase the use of parks for general research, he nurtured an atmosphere of partnership with the academic community. Through a prestigious awards program, he celebrated the excellent work of staff and colleagues and recognized their achievements. Though realistic in his approach to science administration, Mike also is a visionary. His many speeches and articles often articulated the concept of a National Park Service with the responsibility of educating the citizens of this country about living compatibly with nature. His energetic, approachable, and cosmopolitan manner engendered support of the National Park Service and the professional care of the national parks.

The Park Science Interview with Mike Soukup

By the editor and associate editor

**Note*: The following interview is an excerpt. Read the full-length conversation online at http://www.nature.nps.gov/ParkScience for more of Mike's reflections on his career, climate change, building the Natural Resource Challenge, determining research priorities, successes and disappointments, and sharing life with his family.

***Park Science*: What has the transition to private life been like?**

Mike Soukup: The transition has been harder than I had thought. It was difficult to change gears and let go of all the loose ends that an associate director deals with. The worst part is abruptly losing daily contact with key colleagues, your management team, good friends, and in some cases issues in [the Department of the] Interior, like water rights in Black Canyon, that need close attention. The key thing a retiree must grapple with is that you become irrelevant in the daily press of responsibilities and potential opportunities of your former job. One day you're leading the troop, the next day you're just another baboon! At retirement someone reminded me that Charles de Gaulle said something like "The graveyards are filled with indispensable men." You hope that others will continue on what you perceive as the right path. In natural resources there's a great assemblage of folks who can do that, or better.

The other part of transition is having so many possibilities for your time. Luckily, but with some forethought, I have a wife I love to spend time with, eight-year-old twins to homeschool, a new house to outfit, a 38-foot Finnish ketch to maintain, and a modest book contract. I had a lot of thank-yous to write for the kind words, deeds, and gifts at retirement. So the time has flown.

Tell us about the "Washington perspective" of the day-to-day workings of the National Park Service and what it takes to succeed as a high-level NPS manager.

MS: First of all, I wouldn't trade my Washington experience for anything. [The Department of the] Interior is a concentrated feast of opportunity, drama, theater—and a cram course in human nature. The political arena attracts and brings out the best and the worst in people.

The worst part of being in Washington is missing so many opportunities. National Park Service leadership spends so much of its time fending off damaging agendas that can come from political parties, vested interests, and sometimes even supporters. Each new administration comes in to make its mark on the bureaucracy, often with simplistic remedies. Revisiting many of these could be eliminated if there were a system in place that fosters and taps institutional memory. Most of your time is spent in damage control rather than constantly improving and building a stronger agency. That is frustrating, and at times wrenching. But there are ways to contribute that can't be matched elsewhere. You certainly get a front-row seat. You can't possibly understand what's happening (or not) in your park or NPS job without spending a fair amount of time in Washington. It's a trip!

I think to be successful you simply have to have a sense of where your program ought to go. Then you have to be patient and persevere. If you have a vision of where the National Park Service should go that rings true, there are many good people who will want to help [you take it] there. I remain in awe of the talent and motivation available within and outside the Service that are interested in stepping up for national parks.

Finally, if you believe in what you're doing and tell it straight, people will listen. Over time, that will give you credibility and staying power. Staying there for a decade or so is a real advantage. Real traction on tough issues takes time. But it is truly worthy of anyone's time who wants to make a difference.

Preserving institutional memory is a concern of yours. What are the best ways to capitalize on institutional knowledge from people like you who retire?

MS: Just before I left, I worked with Jerry Simpson and Susan Woods in Human Resources to set up an emeritus program aimed especially at scientists and technicians. It should be modeled after academe, providing modest travel, office space, and administrative support for those who would like to remain engaged at a slower pace, or without supervisory burden. I hope this happens—it's a shame to lose hard-won perspective when some recognition and minimal investment might capitalize on the massive investment represented in a 30-plus-year career.

Understanding complex systems is the key to managing them for long-term preservation. Knowledge must be valued, cultivated, accumulated, and assimilated assiduously so that it can be applied with ever greater certainty. When long-term knowledge disappears, in some cases abruptly, it's not only a great shame, it's really poor investment management. In the landscape of the 21st century we won't have leeway for guesswork. The sum of the curve under "seat-of-the-pants management" will not be unimpaired resources.

What will your generation of park managers pass on to future generations?

MS: The superintendents of my generation made a quantum leap in understanding the context of successful park management! Perhaps it was hurried along by the [1980] "State of the Parks" report [to the Congress] by Ro Wauer, [then head of the natural resource management office in

Washington]. Professionalization of the air and water quality programs initiated by [former associate director] Dick Briceland laid some important groundwork for being successful in technical arenas outside park boundaries. These were important steps. Realization of the importance of extra-boundary processes in the long-term health of parks set in motion long-term changes in management perspective that had to occur.

South Florida Research Center made it possible to prescribe what it takes to save the Everglades. [The park and regional office originally opposed establishment of the science center.] I'm afraid, as documented in Michael Grunwald's *The Swamp* (the paperback version has an important update), the opportunity is being lost.

Overall, I am amazed at how good the new generation of superintendents is at working

If politics dictates the answer to a resource issue initially, natural phenomena will still have the last say. Putting Galileo in prison isn't going to make the sun revolve around the Earth.

When I arrived at Everglades National Park, I was told of one past Everglades superintendent who had put a sign on his wall saying, "If it's outside the park, I don't want to hear about it!" That certainly changed when [Superintendent] Mike Finley dramatically championed the coupling of the Everglades with the extra-boundary processes that are determining its future. The Everglades faces the loss of the very resources the park was created to preserve, but not because of anything that was done internally. The imposition of a serious science effort for the Everglades by Nat Reed [former assistant secretary of the Interior] in the form of the

with science and local communities to build a strong consensus on the future quality of life everyone wants. A united, local constituency can counter the tremendous pressure the National Park Service and parks face every day from vested interests and agendas that are usually focused on short-term benefits.

What part did you play in this transformative thinking?

MS: Time will tell. I had an advantage of working at park, regional, and Washington levels, so I got to see how things worked and learned what didn't work. I think I was able to convince NPS leaders that we had to broaden our organizational culture to include scientific excellence in order to be as successful in the future [in preserving parks] as we had been in the past [in providing visitor services and accommodations]. That was made easier because of the lack of success we were having in environmental compliance, which requires we explain the environmental consequences of an action. We had been losing in the courts where the "intuitive" management actions of the Service were being successfully challenged, and we had constant pressure from other agencies to show why we had opposed some of their actions along park boundaries (Bureau of Land Management, USDA Forest Service), upstream (Bureau of Reclamation), overhead (i.e., overflights, Federal Aviation Administration), and on barrier islands (armoring roads, Department of Transportation).

I came to Washington with a lot of respect for park operations and the elegance of successfully managing park use in harmony with long-term protection. While resource health must be the touchstone, a superintendent must cover all the bases, so the proper orchestration of all divisions is necessary. Yet we can't lose sight of the fact that the National Park Service is primarily a—and perhaps the premier—resource management agency. It's essential to never lose sight of that. When I was a regional chief scientist, a park superintendent once looked accusingly at me and said, "If it weren't for these natural resource issues, I'd have time to manage my park." The Service must integrate resource management and science as a priority in park operations, not just as something that's nice to have when an issue blows up.

What was your greatest personal career success?

MS: It was probably shepherding the Natural Resource Challenge from concept to "boots on the ground," though this was a widely shared accomplishment. The Challenge was a distillation of the kind of commitment that the National Park Service has to make to be an authoritative force for unimpaired resources. Dick Sellars's documentation of NPS ambivalence toward science throughout its history set the stage for the National Leadership Council's willingness to adopt a strategy to integrate science into national park management. Every NLC member signed on to a sizable commitment of funding priorities over seven years. It was a bold response aimed at broadening NPS culture so that the Service could be successful in the 21st century when challenges will be much more intense, the arenas more technical, and the stakes higher.

Mike Soukup (1) enjoys an informal retirement party held in his honor on 25 October 2007. Pictured with Mike are (2) Pat Parker, chief of the NPS American Indian Liaison Office; (3) Cliff McCreedy, NPS marine protection specialist; (4) Karen Taylor-Goodrich, NPS associate director for Visitor Services; (5) Josefa O'Malley, attorney advisor with the DOI Solicitor's Office; (6) Giselle Mora-Bourgeois, Diane Pavek, and Dan Sealy of the NPS National Capital Region, and Stephanie Bagozzi, Mike's former staff assistant; and (7) Sue Haseltine, USGS associate director for Biology.

NPS

What was your greatest contribution as associate director?

MS: I hope it was demonstrating the importance, utility, and wisdom of using science as the compass for determining NPS actions and directions. Everyone talks about science-based decisions, but many secretly believe that politics will always determine the answer. When the National Academy of Sciences was asked to review the Comprehensive Environmental Restoration Plan for the Everglades, I asked them to determine "whether science was driving decision making, or whether it was tied up in the trunk." If you settle for a politically derived solution, you probably haven't settled anything. If politics dictates the answer to a resource issue initially, natural phenomena will still have the last say. Putting Galileo in prison isn't going to make the sun revolve around the Earth.

Rather than assume the parks' vast resources are too difficult to understand, the National Park Service can prudently invest in an increasing understanding of complicated systems and become more certain every year. Soon the scientists and managers of the Service can be the most credible determinant on any park resource issue. If the Service harnesses its education potential, it might even determine the "politics" of these issues. I hope I made headway in laying a foundation for the National Park Service becoming the technical authority on the resources it manages.

How successful was the Inventory and Monitoring Program during your tenure? Has it been embraced wholeheartedly by NPS managers?

MS: That's one of the pieces that had been shaped by [my predecessor] Gene Hester's prototype monitoring program that started in the early nineties. With the assistance of Abby Miller, whom I had the wisdom to make my first deputy [associate director], and the pioneering work especially of [marine biologist] Gary Davis at Channel Islands [National Park], it was an obvious cornerstone for the Natural Resource Challenge. I don't think it would have gotten off the ground without [ecologist] Steve Fancy, who is a virtual wizard at making things happen—one of the most valuable people in the Service. Because of the direct involvement of park superintendents and the growing awareness and utility of databases for planning and compliance, the program will, I think, become a priority for managers. It is the key to knowing if and when the Service is truly achieving what the mission asks. How can you seriously manage a park without knowing its resources and its health? Now the National Park Service is positioned to talk about performance management directly related to the agency's mission. It will be a truly ominous signal if the program doesn't prosper.

What steps can the National Park Service take to keep national parks "unimpaired for future generations"?

MS: First, managers must have a credible understanding of what will be required to protect the natural systems, their parts and processes. Once they speak authorita-

CONTINUED ON PAGE 51 >>

The role of education has been sorely neglected of late and needs to be propelled forward in new and powerful ways.

Information Crossfile

Synopses of selected publications relevant for natural resource management

ARTICLES

Dogs detect elusive wildlife better than other methods

SIT! DOWN! COME! STAY! These four words comprise the vocabulary of every "good dog." Some special dogs, however, have added "find it" to their vocabulary, with beneficial outcomes for wildlife conservation, particularly of elusive carnivores such as grizzly bears (*Ursus arctos*), black bears (*Ursus americanus*), wolves (*Canis lupus*), and fishers (*Martes pennanti*). Controlled behavioral tests indicate that domestic dogs (*Canis familiaris*) can distinguish the odors of different species of animals, males or females of a species, and even different individuals within a species (Smith et al. 2001). Additionally, trained dogs can detect taxonomically diverse species simultaneously (Long et al. 2007b). With the DNA extracted from scat, scientists can identify not only species and sex but also population size, home range, paternity, and kinship (Socie 2007).

Investigators and handlers choose dogs for their strong object orientation, high play drive, and willingness to strive for a reward (Wasser et al. 2004). In addition to honing dogs' scent-detection skills, handlers trained them not to chase wildlife (Wasser et al. 2004) (see Banks and Bryant 2007, abstracted on page 19, for the effects of dog walking on native birds). Dogs perfect for scat detection may be considered "crazy" with their off-the-charts energy, drive, and object obsession, but these traits are necessary for a scat-detection dog's work (Socie 2007). One German shepherd recovered 435 (presumed) kit fox (*Vulpes macrotis*) scats along 87 miles (140 km) of transects in the Carrizo Plain Natural Area, California, in 16 days. Investigators were able to isolate DNA from 329 of the samples. Mitochondrial DNA tests developed in the National Zoological Park's Molecular Genetics Laboratory in Washington, D.C., revealed that all 329 scats were indeed from kit foxes (Paxinos et al. 1997). Thus, this dog was 100% accurate in identifying kit fox scats, even in the presence of scat from coyote (*Canis latrans*), skunk (*Mephitis mephitis*), and badger (*Taxidea taxus*) (Wasser et al. 2004). Smith et al. (2001) describe another detection dog—originally trained to find grizzly bear scat but moved to a program to detect scat from kit fox—who could detect kit fox scat at four times the rate of trained (human) observers. The impressive scent discrimination of canines, coupled with the treasure trove of genetic, physiologic, and dietary information contained within scat, makes this method worth considering, particularly for confirming the presence of a species or collecting fecal DNA and hormone information.

Because this method requires virtually no setup, it is "ideal for population monitoring on an annual basis as well as for cross-sectional monitoring of wildlife over large, new areas" (Wasser et al. 2004). Additionally, it does not require the use of attractants, allowing sampling to occur quickly and efficiently across an entire region and potentially minimizing sampling biases. However, if detecting actual animals is important for a study, detection dogs are not used for doing so. As stated in Long et al. (2007a), "the ability of dogs to detect scat long after deposition may confound comparisons between dogs and other methods, such as remote cameras, which detect species presence at the actual time of the survey."

Another consideration for using scat-detection teams—consisting of dog, handler, and orienteer—is cost. Long et al. (2007a) estimate that using a leased detection dog requires approximately 1.5 times more funding ($316 per site) than camera-based surveys ($214 per site) (see Fiehler et al. 2007, abstracted on page 20, for information about "security boxes" for remote cameras) and twice the funding necessary for hair snare surveys ($153 per site). When comparing costs, however, investigators should factor in the relative effectiveness of each method. For many applications (e.g., surveys for endangered species), researchers require a high probability of detecting the target species, and detection dog teams have superior results as compared with remote cameras and hair snares. In a study that covered the entire state of Vermont and a small portion of adjoining New York, scat-detection teams found scat from all three target species (i.e., black bears, fishers, and bobcats [*Lynx rufus*]) at a rate of 3.5 times that of remote cameras alone; hair snares recorded neither fishers nor bobcats. According to Long et al. (2007a), "detection dog teams were also responsible for the majority of unique detections of all three species, yielding the only detections of bears at 65.3% of sites, fishers at 74.5% of sites, and bobcats at 78.6% of sites." As pointed out by MacKenzie et al. (2002), "low probabilities of detection decrease the accuracy and precision of occupancy estimates." Hence, detection dogs are clearly the more cost-effective method if potential users account for the effort necessary to achieve a relatively high probability of detection (Long et al. 2007a).

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—Katie KellerLynn

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Spent lead ammunition poisons California condors

"IT'S THE RIGHT THING TO DO," states Cade (2007), who advocates using nontoxic ammunition such as copper bullets (vs. traditional lead shotgun pellets and bullets) in hunting to reduce the frequency of sickened or killed California condor (*Gymnogyps californianus*). Lead poisoning from spent ammunition in the carcasses and gut piles that condors eat causes the birds' crops to become paralyzed (crop stasis), resulting in starvation and death. Cade's summary of scientific data supports the conclusion that exposure to lead poisoning causes fatalities and physiological malfunctions, which at current levels of exposure will prevent the reintroduced condors from developing self-sustainable populations at least in Arizona, and possibly in California. Cade (The Peregrine Fund, Boise, Idaho) focuses on Arizona "where ammunition lead is the principal cause of deaths that limit the population growth of reintroduced condors" (Wood et al. 2007). Because condors do not breed until they are eight years old and then succeed in fledging only one young every two to three years, natural maintenance of the population is precarious. Lead poisoning, which results in the birds not living long enough to begin breeding, makes population maintenance impossible. Other potential sources of lead poisoning are items in waste dumps and landfills, contaminated ground around lead mines and smelters, contaminated water, atmospheric deposition, and contaminated sewage sludge used as fertilizer (Fry 2003; Johnson et al. 2007); however, to date, the only identified source of lead in exposed condors in California and Arizona is spent ammunition (Pattee et al. 2006). Hence, Cade (2007) suggests changing human behavior through either volunteer action or legislative or regulatory relief. As with the ban of DDT in the late 1960s and early 1970s, "most people familiar with the issue of lead poisoning from spent ammunition now agree that it is only a matter of time until the use of nontoxic ammunition will become mandatory" (Cade 2007).

As of 6 October 2007, the Arizona Game and Fish Department was promoting a voluntary non-lead ammunition program (http://www.azgfd.gov/h_f/highlights/HuntingHighlightsOct2007.html [accessed 18 March 2008]). As of 1 July 2008, the California Department of Fish and Game will require hunters to "get the lead out" by retrieving all killed animals, disposing of carcasses or gut piles, removing bullets and the surrounding impacted flesh when leaving carcasses or gut piles in the field, or using lead-free ammunition (http://www.dfg.ca.gov/wildlife/hunting/condor/ [accessed 18 March 2008]).

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—Katie KellerLynn

ARTICLES (CONT'D)

Lichens: Indispensable members of ecosystems

SMALL AND OFTEN FORGOTTEN, lichens are indispensable members of forest, alpine, desert, and even aquatic ecosystems. Though individually inconspicuous, they are aesthetically pleasing on a grand scale. McCune et al. (2006) point out that lichen communities paint the tremendous rockscapes in Yosemite and Sequoia national parks. Visitors seldom appreciate this phenomenon for what it is but nevertheless enjoy the elegant vertical striping on the massive granite outcrops in these parks.

The diversity of lichens is astounding: foliose (leaflike) lichens such as yellow specklebelly (*Pseudocyphellaria crocata*), fruticose (shrublike) lichens such as clustered coral (*Sphaerophorus globosus*), and crustose (crustlike) lichens such as bullseye lichen (*Placopsis gelida*).

Lichens are also indicators of past environmental conditions and present ecosystem health. For example, *Rhizocarpon geographicum*—Granny Smith apple–colored disks that colonize fresh rock surfaces in alpine areas—document when glaciers receded from a valley, specifically when a particular landform became ice-free. Glacial geomorphologists use this species because of its longevity and great range for dating—up to several thousand years in some alpine areas and perhaps 9,000 years in parts of the Arctic (Lock et al. 1979). Lichens are also useful in dating past seismic rockfall events.

Because many lichen species are sensitive to air pollution, they are useful biological indicators of change in atmospheric conditions. Poor air quality, however, is one of the greatest risks to the vast biodiversity represented in lichen communities (Hutten and Woodward 2002). For example, investigators in the Great Lakes region have found chemical patterns in lichens related to human activities. Bennett (2007) notes, "the soil elements aluminum, iron, and sodium decrease from west to east [across the Great Lakes region], probably because of increasing distance from blowing dust of the Great Plains. However, elements associated with human activities—copper, lead, sulfur, and zinc—increase from west to east with increasing proximity to eastern population centers." Furthermore, lichens have the capacity to absorb high levels of metals, suspected to be responsible for above-normal incidences of childhood leukemia (Associated Press 2005). Lichen chemistry has shown significantly elevated levels of tungsten and cobalt in the small Nevada town of Fallon (Sheppard et al. 2007), which has the "most unique cluster [of incidences of childhood leukemia] ever reported" (Steinmaus et al. 2004).

The symbiotic nature of this dual organism, consisting of fungus and alga or cyanobacterium, is as intriguing as it is significant. All lichens that contain cyanobacteria as a symbiotic partner fix nitrogen, converting atmospheric nitrogen into forms usable by plants and animals. Some lichens (e.g., *Bryoria fremontii*) are an essential winter food source for such species as northern flying squirrel (*Glaucomys sabrinus*) and Douglas squirrel (*Tamiasciurus douglasii*). Indeed many organisms depend on lichens for food—just one way that nutrients, assimilated by lichens, cycle into an ecosystem. In addition to eating it, northern flying squirrels and Douglas squirrels use *Bryoria* for nest material (McCune et al. 2006), as do many other animals. At least 19 species of birds in Sierra Nevada parks use lichens for building or lining their nests (McCune et al. 2006).

Unfortunately the indispensable lichen is often ignored. Primarily for budgetary reasons, most biological inventories throughout the National Park System address only vascular plants and vertebrate taxa (see http://science.nature.nps.gov/im/inventory/biology/index.cfm, accessed 6 February 2008). Despite this systemwide focus, biologists for the Sierra Nevada Network have recognized lichens as a conspicuous part of ecosystems and as important vital signs for evaluating ecosystem conditions and trends at Yosemite and Sequoia national parks and Devils Postpile National Monument. Recently the Sierra Nevada Network released the report *Lichens in Relation to Management Issues in the Sierra Nevada National Parks*. The purpose of this study was to synthesize existing data about lichens in and near the Sierra Nevada parks, as a first step toward developing better baseline information and assessing lichen populations or communities as potential indicators of ecosystem change. This report identifies and categorizes lichens into functional groups and highlights the connection of lichens to management issues such as biodiversity, fire, air quality, water quality, and restoration of drained reservoirs (i.e., mitigating the "bathtub ring" effect). The authors make recommendations for surveying species that are in particularly marginal positions, monitoring communities that are already in transition, and improving floristic inventories. They also suggest "quick surveys" to obtain needed data about lesser-known aquatic and terrestrial lichens (e.g., in calcareous areas and grazed meadows).

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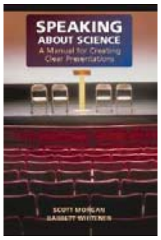
—Katie KellerLynn

SUMMARIES

Speaking about science

TELL THEM WHAT YOU'RE GOING TO TELL THEM; tell them; then tell them what you told them. Though engrained in many of us, this mantra for giving presentations, scientific or otherwise, is faulty. Namely, it is not good storytelling (and it does not reflect the actual research process). This structure reveals the ending too early and can result in a presentation that does not engage audiences. Moreover, effective presentations are not spoken versions of a paper or report. They require preparation that pinpoints the take-home message. According to Morgan and Whitener's book, *Speaking About Science: A Manual for Creating Clear Presentations*, "all data for the talk should be selected with this goal [i.e., the take-home message] in mind. All images should be designed around it." Also, the message needs to be properly placed: not too soon but not as the "exit line" either. Morgan and Whitener encourage potential presenters to ask themselves, "What do I have to show the audience? What are my best data?" *Speaking About Science* also tells readers how to select slides and estimate the appropriate number for a given presentation time (i.e., the "two-minutes-a-slide rule"), "hook" an audience from the start, craft titles that attract attention, and increase the odds of having a successful question-and-answer period.

According to the publisher's description, "the book features step-by-step instruction for creating clear and compelling presentations—from structuring a talk to developing effective PowerPoint slides." It also presents useful techniques for delivery before an audience, as well as how to prepare for a job interview and various types of media interviews (see Nisbet and Mooney 2007, summarized below, about framing science issues). Additionally, readers will learn how to prepare a poster and conduct a useful poster session. The one drawback of the book is that the examples are directed at the medical profession, so examples may not be useful for most resource managers. Nevertheless, the image design (see Dennison et al. 2007, summarized below, for effective ways to communicate complicated data to diverse audiences), text, and stepwise method are intelligible and unambiguous. So before giving your next presentation for the George Wright Society biennial conference, consider consulting *Speaking About Science* as you prepare.



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—Katie KellerLynn

■ ■ ■

Framing science

APPEARING AS PART OF THE "POLICY FORUM" of *Science*, "Framing Science" is a commentary written for scientists about how the public uses the news media and how scientists should shape (or frame) issues—particularly controversial ones (e.g., climate change, evolution, and stem-cell research)—to resonate with an audience's values. Frames organize central ideas and emphasize some aspects of an issue over others. According to the authors, framing allows "citizens to identify why an issue matters, who might be responsible, and what should be done." However, if a "frame" is to be successful, it needs to be positive and respect diversity. Even so, ideology and religion may overshadow the most positive frames about science, making some audiences a challenge to reach.

Reference

Nisbet, M. C., and C. Mooney. 2007. Framing science. Science 316(5821):56.

SUMMARIES (CONT'D)

Visual images promote effective science communication

DENNISON ET AL. (2007) PROVIDES a new process for integrating, interpreting, and communicating science—namely monitoring results—to varied stakeholders. This approach combines synthesis of key findings with information-rich visual elements (e.g., conceptual diagrams, maps, graphs, tables, and photographs). Investigators used the process in a case study of five National Park System units in the mid-Atlantic region, Antietam National Battlefield (Maryland), Assateague Island National Seashore (Maryland), Chesapeake and Ohio Canal National Historical Park (Maryland), Prince William Forest Park (Virginia), and Rock Creek Park (Washington, D.C.), which cover four physiographic provinces: Atlantic Coastal Plain, Piedmont Plateau, Blue Ridge Mountains, and Ridge and Valley. The conceptual diagrams are a means to present ideas, further develop ideas, and transcend jargon. These diagrams can also serve as models to explore specific hypotheses related to management actions. The authors stress the importance of synthesis and context, which "allows people to understand why you are measuring what you are measuring, or why you care about a certain issue." Hence, unlike Nisbet and Mooney (2007) (see previous summary) these authors do not propose "framing" an issue, but rather presenting "the facts" in a visually interesting and informative way. The conceptual diagrams assist scientists in helping an audience to see and interpret the data for themselves. The authors contend that the audience needs to know that the data exist. Though creating effective graphics can be time-consuming, according to the authors, the benefit is dramatically improved communication of science. They conclude that "only when effective science communication is achieved will the relevance of science to society in general be recognized."

Reference

Dennison, W. C., T. R. Lookingbill, T. J. B. Carruthers, J. M. Hawkey, and S. L. Carter. 2007. An eye-opening approach to developing and communicating integrated environmental assessments. Frontiers in Ecology and the Environment 5(6):307–314.

■ ■ ■

The economic value of insects

IN *THE ECONOMIC VALUE OF INSECTS* Losey and Vaughan (2006) calculate the annual economic value of insects at an impressive $57 billion in the United States alone. Furthermore, this estimate is conservative; of the many services that insects provide, this amount factors in only four, dung burial ($0.38 billion), pollination ($3.07 billion), pest control ($4.49 billion), and recreation such as birdwatching ($49.96 billion), as a result of availability of data. Although the examples provided in the article may not illustrate services that would be of high concern for resource managers (e.g., decomposition of cattle dung and pollination of crops), the authors conclude that $57 billion justifies increased investment in the conservation of these often undervalued insect-provided services.

Reference

Losey, J. E., and M. Vaughan. 2006. The economic value of insects. BioScience 56(4):311–323.

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A resource manager's guide to working with people

YOU ARE ABOUT TO ADDRESS a potentially hostile audience at a public meeting. Are you ready? Do you "know" your audience?

You get out of your vehicle, about to start a day's work in the field, and see an angry person approaching. Do you have a plan to defuse the situation?

A program you are passionate about needs resources. Do you know the "tricks of the trade" to get your program funded?

You need access through private land to repair a flood-damaged bridge and trail. Will you be able to negotiate with the landowner?

Your duties include working with the public, managing a budget, and supervising a field area the size of Vermont. How can you most effectively manage your time?

You need to fill an important GS-5/7/9 position. How can you plan for hiring the best person? How will you know whether a candidate will work well with your staff?

You are the project leader for inventorying thousands of acres of prairie, using numerous crews and many volunteers. Will you be able to set the right tone in the field? How will you motivate your crews to get the job done by the end of the field season?

The Conservation Professional's Guide to Working with People, by Scott A. Bonar, provides communication tools to address all of these situations. Bonar presents practical tips for working with colleagues, funders, supervisors, and the public. As stated in the preface, "This book should be on the shelf of environmental professionals who want to improve their 'people skills.' Those who are already good at working with others will learn new tips. Those who are petrified of conducting public meetings, requesting funding, or working with constituents will find easy common-sense advice about how to begin." The book includes examples from history and current events as well as real-life scenarios that resource managers are likely to face, which illustrate how to apply the techniques described.

The Conservation Professional's Guide to Working with People is based on the assumption that applied science and law enforcement, by themselves, are insufficient for managing natural resources and are greatly enhanced by interpersonal skills and flexibility. Director Duane L. Shroufe (Arizona Game and Fish Department) explains in the foreword, "Just as organisms in natural systems must evolve to survive in changing environments, so too must we as professionals responsible for public trust resources evolve to address new challenges and greater expectations." Bonar's book provides the tools necessary for helping resource managers evolve in this changing world of resource management, which most assuredly includes working with people.

Reference

Bonar, S. A. 2007. The conservation professional's guide to working with people. Island Press, Washington, D.C., USA.

—Katie KellerLynn

ABSTRACTS

Four-legged friend or foe? Dog walking displaces native birds from natural areas

Banks, P. B., and J. V. Bryant. 2007. Biology Letters 3(6):611–613.

NEW DATA PROVIDE EXPERIMENTAL EVIDENCE, previously lacking, of the ecological impacts of dog walking in natural areas where this activity is allowed or prohibited. On public lands near Sydney, Australia, including two national parks, investigators monitored the responses of multispecies assemblages of birds to (1) walkers (of varying heights) with dogs (or varying breeds and ages), (2) walkers (single and multiple) without dogs, and (3) no walkers and no dogs (control). Dogs were always on leads. For 10 minutes after the "treatment" passed, a single observer surveyed the 820-foot (250 m) transect for all birds seen and heard within 160 feet (50 m) of the trail segment. These data show that dog walking in wooded areas results in a 35% reduction in bird diversity and a 41% reduction in bird abundance. Additionally, dog walking leads to a 50% reduction in ground-dwelling birds. Another significant finding is that the effects of dogs occur even where dog walking is frequent, suggesting that local wildlife does not become habituated to continued disturbance. These results support the long-term prohibition of dog walking in sensitive conservation areas.

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Restoration of plant cover in subalpine forests disturbed by camping: Success of transplanting

Cole, D. N., and D. R. Spildie. 2006. Natural Areas Journal 26(2):168–178.

COLE AND SPILDIE (2006) IDENTIFY THE NEED for effective techniques to restore vegetation in disturbed subalpine areas—popular recreation destinations because of their scenic mix of forests and meadows, abundant lakes, and mountain views—and provide an assessment of transplanting, soil treatments, and mulch mats in high-elevation locales, namely six severely impacted campsites (closed in 1995) in the Eagle Cap Wilderness in the Wallowa Mountains in northeastern Oregon. This study reveals that scarifying soils to break up compaction and then transplanting locally established plants is a very successful method for reestablishing vegetation in subalpine forests. Most transplants (68%) were still alive after seven years, though transplant success varied among species. Graminoids (e.g., *Juncus parryi* and *Carex rossii*) survived most frequently, particularly those with fibrous roots and without rhizomes. Most transplanted trees (e.g., *Pinus contorta* and *Abies lasiocarpa*) survived and grew rapidly. Most forbs (e.g., *Sibbaldia procumbens* and *Polemonium pulcherrimum*) survived and grew, but at a less pronounced rate than trees; forb transplants tended to survive better when intermixed with shrubs or graminoids. Less than half (45%) of the transplanted shrubs (e.g., *Vaccinium scoparium* and *Phyllodoce empetriformis*) survived. For most species, soil amendments helped to increase growth but not survival, except for shrubs on which soil amendments had no effect. Mulch mats had no effect on any plant types. Cole and Spildie (2006) conclude that these results have wide application because this plant community is common in subalpine areas. Also, more research is needed on soil amendments and

ABSTRACTS (CONT'D)

transplanting for shrubs, given the importance of this plant type and the difficulty of establishing it.

