DOUBLE ISSUE

PARK SCIENCE

INTEGRATING RESEARCH AND RESOURCE MANAGEMENT IN THE NATIONAL PARKS
ISSN 0735-9462

BISON CONSERVATION
IN LIGHT OF HERD HISTORY AND GENETICS STUDIES

ECOLOGICAL DANGERS
OF NONNATIVE BUFFELGRASS FUEL LOADS IN SAGUARO

WORKFORCE SUCCESSION AND TRAINING NEEDS AMONG NPS PROGRAM MANAGERS

EVOLUTION, FIRE, AND A LIZARD SPECIES' FUTURE AT OZARK

REDUCING DIVER IMPACTS ON CORAL REEFS

NEW *PARK SCIENCE* WEB SITE
AND EDITORIAL STYLE GUIDE FOR AUTHORS

USER-CAPACITY INDICATORS AND STANDARDS DATABASE

TRAP TYPES AND SMALL MAMMAL INVENTORIES ALONG THE APPALACHIAN TRAIL

HISTORICAL LANDSCAPES, NATIVE GRASSES, AND GRASSLAND-BIRD HABITAT IN THE NORTHEAST

VOLUME 24 • NUMBER 2 • WINTER 2006–2007

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

From the Editor

Seeing Double

Seeing Double

For its size, this issue of *Park Science* can be considered a double issue. At 96 pages, including 14 feature articles, it is our largest issue ever. A more interesting distinction, however, is the number of resource management topics and fields of study that are discussed in pairs or triplets of articles. Multiplicity pervades this issue and makes for many interesting comparisons and contrasts.

Look no further than our cover article about bison on U.S. federal lands and the feature article about collared lizards at Ozark National Scenic Riverways for interesting analogs to seemingly very different wildlife management issues. Though the animals are unalike, bison (throughout their North American range) and collared lizards (at Ozark) have been living in isolated populations, which limits gene flow and raises concerns for their ability to adapt to environmental change. The connection in *Park Science* is the human effort that has gone into understanding the population genetics as an important factor in planning actions to benefit each species.

A second juncture is the management of cultural landscapes for the interpretation of historical periods and events and the natural resources that lend authenticity to these sites. Management practices and goals strive to achieve historically appropriate landscapes, but as the articles discuss, managers also may need to consider the changeable nature of natural resources in cultural landscapes and the ecological benefits they provide. These issues play out in articles about the management of forests at Gettysburg National Military Park, perpetuation of an important hedgerow at Homestead National Monument of America, and restoration of grasslands in several northeastern national parks to both mimic the historical scene and provide habitat for bird populations.

Our double issue also describes a few management considerations and concerns related to fire. A powerful force, fire and its ecological effects can be far-reaching. How and to what extent prescribed fire affects particular wildlife species is the subject of two articles. A third examines the potential for dangerously high fuel loads from an invasive grass species to alter the natural fire regime at Saguaro National Park, with detrimental consequences for native plants and animals.

Another topic is the use of multiple trap types to reduce bias, sampling error, and sampling effort in small-mammal inventories. Two unrelated accounts in this issue—the summary of a journal article and an investigation conducted along the Appalachian National Scenic Trail—come to the same conclusion: the use of multiple trap types improves the efficiency and accuracy of assessing the composition and structure of small-mammal populations.

Finally, I want to call your attention to the new *Park Science* Web site, launched last fall, which has undergone a complete redesign and is now up to par with the print edition. The new site is a pleasure to use, easy to navigate, and now features a helpful search function. Though it duplicates the material presented in print, the Web site extends the reach of *Park Science* beyond our traditional print audience. You too may find that its greater accessibility will serve your information needs.

As always, we hope this issue is as enjoyable for you to read as it was for us to assemble. May the articles and the multiple topics they explore help clarify unfamiliar issues, stimulate new thinking, celebrate the benefits of scientific inquiry, and help us preserve the natural resources entrusted to our care.