A theft-resistant adjustable security box for digital cameras

Fiehler, C. M., B. L. Cypher, S. Bremner-Harrison, and D. Pounds. 2007. Journal of Wildlife 71(6):2077–2080.

INVESTIGATORS DEVELOP A NEW TECHNOLOGY—an adjustable armoring system for digital wildlife cameras—and evaluate the "security box" for utility, cost-effectiveness, and protection of data. Arc-welded pieces of 0.08-inch (2 mm) thick steel accommodate the Cuddeback digital scouting camera; however, the security box is readily customized to fit any camera and is easily modified for a variety of field conditions, positions, and research needs. The cost of construction (including materials and labor) is approximately $90. The robust appearance of the security box and a posted note describing the purpose of the cameras may have helped to deter theft and tampering, because during the six-month study, none of the cameras were repositioned, vandalized, or stolen. Additionally, the security boxes did not interfere with camera operation, taking 107 photographs of wildlife in 160 days. The article contains a full schematic of the design.

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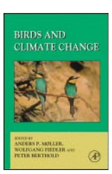

Birds and climate change

Møller, A. P., W. Fiedler, and P. Berthold, eds. 2006. Elsevier, Burlington, Massachusetts.

BIRDS AND CLIMATE CHANGE presents 11 papers, incorporated as book chapters, by leading experts from Finland, France, Germany, Lithuania, the Netherlands, Norway, the United Kingdom, and the United States (Wisconsin). According to the editors, Peter Berthold and Wolfgang Fiedler (Max Planck Research Centre for Ornithology, Radolfzell, Germany) and Anders P. Møller (Université Pierre et Marie Curie, Laboratoire de Parasitologie Evolutive, Paris, France), "the biology of birds has been more thoroughly investigated than that of any other group of organisms." Birds are excellent model organisms because of their very active metabolism, high mobility, and sensitivity to environmental changes. Therefore, in the early 1990s, birds became pioneer indicators of changes related to global warming. In the past 15 years investigators have accumulated such a large amount of data that the Laboratoire de Parasitologie Evolutive, Max Planck Research Centre for Ornithology, University of Constance, and European Science Foundation hosted a special symposium, "Bird Migration in Relation to Climate Change," in which participants could discuss research results and status. *Birds and Climate Change* is essentially the proceedings of this 2003 symposium. Topics include the effects of climate change on arrival and departure dates; migratory fueling; migrating birds (using large-scale data from banded or ringed birds); breeding dates and reproductive performance; avian reproduction; photoperiodic response and the adaptability of avian life cycles; microevolutionary response; avian population dynamics; and ranges, communities, and conservation of birds. Additionally papers discuss future research challenges and long-term studies that investigate responses to climate change.

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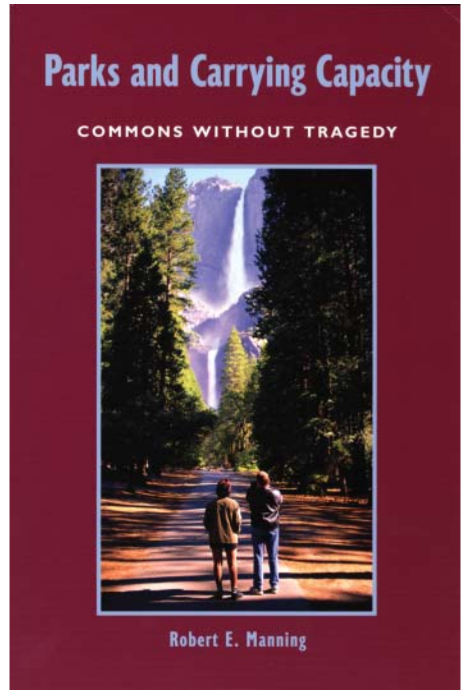
Book Review

Parks and Carrying Capacity: Commons Without Tragedy



By Robert E. Manning
Island Press
Washington, D.C., 2007; 313 pages

Editor's note: The following book review combines two separate but coordinated reviews. We begin with Superintendent Jim Hammett's appraisal of the applicability of carrying capacity research in park management. Social scientist Bill Hammitt then concludes with a brief examination of the science of carrying capacity models for national parks. The two shared similar summaries of the book's premise, incorporated here into the first review. I found their perspectives on "magical" numbers particularly interesting.

The park manager's view

THE NATIONAL PARK SERVICE (NPS) is a responsive bureau. Every park ranger takes pride in responding professionally to emergencies such as an injured climber, lost child, flood, volcanic eruption, vehicle accident, or forest fire. Response is at the core of the NPS psyche. Therefore, it is not surprising that NPS managers react to increasing social, biological, and physical park impacts from visitation primarily through accommodation. We are very good at allowing informal trails to become designated trails, enlarging parking lots, and increasing the number of rafts for rent.

Accommodation has its drawbacks, however. Sooner or later, we run up against the fact that our parks are finite. Furthermore, managing in this way allows the number of visitors and their needs to determine the future of our parks, which can slowly change the resources and visitor experiences that we are mandated to protect. For at least the past 70 years, the National Park Service has struggled with the question "How do we determine how much visitor impact is too much?" Unfortunately, we have not made much progress in answering this crucial question in most national parks. Thankfully, this matter is the central theme of Bob Manning's book, *Parks and Carrying Capacity: Commons Without Tragedy*.

Using the foundation of Garrett Hardin's 1968 article, "The Tragedy of the Commons," which indicates the need for social action to solve shared environmental problems, Manning thoroughly reviews both the concept of visitor carrying capacity and its practical application in national parks. No one is more qualified to write this book than Manning. He has devoted the past 15 years of his career to this issue, working in parks from Acadia in Maine to Yosemite in California and in settings ranging from urban to wilderness.

Manning begins by examining the premise of "The Tragedy of the Commons," why it is applicable to national parks, and how "mutual coercion, mutually agreed upon," as Hardin suggests, is a solution to overuse. He outlines the theoretical as well as empirical thought behind the primary carrying capacity determination processes: Limits of Acceptable Change (LAC) and Visitor Experience and Resource Protection (VERP). Using numerous examples from parks where he has worked, Manning devotes considerable space to the discussion of visitor use capacity indicators and standards, which are the crux of LAC and VERP. He provides an exhaustive summary of how social indicators and standards have been selected using social science and normative theory in a wide variety of settings. While Manning focuses on social indicators, spending less time on biological or physical ones, it is social factors that ultimately are the most difficult for managers to mitigate.

The most important part of the book for park managers is the chapter on trade-offs in park management. Many managers, perhaps most, first try to mitigate obvious visitor impacts that result from crowding. Manning, however, convincingly demonstrates that crowding itself strongly affects visitors' park experiences. Therefore, managing in order to maximize the dependent variables of numbers of visitors and quality of experience becomes mathematically impossible.

This book challenges park managers to switch their operating paradigm from accommodation and mitigation to planning, monitoring, and taking action based on definitive standards of quality for visitor experience and resource condition. This shift is a huge challenge and one that many managers will be reluctant to take on. Selecting indicators and setting standards, for example, take too much research and too much time; funding is unavailable to

Social factors … are the most difficult for managers to mitigate.

monitor resources; and standards tie the managers' hands. Additionally, many managers think it is impossible to implement VERP or LAC without a huge budget for research. Manning, however, challenges these assumptions and shows how selecting indicators and setting standards are not necessarily a complex or prohibitively expensive process. Furthermore, with numerous examples, he repeatedly takes us back to Hardin's "mutual coercion, mutually agreed upon" premise as the only long-term solution for finite resources under increasing demands from visitors.

If anything is wanting in Manning's book, it is a clear explanation that setting standards is ultimately a subjective decision on the manager's part. Too many managers believe that interviews, surveys, confidence intervals, and data will produce magical standards that absolve them from tough decisions. In reality it rarely works this way. Science may inform managers, but managers still have to make decisions about standards that are rooted in their best professional judgment.

Further complicating the science of VERP and LAC, visitors are often displaced from parks by park conditions. Studies have shown, for example, that many visitors who previously visited Yosemite Valley no longer go there because of crowded conditions, and thus these displaced visitors are not sampled in surveys conducted in the park. Nevertheless, their opinions are still important to NPS managers—or should be. Managers must be aware of this and other factors that can affect surveys and incorporate this awareness into the decision-making process.

Despite these few shortcomings, *Parks and Carrying Capacity* is very useful and should be on the mandatory reading list for park managers, particularly those who perceive crowding issues at their parks.

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A social scientist's view

IN NORWAY, SCIENTISTS CAN APPLY to the Norwegian National Science Board for a fellowship during the last five years of their careers to compile and publish their lifetime research. This results in a coherent and holistic record of valuable research through the publication of monographs and books. The process of collecting and synthesizing research findings is a valuable alternative to the ordinary practice of U.S. scientists, who are expected to publish brief, disjointed journal manuscripts until their dying days. Bob Manning, with the recent publication of *Parks and Carrying Capacity: Commons Without Tragedy*, has followed the Norwegian practice of composing a comprehensive monograph of his lifetime research concerning resource and visitor experience conditions in national parks.

Researchers and park scientists will find the first half of Manning's book a great resource summary of the concepts and theories that underlie carrying capacity research. The material on social norms, limits of acceptable change, and selection of park management indicators and standards will not be new to many scientists; however, Manning does an excellent job of packaging this material into a readable format. The information in chapters 2–5, though familiar to many, is essential for what I consider the most valuable contribution of this monograph: the "Visual Research Method." Chapters 6–8 document the visual resource approach and simulation methods for testing visitor use capacities that Manning and his staff have pioneered in the Park Studies Laboratory at the University of Vermont. This is the first comprehensive documentation of this widely used application to study capacity problems in parks, and is a most valuable resource in itself.

While I praise the author for adding this welcome resource to the scientific literature, the research it describes is not without its critics. Many researchers do not believe in the concept of carrying capacity and the setting of magical numbers of users as a park management strategy. Neither does Bob Manning! It is unfortunate that "carrying capacity" appears in the title of the book, for Manning makes it very clear that this book is about managing resource and visitor conditions within acceptable limits.

As a colleague who has respected Bob Manning's research concerning visual resource management, I read his new book before being asked to review it. I recommend that other researchers and students read it as soon as they can for they will find digesting the material well worth the effort.

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Partnerships empower hydrology program at Big Cypress

Hydrologic technician Paul Murphy (right), former hydrologic technician (current management assistant) Christine Clark (center), and helicopter pilot Bill Evans (left) visit a hydrologic and water quality monitoring station that is part of the National Park Service–South Florida Water Management District partnership.

NPS/ROBERT SOBCZAK

Science Notes

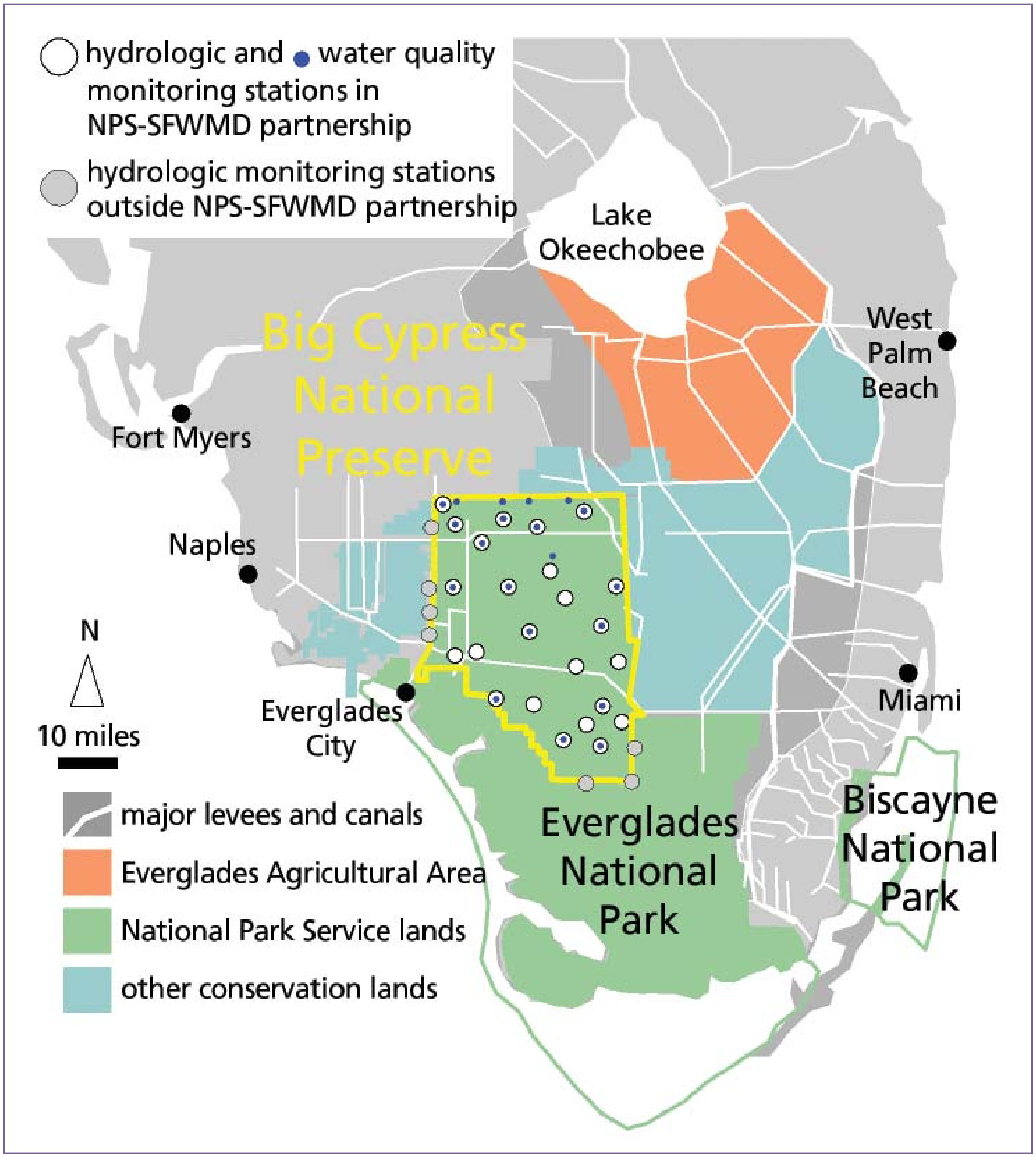

Figure 1. A network of hydrologic and water quality monitoring stations (white, blue-and-white, and gray dots) covers Big Cypress National Preserve in south Florida. Data collected at these stations are significant for understanding the greater Everglades ecosystem, which includes nearby Everglades and Biscayne national parks. The headquarters of the South Florida Water Management District, an important partner for the National Park Service in south Florida, is located in West Palm Beach.

NPS/ROBERT SOBCZAK

MILESTONES OFFER IMPORTANT moments to pause. Serendipitously coinciding with the 20th anniversary of the hydrology program at Big Cypress National Preserve (Florida), the relatively recent dedication of the new resource management laboratory was both a celebration of things achieved and a reflection on the parade of people and events that brought the program to its present state. When the preserve was established in 1974, Everglades National Park staff started collecting hydrologic data at a handful of sites in the new preserve. However, by the mid-1980s, funding shortfalls and complicated logistics forced staff at Everglades to give up these duties. Recognizing hydrology as a centerpiece of the preserve's stewardship mission, preserve staff embarked on this daunting task in 1988.

The preserve's 729,000 acres (295,017 ha) are widely regarded as part of the greater Everglades ecosystem yet are distinct from the vast saw grass plain of Everglades National Park (see fig. 1). More an interwoven mosaic of shallower, less frequently flooded wetlands, Big Cypress National Preserve is best known for its prominent display of cypress domes and strands. At their highest points, cypresses transition into orchid-hiding swamp forests and at their fringes recede into herbaceous marl prairies, which in turn rise into fire-swept pinelands and scattered upland islands of hardwood hammocks—all of which are home to the endangered Florida panther.

As an "aquatic park," Big Cypress is a major piece in the south Florida water puzzle. Its wetland waterways are intimately connected on all sides with natural and human-managed flow systems, which are subject to substantial replumbing efforts as a result of ongoing restoration projects in the Everglades, including the $10 billion Comprehensive Everglades Restoration Plan. With this in mind, the National Park Service gradually developed a hydrology staff at Big Cypress—hiring a seasonal hydrologist in the late 1980s, converting this position to permanent status in 1992, and adding a hydrologic technician in 1995—and embarked on developing partnerships that would become an essential ingredient in the long-term success of the hydrology program. This spirit of partnership was first ignited in 1995 with the NPS Water Resources Division (WRD) in Lakewood, Colorado, while creating the preserve's water resources management plan. The plan provided the nascent program with a navigational chart of the complex array of aquatic issues that lay ahead.

During the planning process, WRD and park staffs identified a significant stakeholder as the South Florida Water Management District, the primary water agency for south Florida, headquartered in West Palm Beach. The foresight to partner with the district not only paid immediate dividends—such as systemic survey of the network to a common datum (i.e., mean sea level), replacement of old-style pen-and-ink chart recorders with digital loggers, and analytical water quality testing from the district's certified lab—but also became the foundation of the preserve's long-term hydrologic and water quality baseline monitoring program. Subsequent renewals to the partnership have resulted in expansion of the network of monitoring stations, and expanded use of the district's robust databases for long-term data storage and retrieval, on-call technical support from district staff, and the recent addition of real-time telemetric data transmission. In exchange the preserve has dedicated its full-time hydrologic technician and helicopter transport to the agreement (see photo, page 23).

Floridians have marveled for decades at the technologic wizardry of spaceflights launched at nearby Cape Canaveral. But many also remember a day when the vast stretches of the seemingly impenetrable and unending Everglades and Big Cypress ecosystems appeared as mysterious as unknown universes. An interesting connection and outcome of the space program was the ability to see these landscapes more clearly from space than from the ground. This new perspective helped staff of the preserve envision a hydrologic network that now includes 20 monitoring stations, 10 rain gauges, 16 water quality stations (sampled six times per year), and four pesticide sampling stations (sampled twice per year) (see map). With the historical clock ticking on 15 years, not only does this network record the history of watersheds and flow ways, but telemetry now brings its pulse to researchers' fingertips.

The human chain that links its partnerships is as significant as technology to the hydrology program at Big Cypress National Preserve. Behind the scenes of successful partnerships are people who collaborate across agency lines, with joint institutional efforts evolving and growing to remain relevant with the passage of time. This collaborative spirit has been a key ingredient in to the preserve's hydrology success story—in its infancy, presently, and one hopes for decades to come.

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Science Notes

Pupfish recovery targets food availability at Devils Hole

Figure 1. A pair of Devils Hole pupfish engages in spawning courtship on 24 September 2007. As of 29 September 2007, 92 adult individuals remained in the wild habitat of Devils Hole, up from 85 in September 2006.

NPS/SARAH FLOOD

THE DEVILS HOLE PUPFISH (*Cyprinodon diabolis*)—a tiny fish with one of the world's smallest known habitats for a vertebrate—was one of the first species listed as endangered in 1966 (fig. 1). Since then, scientists have learned much about the ecology and life history of this species (e.g., Riggs and Deacon 2004). However, a recent population decline beginning in the mid-1990s serves as a reminder of the need for proactive and sustained ecological research and monitoring that guide the development of scientifically credible management strategies. In the absence of this information, the Devils Hole pupfish recovery team has been forced to triage existing hypotheses in order to identify management prescriptions that may stabilize the single wild population, and to buy time to understand the true nature of the observed population decline.

Since 2005, when *Park Science* published the status of the recovery effort for the Devils Hole pupfish (i.e., Wullschleger and Van Liew 2005), two consecutive surveys in spring 2006 and 2007 estimated the population of Devils Hole pupfish at 38 adult individuals. These two counts marked the lowest on record. In the absence of a clear cause of the observed decline in the wild, and therefore a clear solution, response focused on captive propagation experiments and establishment of refuge populations outside of Devils Hole. These ongoing efforts have proved challenging, however, leading managers to further consider methods to stabilize the single wild population.

Managers and scientists have put forth a multitude of viable hypotheses to explain the current decline (see Wullschleger and Van Liew 2005). One hypothesis that has recently received management attention relates to food availability for the Devils Hole pupfish. Though specific monitoring data from which to assess trends in food availability are unavailable, several associated ecological investigations have collected pertinent information. The morphology and life history of the Devils Hole pupfish suggest food is limited annually, particularly in the late fall and winter when primary production is minimal (Minckley and Deacon 1973; Riggs and Deacon 2004). Moreover, research established a positive correlation between primary production and Devils Hole pupfish population size while documenting increased mortality of 0.6- to 0.7-inch (15 to 19 mm) fish during the late fall, presumably in response to starvation rather than old age (James 1969). If food availability has historically acted to regulate the size of the Devils Hole pupfish population under natural conditions, then small reductions in system productivity would likely result in fewer Devils Hole pupfish.

Though annual food limitations appear to be a major feature of the evolutionary history of the Devils Hole pupfish, several lines of evidence suggest that these limitations have increased in magnitude. Anecdotal observations of fish condition made in December 2006 indicated that adult and juvenile fish were emaciated, were mottled, and had eroded fin margins—all potential indications of malnutrition and all thought to be unusual observations. Comparing Devils Hole pupfish gut contents from before and after the initiation of the recent decline reveals the possibility that shifts in the algal community, from one dominated by the green alga *Spirogyra* to one dominated by cyanobacteria, have occurred (Minckley and Deacon 1975; Wilson et al. 2001). Cyanobacteria are thought to decrease the efficiency of energy

If food availability has historically acted to regulate the size of the Devils Hole pupfish population under natural conditions, then small reductions in system productivity would likely result in fewer Devils Hole pupfish.

transfer through the food web, ultimately resulting in reduced biomass at the higher levels of the trophic structure (Stockner and Porter 1988), which in this case are occupied by the Devils Hole pupfish. In a study of energy flow through the Devils Hole ecosystem, researchers did not find the isotopic signature of cyanobacteria in the tissues of Devils Hole pupfish, further suggesting that this energy source was not efficiently transferred (Wilson et al. 2001).

A rigid experimental approach to test the food availability hypothesis was not feasible given the precarious status of the Devils Hole pupfish population. Eventually, however, managers decided to supplement the diet of the wild population in hopes of relaxing the carrying capacity of the system. In January 2007, investigators initiated low-level supplemental feeding using a prepared flake feed developed to nutritionally mimic the diet of the Devils Hole pupfish.

Though supplemental feeding was intended to stabilize the population by potentially compensating for a number of factors that could reduce the carrying capacity of Devils Hole, it also represents a preliminary, if crude, test of one of many viable hypotheses to explain the recent population decline. Initial results from 2007 suggest that larval production has outweighed both 2005 and 2006 levels, and a survey of adult pupfish conducted in late September, which puts the population of adults at 92 individuals, suggests that the population has not continued to decline and that it increased slightly from 2006.

In an attempt to avoid the need to employ crisis management techniques, efforts are under way to implement long-term ecosystem research and monitoring to better understand ecological processes and ecosystem conditions at Devils Hole while specifically targeting individual hypotheses that may explain the recent decline of the Devils Hole pupfish population.

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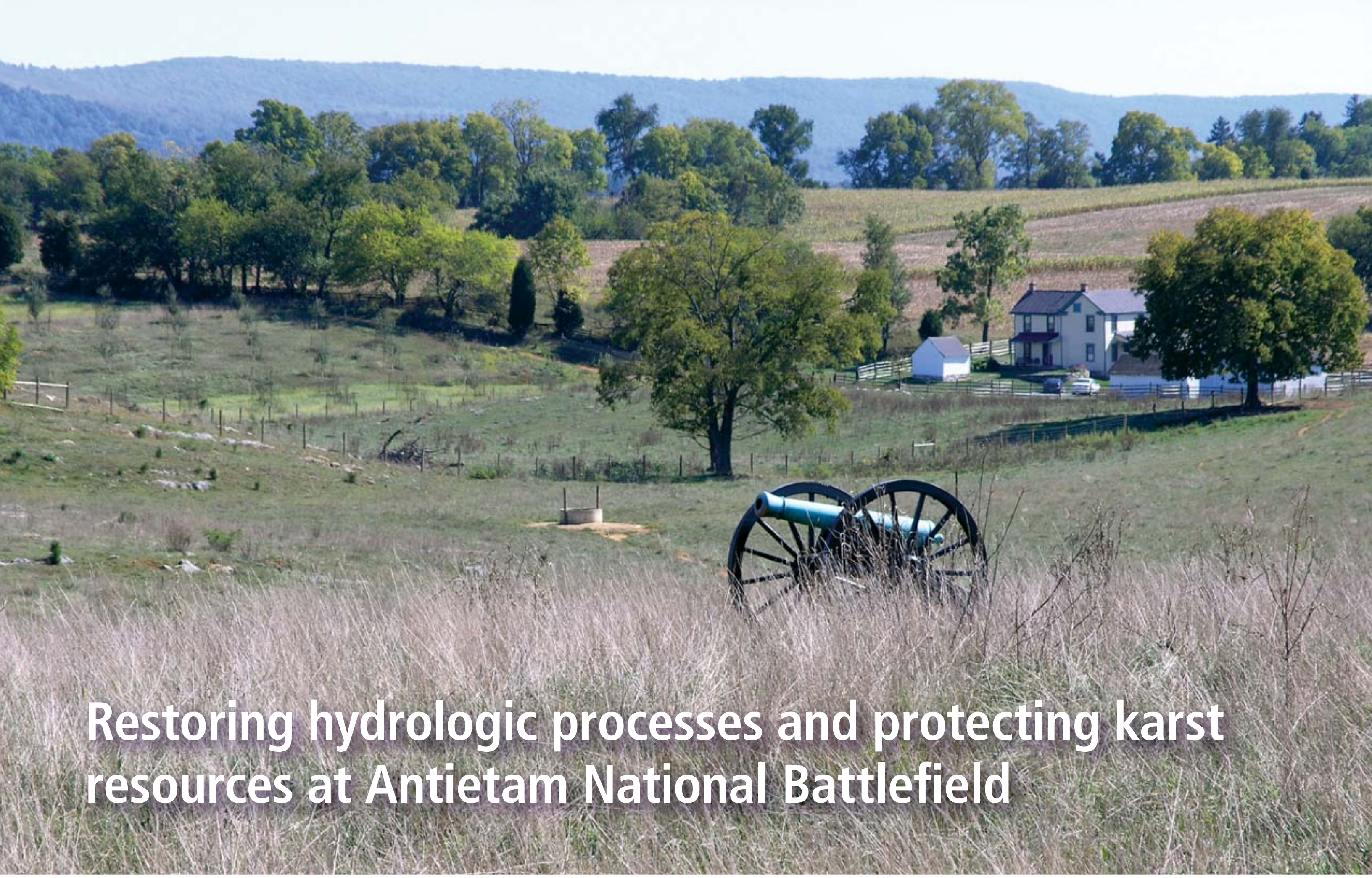

Restoring hydrologic processes and protecting karst resources at Antietam National Battlefield

Figure 1. The Piper Farm at Antietam National Battlefield Park participates in an agricultural permit program designed to retain the appearance of the landscape at the time of the Civil War, when the area was used as pasture and for crop production. Cattle waste and poor drainage, however, created conditions that could have been polluting groundwater and nearby Antietam Creek. Pictured are the historical farmhouse, a cannon that marks the location of artillery at the time of the battle, and a recently replanted apple orchard.

NPS/MICHELLE CARTER

LOCATED IN THE GREAT VALLEY REGION OF the Appalachian Valley and Ridge Province, Antietam National Battlefield (Maryland) encompasses 3,200 acres (1,295 ha) of farmland, pastures, and wooded areas. A portion of this acreage (1,927 acres [780 ha]) is federally managed. As part of the battlefield's agricultural permit program, local farmers use more than 1,200 acres (480 ha) of the federal acreage as cropland and pasture. This program helps restore the landscape to the rural, agricultural appearance it had when General Robert E. Lee's first invasion of the North ended on this battlefield in 1862. Antietam's geologic formations consist mainly of carbonate rock, and contain karst features such as springs and sinkholes. With agriculture being the dominant land use, water quality is of special concern because groundwater in karstic areas is particularly susceptible to contamination.

In 1994, staff at Antietam developed a water quality monitoring program to detect potentially degraded water in the battlefield's springs. Preliminary analysis of the monitoring data revealed that the waters were impacted at least to some degree by agricultural practices. In 1997, investigators from the Maryland Department of Natural Resources sampled various sites at the battlefield, finding high levels of nutrients from agriculture. Siltation and algal growth were indicative of elevated erosion rates and nutrient levels. In order to maintain the agricultural setting, which the enabling legislation mandates, and protect the water in accordance with NPS

Management Policies 2001 (and the more recently updated Management Policies 2006), managers implemented various best management practices, focusing on Antietam's historic Piper Farm (fig. 1).

The Piper Farm includes 105 acres (42 ha) of pasture with a carrying capacity of 55 cattle. Though the battlefield's special use permits require 2 acres (0.8 ha) per animal unit (cow/calf), the only water source was a single well-fed trough in a low-lying section of pasture. Over time, congestion of the animals in this limited space caused deteriorating ground conditions, which raised concerns about sedimentation, soil erosion, and contamination of surface water. Further adding to the problem was

Figure 2. The restoration removed an intermittent pond and berm, improving drainage in the areas where cattle congregated. To disperse cattle, managers routed runoff to two troughs. The area was re-graded and seeded to complete the project, safeguarding groundwater and streams of the Chesapeake Bay watershed. NPS

an abandoned farm pond once fed by a system that historically drained adjacent fields. All that was left of the pond and old drainage system were a constructed berm and an exposed pipe that fed directly into the pasture. The resulting condition was a "wetland" that collected stagnant water and animal waste from congregating cattle. During wet weather, runoff from the site would flow over the pasture through an intermittent streambed that emptied into Antietam Creek. Considering the karstic nature of the area, contamination of groundwater was also likely. Antietam staff became increasingly concerned about the area and started to look for a way to both move the cattle's water source and eliminate the remnants of the pond. Park staff pursued a cost-share partnership with the Washington County Soil Conservation District, which could provide needed technical assistance.

As a result of consultation with the Washington County Soil Conservation District, park staff developed two objectives and corresponding remediation projects. The first was to create two gravity-fed troughs in two pastures using the inflow of water from the old drainage system, grade the pond area to a more natural appearance, and dismantle the berm, eliminating the collection area for water (fig. 2). A new PVC pipe would connect to the existing outlet of the old system and carry the water away from this area to trough number 1 in the same pasture. The overflow from the first trough would then travel through a PVC pipe to fill trough number 2 in the far pasture adjacent to the Piper orchard. Any overflow from the second trough would be routed via PVC pipe to a natural stream channel. Fencing and a riparian buffer would protect this area. The second objective was to rehabilitate the barnyard and cattle chute area. With the two troughs relieving pressure from the current water source at the barnyard, contractors would re-grade and seed the area, following recommendations of the Washington County Soil Conservation District.

Park staff and cooperators successfully completed the project in May 2005. Two water sources now provide more flexibility for grazing operations and rotational grazing. The work was crucial because of the sensitive hydrologic system and because park waters eventually drain into Chesapeake Bay—the largest, most productive estuary in North America. The National Park Service partners with several states and agencies to protect and improve the bay and its resources; completion of the project supported this commitment. Today the water troughs are working as designed, the barnyard has less livestock pressure, and the water that once lay stagnant in the remnant pond is now on its way to Antietam Creek with a much reduced risk of pollution by livestock waste.

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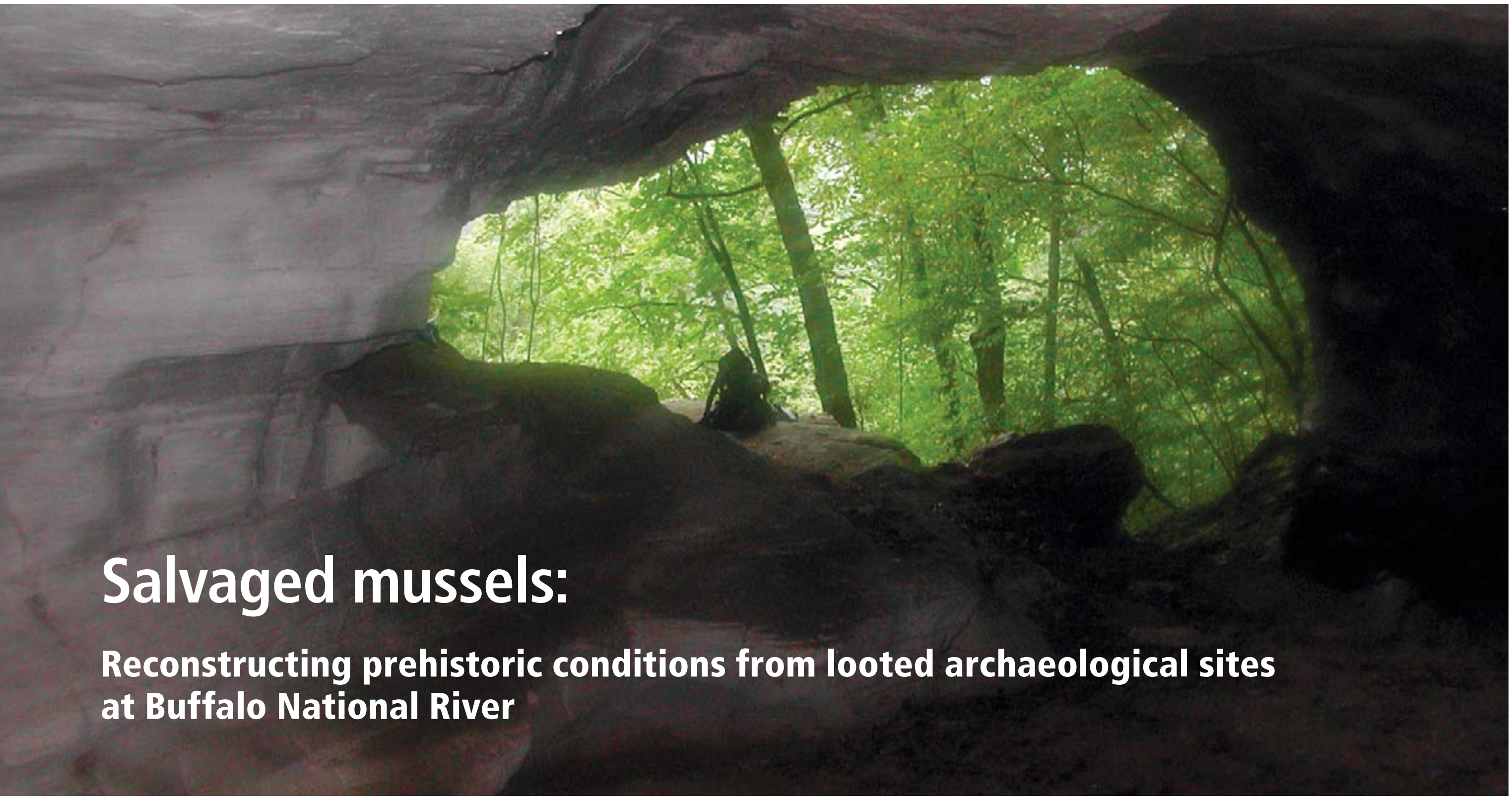

Salvaged mussels:

Reconstructing prehistoric conditions from looted archaeological sites at Buffalo National River

Figure 1 (above). Looting of caves and prehistoric bluff shelters along the Buffalo National River is a tremendous problem that disturbs archaeological context and damages cultural and natural resources. However, resource managers are diligently putting together clues from looted sites that add time depth to their knowledge of the Buffalo River ecosystem. Figure 2 (facing page). A slippershell mussel (length to 1.5 in [3.8 cm]) from a prehistoric shelter is a species that has not been recorded in the park from historical times.

NPS/CAVEN CLARK (ABOVE)

LOOTING OF PREHISTORIC BLUFF SHELTERS along Buffalo National River in northwestern Arkansas is an enormous problem (figure 1). Of the more than 300 recorded bluff shelters, more than 90% have been subjected to illegal digging, which permanently destroys the scientific value of the site. This unsystematic excavation has resulted in the loss of contextual archaeological data, leaving holes in the ground and piles of dirt containing broken artifacts and faunal remains, including bivalve and gastropod shells.

Instead of writing off these heavily disturbed sites, cultural and natural resource managers at Buffalo National River are working together to interpret what is known of these native mussel communities. Mussel shells collected from disturbed sites can be used to extend our knowledge of species diversity, distribution, and change from prehistoric times to the present. Despite the disturbed context within sites, we judge that most shells date from the prehistoric past and are in excess of 1,000 years old. Though the quantitative applications for these data are limited, the simple presence or absence of species allows us to project past species diversity and, with historical descriptions of habitat quality, we can interpret inferences of prehistoric conditions.

Methodology

In concert with conducting archaeological Site Condition Assessments for the Archaeological Sites Information Management System (ASIMS), mussel shells with diagnostic features are now routinely collected from disturbed sites. These are identified with an archaeological site number and transferred to aquatic biologists for identification. We examined mussels from controlled excavations of prehistoric sites to determine if any unusual species were represented. Dr. Alan Christian, malacologist at Arkansas State University, was instrumental in correct mussel identifications, especially for new and rare species.

The results suggest that the Buffalo River ecosystem, as reflected in the prehistoric distribution of mussel species, has remained stable over a long period.

NPS/CAVEN CLARK

Results

Overall, the mollusk fauna assemblage is consistent with modern diversity and distributions. The results suggest that the Buffalo River ecosystem, as reflected in the prehistoric distribution of mussel species, has remained stable over a long period. However, one species, slippershell (*Alasmidonta viridis*; figure 2), was identified at three locations in two counties. While believed to be present based on range and habitat requirements, it was not actually observed and has not been noted in any subsequent inventories of mussels on this river. The finding of slippershell verifies the presence of a new species within the national park, and suggests that other extirpated species are present in the prehistoric sample.

One specimen of rabbitsfoot (*Quadrula cylindrical*), an uncommon Buffalo River species, was identified. Although it was "ubiquitous" in the 1912 census, its virtual absence in both the prehistoric and modern faunal assemblages is difficult to explain.

Conclusions and future directions

The salvaging of both archaeological and biological data creates an avenue for NPS scientists to understand and document the significance of heavily damaged archaeological resources while park managers continue to battle the problem of site looting. It also shows that valuable information is available from disturbed sites and that communication between scientific disciplines is necessary to better manage the natural and cultural resources we have pledged to protect.

We intend to continue sampling looted sites on an opportunistic basis. We also expect to complete an analysis of extant collections, some from controlled excavations.

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Science Notes

Mine portals at New River Gorge: An ecological perspective

Figure 1. Until the late 1990s, abandoned mine portals at New River Gorge were managed only in the context of visitor safety. However, wildlife surveys in the fall seasons of 2002–2006 contributed information about the importance of this habitat in the lives of a variety of rare and sensitive species.

NPS/MATTHEW VARNER

NUMEROUS WILDLIFE SPECIES DEPEND ON cave resources to complete their life cycles. Although abandoned mine portals are an unnatural feature on the landscape, they provide habitat conditions that are similar to cave environments. In the late 1980s, surveys in New River Gorge National River (West Virginia) identified more than 100 abandoned mine portals. Until the late 1990s, however, park staff viewed these abandoned mines only in the context of visitor safety (fig. 1). Now, faunal inventories highlight the portals as habitats for rare species such as cave salamanders (*Eurycea lucifuga*) and Allegheny woodrats (*Neotoma magister,* fig. 2). While in other portions of its range the Allegheny woodrat continues to disappear, in New River Gorge, mine portals have contributed to the stability of the population. Investigators have also identified various bat species using the portals; however, the specific species and extent of use remained unknown until 2002.

Surveys of the portals conducted in the fall seasons of 2002–2006 resulted in the identification of numerous bat species at New River Gorge National River. Most significant was the identification of two federally endangered species: Virginia big-eared bat (*Corynorhinus townsendii virginianus*, fig. 3) and Indiana bat (*Myotis sodalis*). Before 2002, Virginia big-eared bats had not been documented using abandoned mine portals. Since 2002, investigators have identified both endangered species at numerous portals during the fall. The instability of

Figure 2. A recent ear tattoo, visible on this rare Allegheny woodrat, facilitates monitoring of the species in abandoned mine portals at New River Gorge National River. Though this species is in decline across its range, the population at the national river has been stabilized by the availability of mine portal habitat.

NPS/MATTHEW VARNER

the portals, however, limited internal surveys that would ascertain what species use the portals for hibernation. In early 2007, park staff surveyed eight portals in anticipation of the emergence of post-hibernating bats. The first portal survey resulted in the capture and release of nearly 100 bats within two hours. Five species comprised the blizzard of emerging bats, including Virginia big-eared bats and rare eastern small-footed bats (*Myotis leibii*). Bats emerged from all the sampled portals, with half of these portals containing Virginia big-eared bats.

Many species that use the abandoned mine portals at New River Gorge National River have declined across their range, which underscores the importance of the portals managed by the National Park Service. In 2006, staff at New River Gorge initiated efforts to preserve the portal openings by using bat-friendly gates and exterior stabilization; this practice will likely continue through the next decade. Bat-friendly gates, which allow unimpeded movement of bats in and out of the portal but keep humans out, safeguard this significant habitat (see fig. 1). Protection of the portals allows for cultural resource preservation, interpretive opportunities, and protection of habitats recognized as critical for rare subterranean fauna.

Figure 3. The endangered Virginia big-eared bat inhabits abandoned mine portals at New River Gorge National River.

NPS/MATTHEW VARNER

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Science Notes

Park signs and visitor behavior: A research summary

Relying on an illustration and words, this sign is used at Sequoia and Kings Canyon national parks. Though it has not been studied, it seems to frame the injunctive-proscriptive message. Furthermore, it addresses a management issue in a setting where a high number of international visitors, including those who do not read English, are found. The author plans to study this approach.

NATIONAL PARK STAFFS RELY ON SIGNS TO inform visitors of a great variety of expected behaviors. Where park rangers or volunteers physically cannot be present to remind visitors of important rules, signs can be especially helpful. However, as any ranger will attest, signs vary in effectiveness. The reasons for this are numerous, but message content is a critical factor.

Many studies have examined the effectiveness of interventions to reduce the incidence of damage to natural and cultural resources and facilities in outdoor settings. Cialdini et al. (1990, 1991, and 2006) discuss the "Focus Theory of Normative Conduct," which stipulates that social norms can be a powerful influence on human behavior. Normative information either describes typical human behavior (descriptive) or relates desirable behavior in a particular situation (injunctive), and is framed positively (prescriptive) or negatively (proscriptive). Table 1 presents combinations of message patterns that follow this two-by-two conceptualization of norms. These patterns have served as the basis of a series of studies investigating the effectiveness of signs in directing human behavior.

Background investigations

In 1998 my colleagues and I examined signage in park and forest settings (Winter et al. 1998). We found that the majority of signs focused on rules and regulations and related desired behavior in negative terms (injunctive-proscriptive pattern, e.g., "Don't leave the trail"). In 2000 we reported results of surveys with professional interpreters and educators who were asked to judge the anticipated effectiveness of a variety of messages (Winter et al. 2000). The messages presented desired behaviors (injunctive) in positive or negative terms (e.g., "Protect our environment. Please extinguish your fire," and "Don't endanger our environment. Please don't leave your fire burning"). The positively worded messages were viewed as the most effective.

In another study we field-tested the four message types in deterring theft of petrified wood at Petrified Forest National Park in Arizona (Cialdini et al. 2006). We placed signs displaying different messages along park trails and monitored the amount of petrified wood stolen under each condition. The control was the absence of a sign. The least theft occurred in the presence of the sign presenting desired behavior in negative terms (i.e., injunctive-proscriptive), "Please don't remove the petrified wood in the park," paired with an illustration of the desired behavior, in this case a photo of a person admiring petrified wood on the ground. The message associated with the most theft highlighted the unwanted behavior and was negative (i.e., descriptive-proscriptive): "Many past visitors have removed the petrified wood from the park, changing the state of the Petrified Forest."

Sign research at Sequoia and Kings Canyon

Recently I tested similar messages, but without photographs, at Sequoia and Kings Canyon national parks (California) (Winter 2006). Again I used the two-by-two conceptualization in formulating messages (see table 1) with a control of no sign. All messages were polite, presented clearly and singularly on the sign, and expressed prohibition of off-trail hiking and a brief justification. Signs were 12 by 16 inches (30 x 41 cm), constructed of aluminum and placed on iron posts, and featured white lettering on a dark brown background. Signs were placed along trails in pairs (at two opposing points) at four locations that varied in level of use, amount of existing signs, and degree of resource hardening. Tests were conducted on weekend days in randomly assigned time blocks (see Winter 2006). The research team videotaped hikers in full view of the trail (to assuage privacy concerns), and recordings were evaluated by two independent raters and an arbitrator.

The number of people going off-trail varied significantly by experimental condition, with the greatest proportion of off-trail use occurring where there was no sign. The most effective message (5.1% left the trail) presented desired behavior in negative terms (injunctive-proscriptive message; see table 1). Least effective (18.7% left the trail) was the message describing others' behavior in a negative way (descriptive-proscriptive; see table 1).

Table 1. Trail sign messages tested at Sequoia and Kings Canyon national parks, 2006

Message Type	Wording
Injunctive-prescriptive (i.e., desired behavior, positive)	Please stay on the established paths and trails, in order to protect the sequoias and natural vegetation in this park.
Injunctive-proscriptive (i.e., desired behavior, negative)	Please don't go off the established paths and trails, in order to protect the sequoias and natural vegetation in this park.
Descriptive-prescriptive (i.e., others' behavior, positive)	The vast majority of past visitors have stayed on the established paths and trails, helping to preserve the natural state of the sequoias and vegetation in this park.
Descriptive-proscriptive (i.e., others' behavior, negative)	Many past visitors have gone off the established paths and trails, changing the natural state of the sequoias and vegetation in this park.

Comparing just the desired-behavior messages (i.e., injunctive), it was better to tell people not to go off the trail (negative/proscriptive; 5.1% left the trail) than to stay on it (positive/prescriptive; 15.9% left the trail). Messages describing typical behavior (i.e., descriptive) revealed a different pattern: the most effective (11.8% left the trail) were positive (i.e., prescriptive) rather than negative (i.e., proscriptive; 18.7% left the trail).

Conclusion and limitations

The findings from the Petrified Forest and Sequoia/Kings Canyon studies contrast with what interpreters and educators thought would be most effective, suggesting instead the use of injunctive-proscriptive messages (i.e., desired behavior, negative wording) in signage when relaying information pertaining to desired visitor behaviors, rules, and regulations.

It was better to tell people not to go off the trail . . . than to stay on it.

Application of the findings, however, is limited. This research sought to resolve local resource management problems and did not test the influence of the messages beyond the immediate vicinity of the signs or over a longer-term park visit. Furthermore, the research focused on visitors acting out relatively simple and easily accomplished actions. Behaviors that would require more effort or for which the setting presents substantial barriers might not lead to the same outcomes. Nevertheless, the research was carried out in park settings involving the public. The results are helpful in identifying practical management approaches in situations where individual variations in attitudes and knowledge about park management and ecology, outdoor recreation, and outdoor experience cannot easily be known or accounted for.

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PS

Science Feature

The decline of elkhorn coral at Buck Island Reef National Monument:

Protecting the first threatened coral species

By Ian Lundgren

BUCK ISLAND REEF NATIONAL Monument lies just north of the island of St. Croix in the U.S. Virgin Islands. When it was established in 1961, the park encompassed 176-acre (71 ha) Buck Island and 704 acres (285 ha) of marine habitat surrounding it. The park proclamation describes the monument and its "adjoining shoals, rocks, and undersea coral reef formations" as "one of the finest marine gardens in the Caribbean Sea," which are of "great scientific interest and educational value to students of the sea and to the public." Multiple use was prescribed in the original park purpose, allowing fishing in some areas but protecting others. In 2001 the relatively small national monument was expanded to 19,015 acres (7,695 ha), and all forms of resource extraction were completely prohibited (fig. 1).

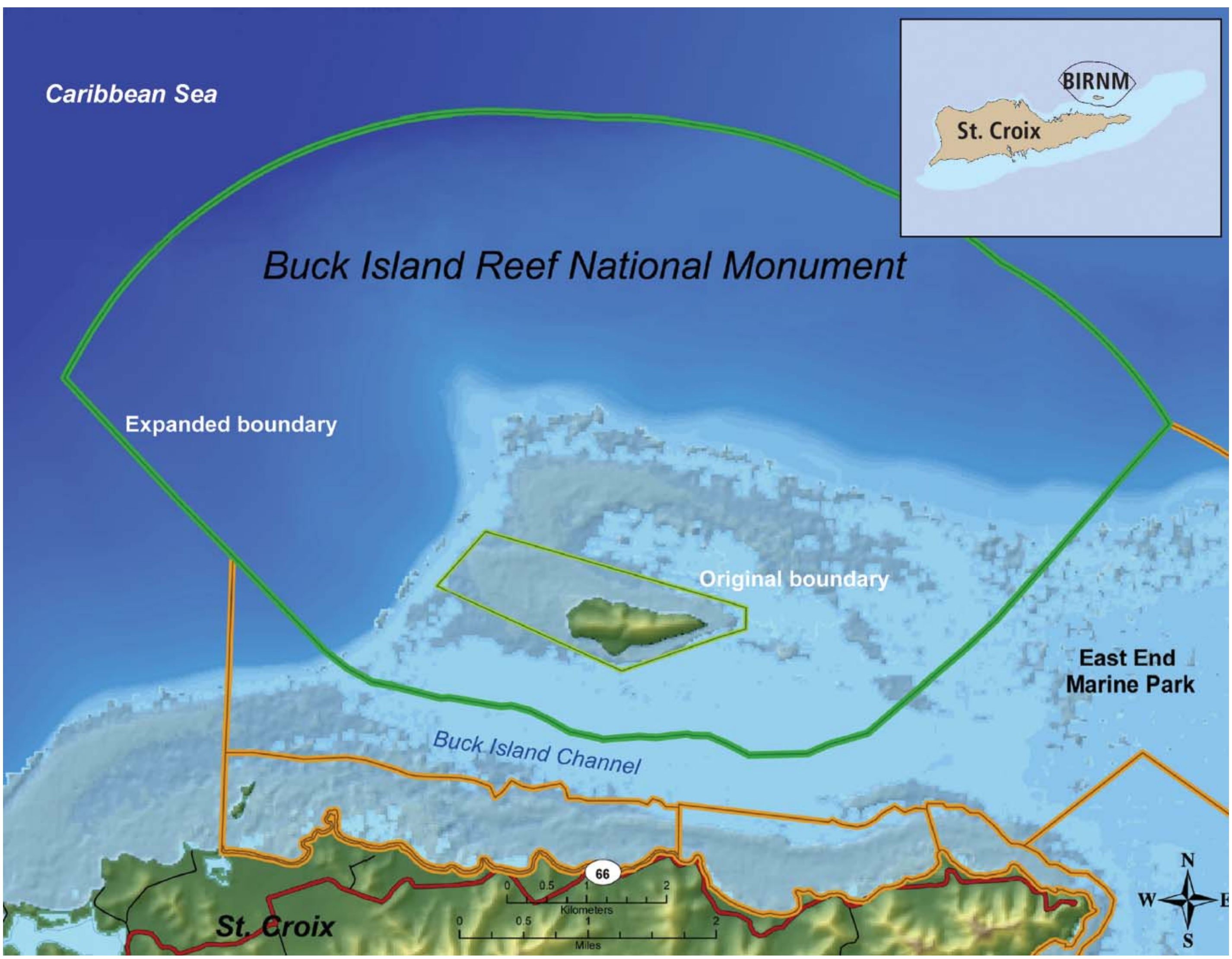

Figure 1. Map of Buck Island Reef National Monument; inset: St. Croix. SOUTH FLORIDA/CARIBBEAN NETWORK

In a tropical marine ecosystem, coral reef communities live in a fragile, interdependent relationship and include essential, interconnected habitats. The 2001 expansion of Buck Island Reef National Monument added coral reefs, sea grass beds, and sand communities, as well as algal plains, shelf edge, deep and dimly lit reefs, and deep oceanic habitats not originally within the monument boundary. These additional habitats preserve ecological links that help sustain the monument and its resources. Another important part of the boundary expansion was placing a vast reef shelf area of elkhorn coral (*Acropora palmata*), a major reef-building species, under management of the National Park Service (see fig. 1).

In 2006, elkhorn coral was listed as threatened under the U.S. Endangered Species Act.

Elkhorn decline

Elkhorn was the dominant coral species in wave-exposed and high-surge reef zones throughout the Caribbean Sea before the 1970s (Adey and Burke 1976). Dense stands of elkhorn coral formed and dominated the barrier reef and unique "haystack features" (patch reefs that resemble haystacks) surrounding Buck Island (fig. 2). However, in the 1970s and 1980s this species drastically declined primarily because of a bacterial syndrome called white-band disease (see sidebar) (Aronson and Precht 2001). Since then, hurricanes, bleaching events, and outbreaks of predators have further decimated the populations of elkhorn coral (see sidebar) (Bruckner 2002). In 2006, elkhorn coral was listed as threatened under the U.S. Endangered Species Act (National Marine Fisheries Service 2006).

Managers' growing concern for elkhorn coral and the impending critical habitat designation under the recovery plan led to coral surveys in 2003–2004 (Mayor et al. 2006). Investigators determined the spatial distribution of the species (fig. 3) and the presence of disease, predation, and wave damage. The surveys estimated that between 97,232 and 134,371 large elkhorn coral colonies (at least a meter in length or height) were present at Buck Island Reef National Monument at that time. Investigators observed white-band disease on 11–12% of elkhorn colonies of all sizes and called for increased monitoring of this species to better understand the dynamics of other stressors, such as bleaching, predation, and severe storms, which can lead to its further decline (Mayor et al. 2006).

Figure 2. Divers enjoy an elkhorn coral haystack feature at Buck Island Reef.

HANK TONNEMACHER

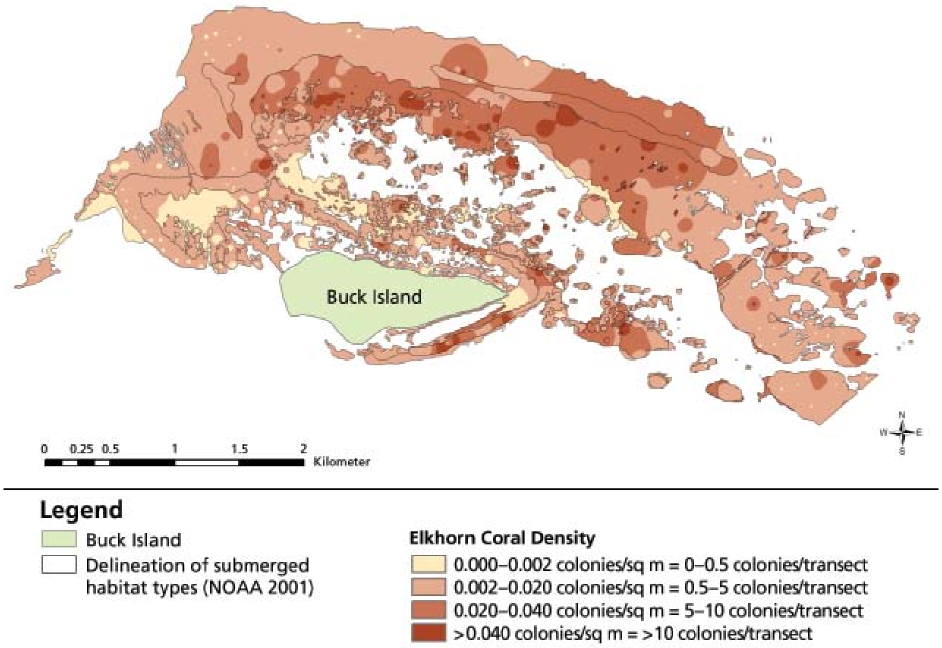

Figure 3. Distribution and density of elkhorn coral colonies at Buck Island Reef National Monument in 2004. PHILIPPE MAYOR

Bleaching event

A beneficial outgrowth of the 2003–2004 monitoring was the impetus to include elkhorn coral monitoring as part of the vital signs monitoring program being developed for Buck Island Reef National Monument by the South Florida/Caribbean Network of the National Park Service. Elkhorn coral monitoring began in March 2005, just before the onset of a major bleaching event, and focused on colonies in the three major types of elkhorn habitat: forereef, backreef, and reef shelf. Investigators monitored sites monthly for health parameters: presence and progression of disease, predation, bleaching, storm damage, and overall change in live tissue cover. This monitoring completely recorded the impact of the bleaching event in late 2005.

Elkhorn coral has anecdotally been known to be resistant to bleaching; however, in 2005, elkhorn reefs experienced the widest-scale bleaching ever reported in the U.S. Virgin Islands. According to the National Oceanic and Atmospheric Administration (NOAA), water temperatures in 2005 exceeded the bleaching threshold at Buck Island Reef National Monument for more than 12 weeks. Data loggers deployed by the National Park Service on both the forereef (33 feet [10 m] deep) and backreef (8 feet [2.5 m] deep) zones of the national monument showed that problematically high water temperatures seemed to be tri-phased during the bleaching event (fig. 4) (Lundgren and Hillis-Starr 2008). Initially temperatures in both the forereef and backreef habitats fluctuated above and below the bleaching threshold, exceeding the threshold 61% of the time on the forereef and 84% of the time on the backreef. By the first week in August, temperatures had exceeded the bleaching threshold at both reef habitats and remained lethal for 10 weeks. In the last phase, temperatures again fluctuated above and below the bleaching threshold as they had before August. The much higher water temperatures over a much longer period in 2005, as compared with historical records from 1991 to the present, explain why this event was so severe (see fig. 4).

The much higher water temperatures over a much longer period in 2005, as compared with historical records from 1991 to the present, explain why this [bleaching] event was so severe.

Biologists documented changes in elkhorn coral conditions by analyzing repeat photography (fig. 5). They preferentially photographed colonies from the planar view (i.e., from directly above) and in shallow water from a consistent oblique angle. They analyzed photos from August and November 2005 and January 2006 using the following categorical evaluation: live healthy tissue retained its normal brown coloration; bleached or mottled tissue was pale or white; and dead tissue had previously been alive but now was covered with algae. The change in live tissue from August 2005 to January 2006 (when bleaching was no longer evident) is the estimated loss as a result of the bleaching event. Of the colonies examined, 82% experienced bleaching, with maximum bleaching for all sites occurring in November 2005. Interestingly, colonies located on the backreef (at a medium depth among the three habitats) were impacted before colonies on the shallower forereef and much deeper reef shelf (fig. 6). More importantly, mortality was twice as high on the backreef and forereef as on the reef shelf (see fig. 6). Mortality on the backreef occurred sooner than on the forereef. The backreef experienced the highest average tissue mortality during the event (66%), followed by the forereef (58%) and the reef shelf (36%) (fig. 7). Overall, out of 44 colonies monitored, only 2 did not experience any mortality during the bleaching event.

Discussion and conclusion

Though shallow elkhorn coral habitat is present on the barrier reef and scattered haystack features surrounding Buck Island, the majority of elkhorn coral habitat

Figure 4. Buck Island Reef National Monument temp logger, 10 m depth forereef underwater trail.

Water temperatures during 2005 bleaching event and historical temperatures since 1991.

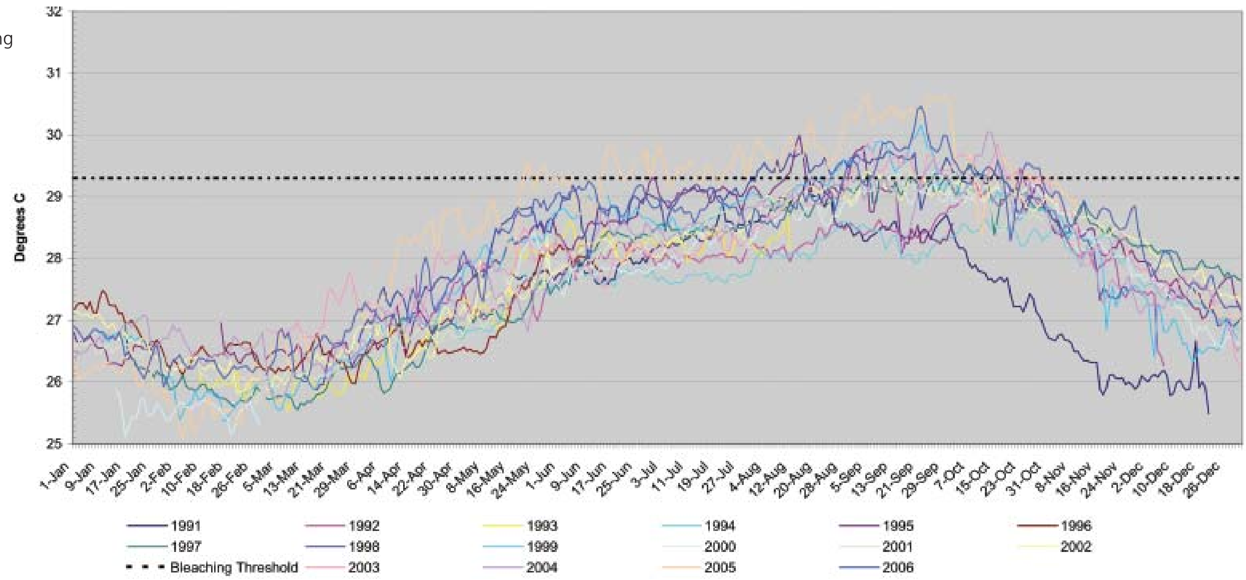

Figure 5. Progression of bleaching in elkhorn corals at two photo-monitored sites, August 2005 to January 2006.