Jeff Selleck

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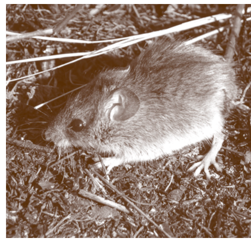
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DEPARTMENTS

COVER ARTICLE

FEATURES

ON THE COVER

Coated in frost on a cold, fall evening, a bison cow traverses snowy terrain of its northern range in Yellowstone National Park, Wyoming. Recent genetics studies and analysis of herd histories of bison on federal lands, including five national parks, are helping wildlife managers understand the many interrelated factors affecting the long-term conservation of this beloved North American species. For more of the story see our cover article on page 22.
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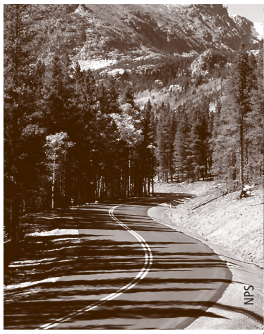
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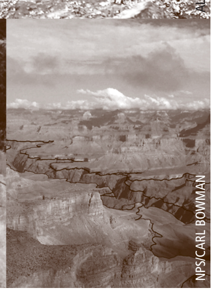
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news & views

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Thank you for your assistance.

—*Editor*

Improvements in *Park Science* Web site

Park Science on the Web (ISSN 1090-9966) has undergone a complete re-design and now functions more efficiently. Located at http://www.nature.nps.gov/ParkScience, the new Web site replaces the old one at http://www.nature.nps.gov/parksci and marks several exciting improvements, including how to subscribe and re-subscribe (see "To continue your free subscription"). The new site is "dynamic," that is, content resides in a database and is displayed by the user on demand.

Templates and style sheets improve the readability and consistency of the pages and reinforce the NPS graphic identity. The six most recent issues of *Park Science* are published in this format. Navigation to articles begins with an issue's home page, which evokes the cover design for that issue, and links to all feature articles and departments. Minimally formatted "printer friendly" pages and PDF files of individual articles are also available for these six issues.

The "Archive" is another improvement and simplifies access to the entire catalog of 79 issues of *Park Science*, from the inaugural edition in 1980 to this edition. Each issue is listed along with its available formats: Web (i.e., dynamic HTML; six issues available), PDF (all editions available), text file (about half of the issues available), and RTF (rich text format, with about half of the issues available). Users can also request copies of individual back issues that are still in print by following a convenient link. Additionally, the "Library Availability" pages list more than 400 U.S. government repository libraries on a state-by-state basis that subscribe to *Park Science*. A search function is now featured in two formats and will help readers locate content from the vast archive of back issues. The quick search—with keywords typed into a text box in the navigation bar—searches all issues in all available file formats (i.e., Web, PDF, ASCII Text, and RTF). The advanced search, as the name implies, can be tailored to search particular issues by volume number or year. For both search types users enter keywords, which can include topic, article title, author, park, and so on. As an alternative, several Internet search engines do a good job of finding *Park Science* articles. In these instances, a search string may be more successful if it includes the words "Park Science" (in quotation marks) along with any keywords, to focus the search on this publication.

Another new function of this Web site is the "Subscribe" link, which allows readers to manage how they receive *Park Science*. As described in the preceding article, they can sign up to receive e-mail notification when a new issue is published online. Alternatively, readers can register for the print edition, update their delivery address, or cancel a subscription.

Prospective authors who wish to publish in *Park Science* will appreciate the link to "Guidance," which shares information about writing for this publication. This includes a description of article categories and their suggested lengths, criteria for developing illustrations, and a discussion of article review procedures. The projected publication schedule and article submission deadlines are also noted. Editorial style (e.g., rules of grammar and punctuation) preferred for this publication is summarized on the Web site and also explained in detail in the new publication "Editorial style guide for *Park Science* and *Natural Resource Year in Review*." The full-length guide is available as a PDF for downloading and may be helpful to authors in developing popular science articles (see following article).


Editorial Style Guide for Park Science and Natural Resource Year in Review

These are the first significant design changes in the *Park Science* Web site in about nine years. They should help make information about the application of research findings to natural resource management in the national parks easier to find and provide for a more productive and successful Web-browsing experience.

Editorial style guide available for natural resource authors

Published in PDF format, "Editorial Style Guide for *Park Science* and *Natural Resource Year in Review*" is available from the new *Park Science* Web site, at http://www2.nature.nps.gov/ParkScience/archive/PDF/Editorial_Style_Guide_12-5-2006.pdf. This comprehensive, 92-page guide addresses questions of grammar, word usage, spelling, punctuation, capitalization, numbers, documentation, and many other areas of style that plague writers and editors of natural resource-related manuscripts. Though this style guide is intended for authors who contribute to *Park Science* and *Natural Resource Year in Review*, it may prove useful to those who write for other National Park Service outlets of popular, natural resource science reports. It is published as Natural Resource Report NPS/NRPC/NRR-2006/004 (D-1794, December 2006).

Correction

All conversions of the number of deer per square kilometer to deer per square mile in the article by Bryan Gorsira, C. Reed Rossell Jr., and Steven Patch ("Effects of white-tailed deer on vegetation structure and woody seedling composition at Manassas National Battlefield Park, Virginia;" Park Science 24[1]:40–47) were incorrect. The factor for converting square kilometers to square miles (0.386) was applied incorrectly. We should have divided, rather than multiplied, the number of deer per square kilometer by the factor to obtain the number of deer per square mile. The correct conversions by article header and page number are as follows:

Background (page 41)
63.4 deer/km^2 (164.2 deer/mi^2)
15.4 deer/km^2 (39.9 deer/mi^2)

Discussion (page 44)
0–30 deer/km^2 (0–77.7 deer/mi^2)
90 deer/km^2 (233.1 deer/mi^2)

(page 45)
20–30 deer/km^2 (51.8–77.7 deer/mi^2)

(page 46)
30 deer/km^2 (77.7 deer/mi^2)
10–17 deer/km^2 (25.9–44.0 deer/mi^2)

Conclusions (page 46)
63.4 deer/km^2 (164.2 deer/mi^2)
15.4 deer/km^2 (39.9 deer/mi^2)

The conversion of 1 deer per 4 acres, given on page 41 as 63.4 ± 7.7 deer/km^2, is correct.

—*Editor*

Next issue: Fall 2007

Author deadline: 1 July 2007
We are accepting manuscripts for feature articles, Highlights, and other departments for publication in the fall 2007 issue of *Park Science*. We welcome submissions that highlight the findings of research and their application to resource management in national parks. Full article guidelines are available on the *Park Science* Web site (see "guidance"). Alternatively, please feel free to discuss an article idea with the editor.

—*Editor*

HIGHLIGHTS

Beetles overcoming purple loosestrife infestations at Delaware Water Gap National Recreation Area

The flowering spikes of purple loosestrife (*Lythrum salicaria*), an invasive alien weed that degrades wetland plant communities and wildlife habitat, turn wetlands into purple carpets. To suppress *Lythrum* populations and allow native species to return to Delaware Water Gap National Recreation Area (Pennsylvania and New Jersey), we took an integrated pest management approach utilizing biological control agents. We expected to wait 5–10 years to see biocontrol results from the methods we are using, and it looks like we are right on schedule.

We released three groups of biocontrol organisms in the park beginning in 1999 to be continued through at least 2007. *Galerucella calmariensis* and *G. pusilla* beetles feed on young shoots and foliage; *Hylobius transversovittatus* beetles are root-borers; and *Nanophyes marmoratus* beetles are flower-feeders. We selected release sites based on location, wetland size and type, purple loosestrife infestation level, and the presence of special concern species. Cornell University and the New Jersey and Pennsylvania Departments of Agriculture provided the beetles.