Colony #130 (SFR)

August 2005
0% mottled/bleached
2% algae cover

November 2005
98% mottled/bleached
2% algae cover

January 2006
0%mottled/bleached
95% algae cover

△ bleaching = 98%

△ mortality = 93%

Colony #409 (NBar)

August 2005
0% mottled/bleached
0% algae cover

November 2005
100% mottled/bleached
0% algae cover

January 2006
10% mottled/bleached
10% algae cover

△ bleaching = 100%

△ mortality = 10%

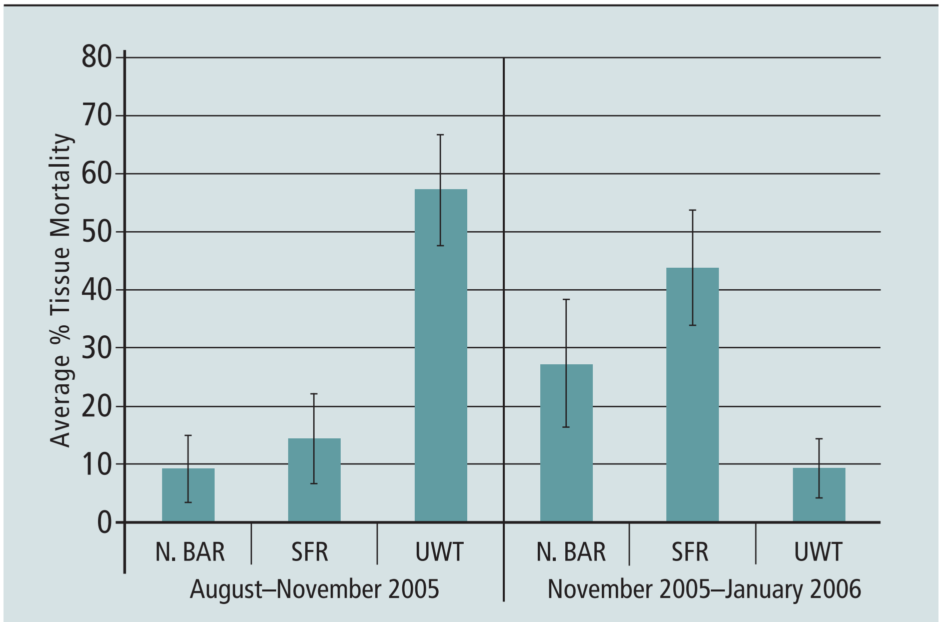

Figure 6. Temporal mortality of elkhorn coral at three monitored sites.

is on the reef shelf north of the island, and is typically deeper habitat (16–33 feet [5–10 m]) than the other elkhorn coral habitats in the national monument (Mayor et al. 2006) (see fig. 3). Rapid and severe bleaching and mortality of the backreef may be linked to restricted water flow and reduced wave action, which increase light penetration and stress, and slightly higher water temperatures (Nakamura and van Woesik 2001). One hypothesis for the greater mortality of the forereef and backreef corals is that the barrier reef was reseeded by coral colonies from the surrounding reef shelf after being destroyed by Hurricane Hugo in 1989 (Vollmer and Palumbi 2007). This would explain the lack of acclimation expected of colonies that are regularly exposed to extreme conditions on the shallow barrier reef (Rowan et al. 1997). Finally, disease could have contributed to mortality during the bleaching event without being detected. Bleached coral can appear identical to tissue affected by disease, especially white-band disease. Bacterial communities with antimicrobial properties normally present in healthy colonies have been known to disappear during bleaching events (Ritchie 2006).

Elkhorn coral colonies located in the backreef, where water flow is restricted and wave action is decreased, are less resistant to bleaching than at other sites and become hotter more quickly; therefore, the backreef would be a poor choice for critical habitat designation under the Endangered Species Act. However, bleaching in backreef colonies could effectively serve as an early detection mechanism, signaling managers to implement a specific monitoring protocol for bleaching events.

The National Marine Fisheries Service is the federal agency that administers the Endangered Species Act in the marine environment, and therefore is responsible for designating critical habitat. The act defines critical habitat as areas that contain "the physical or biological features essential to the species' conservation and which may require special management considerations or protection." The National Marine Fisheries Service is directed to establish critical habitat within one year of listing a species under the act.

Concurrently, Buck Island Reef National Monument is in the final stages of rewriting its general management plan. Under

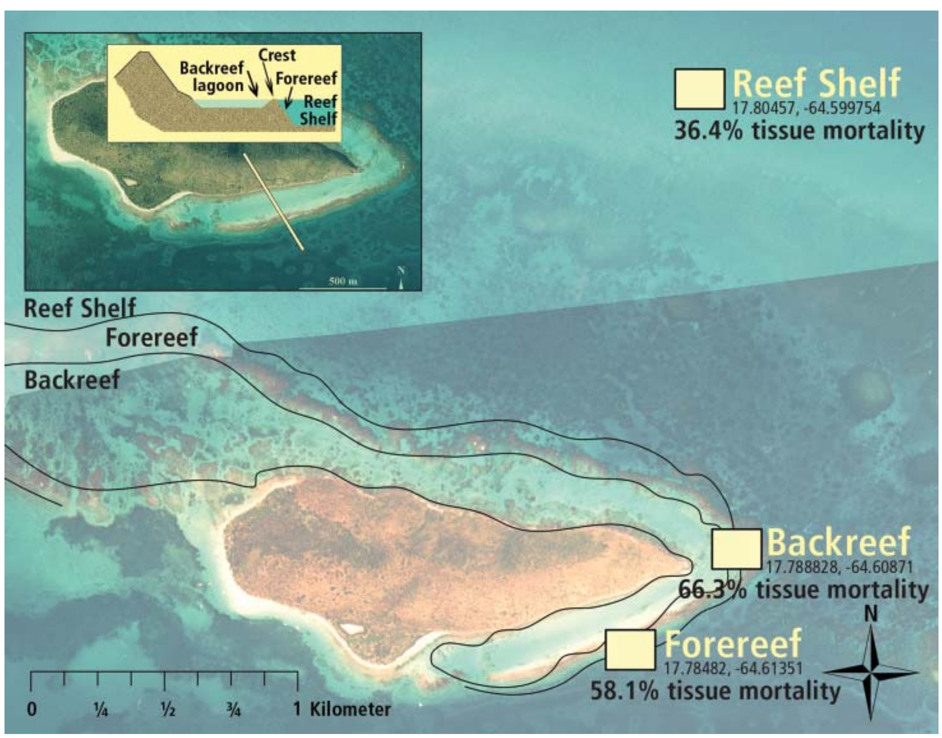

Figure 7. Map of Buck Island Reef National Monument showing monitored locations (forereef, backreef, and reef shelf), percentage of mortality experienced by elkhorn coral colonies as a result of bleaching in 2005, and an inset cross section of the described habitats.

the plan's preferred alternative, much of the elkhorn habitat north of Buck Island would be designated a marine hazard zone, limiting underwater use without permit. This would not affect the famous "underwater trail," though park managers anticipate increasing oversight of snorkelers in this area to ensure that elkhorn coral is well protected as it is being enjoyed by visitors.

Acknowledgments

The extent of our knowledge at Buck Island Reef National Monument is a result of all the researchers who have contributed to it over the past 30 years: Bill and Betsey Gladfelter, Denny Hubbard, Bob Stenek, Caroline Rogers, Philippe Mayor, and others. Zandy Hillis-Starr has dedicated much time and effort to managing elkhorn coral as chief of resource management. Of course, the contributions of staff and contractors such as Brendalee Phillips, Hank Tonnemacher, and Kimberly Woody are invaluable.

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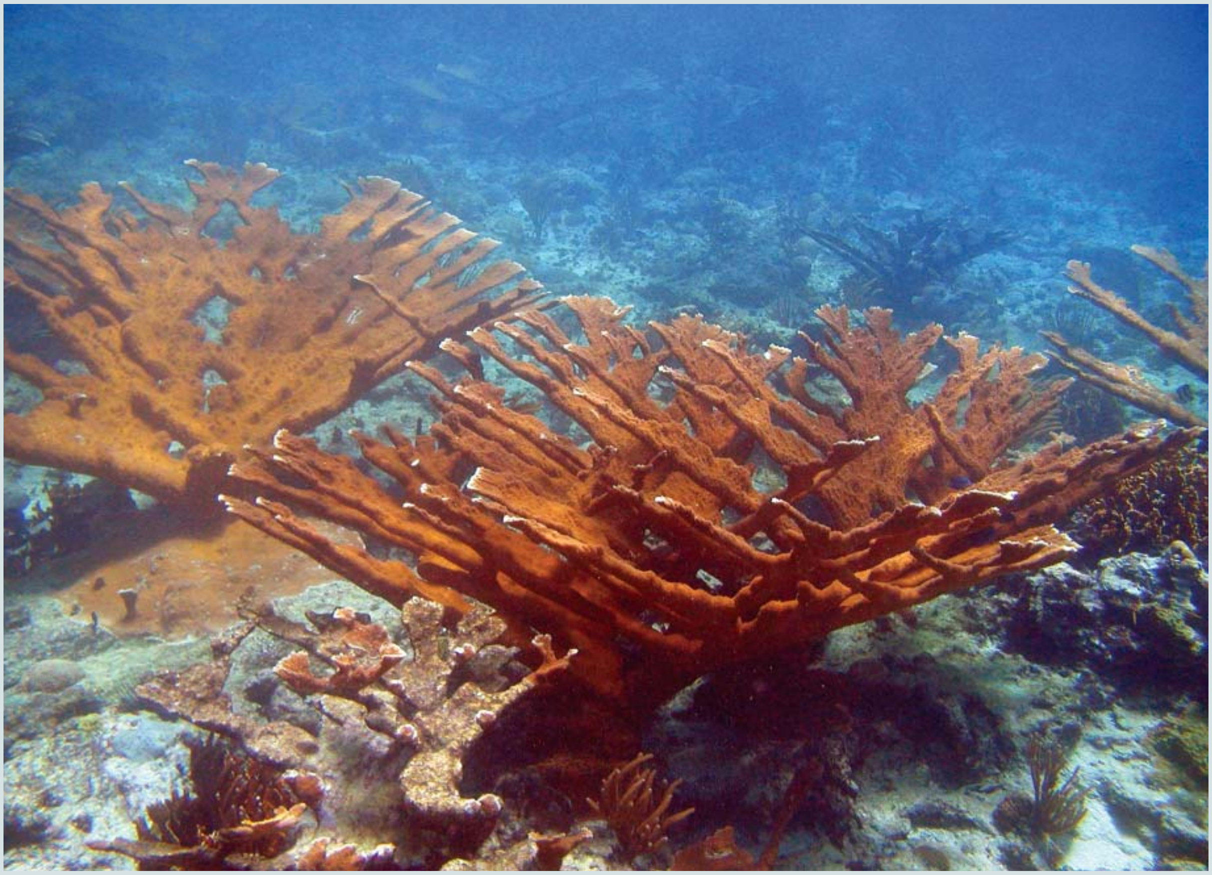
BY IAN LUNDGREN

Basic ecology of elkhorn coral and threats to its

CORALS (SCLERACTINIA) are small colonial invertebrate marine animals. Like jellyfish, they use tentacles to disable their prey; however, they are also sessile (attached to substrate) and excrete a hard calcium carbonate skeleton. When a coral dies, its skeleton forms the structure of coral reefs. Coral polyps, the individual organisms, are symbiotic with unicellular algae called zooxanthellae. Corals derive most of their energy from these algae and in return the algae receive shelter.



PHILIPPE MAYOR

Elkhorn coral is a shallow-water, highly branched species that can grow very large and resemble trees. Though it has been a major reef builder in the Caribbean Sea, this species has undergone drastic declines over the past 30 years as a result of various natural and human causes: disease, hurricanes, predation, and most recently bleaching. In 2006, elkhorn coral and a related species, staghorn coral (*Acropora cervicornis*), were the first coral species to be protected under the Endangered Species Act.

HANK TONNEMACHER

Bleaching

In corals, bleaching is a generalized response to stress, and multiple stresses can increase the severity of bleaching. Corals derive their often brilliant color from symbiotic algae. Under stress, algae are expelled from coral tissue, leaving coral polyps clear, making the underlying white coral skeleton conspicuous, and giving the colony the appearance of having been "bleached." Although almost any type of stress can induce bleaching, the rise in water temperature from global climate change has induced bleaching on a massive scale. Because tropical corals live very close to their upper temperature limit, global climate change has the potential to cause more severe and more frequent mass coral bleaching

survival

ZANDY HILLIS-STARR

NPS

Photos (clockwise from top left, facing page):

Healthy elkhorn coral, storm-damaged coral, fireworms, coral predatory snails, and coral with white pox disease.

NPS

events like the one observed in the Caribbean in 2005. Acidification of oceans from increased carbon dioxide dissolved in ocean water is an additional threat to corals related to climate change.

Disease

Various, poorly understood diseases affect elkhorn coral. First observed in the 1970s, white-band disease appears as a narrow band of infected tissue (bleached) that migrates from the base of the colony toward the branch tips; the cause remains unknown. This disease kills coral tissue and can quickly eliminate entire colonies (2 inches [5 cm] per day). Linked to poor water quality, specifically a bacterium present in human feces (*Serratia marcescens*), white pox disease appears as expanding patches of dead tissue on the coral colony.

Hurricanes

The forces generated by hurricanes in the marine environment can break shallow branching corals such as elkhorn, especially if disease or organisms (e.g., burrowing worms that erode the coral tissue) weaken the corals' skeletons. Hurricanes can very quickly snap coral branches and turn coral thickets into rubble, which cannot reattach themselves to the substrate and thus continue to grow. Although tropical cyclones are naturally occurring, scientists believe that global climate change is increasing the frequency and severity of these storms, which can directly impact coral communities in the Caribbean.

Predation

Snails (*Coralliophila* spp.) and fireworms (*Hermodice* spp.) are the most significant invertebrate predators of corals. Snails are gregarious and individually consume up to 2.5 inches (65 mm) of coral tissue per day. Fireworms prefer coral tips, where growth occurs, and their feeding on individual coral colonies can be extensive. Overfishing of hogfish and lobsters, which eat snails and fireworms, allows these coral predators to multiply, which in turn increases predation on elkhorn corals beyond natural levels.

Science Feature

Assessing the effects of ungulates on natural resources at Assateague Island National Seashore

By Mark Sturm

UNGULATES ARE A THREAT to many of the natural resources at Assateague Island National Seashore (Maryland and Virginia). Feral horses (*Equus caballus*) (fig. 1), Asiatic sika deer (*Cervus nippon*) (fig. 2), and native white-tailed deer (*Odocoileus virginianus*) (fig. 3) roam the barrier island, competing for resources and disrupting natural processes that maintain habitat for a diverse array of plant and animal species of conservation concern. These include the piping plover (*Charadrius melodus*), a shorebird, and seabeach amaranth (*Amaranthus pumilus;* see sidebar, fig. 4), a fleshy-leaved plant. Though these species are threatened with extinction, management of ungulates to help protect them is a complex challenge owing to historical and ecological factors and multiple management jurisdictions.

Assateague Island is located on the highly developed mid-Atlantic coast of the United States. The Maryland portion of the island, 21.7 miles (35 km) long, is managed primarily as Assateague Island National Seashore, while a roughly 1.8-mile (3 km) section is managed by the Maryland Department of Natural Resources as Assateague State Park.

Feral horses have continuously occupied Assateague Island for more than three centuries. Though the origin of the horse

Figure 1. Symbol of Assateague Island National Seashore, feral horses grew in number from 28 in 1968 to a high of 179 in 2002. A successful contraceptive program has reduced the population to 134 individuals in 2008.

NPS PHOTO

population is unclear, by the time the national seashore was established in 1965 the horses had long since become an important regional icon, and they remain very popular among visitors today. Given the horses' historical and cultural significance the National Park Service identified them as a desirable species in 1982 and manages them as wildlife. However, in order to control the size of the population, the park employs a contraceptive program developed for the national seashore (Kirkpatrick 1995) that has reduced the species' numbers from a high of 179 in 2002 to its current size of 134.

Sika deer were introduced to the island in the 1920s by a private landowner (Flyger 1960). Since then, this "deer" species, which is actually a small Asiatic elk, has become naturalized on the island. Both nonnative sika and native white-tailed deer are subject to a congressionally authorized hunting season to control their abundance. Despite considerable annual hunting pressure, sika deer have continued to maintain a sizable population, and at

Figures 2 and 3. Population estimates indicate that nonnative sika deer (top) outnumber native white-tailed deer (bottom) by about three to one on Assateague Island. Both deer species occur throughout the island and are frequently observed in marsh, forest, shrub, and dune habitats.

B. EMERSON (TOP); NPS PHOTO (BOTTOM)

this time their elimination from the island may not be feasible.

For more than two decades scientists have been studying the effects of the three ungulate species on island vegetative communities and natural processes. This article summarizes that program of research and its implications for effective ungulate management strategies.

Initial studies

Growing concern about the ever-increasing horse population and its impacts on vegetation led to initial studies in the 1980s and 1990s. The research focused on the effects of foraging in island dune and low (i.e., lowest-elevation) salt-marsh habitats, since horses spend much of their time in these areas. Stribling (1989) found, for example, that horse grazing altered nutrient cycling in low salt marshes, while Furbish (1990) and Furbish and Albano (1994) discovered that horse grazing reduced aboveground biomass, altered low salt-marsh plant and animal species composition, and at high intensities may change the phenotypic expression (i.e., increased stem density or lower growth form) of cordgrass (*Spartina alterniflora*), the dominant grass species of the low salt marsh. Similarly, Seliskar (1997) found that horse herbivory reduced the abundance of American beachgrass (*Ammophila bevigulata*), a dominant grass species in island dune systems. De Stoppelaire's (2002) research supported this finding, and further revealed that horse herbivory interrupted dune formation and maintenance processes, which are essential to the long-term health and sustainability of the barrier island. All of these findings were attributable only to horses since deer impacts were ubiquitous throughout the treatment areas of all these studies.

Isolating the effects of ungulates

To better understand the effects of herbivory by all three island ungulate species, we decided in 2002 to study the individual influences of horses and deer in island vegetative communities believed to be most commonly used by deer. Previous research using fecal analysis had identified a number of plant taxa consumed by sika and white-tailed deer (Kochenberger 1982; Keiper and Tzilkowski 1983). Using this information we developed a study of ungulate herbivory. We identified multiple potential study sites that had comparable abundance of plant species known to be consumed by both deer species, and then selected four at random in both maritime forest and shrub habitats.

Each study site consisted of three treatments: (1) a horse and deer exclosure (fig. 5), (2) a horse exclosure (deer entered freely) (fig. 6), and (3) a control area where both deer and horses foraged. The exclosures were constructed in fall 2002 and the treatment areas measured 66 × 98 feet (20 × 30 m). Given this design, data from treatment areas excluding both horses and deer reflected the vegetative response to "rest" from all ungulate herbivory, whereas data from treatments that allowed only deer to enter reflected the vegetative response to herbivory by both deer species in the absence of horses.

From 2003 to 2005 we collected data in both the early (spring) and late (summer) growing seasons. We used an adapted pin-sampling technique that sampled from 0 to 4.9 feet (0 to 1.5 m) aboveground, which reflects the range where the vast majority of deer and horse herbivory occurs. We measured and monitored changes in plant species mean height, diversity, evenness, richness, and abundance. We conducted analysis of variance (ANOVA) and Tukey tests on each of these parameters. Also, with help from

Figure 4. Assateague Island preserves some of the only remaining habitat for plants and animals of management concern on the mid-Atlantic coast, including the seabeach amaranth. This threatened annual plant species is vulnerable to trampling and herbivory by ungulates.

NPS PHOTO

Figure 5. With the goal of better understanding the ecological role of ungulates at Assateague Island National Seashore, managers conducted research beginning in 2002 to isolate the influences of horses and deer on park vegetation and ecosystem processes such as invasion by exotic plant species. Exclosures like this kept horses and deer out, allowing scientists to study vegetation without pressure from ungulates.

NPS PHOTO

Figure 6. Used in recent studies, exclosures like this prevented horses from eating and trampling vegetation. Scientists were thus able to isolate the effects of deer on park vegetation.

NPS PHOTO

the NPS Northeast Coastal and Barrier Island Network, we used species relative abundance estimates to conduct analysis of similarity (ANOSIM), a nonparametric technique used to analyze community data. Significant ANOSIM results led us to further conduct similarity percentage analysis (SIMPER), which assesses the level of similarity among areas. We used a protected experiment-wise error rate (α_e) of 0.05 throughout these analyses, which revealed patterns of influence that were directly attributable to deer or horse herbivory, or to the combination of both (see examples in table 1).

Results and discussion

This research has given us a new level of understanding of the role of horse and deer herbivory in the development of Assateague Island's maritime forest and shrub communities. For example, we found that deer primarily limit red maple (*Acer rubrum*) sapling recruitment (table 1). The ecological implications of this effect are great, since it restricts the reproductive capacity of red maple, which today is an important component of many Assateague Island habitats. We also learned that deer herbivory significantly increases the abundance of phragmites (*Phragmites australis*), a nonnative, invasive plant species (table 1). Phragmites apparently compensates for herbivory by increasing the number of shoots and runners it produces; therefore, deer are affecting the rate at which native plant communities are being replaced by homogeneous stands of this invasive exotic. In addition to having important biological ramifications, this finding is significant financially, since we are currently preparing to implement a costly phragmites treatment program.

Horse herbivory was similarly found to be influencing the growth and development of maritime forest and shrub habitats. For example, horses significantly reduced overall species diversity during the summer in forest understory habitats. This is likely the result of foraging combined with other destructive behaviors such as trampling and rubbing. In areas of the forest understory where horses were excluded, plant diversity quickly increased regardless of whether deer were present; however, we found the highest plant species diversity in forest treatments where both horses and deer were excluded. This research also confirmed the finding of Seliskar (1997) and De Stoppelaire (2002) that horse herbivory reduces American beachgrass abundance. Understanding this aspect of the influence of horse herbivory is key because of the important role American beachgrass plays in dune development and maintenance. Table 1 reveals further examples of many other important results that were attributable to horse or deer herbivory.

Complementary studies

In addition to understanding vegetation impacts, we wanted to know more about horse and deer abundance and movements on the island to better understand the relative vegetative influence of each species. The horse population is relatively certain at any given time, since we closely monitor it as part of our contraceptive program to help control population growth. Estimating the size of the island's deer populations, however, was more problematic.

Both species of deer are secretive and their habitats are often dense, making the animals difficult to detect. Given these difficulties, we used distance sampling in part because this survey method could account for individuals that went undetected (Buckland et al. 2001). Using a stratified random sampling design, we established 35 cross-island transects each year from 2003 to 2006 to sample the island's diverse habitats for deer. We typically established the transects several weeks before they were surveyed in order to allow deer to become acclimated to them. We collected these data in February, after the hunting season yet before the birthing season, a time of year when both deer populations experience annual lows. Our estimates were fairly consistent from year to year and revealed an abundance of about 26 sika deer (95% confidence interval [CI]: 17–40) and 8 white-tailed deer (95% CI: 4–15) per square mile (Sturm 2007). This equates to 10.0 (95% CI: 6.6–15.4) sika and 3.1 (95% CI: 1.5–5.8) white-tailed deer per square kilometer.

Cooperators with the U.S. Geological Survey and Pennsylvania State University have also been investigating the movements and habitat use of sika and white-tailed deer using radiotelemetry in a related study that concluded in fall 2007 (Diefenbach 2005). The final report is pending; however, preliminary results reveal movement and dispersal differences between species.

Conclusion

This research has shed new light on the individual and combined effects of horse and deer herbivory on the maritime forest and shrub plant communities of As-

Table 1. Plant response to ungulate herbivory at Assateague Island National Seashore, 2003–2005

Common name	Scientific name	Habitat[1]	Horse or deer[2]
	Increase in height		
Tapered rosette grass	*Dichanthelium acuminatum*	Shrub	Deer
Bayberry/waxmyrtle	*Morella* spp.	Shrub and forest	Deer
Greenbrier	*Smilax rotundifolia*	Forest	Horse
	Increase in abundance		
Common reed[3]	*Phragmites australis*	Shrub	Deer
Common threesquare	*Schoenoplectus pungens*	Shrub	Both
	Decrease in height		
Sand-heather	*Hudsonia tomentosa*	Shrub	Horse
Seaside goldenrod	*Solidago sempervirens*	Shrub	Deer
	Decrease in abundance		
Red maple (saplings)	*Acer rubrum*	Forest	Deer
American beachgrass	*Ammophila breviligulata*	Shrub	Horse
Slender woodoats	*Chasmanthium laxum*	Forest	Horse
Bull thistle	*Cirsium* spp.	Shrub	Deer
Hyssopleaf thoroughwort	*Eupatorium hyssopifolium*	Shrub	Deer
Marsh fimbry	*Fimbristylis castanea*	Shrub	Horse
Beach pinweed	*Lechea maritima*	Shrub	Deer
Blackberry	*Rubus* spp.	Shrub	Deer
Seaside goldenrod	*Solidago sempervirens*	Shrub	Deer
Muscadine grape	*Vitis rotundifolia*	Shrub and forest	Deer

Note: Plant taxa include early- and late-season species, annuals and perennials, species that reproduce and disperse via various means, and species that respond differently to environmental stressors such as drought or periodic flooding.

[1]Habitat type where the response occurred (forest or shrub).

[2]Observed response attributable to horse or deer herbivory, or the combined effects of both.

[3]The significant increase in abundance by *Phragmites* was found after four years of data collection. All other results were significant after three years of data collection.

sateague Island. We have begun to understand how horses and deer, individually and collectively, influence the recruitment and expansion of dominant native and nonnative plant species. We are also learning how they directly and indirectly affect the survival and reproductive success of threatened and endangered species (see sidebar). Of great importance, we understand how they can interrupt essential barrier island processes such as dune formation. Finally, we have gained insights into the potential for interspecific competition between sika and white-tailed deer and better understand their relative influence on sensitive vegetative parameters.

The implications of this work are broad: We are moving toward holistic management of the island's horses, deer, and vegetative communities. We are developing monitoring protocols to measure vegetative parameters affected by ungulates. Ultimately, we plan to implement a robust yet conceivably simple adaptive management program designed to inform decisions pertaining to ungulate management and the preservation of the vegetative communities upon which they depend. Over the long term we anticipate that this approach will help us successfully manage Assateague Island National Seashore's horse and deer populations as well as the extent of their individual and combined effects on ecosystem health and integrity. With a little luck this program may one day serve as a model for monitoring, managing, and mitigating the effects of multiple cohabitating native and nonnative wild ungulate populations. The final project report (Sturm 2007) is available from http://www.nps.gov/nero/science/FINAL/ASIS_horsedeer/ASIS_horsedeer.htm.

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About the Author

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PS

BY MARK STURM

Saving the seabeach amaranth

SEABEACH AMARANTH IS AN ANNUAL VAS-cular plant species that grows in sparsely vegetated coastal beach habitats, which are created and maintained by natural disturbances such as storms and extreme high tides (see fig. 4, page 46). Seabeach amaranth is federally listed as threatened with extinction in large part because coastal development has eliminated much of its critical habitat throughout its range (Massachusetts through South Carolina). After an absence of more than 30 years, seabeach amaranth was rediscovered on Assateague Island National Seashore in 1998 (Ramsey et al. 2000), after which the park initiated a species restoration project that took place from 2000 to 2002 (Lea et al. 2003).

Monitoring during the restoration project revealed that average plant size was exponentially correlated with seed production (Lea et al. 2003). In other words, larger plants produce disproportionately more seeds. Therefore, successful management strategies for this species should encourage increased plant size. Following restoration, monitoring revealed a sharp decline of more than 40%, from 912 individual plants in 2002 to 503 in 2003. Though ORV (off-road vehicle) use and other activities may limit seabeach amaranth expansion, further monitoring revealed that ungulate herbivory was the primary cause of the observed decline. In 2006 a comparative study that paired 70 caged (i.e., protected) and uncaged seabeach amaranth plants revealed that ungulate herbivory reduced average survival throughout the growing season by 27% and reduced plant size by an average of 58%. This represents an estimated 500% reduction in seed productivity. During this study the type of ungulate herbivory (horse or deer) was documented whenever possible, and horses and deer were roughly equally responsible for the observed reductions in amaranth survival and average plant size. After three years of deploying 150 to 220 protective cages (fig. 7), Assateague Island National Seashore's seabeach amaranth population has rebounded, numbering 2,179 in 2007.

Successful management strategies for [seabeach amaranth] should encourage increased plant size.

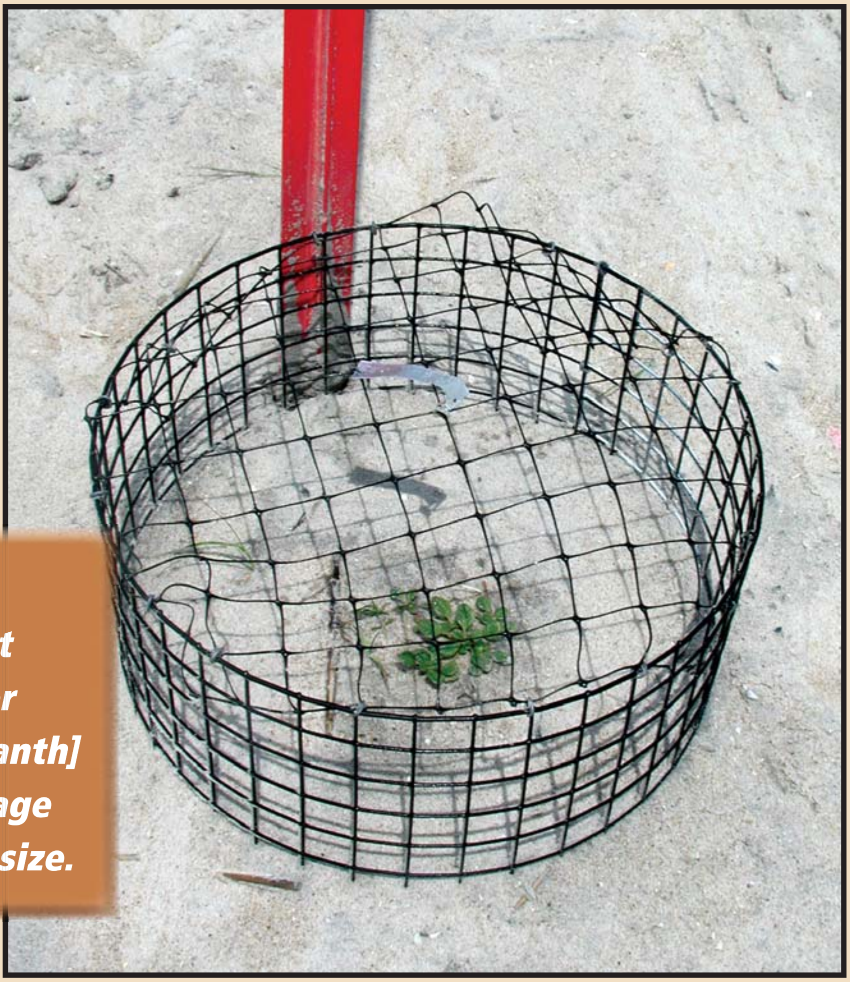

Figure 7. A sensitive species, seabeach amaranth is aided at Assateague Island National Seashore by a management program that protects a portion of the annual population from being eaten and trampled by horses and deer so they can mature and produce seeds. Conservation efforts have helped the plant population increase to nearly 2,200 individuals in 2007.

NPS PHOTO

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PS

Interview with Mike Soukup

Continued from page 13

tively, those who value their nation's heritage will decide whether to protect it or not. The intermediate step is to get credible messages to park visitors, park neighbors, and national constituencies. The role of education has been sorely neglected of late and needs to be propelled forward in new and powerful ways. I was always amazed at the range of people willing to step in and help national parks. I think a fully functioning NPS can shape the future of the nation, and by example, the world.

What will be the biggest challenge to face park managers over the next 10 to 100 years?

MS: My candidate would be developing the capability to transform information into understanding. The mission requires that the men and women of the National Park Service understand complex resources—that is, that they master systems ecology. This is achieved by constantly improving information and reducing uncertainty. The big challenge is in not only collecting lots of the right information but in integrating and assimilating it into usable knowledge. The Service needs to develop and retain the staff to do this. I truly hope the host of new technical folks who came into the National Park Service through the Natural Resource Challenge will be able to spend their professional careers in the Service, with their full value to the NPS mission understood.

What are the priorities and goals for scientific research in parks for the future?

MS: You can't always predict them—and you shouldn't need to. I would argue that making parks hospitable places for researchers (e.g., with a robust array of Research Learning Centers) will pay off over time if the National Park Service constantly integrates new information into working models of park resources. Managers can always detect missing data and relationships that can be targeted as new research priorities. Before long, as in the Everglades, the Service will approach a functional understanding of how to protect the resources.

What should park managers fight for and what is best compromised, regardless of political climate?

MS: I think most park managers know what is important and worth jeopardizing their careers for. Certainly in practical terms, one must choose one's battles, but any issue that threatens impairment or irreversible impacts should be cause for drawing battle lines. Time spent in the career doghouse goes with the territory, but can build character.

One way to manage those situations is exposure. A process that allows wide exposure and a thoughtful weighing of options is the best way to navigate among the agendas stemming from widely different philosophies. This happened during the revision of Management Policies in 2006. I hope the Centennial Initiative will result in a wider comprehension that national parks are a direct reflection of the nation's heritage and are both symbolically important and valuable assets that warrant the most cautious management. I think the national heritage aspect of the National Park System ought to be given much more deference by other agencies who often think of national parks as annoying roadblocks for their agendas.

A national system of parks, all acting with credibility in word and deed and providing powerful experiences and educational programs, could catalyze real change in the modern landscape.

You mention "practical environmentalism" in your introduction to *Natural Resource Year in Review—2006*. What is this?

MS: I think the skills we learn and practice in managing parks unimpaired for present and future generations establish a mind-set that would also be important for the public at large to adopt in their daily relationship with the planet. For example, as an organization the National Park Service is acutely aware of its impacts and the need to minimize its footprint within parks. It is vigilant for invasives. It fights hard for natural quiet, clean air and water, dark night sky, "leave no trace," sustainable uses, energy efficiency, and so on. The same thought processes and actions, if practiced by everyone, would begin to change behavior and lessen the impact [that more than] 6 billion humans are having on the planet. Conspicuous consumption is a dubious cultural icon for America to continue to export. If the National Park Service could teach these lessons by example to 100 million park visitors a year, it would not be insignificant. I've seen communities that increasingly realize that there is something very special about having a national park in the neighborhood and that maybe some things are going on there that need emulating. A national system of parks, all acting with credibility in word and deed and providing powerful experiences and educational programs, could catalyze real change in the modern landscape.

PS

Case Study

Collaboration of the Natural Resource and Museum programs:

A research tool for information archives at Dinosaur National Monument

By Lynn Marie Mitchell and Ann Elder

ANYONE WHO HAS BROWSED the natural resource section of a national park library or the files in the resource manager's office probably has encountered handwritten numbers beginning with the letters "NP" or "BibKey" on the cover or first page of print materials. These numbers indicate that the materials contain park-related information that has been deemed significant and that has been cataloged. The numbers link these materials to corresponding records in NatureBib, the NPS natural resource bibliographic database developed by the Natural Resource Program Center (NRPC) in Fort Collins, Colorado.

The cataloging of published and unpublished park-related reports, journal articles, conference proceedings, theses, dissertations, and similar documents provides a valuable information resource for park managers, scientists, interpreters, and other users. The bibliographic database makes finding citation information easy. However, it does not ensure proper management of or easy access to the physical items themselves—some of which are one of a kind—that are scattered throughout park offices, libraries, and files. Through NatureBib the National Park Service (NPS) has invested significant resources to locate, identify, and electronically catalog park-related natural resource information. The physical location of these items is not regulated and cannot easily or reliably be determined. Fortunately, the NPS Service-wide Museum Program has a system for preserving, cataloging, and managing archival materials that maintains the links between the items and their records in NatureBib.

The cataloging of published and unpublished park-related reports, journal articles, … and similar documents provides a valuable information resource for park managers, scientists, interpreters, and other users.

One of the strengths of the Service-wide Museum Program is its ability to preserve archival materials in perpetuity, regulate their location for the long term, and provide access. The Museum Program maintains the Automated National Catalog System (ANCS+), a database that facilitates cataloging and is a key accountability component for NPS museum collections. The museum personnel in a park, however, often do not have the resources or expertise to evaluate the scientific significance of information as thoroughly as park or regional natural resource staffs. This presents the perfect opportunity to capitalize on the strengths of two programs to develop a powerful research tool for park managers, scientists, interpreters, and other users while ensuring the long-term preservation of these important materials.

In this article we discuss how staff at Dinosaur National Monument (Colorado and Utah) was able to capitalize on the strengths of the Inventory and Monitoring and Museum programs to solve a records management problem involving historical documents dating to the early 1900s. We also discuss the influence of this project on the archival cataloging protocols for the Intermountain Region and NatureBib.

More than dinosaurs at Dinosaur

In April 2001 we completed the first systematic museum archival assessment of natural resource information for Dinosaur National Monument. During this process, we found the office of the former resource management specialist to contain an enormous collection of natural resource records and documentation, including raw data (e.g., field notes, wildlife observation cards), photographic images and slides, maps and drawings, central file material, unpublished reports, theses and dissertations, correspondence, and other types of natural resource programmatic information (fig. 1). Surveyors noted that hundreds of individual items were labeled with NatureBib numbers for which corresponding records had been created in the NatureBib database. These materials were spread throughout the office: in piles on the floor, stacks on bookshelves, folders in file cabinets, map tubes, and numerous binders containing photographs and slides.

When the resource management specialist position was vacated in 2002, park managers decided to lock the office until it could be inventoried and the materials boxed in preparation for future archival processing and cataloging. The lockdown meant that resource managers who had relied on this information in the past would not be able to access the office on their own to search for it. From the moment the door was closed, the pressure was on the park museum curator to establish order and accountability to protect this wealth of information and to make the materials easily accessible.

In spring 2003 we began the formal process of sorting this material by various topics and projects so that it could be cataloged and accessioned into park archives. Every paper, document, map, and slide from every stack, pile, and file was evaluated. The initial sort resulted in approximately 75 boxes categorized by management issue, including bighorn sheep, Mormon crickets, peregrine falcon recovery, endangered fish, vegetation management, fire effects, deer and elk management, grazing, and river management. The boxes were moved to a secure area where park staff and researchers could access them. The sorted information was not yet cataloged, and the only way managers could locate what they needed was by searching through entire boxes. The Museum Program at Dinosaur National Monument had yet to make the information easy to find.

Cataloging begins

In FY 2003, Dinosaur National Monument received its first backlog cataloging project funds as part of the Service-wide Comprehensive Call. Park staff chose grazing as the first collection of materials to be cataloged because cattle and sheep grazing within the park is a critical management issue. Cataloging was completed by the Intermountain Region Museum Service Archives Program. Subsequently, we have cataloged land records (e.g., grazing, water, air quality studies); ecology study of the Green River, 1962–1965; natural history records, 1940–1995; mule deer migration and ecology, 1963–1969; bighorn sheep management, 1940–2001 (fig. 2); Mormon cricket management, 1961–1992; and feral horse removal, 1973–1979. Peregrine falcon recovery and the deer and elk pellet project were cataloged in FY 2007. To date we have cataloged more than 138,560 items into 231 records or record groups and have given each collection a finding aid, which is a key access tool that is tailored to the anticipated use of the collection.

Figure 1 (above). Without proper cataloging, resource management records generated by field staffs may take on whatever organizational structure works best for the originator, limiting their access and use. A cataloging project at Dinosaur National Monument combined the expertise of the Museum and Inventory and Monitoring programs of the National Park Service to create permanent catalog records for important natural resource information so that it can be easily discovered and broadly used. NPS

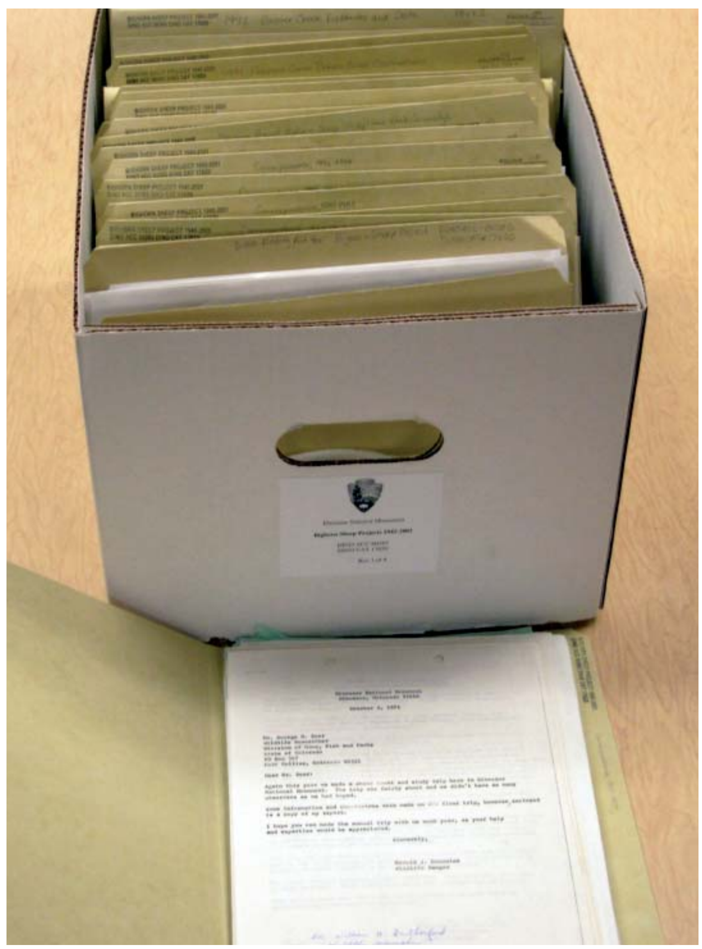

Figure 2 (right). Box 1 of the Bighorn Sheep Project, 1940–2001, after processing and cataloging. NPS

Intermountain Museum Services Program
Tucson, Arizona

NatureBib Form

The Project Archivist should complete this form to permanently link previous bibliographic reference numbers to the ANCS+ catalog record. Provide a completed copy of this form for each number to the MSP Archivist. The citation number will be based on one of the following:

Bibkey ID:
or
NPBib ID: 35779
or
NRBib ID:

Folder Title: Thesis "Ecological Evaluation of the Dinosaur National Monument Bighorn Sheep Herd"
Document Title: "Ecological Evaluation of the Dinosaur National Monument Bighorn Sheep Herd"
Item(s) Description: Thesis of Gary Thaddeus Skiba, based on field worked conducted at Dinosaur National Monument between June and September, 1978 and May to December, 1979. Thesis addresses: 1) population size, 2) population parameters (sex/age ratios and survival rates), 3) physical and physiological parameters of the herd, 4) determination of disease and inbreeding as limiting factors, and 5) descriptions for distribution, movements, and habitat use.

Item(s) Location: Dinosaur National Monument
Collection Title: Bighorn Sheep Project, 1940-2001
Park Accession No: DINO ACC-00385
Park Catalog No: DINO CAT. 17620

- ❑ Bibkey/NPBib/NRBib ID printed on the first page
- ❑ Bibkey/NPBib/NRBib ID printed on folder
- ❑ Bibkey/NPBib/NRBib ID entered into the 'Summary Note' field in the Collection, Series and File Unit levels in ANCS+

Figure 3. Form used by archivists to link NatureBib materials cataloged in the Museum Program's ANCS+ to the Natural Resources Program.

As part of the cataloging process, we preserved NatureBib numbers, creating a permanent link between the Service-wide Museum Program's ANCS+ record and the NRPC NatureBib database. The Intermountain Region Museum Services Program developed a NatureBib form (fig. 3) that we used to record and track specific NatureBib numbers or their predecessors: NPBib and NRBib. A project archivist completes the form for each item that has a NatureBib number. The form links the item to the park accession and catalog number, and a copy remains in the file folder containing the informational materials. An additional copy is retained by the park curator for reference in the appropriate accession folder. A spreadsheet is furnished to the NPS natural resources bibliographic coordinator with the Natural Resource Program Center, who maps the data to the "ANCS+" field in the NatureBib database. The project archivist also places the NatureBib number in the "Associated Materials" field throughout the archives module of the ANCS+ catalog record.

With this process complete, park managers and researchers can locate a specific NatureBib reference by searching either the ANCS+ or NatureBib database. Users of NatureBib can search electronically for the associated park accession number where the references are permanently housed. Users of ANCS+ can search electronically and find all NatureBib numbers associated with a single accession. When physically searching a project such as "peregrine falcon recovery, 1978–1999," researchers can quickly locate all similar NatureBib references by looking for the NatureBib forms filed with the items or the NatureBib numbers on the file folder or storage enclosure. The link is preserved between the databases of the two programs.

A successful archival collection

A well-processed and -cataloged archival collection should ease the search for requested resource materials. Finding aids are fundamental research tools for gaining access to unique and diverse archival collections. Dinosaur staff requested that finding aids be easy to use, easy to distribute to both park staff and outside researchers, and easy to update. The Intermountain Region Museum Services Program developed a process whereby specific fields can be mapped from ANCS+ to a word processor template. These finding aids meet professional archival standards by including a collection history; scope, content, and arrangement sections; series descriptions; and a container list or index. A sample of a finding aid is available on the *Park Science* Web site (http://www.nature.nps.gov/ParkScience/graphics/vol_25_1/Mitchell_DINO_BighornSheeProjectFindingAid.pdf).

After we had cataloged a significant number of archival collections from the national monument, data managers with the Northern Colorado Plateau Inventory and

Monitoring Network visited Dinosaur to evaluate additional materials for inclusion in NatureBib. They found that their ability to retrieve previously identified NatureBib references was greatly enhanced by our cataloging efforts. Working with cataloged collections reduced by approximately 25% the amount of physical information that had to be reviewed because duplicates, non-park-specific information, and temporary records were removed in accordance with the NPS Records Disposition Schedule (i.e., Director's Order 19). The data managers also surveyed previously unavailable materials to establish new citations. One of the greatest advantages of the cataloging was that similar NatureBib references were now located together because materials were organized by topic.

> ***[Managers] found that their ability to retrieve previously identified NatureBib references was greatly enhanced by our cataloging efforts.***

The new archival protocols developed for use at Dinosaur National Monument were incorporated into the recently published *Intermountain Region Archival Processing and Cataloging Handbook*, which has been distributed to every park in the region. This handbook was written for and by project archivists who are completing regional archival cataloging projects and includes a completed NatureBib form and an example of an archival finding aid.

Lessons learned

The linking of NatureBib and ANCS+ combines the strengths of the Service-wide Museum Program and natural resource programs at the park, regional, and national levels to create a tool that promotes research, preserves documents, and enhances access. The NPS Inventory and Monitoring Program's efforts to capture through NatureBib a vital collection of information needed by parks to manage their natural resources is strengthened by the permanent location and physical protection afforded by the Service-wide Museum Program. End-users of NatureBib benefit by having this bibliographic information stored in NatureBib tied to topical projects identified with permanent museum accession and catalog numbers that will not change. End-users of the very powerful ANCS+ search engine can use finding aids to locate NatureBib references and benefit when search time is minimized because all materials of a certain topic are found together.

The work at Dinosaur National Monument has shown that collaboration between natural resource and museum programs can further the efforts of each for the benefit of park resources. Any park with active museum and natural resource programs has the potential to link their ANCS+ and NatureBib databases. Museum cataloging can be funded through Service-wide Comprehensive Call proposals that meet appropriate criteria. Benefits extend beyond museum and natural resource staffs. Interpreters benefit from having information organized by topic, making retrieval of applicable materials more efficient. Visitors benefit because interpreters have access to a greater depth of knowledge on which to base their programs and exhibits. We hope that the effort to preserve NatureBib numbers using ANCS+ is only one of many fruitful collaborations to come between these programs.

Acknowledgments

We thank managers and staffs of Dinosaur National Monument and the Intermountain Regional Museum Services Program for their tireless efforts, professional encouragement, ability to adapt at a moment's notice, and other forms of support they have given this project over the past five years. Additionally, we thank Mary Risser, Tef Rodeffer, Margaret Beer, and Greg McDonald, who critically reviewed this article, and the Intermountain Region for its support of Ann Elder with a Cultural Resource Development Detail to produce this article. Missy Powell field-tested processes described in this article while data mining for the Inventory and Monitoring Program, Northern Colorado Plateau Network.

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Case Study

Using virtual Research Learning Centers for disseminating science information about national park resources

By Tomye Folts-Zettner, Tom Olliff, Cheryl McIntyre, and Tom Porter

HOW CAN SCIENTISTS AND scholars engage busy park superintendents and the general public with the results of their research? Several programs in the National Park Service (NPS) are mandated to provide scientific information in different forms: peer-reviewed papers, quick references for superintendents, reports to managers, and articles geared toward a general audience. How can we make these documents and their data more useful? How might we centralize storage of this information and make retrieval and use easy for a variety of audiences?

A collaboration among 51 national park units in five NPS Inventory and Monitoring (I&M) networks, three Cooperative Ecosystem Studies Units (CESUs), and six nonprofit partners has developed an approach to answering these questions: using virtual Research Learning Centers as a means of storing, organizing, and reporting information that results from science conducted in the National Park System. Based on the Research Learning Center program created under the Natural Resource Challenge, the Greater Yellowstone Science Learning Center (GYSLC) and the Learning Center of the American Southwest (LCAS) maintain Web sites that provide quick, easy access to the most recent scientific information for natural and cultural resources found in their member parks. Designed to reach a varied audience (agency managers and resource specialists, university scientists and students, educators and guides, media representatives, members of the public, and other stakeholders), data are presented in a hierarchy of increasing detail, allowing users to access both general concepts and project-specific results.

The virtual Research Learning Center concept grew out of practical need and fiscal necessity. First, the Web sites of national park units are, by design, geared primarily toward providing visitor services information, channeled through Web pages organized by park unit. Although resource information is often available, it can be of limited depth and scope, and difficult to access. In particular, full-length documents, such as study plans, completion reports, reports to managers, and annual reports are seldom available on these sites, and can be obtained only by request from the author or a library. Finally, park Web sites are limited to describing resources within the specific, bounded areas of their units. To gain a regional perspective, users often must piece together bits of information gleaned from numerous sites, making cohesive knowledge or understanding difficult to achieve.

Designed to act as a complement to park Web sites, the virtual Research Learning Centers take a resource-centric, rather than park-centric, approach to information organization and communication; that is, they are organized around resources, not simply park units, even though information is also assessable by park unit. Under this framework, resources no longer "stop" at a park's boundaries. They can be viewed in a regionally holistic manner that encourages exploration at multiple levels of scale and detail, and that highlights the significance and connectivity of smaller parks with their larger neighbors. We also believe that the resource-centric approach will help to de-emphasize the artificial boundaries between "cultural" and "natural" resources. Because Research Learning Centers are designed to be interdisciplinary, one of the exciting goals and challenges for the GYSLC and LCAS is to go beyond simply making information on natural and cultural resources available to exploring their interaction and interdependence. As such, these new Web sites present an opportunity to interweave the Natural Resource Challenge (NPS 1999) and the Vanishing Treasures Initiative (NPS Intermountain Region 1998).

Creating a Web-based "one-stop shop" for science outreach was more fiscally attainable for parks within the Greater Yellowstone I&M Network than trying to staff a physical Research Learning Center and develop programs in each park. Accord-

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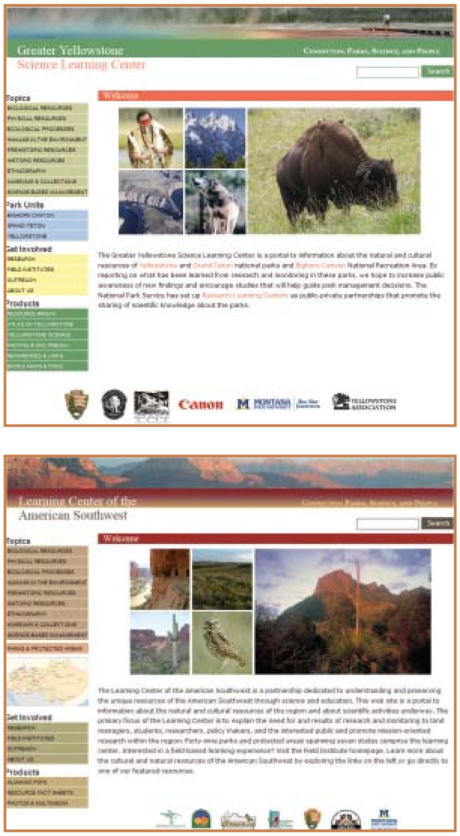

Figure 1. The two virtual learning centers have a similar look and feel, and a nearly identical navigation structure as shown here for the GYSLC.

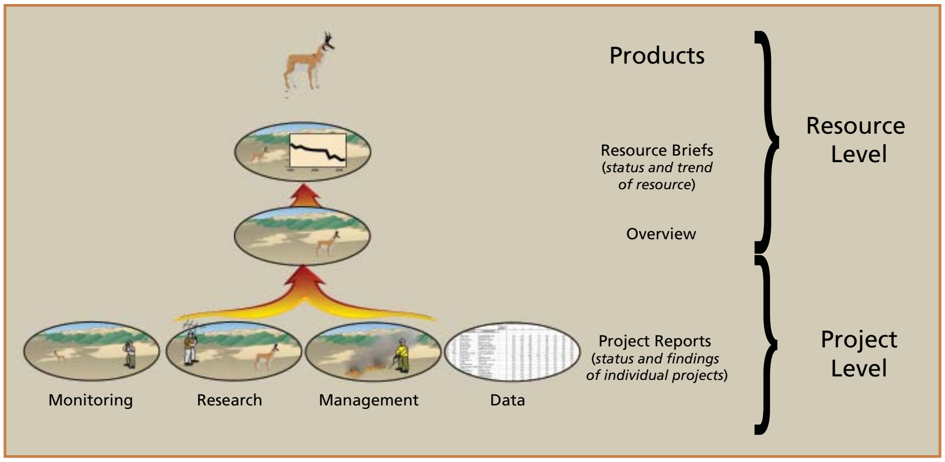

Figure 2. Research Learning Center products are hierarchical, from resource-level materials to project-level materials.

ingly, the parks led the way in developing the GYSLC, a virtual center that is accessible, interactive, and easily updated and has multiple layers of information products to meet the needs of different audiences. In 2005, Canon U.S.A., Inc., agreed to fund this prototype effort through the Eyes on Yellowstone program, administered by the Yellowstone Park Foundation. This funding paid for staff and partners to design the look and architecture of the Web site and develop initial content, and also supported Web hosting on a dot-org site—largely to accommodate the non-NPS partners who will directly contribute to the site, and to avoid overburdening the bandwidth of the parks' official Web sites. Though promotion for the public rollout is yet to come, the GYSLC is available now at www.greateryellowstonescience.org.

Subsequently, parks within the Sonoran Desert, Southern Plains, Southern Colorado Plateau, and Chihuahuan Desert I&M networks, which share many similar resources, collaborated to create the Learning Center of the American Southwest. This Web site, still in development, is expected to be launched in fall 2008 at www.southwestlearning.org. To facilitate user familiarity, the two sites share a nearly identical navigation structure (fig. 1).

How the Web sites work

From the home pages, users can choose from a list of topics that include natural and cultural resources as well as supporting concepts, such as environmental factors that influence these resources (e.g., climate, land use), museums and collections, and integration of science and management. This arrangement allows users to quickly locate a variety of scientific information about a given resource. The sites offer a dual navigation system that lets users choose from a list or map of network parks and then access a list of park-specific topics.

For each resource addressed on the Web sites, content is presented in a hierarchy of increasing detail, allowing the user to drill down from information consolidated at the resource level to information about specific projects (fig. 2). Each resource has its own introductory page with a paragraph describing the resource and a list of available information products, presented in downloadable, printable formats. *Resource Briefs*, updated annually, are a one-page synopsis of the significance, status, and trends of the resource, with a short discussion of the stressors and drivers affecting it. For natural resources, the *Overview* provides an in-depth description of natural history, management history, and ecological function. Cultural resources are described in similar detail in terms of origin, significance, and context. In some cases, *Fact Sheets* provide condensed information from the *Overview*. *References/Links* enables a user to find management documents, laws and regulations, and non-NPS publications and programs relevant to the resource. *Researchers* offers Internet links to scientists, agencies, and organizations associated with the resource.

More detailed information on scientific investigations can be found in *Projects*, which lists past and ongoing projects for the resource in the region. From here, links may include a *Project Summary*, providing a synthesis of methods, current status, and results. Annual *Project Reports* outline the past year's work effort on a project and include a short narrative that puts these results into context and discusses possible management implications. A *Project Protocol* or *Study Plan* may provide detailed methodology for the given project, while *Project Contacts* lists the project investigators and their contact information.

To maximize efficiency of the Web sites as portals of information delivery and exchange, GYSLC and LCAS partners intend to transform their routine reporting to use common formats ready for posting to the sites. For instance, new agreements with cooperators could specify deliverables that are consistent in format with virtual Research Learning Center products. Efficiencies will also be gained in areas such as annual reporting. *Fact Sheets, Overviews, Protocols,* and *References/Links* pages are all relatively static documents that will require minimal updating. The remaining products require regular reporting, but much of this can be accomplished by updating information already formatted in an existing template, rather than generating a whole new report each year. This approach also greatly lessens the time that elapses before information becomes available.

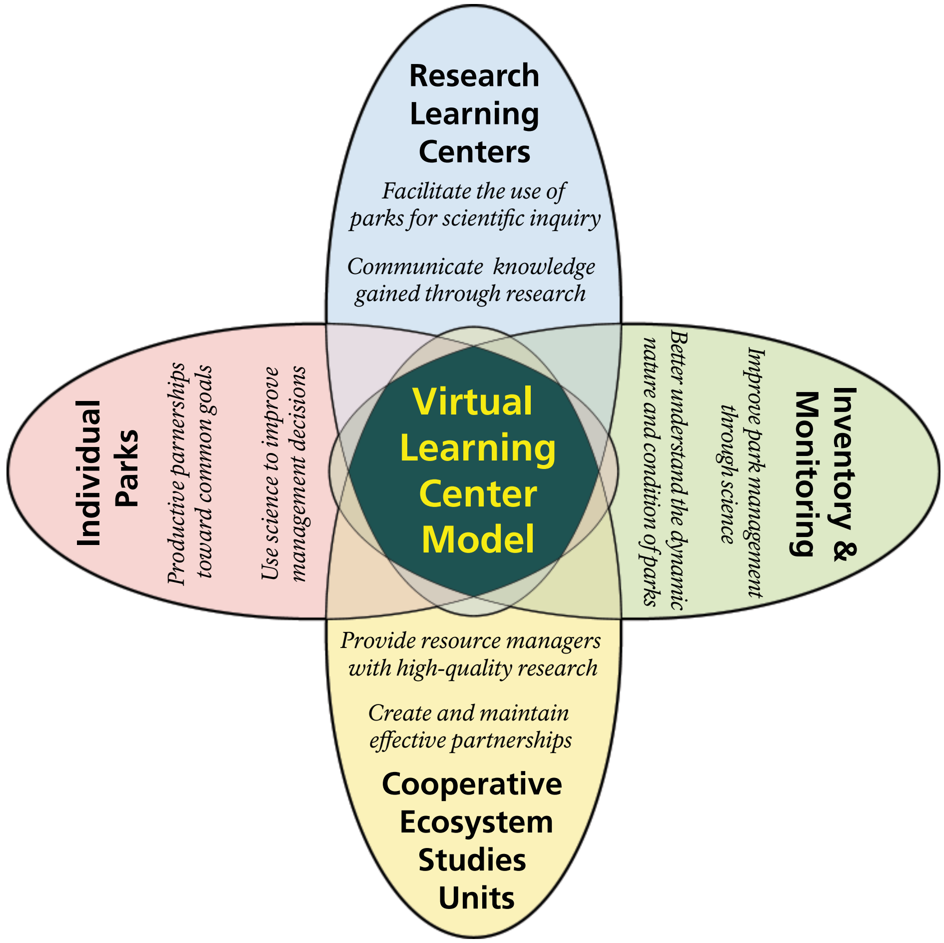

Figure 3. Research Learning Centers allow for increased efficiency by combining efforts for goals that overlap among programs.

A cross-program model for attaining mutual goals

Government mandates and the limitations of NPS fiscal resources demand that we constantly strive to increase efficiency. The GYSLC and LCAS promote these efforts by attempting to minimize duplication of effort among programs and allowing the resulting savings to be redirected to projects. In particular, the initial NPS partners in the virtual Research Learning Center effort (i.e., Research Learning Centers, CESUs, the I&M Program, and individual parks) have scientific goals (fig. 3). Other programs with scientific goals, including the Exotic Plant Management Teams established under the Natural Resource Challenge, have also expressed interest in partnerships. By combining efforts, we hope to gain considerable efficiency and effectiveness by identifying where the goals of these programs overlap and expanding partnerships within the NPS and among other organizations.

Individual parks both contribute to and gain from this facilitation of enhanced collaboration and communication among programs. The synthesis of park resources is ideal for informing new park employees and volunteers. Easily assimilated park resource information is readily available for use in supervisors' reports, interpretive programs, planning efforts, and visitor-oriented printed materials. The GYSLC and LCAS Web sites are linked to the parks' official Web sites, allowing the latter to become part of a comprehensive, Web-based information system.

The GYSLC and LCAS are similarly efficient outlets for fulfilling I&M Program reporting requirements and science outreach goals, and for rapidly reporting project results to inform park management decisions. Enhanced communication of activities among I&M networks with similar resources is also achieved, and in cases where monitoring is conducted by park staff or with park funding, the Research Learning Center Web sites facilitate integration of park-based and network-based

One of the exciting goals and challenges for the GYSLC and LCAS is to go beyond simply making information on natural and cultural resources available to exploring their interaction and interdependence.

science by reporting through a common platform. This enhances communication between network and park staffs and can lead to broader understanding and application of monitoring results.

The GYSLC and LCAS benefit their associated CESUs by serving as a forum to increase awareness of research needs; providing research-permit and logistical information to scientists who want to conduct research in parks; connecting scientists performing different studies on similar resources; and offering a template and platform for posting reports and data. The potential for expansion of partnership opportunities can widen the scope of CESU research efforts. Rapid reporting of project results meets the CESU goal of providing a source of timely, usable knowledge for technical assistance to resource managers.

Finally, virtual Research Learning Centers can complement and promote the efforts of physical Research Learning Centers—facilities that provide an "in-park" lab and housing—and foster synergistic effects. Many of the varied products and services of other Research Learning Center programs can be readily incorporated into these virtual sites. The GYSLC and LCAS Web sites increase awareness of field institutes, can promote opportunities for citizen scientists and volunteers to assist with needed research, and provide Research Learning Center staff with additional information to synthesize and transfer to local communities and broader audiences, resulting in expanded capacity for educational activities and learning opportunities.

Conclusion

Our approach to dissemination of science through virtual Research Learning Centers provides an efficient, effective venue for reaching a wide audience, ranging from park superintendents to scientists, educators, and the public. Once it is developed, the ease of information update, through shifting reporting practices, will ensure that the most current data are available to all who are interested. The benefits of these Web sites extend not only to all levels of the National Park Service but also to a cadre of partners and the public. The structure of these Research Learning Center Web sites will be made available to other interested NPS I&M networks and Research Learning Centers in the hope of creating a broader and more interconnected information resource system for the National Park Service.