Galerucella releases were made throughout the park from 1999 to 2004, with 22 sites receiving initial releases in 1999 or 2000 and eight key sites receiving supplemental releases in 2002 or 2003. The root-boring *Hylobius* beetles have been released at 10 sites (2000–2004) and the flower-feeding *Nanophyes* at five sites (2003–2006) (table 1). Additional *Hylobius* and *Nanophyes* beetles will be purchased and released in 2007.

Table 1. *Lythrum* biocontrol beetle releases 1999–2006, Delaware Water Gap National Recreation Area

Year	*Galerucella*	*Hylobius*	*Nanophyes*
1999	11,000	N/A	N/A
2000	65,300	1,200	N/A
2002	13,250	300	N/A
2003	30,000	400	1,300
2004	200	100	950
2006	N/A	N/A	850
Total	119,750	2,000	3,100

Note: Figures are for total individuals released.

Monitors visit release sites annually for up to five years to determine success or failure in establishing viable beetle populations following protocols developed at the New Jersey Department of Agriculture Beneficial Insects Lab. *Galerucella* beetles have established at 11 of 14 key sites and dispersed along the Delaware River and from other release sites. (Upper Delaware Scenic and Recreational River, Pennsylvania and New York, also has a biocontrol program and staff has observed *Galerucella* spreading along the Delaware there.) *Nanophyes* have not been recovered and establishment in the park is not confirmed. *Hylobius* adults are nocturnal and larvae feed within plants. Because of the secretive nature of this beetle, we have not monitored these root-borers.

We chose 14 sites to monitor effectiveness of the biocontrol organisms in suppressing purple loosestrife. We visit these sites at least once every two years, any time from late June to mid-July, when purple loosestrife plants should be well grown, flower buds present in healthy plants, and feeding damage evident. Purple loosestrife abundance, based on visual estimates of percentage of cover, is ranked as low (<25%), medium (25–75%), or high (>75%). Feeding damage is ranked on a scale of one (little or no damage) to five (damage severe and extensive) (fig. 1). We consider a site to be rated "control achieved" (i.e., management objective met) when purple loosestrife abundance is low and biocontrol beetles are established at the site. In 2005–2006, purple loosestrife abundance was low, accompanied by moderate to severe *Galerucella* feeding damage, at 7 of 14 monitoring sites (table 2).

Figure 1. At high population densities, Galerucella beetles skeletonize Lythrum plants as they have these along the Delaware River shoreline in June 2004.

NPS

Results of plot-based sampling at one site (fig. 2) indicate that the downward trend in purple loosestrife abundance, and the upward trend in beetle feeding damage between 2001 and 2006, is statistically significant. Furthermore, in the summer of 2006, we observed that most of our marshes were not purple (fig. 3). We conclude that biocontrol agents have contributed to a significant decline in purple loosestrife abundance at this site. Overall, our results to date are consistent with those seen at other sites in Pennsylvania and New Jersey, where *Galerucella* have dispersed to new areas and control has been achieved at release sites in 5–10 years.

—***Jeffrey Shreiner***, *Biologist, Delaware Water Gap National Recreation Area; jeffrey_shreiner@nps.gov.*

Table 2. Changes in purple loosestrife *(Lythrum salicaria)* cover, 1999–2006, Delaware Water Gap National Recreation Area

	Lythrum Cover		
Site Name	**2005–2006[1]**	**2003–2004**	**1999–2000**
Bevans	**Low[2]**	Moderate	**Low**
Birchenough	**Low[2]**	High	High
Bushkill Access	High	Moderate	High
Camp Kittatinny	**Low[2]**	Moderate	High
Community Drive		**Low[2]**	Moderate
Conashaugh Corner	Moderate	Moderate	Moderate
Flat Brook Pompey	High	Moderate	High
Montague Rivershore	**Low[2]**	Moderate	Moderate
Old Dingmans	**Low[2]**	Moderate	Moderate
Old Dingmans Upper Pond	**Low[2]**	High	High
Shimers	Moderate	Moderate	Moderate
Smith Ferry Rivershore	Moderate	Moderate	Moderate
Sussex VoTech	**Low[2]**	Moderate	Moderate
Thunder Mountain		Moderate	Moderate

Note: Change is measured from pre-release conditions in 1999–2000 to 2006 conditions.
[1]Key to *Lythrum* cover: Low: <25%; Moderate: 25–75%; High: >75%.
[2]Management objective for *Lythrum* suppression has been met.

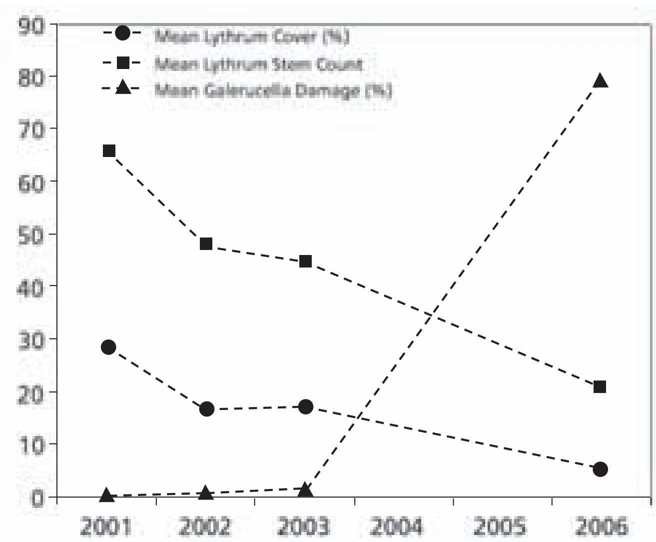

Figure 2. Trends in Lythrum abundance and Galerucella feeding damage, 2001–2006, Birchenough wetland, Delaware Water Gap National Recreation Area.

Figure 3. These photos illustrate purple loosestrife suppression before (top, August 2002, *Lythrum* spikes in foreground) and after (bottom, August 2006) the introduction of biocontrol agents at Camp Kittatinny wetland, Delaware Water Gap NRA. NPS (2)

Airborne mercury issues detailed on updated NPS Web site

Rising levels of mercury in the global atmosphere and increasing recognition of its effects on ecosystems has raised concerns for mercury impacts on National Park System lands. In aquatic ecosystems, mercury can be readily transformed into bio-available methylmercury, and accumulation of this contaminant in the environment can result in fish consumption advisories and increases of mercury toxicity in predatory animals such as common loons and alligators. Recent studies have also shown that mercury is accumulating in terrestrial ecosystems, with elevated levels of mercury documented in invertebrates, forest songbirds, and mammals across the United States (Schweiger et al. 2006; Evers 2005; Environmental Protection Agency 1997). Abnormally high levels of mercury ultimately lead to reduced reproductive success, impaired growth and development, behavioral abnormalities, reduced immune response, and decreased survival. In response to these concerns, the Air Resources Division of the National Park Service recently updated its airborne mercury Web site to include several new information products that are now available for use.

The Web site features an overview of mercury research in national parks, highlighting major projects and their findings. The wide range of mercury studies can assist park staffs in identifying information needs and management actions. For instance, one report for Acadia National Park (Maine) concludes that soils burned by forest fires contain higher methylmercury concentrations than if they had not burned (Amirbahman et al. 2004), a finding that may have implications for fire management. Another survey in Acadia found that mercury may be the cause of declines in the northern dusky salamander population (Bank et al. 2006). At Everglades National Park (Florida), mercury concentrations in frog leg tissue exceeded federal advisory limits (Ugarte et al. 2005), while wading birds contained liver mercury at concentrations associated with reproductive impairment in ducks and pheasants (Sundlof et al. 1994). Rumbold et al. (2002) noted that alligators in Everglades were more highly exposed to mercury in their environment than alligators elsewhere. Additionally, a research finding at Voyageurs National Park (Minnesota) suggests that stability in lake water levels affects methylating microbes (i.e., sulfate-reducing bacteria that add carbon, or the methyl group, to previously bio-unavailable forms of mercury), thus reservoirs can be managed to decrease the rate of this biological process (Sorenson et al. 2005).