Acknowledgments

Numerous individuals contributed to the ideas and implementation of these learning centers as well as to this article. We are particularly grateful to Alice Wondrak Biel for her extensive and helpful editing. Tami Blackford and Ann Rodman of Yellowstone National Park, and Robert Bennetts of the Southern Plains Network contributed substantially to all phases of this effort. We also appreciate the editorial suggestions and assistance of Jeff Selleck.

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Using landscape analysis to evaluate ecological impacts of battlefield restoration

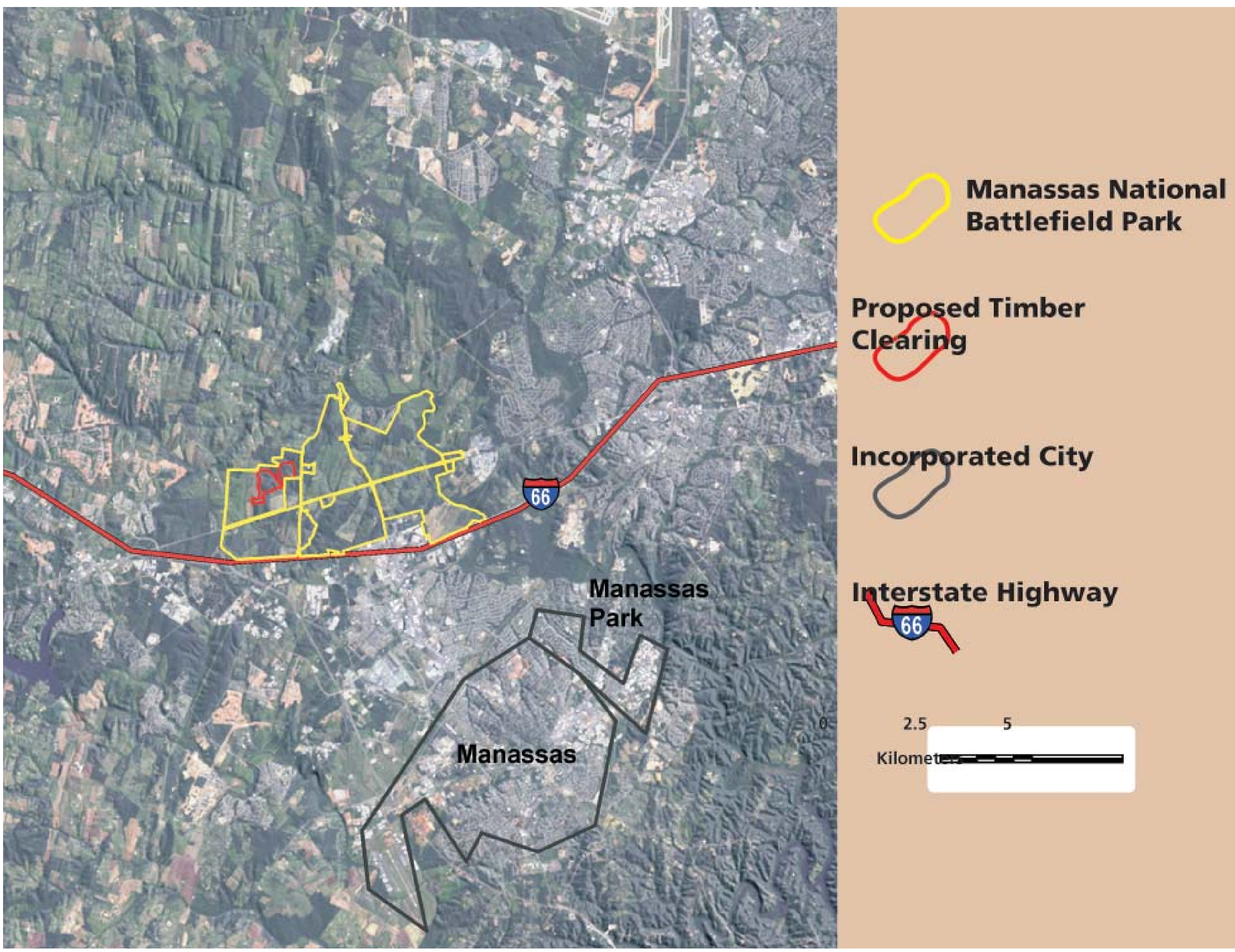
By Todd R. Lookingbill, Shawn L. Carter, Bryan Gorsira, and Clayton Kingdon

MANASSAS NATIONAL BATTLEFIELD PARK (VIRGINIA) was established to preserve the scene of two significant Civil War battles: the First Battle of Manassas, fought on 21 July 1861, and the Second Battle of Manassas, fought 28–30 August 1862. The park also serves as important wildlife habitat in the region. For Manassas and the other 10 parks of the National Capital Region Network, intense land use is a pervasive influence and tends to result in systems dominated by external stressors. The significance of these parks as natural resource refuges likely will increase as urbanization in and around Washington, D.C., leads to continued land conversion of adjacent habitats. Development is rapidly usurping natural areas in northern Virginia, and Manassas National Battlefield Park retains a regionally significant source of intact forest habitat (fig. 1).

During the Civil War, Manassas National Battlefield Park was a patchwork of open fields and woodlots scattered across gently rolling hills. Much of the landscape has retained its battlefield character, but secondary forests have replaced open fields in some geographically significant areas. For instance, several skirmishes occurred before the Second Battle of Manassas on 326 acres (132 ha) of farmland rented by John Brawner at the time. This area is now situated along the far northwest corner of the park and has not

Figure 1. This Landsat ETM+ true-color composite image from 18 June 2002 shows the location of Manassas National Battlefield Park in the context of its urban and agricultural surroundings. This is one of several satellite images acquired as part of the Natural Resource Challenge (National Park Service 1999) and used by National Capital Region Network staff in making management decisions.

SATELLITE IMAGE: USGS EROS DATA CENTER



been maintained since the battles. Current vegetation consists of a mix of mature basic oak-hickory forest interspersed with Virginia pine–eastern red cedar successional forest (Fleming and Weber 2003). These nonhistorical woodlands directly impact interpretation of the battles because forest vegetation now blocks the lines of sight that dictated troop movements and cannon fire (fig. 2). Open fields were a historically significant factor in shaping the outcome of much of the fighting.

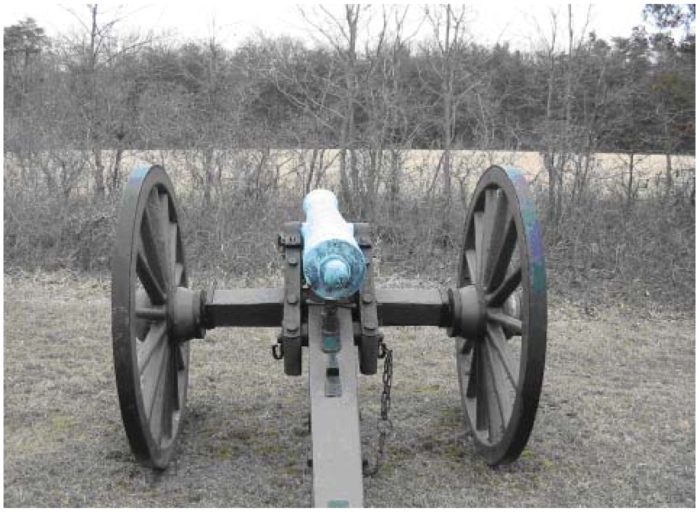


Figure 2. Cannon fire along the flank of the attack was instrumental in turning back the Union advance at Manassas. Battle conditions at the time allowed clear line of sight for these cannons, which now face into a regenerating forest. To re-create these historic conditions, the National Park Service is considering a 124-acre (50 ha) cut of forest to the north of this position.

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The need to maintain a historic battlefield setting within a piedmont-forest ecosystem creates two potentially opposing management strategies. The National Park Service must consider the effects of its management actions on internal park dynamics and regional-scale ecological processes. Park staff must continually balance natural resource protection (e.g., protecting large tracts of native forest) with cultural landscape preservation (e.g., preventing regeneration to preserve battlefield scenery). In order to restore historic battlefield conditions, the National Park Service plans to clear approximately 124 acres (50 ha) of timber bordering the Brawner Farm (see fig. 6). Harvesting at Manassas provides a case study of how analysis of potential changes in land cover and use (landscape dynamics) can be used to evaluate competing cultural and natural resource factors as a precursor to management action. Monitoring of landscape dynamics can be an extremely valuable source of information for natural resource managers working in mixed land use settings (Gross et al. 2006) and is currently the single most common "vital sign" monitored by the Inventory and Monitoring Program across the country (257 parks in 24 networks).

Connectivity

As a consequence of urbanization, suitable habitat for plants and animals rarely occurs in large, contiguous units within the region. Instead, habitats are fragmented into individual parcels that lie within a matrix of less suitable land. In addition to their individual attributes (e.g., area, amount of edge, shape, and composition), these discrete, homogenous blocks of habitats, referred to as patches, have important properties associated with their collective spatial configuration. For plant and animal populations to thrive, individuals must be able to intersperse among patches. Connectivity is the measure of the spatial continuity of a network of patches or the ability of organisms to move from patch to patch across the landscape (Calabrese and Fagan 2004). Typically, habitat patches that are in closer proximity to one another will foster more dispersal; however, dispersal may occur between patches that are separated by greater distances via connectivity corridors (Beier and Noss 1998). Unfortunately, questions of optimal corridor width and configuration remain unresolved and are most likely influenced strongly by local environmental conditions (Petranka and Smith 2005).

We were interested in whether the proposed forest cut would result in isolation of ephemeral ponds used by the park's breeding amphibian populations, which are a group of species of concern for park management. Results of a 2000 field survey documented

Figure 3. One consideration in assessing the removal of forest resources is the potential isolation of ephemeral ponds found in forests west of the proposed cut. These temporary pools provide valuable habitat to the park's amphibian populations.

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nine vernal (ephemeral) pools within the park (fig. 3) based on the presence of obligate amphibian species: spotted salamander (*Ambystoma maculatum*), marbled salamander (*Ambystoma opacum*), and wood frog (*Rana sylvatica*) (Loomis and Heffernan 2003). Isolation of ponds could affect the breeding success and survival of these animals. From the perspective of amphibian spatial dynamics, these ponds may be viewed as patches; however, growing evidence suggests that this interpretation misrepresents the importance of the terrestrial environment. The forest habitat surrounding the ponds influences feeding, overwintering, and nesting behavior (Semlitsch and Bodie 2003), as well as dispersal

Nonhistorical woodlands directly impact interpretation of the battles because forest vegetation now blocks the lines of sight that dictated troop movements and cannon fire.

and movement of amphibians among ponds (Marsh and Trenham 2001). Therefore, we conducted a landscape analysis focusing on the pre- and postharvest distribution of forest habitat to evaluate potential changes in connectivity for amphibians resulting from the proposed Brawner Farm cut.

We would like to emphasize that this analysis is for amphibians and does not provide information about the potential benefit or harm of the cut to any other species. Amphibians were chosen specifically because of their demonstrated sensitivity to disturbance and widespread use as indicator species (e.g., Petranka and Smith 2005; Semlitsch et al. 2007). Nevertheless, because we selected forest patches as our focal unit of study, the results are similarly applicable to other forest-dwelling species with limited dispersal potential across nonforest land cover. For example, Corry and Nassauer (2004) report dispersal capabilities in nonforest of 886–1.411 feet (270–430 m) for small mammals, such as the least shrew (*Cryptotis parva*) and white-footed mouse (*Peromyscus leucopis*), within the range of distances analyzed. We expect that conditions will improve for a variety of other species (e.g., white-tailed deer, quail, and other avian species) following the cut.

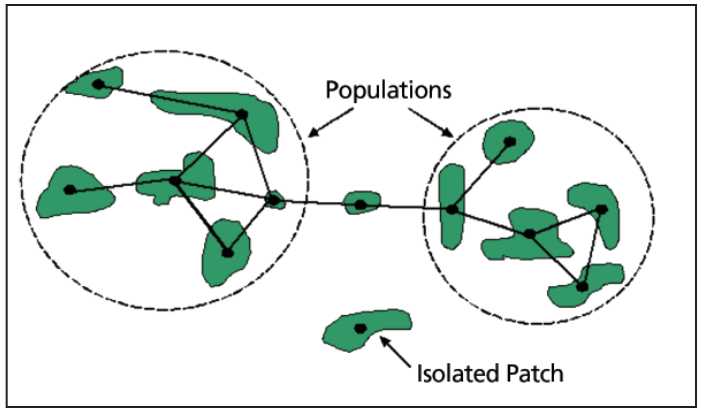

Figure 4. Investigators now use graph theory to assess the consequences of habitat modification on landscapes. Each green habitat patch of this hypothetical landscape is represented by a node (black dot). Lines between nodes represent potential dispersal movement, or connectivity, between pairs of patches. Two potentially separate populations are shown connected by a "stepping-stone" patch. An "isolated patch" that has been separated from its neighbors is also shown.

Methods

We used graph theory, a well-developed framework for evaluating network connectivity, in our analysis. Methods associated with graph theory are used for evaluating spatial properties of communication and transportation networks (Harary 1969; Hayes 2000a and b) and more recently for assessing the consequences of habitat modification on landscapes (Bunn et al. 2000; Urban and Keitt 2001; Ferrari et al. 2007). Our analysis considers the landscape as a network of forest patches (fig. 4). In some cases the patches contain vernal pools and act as amphibian breeding habitat; in other cases the patches act only as preferred pathways for amphibians. The dispersal capabilities of the focal organism determine whether two patches are close enough to be considered connected. A landscape that is completely connected is one in which every patch can be reached from any other patch, either directly or via several intermediate connections.

Our analysis integrated remotely sensed satellite imagery with digitized polygons of fencerows depicted on a Natural Heritage land cover map of the park (Fleming and Weber 2003). We used a 2006 SPOT satellite image to create a forest map for the park and adjacent land (total size was equal to six times the area of the park). To gain a broader understanding of landscape dynamics, we chose not to limit the analysis to park boundaries. Using GIS, we merged the fencerow data with the SPOT data and identified contiguous forest patches. In the study area we identified 3,800 forest patches, 629 of which were at least 2.5 acres (1 ha) in size. These 629 patches represent 10,378 acres (4,200 ha) or approximately 40% of the total area in this fragmented landscape.

Continued monitoring will track changes in the amount of forest cover in and around the park. Nearly all remaining land was nonforest, composed of shrub and grassland.

We created a series of graph representations of the park using the forest patch map. For the graph models we defined the maximum distance (D_{max}) that an amphibian would be able to travel through nonforest to disperse from one patch to another. Because amphibians are vulnerable to desiccation, they are usually restricted to forest habitat, may be unable to cross large clearings, and are generally considered poor long-distance dispersers (Duellman and Trueb 1986). In a review of 64 salamander dispersal studies, 94% of the maximum reported dispersal distances were less than

To gain a broader understanding of landscape dynamics, we chose not to limit the analysis to park boundaries.

0.6 mile (1 km) and 64% were less than 1,312 feet (400 m) (Smith and Green 2005). Experimentally derived dispersal distances across open fields are reported to be even lower (i.e., on the order of tens of meters) (Marsh et al. 2004). We therefore assumed an unlimited movement potential within forest patches, and examined the connectivity of the landscape for organisms capable of dispersing 33 feet (10 m) (Marsh et al. 2004) to 1,312 feet (400 m) (Smith and Green 2005) across nonforest habitat.

By modeling this range of potential dispersal capabilities, we identified a critical dispersal threshold (D_{crit} = 100 m) (fig. 5). This indicates the minimum distance an organism must be capable of traveling through nonforest in order to move among all available habitat in the park. We used D_{crit} to construct two graphs representing potential amphibian connectivity under pre-treatment and post-treatment conditions. For each of these landscapes, we evaluated the total amount of connected forest and the connectivity status of known ephemeral ponds in the park.

Results

For amphibians and other animals (e.g., forest mice and shrews) capable of crossing 328 feet (100 m) of nonforested area, more than 95% of the forest in the network is considered to be connected for both pre- and post-treatment scenarios (fig. 5). For animals with more limited dispersal abilities (e.g., 32.8 feet [10 m] of nonforest), the network is considerably less connected under current conditions, but is also minimally reduced by the proposed cut (change of less than 2% between the two scenarios). This apparent insensitivity to the harvesting treatment is partly due to a large patch of intact forest located in the center of the landscape. This patch alone contains 64% of the total forest area and provides a corridor that facilitates interpatch movement. Given the current level of fragmentation, the management action is unlikely to have a significant impact on the ability of amphibians to move between forest patches at the landscape scale.

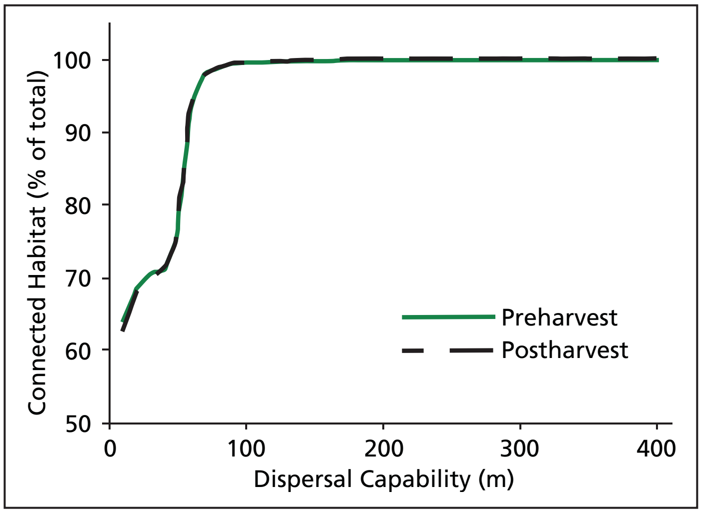

Figure 5. Comparison of connected habitat pre- and postharvest reveals the relatively small predicted effect of the cut. Connected habitat represents the percentage of forest that can be reached by an organism capable of dispersing a given distance across nonforest habitat. A threshold of connectivity occurs at 328 feet (100 m) such that amphibians capable of moving 328 feet (100 m) from one forest patch to another can move among greater than 95% of the habitat, but an organism capable of moving only 164 feet (50 m) can reach only 75% of the forest in the region. However, even for these poorer dispersers, network differences are relatively minor pre- and postharvest.

At the local level, the ephemeral pools to the west of the proposed cut are in danger of becoming isolated (fig. 6). One option would be to reduce harvesting in the western portion of the cut unit, but this would considerably reduce the effectiveness of the management goal to restore the battlefield. Alternatively, the existing fencerow trees along the western border of the cut could be augmented to allow establishment of a new connectivity corridor. Also, regrowth of forest habitat immediately surrounding the potentially more isolated vernal pools may offset the loss of habitat resulting from the forest cut.

Cahoun and deMaynadier (2004) recommend establishing two types of vernal pool management zones in forest habitats. “Vernal pool protection zones,” which are approximately 3.5 hectares (8.6 ac), serve to shade and protect the immediate surrounding habitat. "Amphibian life zones," approximately 32 hectares (79 ac) in area, protect upland habitats needed by amphibians for foraging and during dry periods. In anticipation of the cut, the National Park Service established a protection zone/regeneration buffer around the potentially impacted vernal pool habitat in the Brawner Farm area, which increased surrounding habitat by 250% from 11 to 38 acres (4.5–15.5 ha) (fig. 6). While this action has the benefit of meeting both cultural and natural resource demands, park staff has adopted it with caution, as the harvesting and regrowth of forest occur on very different time scales.

Conclusions

Preserving ecological function in cultural settings presents a challenge to natural resource management. Our analysis provides a tool for anticipating the potential ecological consequences of changes in land cover associated with restoring battlefield scenery. Based on the results of this project, we expect that landscape connectivity will remain high following the proposed timber harvesting in Manassas National Battlefield Park, but at least one important region of amphibian habitat may become more isolated. The analysis allows us to be proactive rather than reactive in identifying and implementing management options to mitigate the impacts of habitat loss.

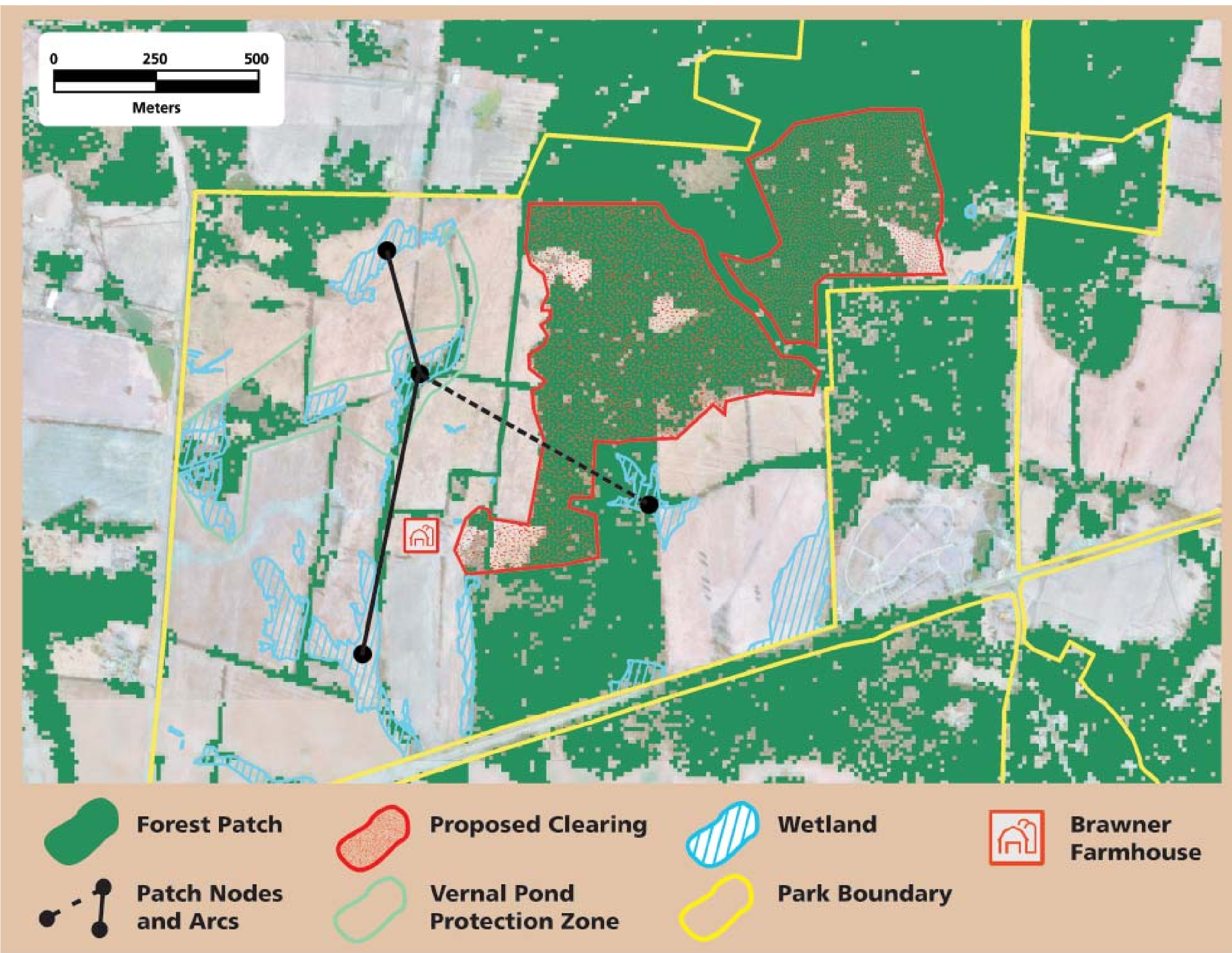

Figure 6. USGS digital ortho quarter quads (DOQQ) show network connections for significant wetland resources overlaid for the Brawner Farm and vicinity. Critical vernal ponds contained within the vernal pond protection zone could become isolated from the rest of the park after the proposed cut is completed. The dashed black line represents the pre-treatment connection from the proposed vernal pond protection zone to one of a number of large wetlands in the middle of the park. The vernal pond protection zone represents restoration actions the National Park Service has taken in anticipation of the cut.

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A behavioral intervention tool for recreation managers

By Shawn Meghan Burn and Patricia L. Winter

DEPRECIATIVE BEHAVIORS AND OTHER UNDESIRABLE recreationist actions continue to be a topic of great interest for recreation management (fig. 1). Maintaining park ecosystems involves responding to and preventing damage from depreciative recreationist behavior, and recreation managers are charged with developing and selecting effective tools to address the costly and perplexing impacts of undesirable recreationist behavior.

This article describes the *Environmental Intervention Handbook for Resource Managers* (EIH), a tool we designed to help managers modify depreciative recreationist behavior. The handbook is based on a model of pro-environmental behavior change derived from social science research. It provides "treatments" of depreciative behavior following a "diagnosis" of the barriers to the desired behavior. We use the term "pro-environmental behavior" to refer to those behaviors that promote environmental sustainability and do not contribute to environmental degradation. The handbook is self-guided and draws from the expertise of managers in their own settings. It provides guidelines, checklists, and worksheets for barrier identification and intervention design.

Barriers to pro-environmental behavior

The EIH begins with a description of five barriers to pro-environmental behavior along with barrier identification worksheets, summarized as follows:

1. Social norms barriers occur when recreationists perceive that depreciative behaviors are socially acceptable (Burn 1991; Schultz 1998; Winter and Koger 2004). Not knowing what to think or do, or seeking social approval, recreationists may behave as they see other recreationists do, or as they perceive past recreationists did (Cialdini et al. 1990). For example, the remains of a fire ring may suggest that building a fire is acceptable when it is not. Recreationist groups may have norms consistent with depreciative behavior. To identify social norms barriers, managers are encouraged through the worksheet to (1) describe any social norms that suggest the desired behavior is appropriate and consider whether these vary for different groups of users, and (2) describe any evidence in the setting of current or past misuse that may communicate to new users that the inappropriate behavior is commonplace and accepted, and (3) ask, "Even if social norms don't clearly support depreciative behavior, do they fail to clearly support desired behavior? In other words, is it clear to people that admired recreationists or recreationists similar to themselves behave in the desired pro-environmental way?"

Figure 1. Common depreciative environmental behaviors include littering and defacing natural objects with graffiti.

USDA FOREST SERVICE PHOTO (3)

2. Competing attitudes barriers operate when the depreciative behavior is more convenient or lower in cost than the desired behavior, or because it better meets recreationists' perceived needs (Cheung et al. 1999; Cottrell and Graefe 1997). For example, recreationists may ride horses, bikes, or all-terrain vehicles (ATVs) off-trail because off-trail riding provides a greater challenge or access to exceptional scenery. This barrier identification worksheet asks recreation managers to describe ways in which the undesired behavior is more convenient or rewarding than the desired one, and to identify other competing attitudes, values, or motives interfering with performance of the environmentally responsible behavior.

3. Setting design barriers occur when the physical features of the setting make the desired behavior difficult or pose little barrier to depreciative behavior (Guaguano et al. 1995). For example, improper waste disposal is likely when trash receptacles are few or full, and driving in undesignated areas may occur if there are no fences, gates, or strategically placed boulders to prevent it. This barrier identification worksheet asks recreation managers to specify how the setting's features may encourage the undesirable behavior and how they make the desired behavior difficult or unlikely.

The* Environmental Intervention Handbook for Resource Managers *.... provides "treatments" of depreciative [recreationist] behavior following a "diagnosis" of the barriers to the desired behavior.

4. Ignorance and misinformation barriers occur when people are unaware of the negative environmental consequences of their actions, or do not know how to do the things managers want them to (Lindsay and Strathman 1997). For example, children may be allowed to dam a stream because parents are unaware of the impact on riparian habitats. Recreationists may know that fire safety is important but not how to accomplish it. Recreationists are also sometimes unaware of changes in recommended recreational practices. To identify ignorance and misinformation barriers, recreation managers are asked to specify the ways in which the inappropriate behavior may be due to ignorance or misinformation, including the types of users who may be in need of information and what type of information they are lacking.

5. Habit barriers operate when recreationists unthinkingly perform depreciative behaviors out of habit or tradition. For example, some individuals may continue to use outdated camping techniques although rules or forest practices have changed. To evaluate this barrier, recreation managers are prompted to think about whether the undesired behavior may be engaged in by recreationists out of habit or tradition.

Interventions to promote pro-environmental behaviors

After identifying barriers, managers are ready to select corresponding research-tested interventions guided by worksheets with intervention options and real examples from recreation managers. We share highlights from the intervention worksheets here.

The social norms barrier intervention worksheets offer a variety of approaches, including creating or illuminating pro-environmental norms through modeling (Aronson and O'Leary 1983; Burn 1991). The worksheets suggest that managers enlist the help of respected and influential group members in cases where a group who regularly visits the site performs the undesired behavior, and that managers use role models in media education. For example, in one instance a horseback club adopted a trail and took care of it and its signs, and encouraged their peers to follow guidelines such as using the official posts—not trees—to tie their horses. At another site, visitors had to watch a videotaped behavior demonstration before they received access to a wilderness area. Because past recreationist behavior often leaves traces that inadvertently suggest that depreciative behavior is normative (Cialdini et al. 1990), the worksheets also recommend that managers clean up and rehabilitate degraded areas as quickly as possible. Likewise, in order to avoid inadvertently suggesting that depreciative behavior is the norm, they recommend that managers emphasize in interpretive situations and other communications that a minority of recreationists cause the most damage (Cialdini et al. 2006).

The competing attitudes intervention worksheets offer three options. One is to link the desired environmentally responsible behavior to attitudes and values important to the user group in question (Aitken et al. 1994; DeYoung 2000). For example, in one setting where recreationists fed wildlife, resource managers emphasized that not feeding the wildlife was more consistent with loving them. Commitment strategies are also recommended to make the desirable attitude dominate behavior (Burn 1991; Cobern et al. 1995). At one wilderness park, recreationists signed a pledge to adhere to recommended practices before a permit was issued. Obtaining commitments may be time-consuming and commitments made to peers may be more effective, so the worksheets recommend using "indigenous personnel" such as Scouts or club members (Burn 1991; Cobern et al. 1995). Another worksheet option is to address competing attitudes, values, or motives. For example, managers found that ATV users' desire for challenge trumped environmental concerns. They solved the problem by designing challenging ATV trails.

The worksheet for setting barrier interventions presents two options: determining which setting features interfere with performance of the desired behavior and removing these barriers if possible, or determining which setting features could be added to create a barrier to the undesired behavior (Dwyer et al. 1993; Huffman et al. 1995). One example is a forest where overgrown lake vegetation made using official boat launches difficult; removal of this physical barrier solved the problem. Other examples are using mulch, rocks, or boardwalks to define trails clearly.

The worksheets for ignorance barriers focus on educational and informational efforts. Effective interventions actively involve participants, present credible information and knowledge effectiveness, and incorporate specific behavioral recommendations (Gardner and Stern 1996; Zelezny 1999). Worksheet examples include the resource managers who encouraged responsible ATV use through booklets, mailings, and brief radio messages. Users of the handbook are reminded that pro-environmental communications should reflect the background attitudes and behaviors of the target audience, so that the message matches the audience, and should reflect social psychological research on factors found to increase effectiveness (Bator and Cialdini 2000; Burn and Oskamp 1986; Roggenbuck 1992). They are also reminded that education is most effective with low-cost, easy-to-perform behaviors and when other barriers to desired behaviors are addressed. The worksheets note that prompts (signage), commitment strategies, and environmental alterations may also increase the effectiveness of informational interventions.