Other products include a fact sheet titled "Airborne Mercury Issues," which gives a brief, topical overview that is useful in communicating mercury issues in parks, and links to other relevant Web sites. Among the links are Web sites that detail mercury thresholds for selected wildlife and national, regional, state, and park-specific information on mercury effects on health and the environment. Many national parks, for example, are located where fish consumption advisories are statewide (i.e., not focused solely on specific water bodies). These include national park units in the Great Lakes region and northeastern United States.

Control of local sources of mercury is an important strategy for its reduction in park ecosystems.

Human activities have greatly increased the amount of mercury cycling in the atmosphere, soils, lakes, and streams through processes such as burning coal for electricity and incinerating municipal, hazardous, and medical waste. Although mercury is a growing global problem, recently published research suggests that much mercury deposits near its source, thus control of local sources of mercury is an important strategy for its reduction in park ecosystems (Keeler et al. 2006). Control technologies are now available to reduce mercury emissions from industrial sources. The National Park Service monitors mercury in wet deposition at several park units across the country through the National Atmospheric Deposition Program / Mercury Deposition Network, which includes 95 sites. Through analysis of mercury effects and information sources such as the airborne mercury issues Web site, the National Park Service facilitates the use of parks for scientific inquiry, supports science-informed decision making, and communicates the relevance of and provides access to research knowledge.

The updated Web site is at http://www2.nature.nps.gov/air/Studies/ air_toxics/mercury.cfm.

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*—**Colleen Flanagan**, Biological Technician, Rocky Mountain National Park, for NPS Air Resources Division. For further information on mercury and national parks please contact **Ellen Porter**, Biologist, Air Resources Division; ellen_porter@nps.gov.*

Invasive plant species listed in comprehensive database

"WeedUS," a database of alien, invasive plant species affecting national parks and other natural area ecosystems of the United States, may be the most comprehensive information source of its kind. As of December 2006, this online resource had listed more than 1,000 aquatic and terrestrial species—with more being added as their native origin, natural range, taxonomic status, and other information are confirmed. It is available in Web format and as a spreadsheet that can be downloaded.

The database is part of the Weeds Gone Wild Web site (http://www.nps.gov/plants/alien/, click on "invasive plants list," then see "WeedUS Plant List") and a product of the Plant Conservation Alliance's Alien Plant Working Group. The National Park Service and nine other federal agencies collaborate formally in the group with the support of more than 200 nonfederal cooperators, including state and local resource management agencies, exotic pest plant councils, The Nature Conservancy, and universities.

In order to be listed in the database, a plant species must be documented in a "natural area," which generally excludes intensively managed lands such as croplands and forestry plantations. Additionally, the species must be confirmed as exotic, established, self-reproducing, spreading, and exhibiting such invasive behavior as causing harm to native species, habitats, natural features, or ecological processes.

Each record in the database lists the genus; species; author; synonyms (selected); common name; family; plant habit(s); native origin; U.S. nativity; states, national parks, and regions where invasive; federal noxious weed status; and source references for a species, as known. For consistency, taxonomy follows John Kartesz's Synthesis of North American Flora (1999).

Information for WeedUS is derived from a wide variety of sources: publications, reports, surveys, and observations and expert opinions of botanists, ecologists, invasive species specialists, and other natural resource management professionals. Information about species living on national park lands was obtained through an e-mail survey of about 60 national parks. The database was started in 1997 and has been available online as an abbreviated plant list since 1999. The entire database went online in June 2006. It is continuously peer reviewed and updated. In 2007, we plan to partner with the Lady Bird Johnson Wildflower Center to add several new features to the database and Web site.

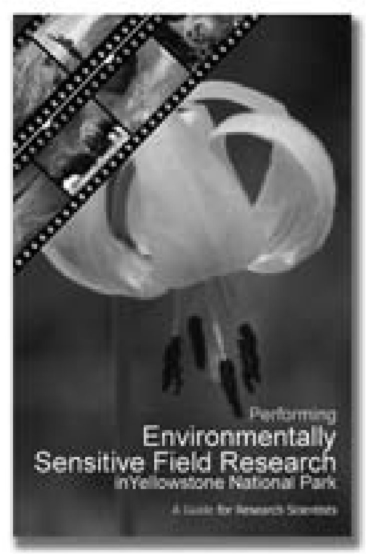
Applications of the information are far-reaching and include (1) corroboration of species as invasive, (2) mapping of state and regional invasive plant occurrences, (3) identification of areas with high invasive potential, (4) identification of possible gaps in distributional information, (5) prediction of potential spread, and (6) identification of plant families with high numbers of invasives.

In addition to the database, the Web site also features fact sheets on 60 of the invasive plant species, related articles and publications, a wall calendar (for downloading and printing), and more.

*—**Jil M. Swearingen**, Invasive Species Management Coordinator, National Capital Region, Center for Urban Ecology, Washington, D.C.*

Yellowstone brochure promotes low-impact field research practices

Research in national parks is a vital function, providing managers with the information they need to understand and protect important park resources and developing knowledge about our world for the benefit of society. In the national park setting research can inform managers specifically of trends in the health of ecosystems and identify gaps in knowledge that are critical for sound



park management. Park regulations and legislation, such as the 1998 National Parks Omnibus Management Act, remind us of the National Park Service's obligation to encourage, support, and use research: "The Secretary is directed to assure that management of units of the National Park System is enhanced by the availability and utilization of a broad program of the highest quality science and information."

This century, Yellowstone National Park (Wyoming, Montana, and Idaho) has seen an increase in the number of scientific studies concerning the flora, fauna, and microbial life unique to this preserved parkland. Issues such as declining species, climate change and global warming, loss of wildlife habitat, and the push for advancements in biotechnology have increased importance of conducting studies in pristine, natural environments such as national parks. In Yellowstone alone, more than 200 research groups supported by more than 350 field technicians are conducting scientific investigations. This high volume of research activity increases the potential risk of related impacts to these special park environments. As important as it is, the quest for scientific knowledge in national parks must be balanced with the need for park protection. The decision to permit research in national parks hinges on the benefits of what can be learned through the activity compared with any potential risk to park resources or values.

A related concern is the effect of research on park visitors. For example, the use of low-flying aircraft, placement of radio collars on wildlife, deployment of field equipment, and repetitive visits to field research sites have the potential to detract from the experience of a visit to a national park. In Yellowstone we are working to reduce the frequency of such activities and are also encouraging researchers to anticipate and minimize their impacts. We have found that modeling our research philosophy after that of the Leave No Trace recreation education program—very popular for teaching minimal-impact outdoor recreation practices—is helping to change the way scientists view, and subsequently plan, their field activities.

In late 2005, Yellowstone teamed up with the Thermal Biology Institute (Montana State University) to produce a brochure titled "Performing Environmentally Sensitive Field Research in Yellowstone National Park" (see photo of brochure cover). The tenets of this brief, color publication reflect the seven basic principles of the Leave No Trace program and outline best field practices to help researchers leave their study sites appearing untouched. Many of the published recommendations were made by park researchers themselves. The brochure reminds researchers to collect only what their permit authorizes and to reduce the size of samples taken from any one area. That is, sampling should be spread out in study sites where the removal of large specimens might be evident (such as microbial mats in thermal areas or geologic specimens at prominent rock outcroppings). It also reminds them to police their study areas, taking care to not leave markers, plastic sample collection bags, or other research-related materials upon departure. Guidelines for researcher safety, particularly around thermal areas and wildlife, are another important part of the brochure and are spelled out concretely. Researchers are reminded to make safety their top priority at all times.