When habit barriers are the issue, a variety of strategies may be needed. The worksheets recommend commitment strategies, verbal or written prompts, and changes in setting to remind recreationists and stimulate new pro-environmental habits. For example, resource managers at one location added signage and toured campsites to remind them of new rules and practices. The worksheets note that although incentives such as monetary rebates, raffle tickets, and discount coupons may temporarily increase pro-environmental behaviors, they are usually impractical because of the need for behavior monitoring and incentive costs (Geller 2002; Porter et al. 1995). Disincentives for depreciative behaviors (e.g., citations and fines) can work when resource managers make enforcement a priority and penalties are unpleasant enough to offset the rewards of the depreciative behavior.

Peer assessments of the handbook

After peer review of a draft in 1996, we pilot-tested the handbook at a watershed on national forest lands in Washington State at risk for closure because of human impacts. We distributed the finalized handbook to a number of people in different agencies and geographic areas.

In 2005 we conducted a follow-up evaluation to assess whether the handbook was working as the tool we intended it to be and what we might do to improve its usefulness to recreation managers. Respondents strongly agreed that depreciative behaviors were a concern in their jobs and had a negative impact on the environment, agency budgets, and resource manager time. The majority also indicated that strategies to deal with depreciative activities were useful, yet many perceived informational materials to help resource managers address depreciative behaviors as relatively unavailable and of poor quality. The handbook was evaluated favorably by respondents with regard to usefulness, practicality, straightforwardness, ease of understanding, and effectiveness. We used suggestions for improvement to revise the handbook, which is now available from the second author.

Conclusion

Managers overseeing recreation settings and other areas open to public use should find the handbook helpful in organizing their own observations about resource damage, including how it is occurring and who is causing it. Furthermore, its guidance can lead to the development of interventions that capitalize on the manager's expertise in the setting, leading to solutions that reflect the latest findings in social psychological research and result in positive changes on the ground.

The handbook was evaluated favorably … with regard to usefulness, practicality, straightforwardness, ease of understanding, and effectiveness. [A revised version] is now available from the second author.

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Adaptive management for national parks: Considerations for an experimental approach

By Tony Prato

THE CONCEPT OF ADAPTIVE MANAGEMENT WAS DEVELOPED in the mid-1970s as a means to account for uncertainty in the way ecosystems respond to human intervention (Holling 1978; Walters 1996). Adaptive management postulates that "if human understanding of nature is imperfect, then human interactions with nature [e.g., management actions] should be experimental" (Lee 1993). Kohm and Franklin (1997) state that "adaptive management is the only logical approach under the circumstances of uncertainty and the continued accumulation of knowledge." Adaptive management improves understanding of ecosystem responses to human interventions, such as management actions, and promotes shared understanding of ecosystems by stakeholders, scientists, policymakers, and managers. The methods used to apply adaptive management to national parks are often site- and problem-specific (see examples below), which makes it difficult for park managers to use them in other park units. In this article, I propose a generic analytical framework for adaptively managing natural and cultural resources and visitors to national parks and other protected areas.

Nature of adaptive management

Adaptive management is not management by objective with feedback, trial and error, or prediction and planning, although it can involve these elements. It is a form of integrated learning that acknowledges management outcomes can be surprising and unpredictable. This framework is appropriate when a manager can influence the state of an ecosystem (defined in terms of the attributes of interest) by implementing management actions, but is uncertain about whether those management actions alter the state of an ecosystem. A case in point is a park manager who wants to determine the optimal number of campsites to have or backcountry camping permits to issue in order to sustain desirable levels of plant diversity and backcountry user satisfaction. In this case the manager is able to control the number of campsites and permits, but is uncertain about how varying their number influences plant diversity and user satisfaction.

Adaptive management can be either passive or active. With passive adaptive management, a manager (1) formulates a predictive model of how a coupled natural-human system responds to management actions, (2) selects the best management actions based on model predictions, (3) implements and monitors those management actions, (4) uses monitoring results to revise the model, and (5) adjusts management actions based on the revised model. Advantages of passive adaptive management are that it is relatively simple to use and can be less expensive to apply than active adaptive management, depending on the sophistication of the monitoring applied. Disadvantages are that it does not produce statistically reliable information about the impacts of management actions on ecosystems because of the lack of experimental controls and replication or randomization of management actions.

Adaptive management improves understanding of ecosystem responses to human interventions, such as management actions, and promotes shared understanding of ecosystems by stakeholders, scientists, policymakers, and managers.

Active and passive adaptive management embody the notion that managers cannot accurately predict the outcomes of management actions because of scientific, organizational, community, and political uncertainties. Active adaptive management uses experiments to test hypotheses about ecosystem states and maximizes the capacity of managers to learn about ecosystems and achieve their management goals. Because active adaptive management incorporates experimental controls and replication and randomization of management actions, it provides statistically reliable information about ecosystem responses to management actions that can be generalized to other areas. This is usually not the case with passive adaptive management. Active adaptive management requires major investments in research, monitoring, and modeling and has prerequisites that may not be satisfied (Prato and Fagre 2005).

Adaptive management is now employed in Banff National Park in Alberta, Canada, to develop a human use management strategy for the park (Parks Canada 2002). Elk and bison populations in Elk Island National Park in Alberta are managed through an adaptive landscape management approach. Federal and state agencies implementing the Interagency Bison Management Plan in the United States use adaptive management to test and validate ongoing strategies to reduce the risk of brucellosis transmission from bison to cattle outside Yellowstone National Park (Status Review Team 2005). In addition, it is used to manage snowmobile use in Yellowstone and Grand Teton national parks. In the lower Colorado River, which flows through Grand Canyon National Park, adaptive management improves understanding

Figure 1. In 1996, dam operators sharply increased water releases from the Glen Canyon Dam on the lower Colorado River. The adaptive management experiment increased water flows to 45,000 ft^3/s (1,260 m^3/s) for one week in an effort to rebuild sandbars using sand from existing channel eddy deposits. This successful experiment was repeated in 2004, pictured here.

BUREAU OF RECLAMATION/DAVE WALSH

of how water releases from Glen Canyon Dam influence sediment, vegetation, fish and wildlife habitat, and other resources (fig. 1). All elements of the Comprehensive Everglades Restoration Plan incorporate an adaptive management approach designed to enhance the achievement of the plan's ecosystem restoration goals (fig. 2). The adaptive management applications in Yellowstone National Park are passive, and those in Grand Canyon and Everglades national parks are active.

User capacity example

In order to facilitate comprehension of the proposed adaptive management framework, I describe it using a simple, hypothetical example of user capacity for national parks. The National Park Service defines user capacity as the types and levels of public use that can be accommodated while sustaining desirable resource and social conditions (Rees et al. 2007). The user capacity example considers a national park manager who wants to determine the optimal number of backcountry campsites or camping permits needed to achieve or sustain desirable levels of plant diversity and user satisfaction. These management goals are assumed to be competitive, which means that increasing the number of campsites/permits decreases plant diversity and increases user satisfaction, and vice versa.

Determining the optimal number of campsites/permits requires the park manager to infer ecosystem states based on measurements or assessments of the impact of the number of campsites/permits on plant diversity and user satisfaction. Suppose the manager defines three ecosystem states for user capacity: (1) S_1 is high plant diversity and low user satisfaction; (2) S_2 is moderate plant diversity and moderate user satisfaction; and (3) S_3 is low plant diversity and high user satisfaction, where S_1 and S_3 are deemed undesirable states and S_2 is considered a desirable state. These ecosystem states can be defined based on user capacity standards like those employed in the VERP (Visitor Experience and Resource Protection), LAC (Limits of Acceptable Change), VIM (Visitor Impact Management), and VAMP (Visitor Activities Management Process) methods (Rees et al. 2007). In addition, suppose the manager selects three measurable resource or social conditions for plant diversity and user satisfaction: (1) C_1 is $< 40\%$ of potential plant diversity and $> 75\%$ of the users satisfied; (2)

Figure 2. Florida Everglades. The goal of the Comprehensive Everglades Restoration Plan is to capture freshwater that now flows unused to the ocean and the Gulf of Mexico and redirect it to natural areas that need it the most.

NPS

C_2 is 40–80% of potential plant diversity and 40–75% of the users satisfied; and (3) C_3 is > 80% of potential plant diversity and < 40% of the users satisfied. These percentages are meant to be illustrative, not definitive. In practice, the manager can choose any number of ecosystem states and resource or social conditions. In general, ecosystem states refer to the status of an ecosystem with respect to certain desirable or undesirable properties (e.g., plant diversity and user satisfaction), and conditions refer to measured values of the properties.

The manager can make two kinds of errors in inferring an ecosystem state from a resource or social condition. First, he or she may decide the ecosystem state is desirable (S_2) when it is actually undesirable (S_1 or S_3), which can create a false sense of security regarding the state of the ecosystem with respect to user capacity. Second, he or she may decide the ecosystem state is undesirable (S_1 or S_3) when it is actually desirable (S_2), which can prompt the manager to implement a new management action when it is not needed, resulting in inefficient use of human and financial resources. Such errors may occur because (1) plant diversity and user satisfaction (and hence ecosystem states) vary over time and space in response to variability in environmental processes and other factors beyond the control of the manager, such as climate change; and (2) plant diversity and user satisfaction are measured with errors, which can mask the true values of these variables. The next two sections describe an analytical framework for implementing active adaptive management under risk and uncertainty.

Adaptive management under risk

In the risk case, the manager does not know for certain how management actions influence the ecosystem and is able to assign subjective prior (or initial) probabilities to ecosystem states. Hypotheses about the most likely ecosystem state are evaluated using the posterior probabilities of ecosystem states estimated by applying Bayes's rule to the prior probabilities of ecosystem states, experiments conducted to determine the ecosystem impacts of management actions, and other information (Prato 2005). In the context of resource management, Bayes's rule is a method of determining posterior probabilities of ecosystem states by updating the prior probabilities of those states using experimental information. This approach minimizes the aforementioned errors. Adaptive management for the risk case involves (1) determining the optimal number of campsites/permits in the first evaluation period (i.e., the number of consecutive years over which the adaptive management experiments are conducted), (2) implementing the optimal number of campsites/permits, and (3) adjusting the optimal number of campsites/permits in subsequent evaluation periods if justified based on monitoring information. The experiments for the user capacity example involve (1) selecting a random sample of backcountry campgrounds and users; (2) randomly assigning different numbers of campsites/permits to subsets of the sample (e.g., five campgrounds have 4 campsites, five campgrounds have 6 campsites, five campgrounds have 8 campsites, and five campgrounds have 10 campsites); (3) measuring plant diversity and user satisfaction for all subsets; and (4) determining posterior probabilities of ecosystem states for all subsets. The optimal number of campsites/permits is the number for the subset of the sample having the highest posterior probability of S_2, which is considered to be a desirable ecosystem state.

Adaptive management under uncertainty

The uncertainty case, in which there is uncertainty about the impacts management actions have on ecosystem states, assumes the

[Adaptive management] is a form of integrated learning that acknowledges management outcomes can be surprising and unpredictable.… Adaptive management can be either passive or active.

Table 1. Hypothetical estimated net losses (L) from increasing the number of campsites/permits in backcountry campgrounds under three ecosystem states in the first evaluation period

	Ecosystem state			Maximum
Increase[a]	S_1[b]	S_2[c]	S_3[d]	net loss[e]
$A_1 = 2$	$L(A_1, S_1) = 8$	$L(A_1, S_2) = -5$	$L(A_1, S_3) = -7$	-7 (S_3)
$A_2 = 4$	$L(A_2, S_1) = 10$	$L(A_2, S_2) = -10$	$L(A_2, S_3) = -9$	-10 (S_2)
$A_3 = 6$	$L(A_3, S_1) = -20$	$L(A_3, S_2) = 5$	$L(A_3, S_3) = -18$	-20 (S_1)

[a]In number of additional campsites above four.
[b]High plant diversity and low user satisfaction.
[c]Moderate plant diversity and moderate user satisfaction.
[d]Low plant diversity and high user satisfaction.
[e]The state with the maximum net loss is shown in parentheses.

manager is unable to assign prior probabilities to ecosystem states, which rules out use of Bayes's rule. Three criteria can be used to determine the optimal number of campsites/permits under uncertainty: the safe minimum standard of conservation, the precautionary principle, and the minimax regret criterion. The safe minimum standard is designed "to preserve some minimum level or safe standard of a renewable resource unless the social costs of doing so are somehow intolerable, unacceptable or excessive" (Berrens et al. 1998). A difficulty with applying the safe minimum standard to park management is defining the minimum levels or safe standards of renewable resources.

The precautionary principle states that "where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (United Nations 1992). This principle is not particularly relevant to user capacity and other park management issues for which the ecological harm done to park resources by human activities can be reversed by limiting such activities. For example, in the case where user capacity is exceeded, the park manager can implement several management actions designed to rectify the problem.

The minimax regret criterion is suitable for assessing user capacity and other park management issues. A simplified, hypothetical example is used to demonstrate the application of the minimax regret criterion. In the example, the park manager determines the optimal number of campsites/permits, which is the number that minimizes the maximum net loss (L). The latter is defined as the costs in terms of losses in plant diversity minus the benefits in terms of gains in user satisfaction from increasing the number of campsites/permits. Net losses can be determined using an index of plant diversity and an index of backcountry user satisfaction. Suppose the manager determines the plant diversity index is 60 with six campsites and 80 with four campsites, and the user satisfaction index is 80 with four campsites and 90 with six campsites under S_3. Then suppose the manager determines that the net loss from adding two campsites (A_1) when the ecosystem state is S_3 is $L(A_1, S_3)$ = (plant diversity index with six campsites − plant diversity index with four campsites) + (user satisfaction index with six campsites − user satisfaction index with four campsites) = $60 - 80 + 90 - 80 = -10$. A net loss of 10 and other hypothetical net losses in the first evaluation period are shown in table 1. The last column in the table shows the maximum net losses for the three increases in campsites/permits over the three ecosystem states, namely −1 with A_1, −10 with A_2, and −20 with A_3. Since the maximum net loss is lowest with A_1, the optimal increase in campsites/permits is two.

Adaptive management under uncertainty involves applying the minimax regret criterion to the net losses for consecutive evaluation periods. For example, if A_1 is the optimal increase in campsites/permits in the first evaluation period and A_2 is the optimal increase in campsites/permits in the second evaluation period, the manager should increase the number of campsites/permits from two to four. As with the risk case, the optimal number of campsites can vary over time with the uncertainty case.

Conclusion

I propose a generic analytical framework for implementing active adaptive management for national parks under risk and uncertainty. Implementation of the framework requires the park manager to specify the prior probabilities of ecosystem states and measure the ecosystem impacts of management actions in the risk case or determine the net losses for different management actions and ecosystem states in the uncertainty case. Although the framework is described using a simplified, hypothetical example of managing user capacity in national parks, the generic nature of the framework makes it suitable for adaptive management of a wide range of park management issues, such as protecting the habitats of threatened and endangered species in the vicinity of protected areas (e.g., Prato 2005, 2006) and alleviating multiple external threats to national park ecosystems (Prato 2004).

On the positive side, active adaptive management produces scientifically defensible information about ecosystem responses to management actions, which is often not the case for passive adaptive management. On the negative side, applying active adaptive management requires considerable information. Obtaining that information would require major investments in research, monitoring, and modeling, which may not be feasible for some park units. A park manager's decision to use passive adaptive management, active adaptive management, or neither should be based on a careful comparison of the benefits and costs of the approaches.

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Cultivating connection: Incorporating meaningful citizen science into Cape Cod National Seashore's estuarine research and monitoring programs

By Brett Amy Thelen and Rachel K. Thiet

LONG BEFORE BIODIVERSITY BECAME A MAINSTAY OF the conservation lexicon, amateur naturalists were trekking through the field, observing and recording the occurrence and distribution of species. Today, volunteer participation in ecological research is hailed as a pillar of effective community-based environmental management. This "citizen science" integrates environmental education with conservation biology, and can thus inform ecological management while fostering public awareness of critical environmental issues.

Even with the additional effort required to train and supervise volunteers, citizen science programs can save considerable expense and time in the field (Darwall and Dulvy 1996; Newman et al. 2003), allowing for the expansion of existing research programs (Darwall and Dulvy 1996; Fore et al. 2001). Furthermore, participating in citizen science programs may strengthen volunteer commitment to conservation (Evans et al. 2005). Miles et al. (1998) found that volunteers in ecological restoration initiatives developed a "hands-on, healing relationship" with the natural world. This relationship can spur further environmental action: 4.5% of the volunteers participating in a U.K. mammal survey subsequently switched to conservation-oriented careers, while some 30% joined conservation groups (Newman et al. 2003). Because of this potential for inspiring community involvement in environmental issues, participatory science has been identified as one of the most urgently needed environmental education initiatives for cultivating successful community-based environmental management (Evans and Birchenough 2001; Danielsen et al. 2005).

Despite the benefits of citizen science, some scientists have expressed concern about the validity of volunteer-generated data. Indeed, certain projects are not appropriate for volunteer involvement: complex research methods (Newman et al. 2003) and projects that require long hours of arduous or repetitive work (Darwall and Dulvy 1996; Newman et al. 2003) and taxonomic identification to the species level (Penrose and Call 1995; Darwall and Dulvy 1996; Fore et al. 2001) may not be suitable for volunteers. Without proper training in research and monitoring protocols, volunteers are also more likely to introduce bias into their data (Eaton et al. 2002; Danielsen et al. 2005).

When designed with these limitations in mind, however, citizen science initiatives can make important contributions to science and management. Numerous studies have demonstrated that volunteers can successfully perform basic data collection tasks when given a half day or more of practical field training (Darwall and Dulvy 1996; Graham et al. 1996; Evans et al. 2000; Fore et al. 2001; Foster-Smith and Evans 2003). In fact, Fore et al. (2001) found no difference between freshwater macroinvertebrate samples collected by trained volunteers and control samples collected by professional scientists. Because much of the fieldwork needed for ecological monitoring is labor-intensive but technically straightforward (Foster-Smith and Evans 2003), volunteer monitoring projects carry considerable scientific potential.

Numerous studies have demonstrated that volunteers can successfully perform basic data collection tasks when given a half day or more of practical field training.

Today many organizations engage citizens in ecological research and monitoring through participatory science programs (Penrose and Call 1995; Eaton et al. 2002), but the success of these programs varies according to their unique ecological, social, and organizational settings. For instance, whereas a local organization might find volunteer monitoring useful for informing small-scale water quality management decisions, a national park might determine that the same monitoring protocol does not meet its need for data that can withstand scientific scrutiny in a peer-reviewed journal or court of law (Penrose and Call 1995). In order, then, to engage more communities in valid, valuable ecological monitoring, it is first necessary to evaluate pilot citizen science projects across a variety of ecosystems and organizations (Foster-Smith and Evans 2003).

"Citizen science" integrates environmental education with conservation biology, and can thus inform ecological management while fostering public awareness of critical environmental issues.

As a prototype park for the National Park Service (NPS) Inventory and Monitoring Program, Cape Cod National Seashore (Massachusetts) already takes a lead in the development of monitoring protocols for Atlantic and Gulf coastal ecosystems. This role also provides an opportunity for the national seashore to serve as a model for integrating citizen science into ecosystem monitoring efforts. Cape Cod scientists have identified a need for baseline information about benthic mollusk populations in restoring estuaries; because mollusks are relatively easy to sample and are culturally and commercially important in coastal New England, national seashore managers also support volunteer involvement in mollusk monitoring.

The objectives of this study were to determine (1) whether volunteers can collect reliable, reproducible data on mollusk populations for use in Cape Cod National Seashore's estuarine monitoring and management programs, and (2) whether such citizen science projects increase participant support for estuarine restoration on Cape Cod.

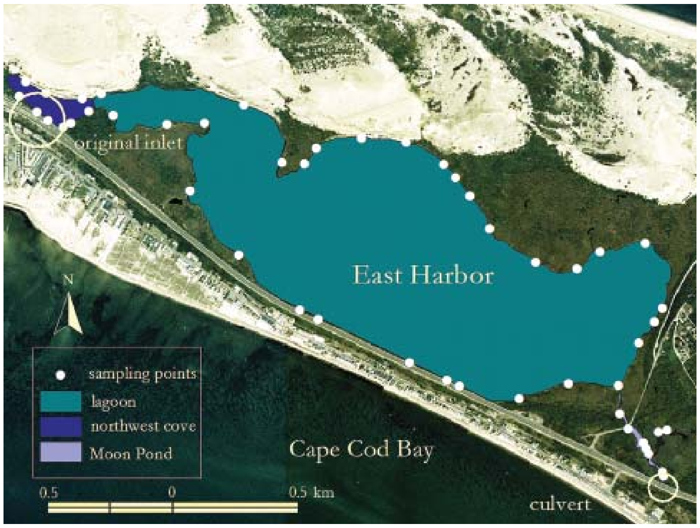


Figure 1. Mollusk sampling locations at East Harbor, Cape Cod National Seashore. Benthic mollusk sampling was conducted from 10 July to 26 August 2005 in three regions of East Harbor that vary markedly in salinity and distance to Cape Cod Bay: Moon Pond (creek), the central lagoon, and the northwest cove.

IMAGE COURTESY OF MASSGIS

Methods

Study site

East Harbor is a 719-acre (291 ha) coastal lagoon and salt marsh that originally functioned as an estuary, connected to Cape Cod Bay by an inlet at its western end (fig. 1). In 1868 it was completely isolated from the bay by the construction of a solid-fill causeway for trains and automobiles (Portnoy et al. 2005). After this construction, salinity throughout East Harbor decreased to near-freshwater conditions, the waters became highly eutrophic (i.e., nutrient-enriched) with large blooms of nitrogen-fixing cyanobacteria, and fish and invertebrate numbers declined precipitously. In December 2001 a massive fish kill prompted an experimental opening of the culvert that connects the system to Cape Cod Bay (Portnoy et al. 2005; fig. 1).

The culvert was permanently opened in November 2002, and salinity throughout the lagoon has increased dramatically since then. By September 2004, at least 15 species of estuarine fish, crustaceans, and invertebrates had also recolonized East Harbor (Portnoy et al. 2005).

Volunteer recruitment and training

Fourteen volunteers were recruited from a local AmeriCorps program and by publicizing the project in local newspapers. They spent approximately 285 total volunteer-hours doing supervised fieldwork, with eight volunteers contributing more than one field day to the project. Sixty-three percent (five) of these active volunteers were year-round residents of lower Cape Cod; 50% (four) were affiliated with AmeriCorps–Cape Cod or Cape Cod National Seashore; 88% (seven) were between the ages of 18 and 34; and 88% (seven) had an undergraduate degree.

Prior to data collection, all volunteers participated in three hours of field training, which included a one-hour introduction to estuarine restoration and hands-on practice of mollusk sampling (described below). All volunteers received the same training, and volunteer fieldwork was supervised by the first author, an independent researcher under permit to the park, at all times.

To determine whether participating in this project increased volunteers' support for estuarine restoration on Cape Cod, we administered written pre- and post-program questionnaires to all regular participants. Questionnaires contained a combination of open-ended questions and Likert scale responses, in which volunteers used a five-point scale to record their agreement with 15 statements about conservation, restoration, and citizen science (Thomson and Hoffman 2003; table 1).

Mollusk sampling

To evaluate the validity of volunteer-generated data, we enlisted the support of two professional researchers with extensive shellfish experience on lower Cape Cod: Kurt Schlimme, former deputy shellfish constable for the town of Wellfleet, Massachusetts, and Krista Lee, physical scientist for Cape Cod National Seashore. Benthic mollusk sampling was conducted from 10 July to 26 August 2005 in three regions of East Harbor that vary markedly

Figure 2. Northern quahogs (*Mercenaria mercenaria*) were one of several culturally and commercially important mollusk species detected by volunteers in the restored East Harbor estuary, Cape Cod National Seashore.

BRETT AMY THELEN

Table 1. Selected questions from the written pre- and post-program questionnaire used to measure shifts in volunteer attitudes toward estuarine restoration after participating in this citizen science project

Please rate the extent to which you agree or disagree with each of the following statements (1 = Strongly Disagree, 2 = Disagree Somewhat, 3 = No Opinion, 4 = Agree Somewhat, 5 = Strongly Agree)
I am familiar with Cape Cod National Seashore's estuarine restoration program.
I am concerned about the effects of estuarine restoration on freshwater plant species.
I am concerned about the effects of estuarine restoration on freshwater animal species.
Estuarine restoration benefits people in coastal communities.
Estuarine restoration should be a top priority at Cape Cod National Seashore.
Open-ended questions: please write your answer below
What have you learned about *ecological restoration* as a result of participating in this citizen science project?[a]
What have you learned about *wetlands ecology* as a result of participating in this project?[a]
What worked well in this project?[a]
What did *not* work well in this project?[a]
What recommendations do you have for improving the citizen science experience at Cape Cod National Seashore?[a]

Note: The pre-program survey also contained questions about participant demographics. For a full list of the questions in the citizen science questionnaire see the Web edition of this article at http://www.nature.nps.gov/ParkScience/index.cfm?ArticleID=236.

[a]Included only in the post-program survey.

in salinity and distance to Cape Cod Bay: Moon Pond (creek), the central lagoon, and the northwest cove (fig. 1). Fifty sampling points (10 in Moon Pond [creek], 30 in the central lagoon, and 10 in the northwest cove) were systematically selected to ensure that sampling was evenly distributed throughout each region. At each point, mollusk species richness and density were sampled using a combination of one 3.9-inch (10 cm) diameter benthic core and digging within a 4.84-ft^2 (0.45 m^2) quadrat (Dethier and Schoch 2005). Sediment from benthic cores and quadrats was wet-sieved through 0.08-inch (2 mm) and 0.25-in (0.64 cm) mesh, respectively; all mollusks retained on the sieves were counted live and identified to genus or species (figs. 2 and 3). Data obtained from both methods were extrapolated up to individuals 10.76 ft^{-2} (1 m^{-2}), a common way to express mollusk density (Hunt et al. 2003; Poulton et al. 2004).

Volunteers and professional researchers sampled each point within one week of each other, using the same protocol and field equipment. To account for potential differences in mollusk diversity and abundance due to disturbance during sampling, each point was divided into two immediately adjacent quadrats, one for volunteer sampling and the other for sampling by our professional researchers.

Data analysis

To assess the validity of volunteer-generated data, we compared volunteer with professional data for species richness and the density of the four most abundant mollusk species. All data were non-normally distributed because of high variability in species

Figure 3. Researchers sampled mollusk species using a combination of benthic cores and digging within 4.84-ft^2 (0.45 m^2) quadrats. Sediment from cores and quadrats was wet-sieved through 0.08-inch (2 mm) and 0.25-inch (0.64 cm) mesh, respectively; all mollusks retained on the sieves were counted live and identified to genus or species.

SARAH EDDY

richness and density among sample plots, and data transformation did not improve normality. Thus, we used nonparametric Wilcoxon rank-sum tests (Zar 1999) to compare volunteer-generated data with the data collected by professional researchers.

Statistical analysis of volunteer responses to the written questionnaires was precluded by the low number of program participants; we summarize qualitative trends below.

Results

Volunteer vs. professional data quality

For species richness and density of the four most abundant mollusk species, we found no significant differences between data collected by citizen science volunteers and data collected by professional researchers, both across East Harbor as a whole and in each region individually (Wilcoxon rank-sum tests, $p \leq 0.05$; table 2, figs. 4 and 5). Citizen scientists detected 14 mollusk species throughout East Harbor while professional researchers detected 15; volunteers and professionals detected 13 species in common (table 2).

Volunteers and professionals found roughly equivalent densities for the four most abundant mollusk species; however, densities quantified using benthic cores were highly variable, both among sample plots within each region of East Harbor and between observer groups (fig. 5).

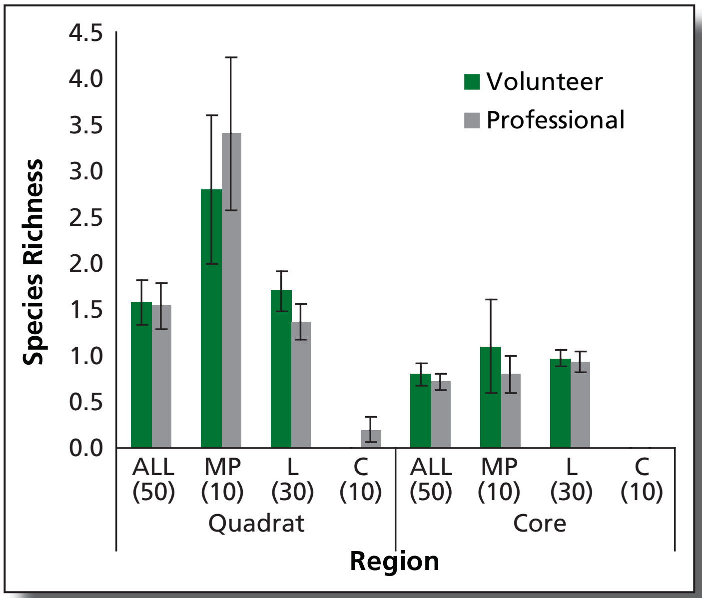
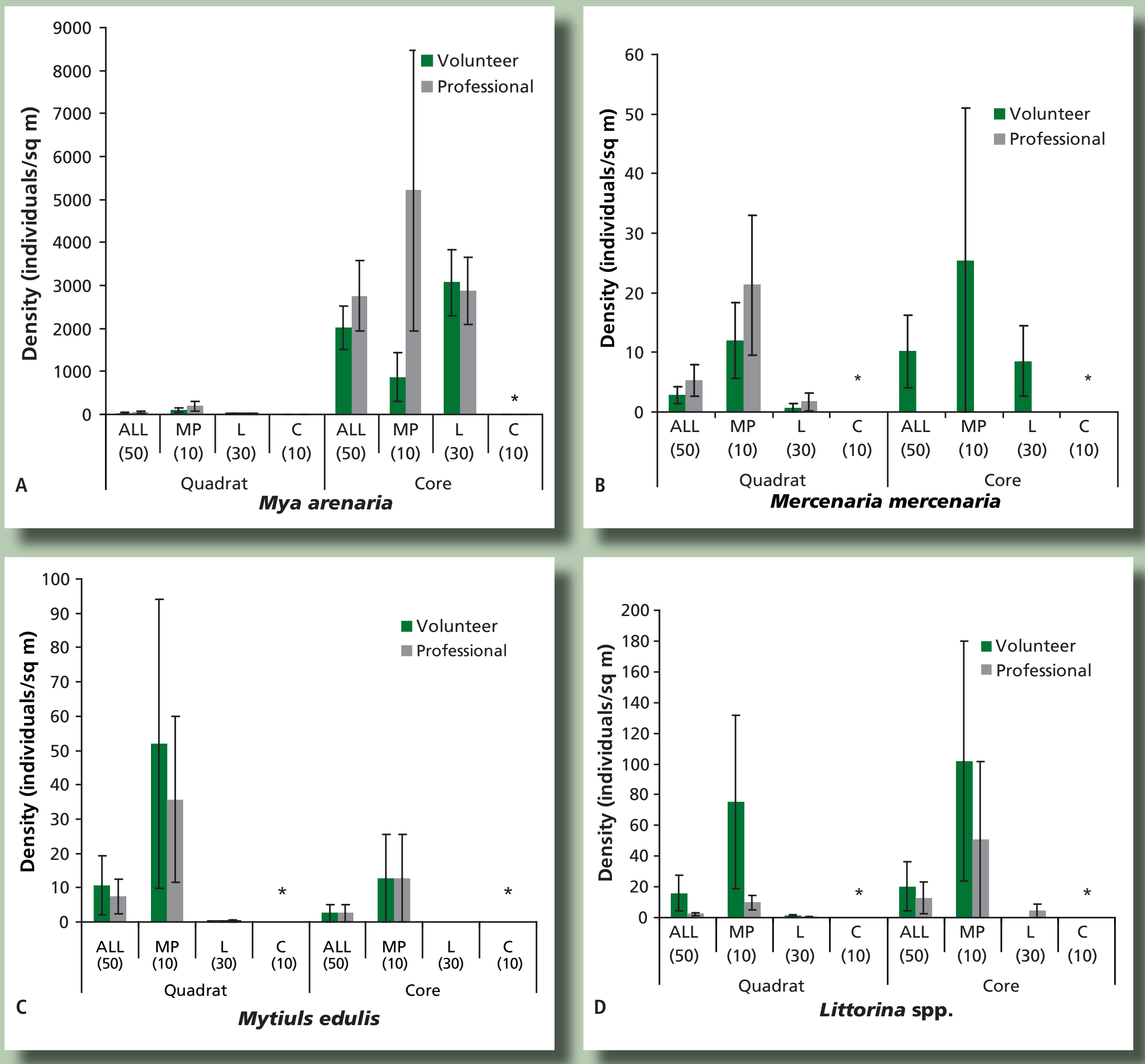


Figure 4. Mean mollusk species richness (± SE) at East Harbor, Cape Cod National Seashore, by observer, region, and sampling method. ALL = East Harbor as a whole, MP = Moon Pond (creek), L = central lagoon, C = northwest cove. Number in parentheses denotes sample size.

Table 2. Mollusk species detected at East Harbor, Cape Cod National Seashore, by volunteers and professional researchers, 2005

		Detected by	
Common name	**Scientific name**	**volunteers**	**professionals**
Softshell clam	*Mya arenaria*	X	X
Periwinkle	*Littorina* spp.	X	X
Blue mussel	*Mytilus edulis*	X	X
Northern quahog	*Mercenaria mercenaria*	X	X
Dwarf surfclam	*Mulinia lateralis*	X	X
Amethyst gemclam	*Gemma gemma*	X	X
Jingle	*Anomia* spp.		X
Ribbed mussel	*Geukensia demissa*	X	X
Northern moonsnail	*Euspira heros*	X	X
Common razor clam	*Ensis directus*	X	X
False angelwing	*Petricola pholadiformis*	X	X
Bubble snail	Order Cephalaspidea	X	X
Atlantic surfclam	*Spisula solidissima*		X
Baltic macoma	*Macoma balthica*	X	X
Stout tagelus	*Tagelus plebeius*	X	X
Atlantic dogwinkle	*Nucella lapillus*	X	

Note: Species are listed in order of abundance. Eastern oysters (*Crassostrea virginica*) were also observed anecdotally by both volunteers and professionals, but were not found in any sample plots.



Figures 5a–d. Mean density (± SE) of the four most abundant mollusk species at East Harbor, Cape Cod National Seashore, by observer, region, and sampling method. ALL = East Harbor as a whole, MP = Moon Pond (creek), L = central lagoon, C = northwest cove. Number in parentheses denotes sample size. Asterisks denote regions and sampling methods for which no mollusks were detected. The magnitude of variability illustrated here appears greater than it actually was in the field because we extrapolated data to individuals 10.76 ft^{-2} (1 m^{-2}).

Participant attitudes toward estuarine restoration

Qualitative comparison of pre-and post-participation questionnaires revealed several trends. Forty-five percent of all participant responses to the survey questions were the same in both pre- and post-program surveys. However, after participating in this project, 50% (four of eight) of active volunteers reported increased familiarity with Cape Cod National Seashore's estuarine restoration program, increased agreement with the idea that estuarine restoration benefits people in coastal communities, increased support for continued restoration efforts, and decreased concern about the effects of estuarine restoration on freshwater plant and animal species in impacted areas. One participant summarized her experience by saying, "We all learned from each other, it wasn't too difficult for a layperson, and it gave me a much deeper sense of connection to the landscape, which was exactly my goal."

In response to our open-ended request for recommendations for improving the citizen science experience at Cape Cod National Seashore, 50% (four of eight) of active volunteers specifically requested more opportunities for participating in ecological research and monitoring on Cape Cod. Furthermore, the field sampling itself was highlighted as a valuable educational experience: no volunteers reported learning more from the training than from the fieldwork, but 38% (three of eight) of respondents reported learning more from the fieldwork than from the training.

Discussion

This study is a first approximation of the efficacy of engaging volunteers in monitoring culturally and ecologically important natural communities at Cape Cod National Seashore. Mollusk data collected by citizen scientists were comparable to those collected by professional researchers, thus demonstrating that supervised volunteers are capable of collecting reliable data on mollusk populations for use in monitoring and restoring estuaries at Cape Cod National Seashore. These findings are promising, given that the national seashore prioritizes estuarine restoration and is managing restoration work at the four largest tidally restricted estuaries on Cape Cod (Portnoy et al. 2003).

Density data collected using benthic cores showed high variability among sample plots within each region of East Harbor, and between observer groups. Both instances of high variability may be due to the naturally patchy, sparse distribution of mollusks in the field (Hunt et al. 2003; Commito et al. 2006). When coupled with the small number of plots sampled, this variability may have reduced our statistical power to detect significant differences between professional- and volunteer-generated data. Future researchers should minimize these potential problems by sampling more intensively.

It is also important to note that, though we encouraged volunteer autonomy in the field, the first author consistently assisted with fieldwork and regularly answered volunteer questions about methodology and species identification, and two volunteers expressed uncertainty about their ability to sample successfully without supervision. In fact, other studies suggest that sustained personal communication with scientists and hands-on field training are essential to the success of citizen science projects. Evans et al. (2005) found that face-to-face contact between scientists and volunteers was vital to one avian citizen science program near Washington, D.C., and volunteers in a U.K. mammal survey were unable to perform monitoring tasks without field training, even after receiving written instructions (Newman et al. 2003). Indeed, more than half of the volunteers participating in our study identified thorough, informative training as one of the project's key strengths.

The chief of natural resources at Cape Cod National Seashore estimates that overseeing the recruitment, training, and supervision of volunteers for this one-year study achieved no significant cost savings over using regular NPS staff. However, citizen science initiatives can be cost-effective over time, especially if volunteers make long-term commitments to ecological monitoring (Darwall and Dulvy 1996; Newman et al. 2003), or if one professional researcher or park manager supervises multiple volunteer projects. Participatory science programs may be particularly well suited for national parks with Research Learning Centers, which were designed as "places where science and education come together to preserve and protect areas of national significance" (National Park Service 2005). Some parks may be interested in establishing unsupervised citizen science projects; in these cases, further research is needed to determine whether high-quality data can be generated by unsupervised volunteers.

Our pre- and post-program surveys reflect an additional benefit of citizen science: increased support for estuarine restoration. We did not record a sea change in attitudes toward restoration among our participants, largely because they were highly supportive of ecological restoration from the start. However, our volunteers expressed strong interest in preserving estuarine restoration as a management priority at Cape Cod National Seashore and in expansion of citizen science opportunities on lower Cape Cod. By talking with neighbors, friends, and family, these citizen scientists may become effective ambassadors for restoration, recruiting additional volunteers and expanding the project's impact within the greater community (Evans et al. 2005). Such public support is vital for parks like Cape Cod National Seashore, which operate within a mosaic of privately owned land and regularly encounter local resistance to restoration efforts.

Conclusion

Volunteer involvement in ecological monitoring has been shown to facilitate swift, meaningful conservation actions within local communities, both through direct action and by fostering community-wide conservation dialogue (Danielsen et al. 2005). At the same time, research by professional scientists is more likely to influence environmental policy at the state and federal levels. By pairing reliable, locally relevant data collection with the NPS information infrastructure, citizen science partnerships between national parks and local communities carry great potential for enhancing estuarine restoration, both locally and nationally.

Acknowledgments

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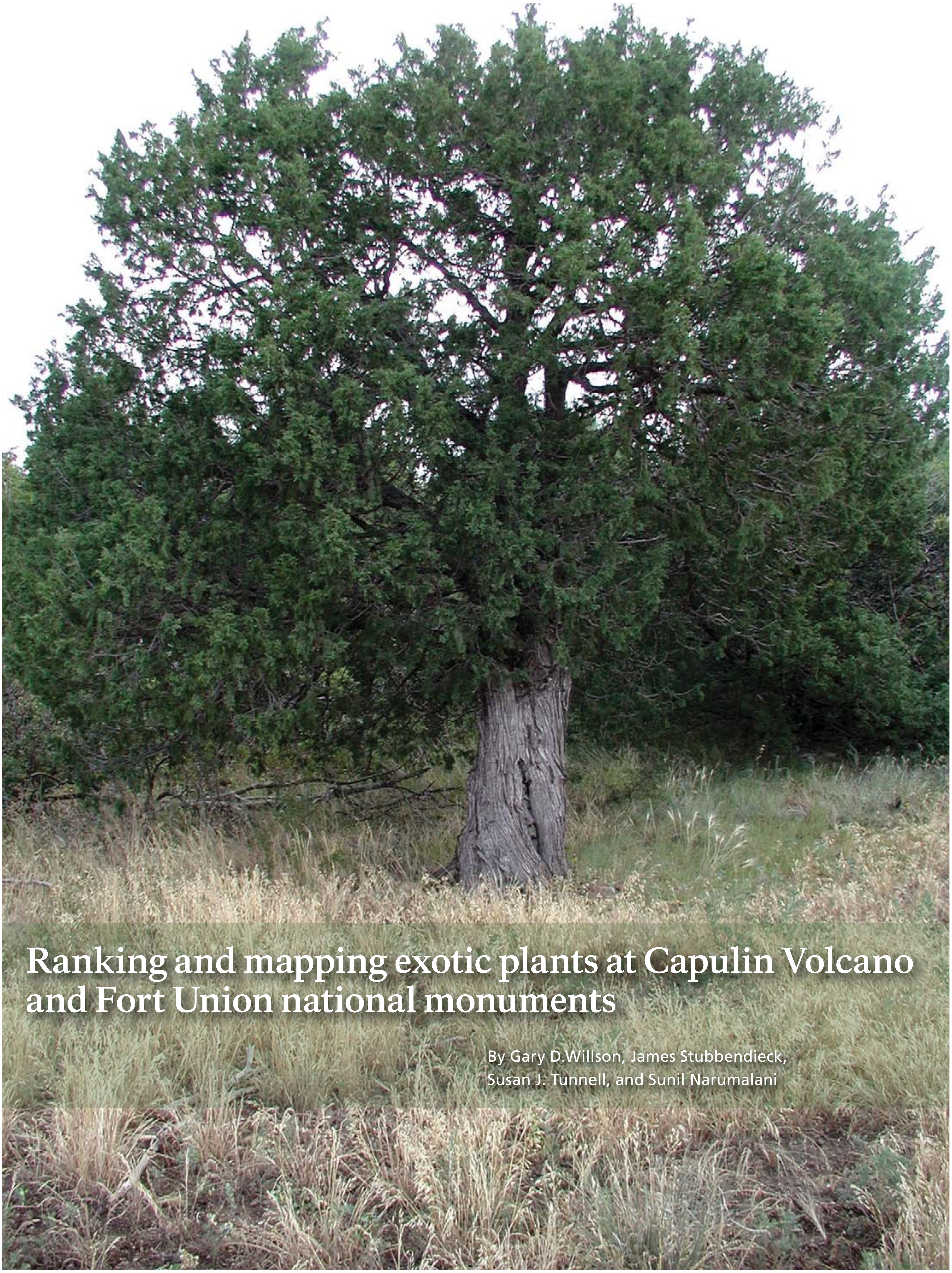

Ranking and mapping exotic plants at Capulin Volcano and Fort Union national monuments

By Gary D.Willson, James Stubbendieck, Susan J. Tunnell, and Sunil Narumalani

THROUGHOUT THE GREAT PLAINS AND ROCKY MOUN-tains, exotic plants are jeopardizing the integrity of natural ecosystems (U.S. Geological Survey's Invasive Species Working Group 2000). The National Park Service has identified management and control of invasive, exotic plants, especially state-listed noxious weeds, as a high-priority resource management issue. Noxious weeds are invasive plants that threaten agricultural crops and rangeland and whose control is mandated by state law. In the Intermountain Region, resource managers in 19 National Park System units have prioritized areas where exotic plants need to be inventoried and their population distribution mapped before effective and efficient management can be implemented (Intermountain Regional Office 2001).

At the request of the Intermountain Region, the Great Plains Cooperative Ecosystem Studies Unit organized a team of range ecologists and a remote sensing specialist at the University of Nebraska–Lincoln to inventory and map noxious weeds within two park units in New Mexico: Capulin Volcano National Monument and Fort Union National Monument. During the initial stages of this effort, we proposed to map all noxious weeds that are included on the New Mexico noxious weed list over the entire area of both national monuments. Review of the plants at these national monuments, however, led us to modify our original objective. Only one noxious weed—field bindweed (*Convolvulus arvensis*)—was known from Capulin Volcano. Field bindweed was also the only known noxious weed from Fort Union. Additional exotic plants not classified as noxious weeds were present at both national monuments, however. Without management, many of these exotics have the potential to become state-listed. Instead of mapping all the exotic plants in each unit, we used a ranking system to first determine which exotic plants were serious pests and then mapped only those species.

Exotic species ranking system

The exotic species ranking system (Hiebert and Stubbendieck 1993)—a decision-making tool in natural resource management—allows resource managers to rank exotic plants by numerical scores. The ranking system is divided into two main sections: (1) significance of impact and (2) feasibility of control or management. Significance of impact is further divided into current level of impact and innate ability of a species to become a pest. A score for current level of impact (−8 to 50 points) is based on the present degree and extent of impact caused by the species; a score for innate ability of the species to become a pest (4 to 50 points) is based on a plant's life history and traits that predispose it to become a problem. A score for feasibility of control (3 to 100 points) is based on the abundance of a species and the ease and side effects of control measures. The ranking system also provides for a qualitative assessment (low, medium, or high) of urgency of control by identifying the potential financial and ecological impacts of delayed action.

Figure 1 (previous page). Japanese and downy brome at Capulin Volcano National Monument, New Mexico.

NPS PHOTO/GARY WILLSON

We used this system because it had been extensively tested and applied in several park units in the Midwest (Stubbendieck et al. 1992; Stumpf et al. 1994) and was published and distributed as an NPS natural resource report (Hiebert and Stubbendieck 1993). The ranking system can assist resource managers in making sound decisions regarding exotic plant management by separating innocuous from disruptive species. An advantage of the system is that it allows resource managers to rank the exotic plants without prior extensive field visits, though field visits are necessary when making final decisions about the management of high-priority species.

Ranking and mapping strategy

To determine our strategy for mapping exotic plants, we first visited the two national monuments in March 2003. We used species lists compiled by park staffs and the New Mexico Natural Heritage Program as a starting point for determining the exotic plants present. We visited each national monument to become familiar with the plant communities and conferred with park staffs about their concerns.

We returned to the national monuments in August 2003 to rank the exotic plants, assess urgency of control, and determine which species to map. Following a thorough field inventory of the plant communities and additional review of the plant lists, a team composed of researchers from the University of Nebraska–Lincoln and the resource manager at Capulin Volcano ranked each exotic plant using the exotic plant ranking system. Based on what they learned from ranking exotics in 10 parks in the Midwest Region, Stubbendieck et al. (1992) consider all species with a significance of impact score of 50 or higher to be highly disruptive. We followed a similar approach and decided to map only exotics with a score of 50 or higher. In addition, we provided background information about species that rated medium or high in urgency of action in order to alert park staffs to the possibility of increased effort and cost to control these plants in the future. Using a global positioning system (GPS), we mapped the highly disruptive species and used the coordinates to delineate areas of exotic plant occurrence.

Results

At Capulin Volcano National Monument, we ranked 21 exotic plants and decided that Japanese brome (*Bromus japonicus*) and downy brome (*Bromus tectorum*) were the species of primary concern (i.e., highly disruptive) (fig. 1 and table 1). These two annual bromes are very similar in biology, ecology, and distribution and are suspected of interbreeding. We mapped Japanese brome and downy brome within the same GPS polygons because both species occurred together, and mapping the species separately at the selected scale was not feasible. The area occupied by annual brome totaled 44.8 acres (18.1 ha) (fig. 2). A biplot of the relationship between the significance of impact and the feasibility of control reveals that three species (Japanese brome, downy brome, and smooth brome [*Bromus inermis*]) are serious threats and difficult to control (fig. 3). Although smooth brome also shares these characteristics, it does not pose an eminent serious threat (i.e., low urgency) to the resources at Capulin Volcano because of the small number of populations that are located primarily along roadsides within the national monument. In addition to Japanese and downy brome, we found common horehound (*Marrubium vulgare*) to be a species of medium urgency because of its invasive potential; however, because the significance of impact score for the species was lower than 50 and only one very small population, which is already actively managed, occurs in the national monument, we did not map it.

By first ranking species to determine the most disruptive, we were able to identify species of concern and focus our efforts on mapping those species.

We ranked 22 exotic species at Fort Union National Monument (table 2). The only species that ranked high enough to map (scoring 50 or higher for significance of impact) was field bindweed (fig. 4). This was also the only species we identified as of medium or high urgency. Field bindweed occupied 3.3 acres (1.3 ha) and was restricted to the residence area and the roadside near the front gate (fig. 5). These highly disturbed areas are ideal for field bindweed to establish and persist over time. Many of the other exotic plants present were restricted to a low, wet area adjacent to Coyote Creek. These plants are of little threat because of their reliance on water and the lack of permanent streams and wet areas in the national monument.

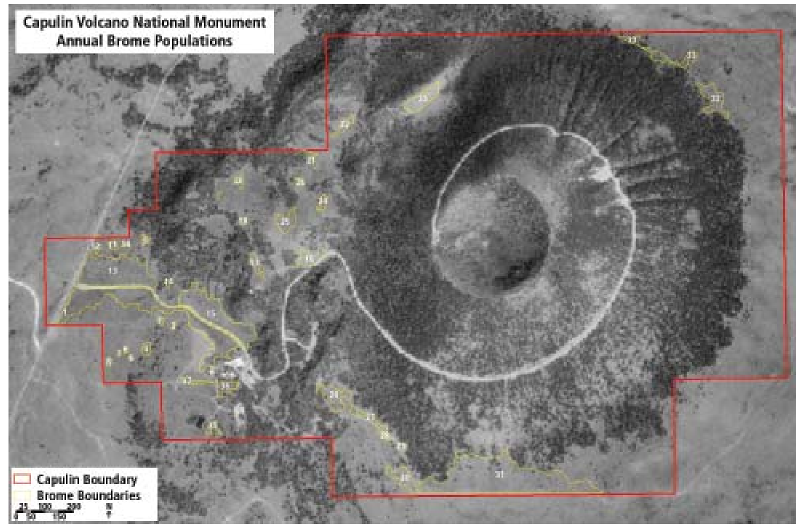

Figure 2. Investigators mapped populations of annual brome (*Bromus japonicus* and *Bromus tectorum* [shown in yellow]) at Capulin Volcano National Monument. These species are highly disruptive and of primary concern for resource management at the national monument.

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Discussion

The exotic species ranking system was a useful decision-making tool at Capulin Volcano and Fort Union national monuments. By first ranking species to determine the most disruptive, we were able to identify species of concern and focus our efforts on mapping those species. At both national monuments, we found far fewer exotic plant species than are present in parks in the Midwest, where the ranking system has been extensively applied, and possibly in other parks in the Intermountain Region (table 3). For example, of the 92 exotic plants found at Pipestone National Monument in Minnesota, 11 were highly disruptive. By comparison, Capulin Volcano had 3 and Fort Union had 1 (table 3).

At Capulin Volcano, we mapped widespread infestations of two highly disruptive species, Japanese and downy brome. We recommend that exotic plant management at Capulin Volcano focus on these species. Smooth brome and common horehound need monitoring so it can be determined whether populations are increasing and require proactive management. Other exotic plants in the national monument, such as Russian thistle (*Salsola tragus*) and kochia (*Kochia scoparia*), are annuals that can exploit a newly disturbed area with a rapid increase in individual plants. High population numbers may occur one year and low population numbers the next. Although these species do not pose long-term problems, disturbed areas in the national monument that are undergoing native plant restoration may require management to reduce competition from annual exotics.

Table 1. Ranking of exotic plant species at Capulin Volcano National Monument

Species	Significance of impact: Level of impact[1]	Significance of impact: Innate ability to become a pest[2]	Significance of impact: Total	Feasibility of control[3]	Urgency
Agropyron cristatum	3	27	30	41	Low
Bromus inermis	23	36	59	36	Low
Bromus japonicus	26	25	51	44	Medium
Bromus tectorum	26	27	53	44	Medium
Chenopodium album	–6	26	20	56	Low
Cichorium intybus	–8	32	24	65	Low
Convolvulus arvensis	4	43	47	31	Low
Cynoglossum officinale	7	23	30	50	Low
Descurainia sophia	3	26	29	41	Low
Echinochloa crus-galli	–8	26	18	60	Low
Euphorbia davidii	–8	30	22	40	Low
Kochia scoparia	10	34	44	70	Low
Marrubium vulgare	13	32	45	37	Medium
Melilotus officinalis	11	27	38	36	Low
Polygonum convolvulus	–8	21	13	50	Low
Salsola tragus	4	23	27	61	Low
Setaria pumila	10	24	34	44	Low
Setaria viridis	10	24	34	44	Low
Tragopogon dubius	5	32	37	40	Low
Tragopogon pratensis	5	25	30	65	Low
Verbascum thapsus	17	16	33	26	Low

[1] –8 to 50 points possible
[2] 4 to 50 points possible
[3] 3 to 100 points possible

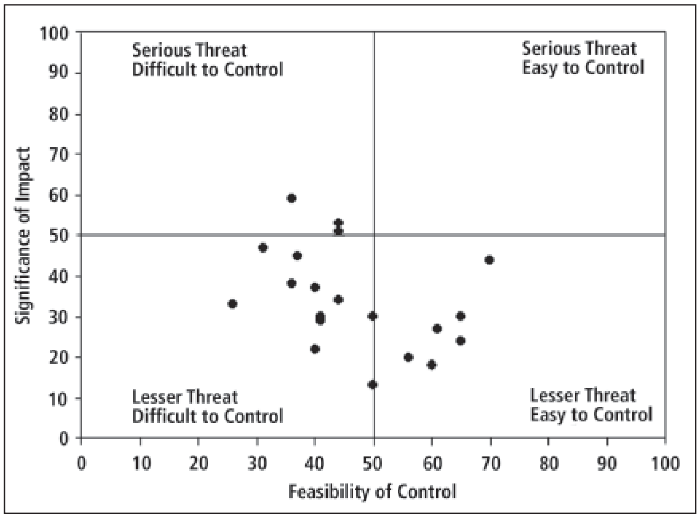

Figure 3. Capulin Volcano National Monument contains 21 species of exotic plants. Two species (*Setaria pumila* and *Setaria viridis*) scored the same, so the plot shows only one dot for both plants. The species that are serious threats and difficult to control are smooth brome (*Bromus inermis*), Japanese brome (*Bromus japonicus*), and downy brome (*Bromus tectorum*). The plot illustrates that few exotics are in the category of serious threat and difficult to control, which is the primary finding of the project.

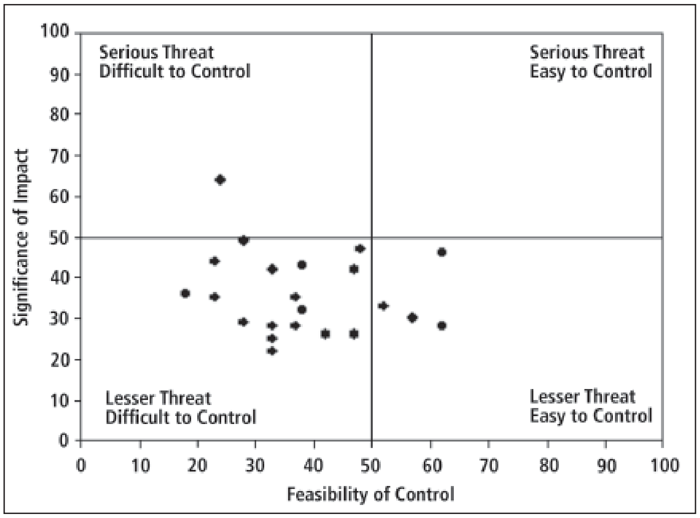

Figure 4. Fort Union National Monument contains 22 species of exotic plants. Field bindweed (*Convolvulus arvensis*), shown in the upper left quadrant, is a serious threat and difficult to control.

Table 2. Ranking of exotic plant species at Fort Union National Monument

Species	Significance of impact: Level of impact[1]	Significance of impact: Innate ability to become a pest[2]	Significance of impact: Total	Feasibility of control[3]	Urgency
Agrostis gigantean	3	32	35	23	Low
Bromus carthus carthus	3	27	30	57	Low
Bromus japonicus	18	25	43	38	Low
Bromus tectorum	22	27	49	28	Low
Convolvulus arvensis	21	43	64	24	Medium
Cynodon dactylon	21	26	47	48	Low
Erodium cicutarium	3	25	28	33	Low
Kochia scoparia	12	34	46	62	Low
Lactuca serriola	5	21	26	42	Low
Marrubium vulgare	10	32	42	33	Low
Melilotus lupulina	3	29	32	38	Low
Medicago officinalis	17	27	44	23	Low
Medicago sativa	3	22	25	33	Low
Plantago lanceolata	3	25	28	37	Low
Plantago major	3	26	29	28	Low
Salsola tragus	10	23	33	52	Low
Sonchus asper	3	23	26	47	Low
Taraxacum officinale	4	32	36	18	Low
Tragopogon dubius	3	32	35	37	Low
Tragopogon pratensis	3	25	28	62	Low
Ulmus pumila	6	36	42	47	Low
Verbascum thapsus	6	16	22	33	Low

[1]–8 to 50 points possible

[2]4 to 50 points possible

[3]3 to 100 points possible

Table 3. Number of exotic plant species from selected National Park System units

Unit	State	Exotics	Highly disruptive exotics
Capulin Volcano National Monument	New Mexico	21	3
Effigy Mounds National Monument	Iowa	65	8
Fort Union National Monument	New Mexico	22	1
Pipestone National Monument	Minnesota	92	11
Scotts Bluff National Monument	Nebraska	44	9
Wilson's Creek National Battlefield	Missouri	48	18

The only highly disruptive species we mapped at Fort Union National Monument was field bindweed. This plant was restricted to disturbed areas near residences and along the roadside. We consider the plant community at Fort Union a stable shortgrass prairie without serious threats from exotic plants at present. Places of potential concern at Fort Union are the wet areas near Coyote Creek and areas of disturbance around the residential buildings and roads. As exotic plants become established, management should be directed toward control in these areas to avoid spreading. However, the dry climate of Fort Union will most likely limit exotic plant occurrence to areas with supplemental water.

The remaining exotic plants at Capulin Volcano and Fort Union occur in small, scattered populations, which do not now threaten the national monuments' native plant communities. Biplots of the relationship between the significance of impact and feasibility of control for Capulin Volcano (fig. 3) and Fort Union (fig. 4) show that these species fall within the lesser-threat quadrants. A majority of these plants are found in anthropogenic and naturally occurring disturbed areas. However, some of these species have the capacity to become problematic if they find an invasion pathway, but the dry climate of both national monuments is most likely limiting their expansion.

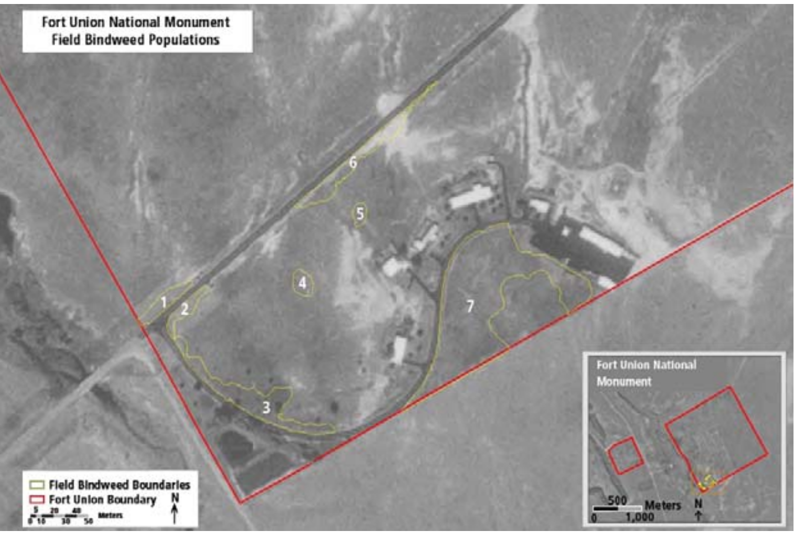

Figure 5. Investigators mapped populations of field bindweed (*Convolvulus arvensis* [shown in yellow]) at Fort Union National Monument. This species is highly disruptive and a species of concern for resource management at the national monument.

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Conclusion

Capulin Volcano and Fort Union national monuments were established as units of the National Park System for their geologic and historical resources, respectively. Both of these national monuments contain native plant communities. National Park Service management policies require that natural resources, including native plant communities, be protected from threats such as invasive, exotic plants. Because of their small size and primary management mission, neither national monument employs a full-time natural resource manager. Fortunately, we found that very few highly disruptive exotic plants had invaded the national monuments, possibly because of the dry climate. Managers at both national monuments can draw on the resources of the Chihuahuan Desert Southern Shortgrass Prairie Exotic Plant Management Team to control the disruptive exotics that do occur. The distribution maps of disruptive exotic plants that we provided should facilitate their effort. Finally, both national monuments are included in the Southern Plains Network, which proposes to monitor the response of exotic plants to management in each unit in the network.

We found that very few highly disruptive exotic plants had invaded the national monuments.

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Field Moment

Organ Pipe Cactus National Monument

25 May 2004

CLOAKED IN POLLEN, A normally cinnamon-brown-colored lesser long-nosed bat (*Leptonycteris curasoae yerbabuena*), a federally endangered species, is in the gloved hand of biological technician Ami Pate at Organ Pipe Cactus National Monument (Arizona). "Usually this time of year, the lesser long-nosed bats can be found with a dusting of light, cream-colored saguaro cactus flower pollen on their heads," Pate explains. "However, most of the ones we caught that night were covered in bright yellow agave pollen because saguaros were not in bloom. The bats practically stained the mist net orange!"

NPS/AMI PATE (2)

Lesser long-nosed bats are well adapted to feed on and pollinate saguaros (*Carnegiea gigantea*), organpipe cactus (*Stenocereus thurberi*), and agaves (*Agave* spp.). They easily see and smell the night-blooming flowers, which have a strong melon scent, and with their long snouts and brush-tipped tongues extract rich quantities of nectar produced by the desert plants to ensure that pollinators find them during their brief blooming period.

Pate and her resource management colleagues conduct annual bat surveys at Bull Pasture, an area of dense succulents in the national monument. Over a period of several nights in late spring, the survey crew captures and identifies feeding bats, which are then released. The baseline information helps managers assess population trends and other changes in the desert ecosystem.

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