We hope this brochure will guide scientists in the development of field research methods that take into account not only scientifically sound techniques but also environmentally friendly research practices that help preserve Yellowstone's resource treasures and their related values. The brochure can be downloaded from the Internet at http://www.nps.gov/archive/yell/technical/researchpermits/pdfs/LNTBrochure72dpi.pdf.

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Bats inventoried across the Northeast Region

Bats circling in the sky and swooping low over water are a familiar sight at many national parks in the Northeast. Until recently, however, natural resource managers did not always know what species were present at their parks or the habitat needs of these flying mammals. With the inception of the Inventory and Monitoring (I&M) Program and funding provided through the Natural Resource Challenge, bats have now been surveyed at 14 national parks, including a section of the Appalachian National Scenic Trail in Maine, in the four I&M networks of the Northeast Region (see table 1). Many dedicated individuals, universities, and agencies have been involved with the cooperative projects, some of which remain ongoing.

Among the species of special concern recorded in these surveys were the federally endangered Indiana myotis (*Myotis sodalis*) and the Virginia big-eared bat (*Corynorhinus townsendii virginianus*) (fig. 1, page 12), and other species considered rare, such as the eastern small-footed myotis (*Myotis leibii*) and Rafinesque's big-eared bat (*Corynorhinus rafinesquii*). Each of these species was confirmed at New River Gorge National River (table 1).

Investigators have developed special netting and sonar devices to detect bats, which "hang out" in places that are hard for humans to see, and are typically active at night. Mist nets, also used in bird studies, are fine nylon nets placed in front of an opening to a cave, over water, or other areas frequented by bats. As the bats fly through the area or return to their roosts at night, for example, they

Table 1. Bat species documented at northeastern national park units in 2006 surveys

Species	National Park System Unit*													
	BLUE	GARI	NERI	ALPO	FONE	FRHI	JOFL	DEWA	VAFO	HOFU	GETT	EISE	ASIS	APPA
Little brown myotis (*Myotis lucifugus*)	A, N	A, N	A, N	A, N	A, N	A, N	A, N	A, N	N	N	N	N		A, N
Eastern pipistrelle (*Pipistrellus subflavus*)	A, N	A, N	A, N	A, N	A, N	A, N	A		A, N		N	N		A
Big brown bat (*Eptesicus fuscus*)	A, N	A, N	A, N	A, N	A, N	A, N	A, N	A	N	N	N	N	A, N	A, N
Eastern red bat (*Lasiurus borealis*)	A	A, N	A, N	A, N	A, N	A, N	A	A	N	N	N	N	A, N	A, N
Northern myotis (*Myotis septentrionalis*)	A	A, N	A, N	A, N	A, N	A, N	A, N	A, N	N	N	N			A, N
Eastern small-footed myotis (*Myotis leibii*)	A	A, N		A, N										N
Silver-haired bat (*Lasionycteris noctivagans*)	A		A		A, N						A, N		A, N	
Hoary bat (*Lasiurus cinereus*)	A	A	A, N	A	A	A	A	A			N		A	A, N
Rafinesque's big-eared bat (*Corynorhinus rafinesquii*)		N												
Virginia big-eared bat (*Corynorhinus townsendii virginianus*)				N										
Indiana myotis (*Myotis sodalis*)	A		A		A, N									

Note: A = acoustically detected; N = Net capture.
*BLUE = Bluestone National Scenic River (W.Va.); GARI = Gauley River National Recreation Area (W.Va.); NERI = New River Gorge National River (W.Va.); ALPO = Allegheny Portage Railroad National Historic Site (Pa.); FONE = Fort Necessity National Battlefield (Pa.); FRHI = Friendship Hill National Historic Site (Pa.); JOFL = Johnstown Flood National Memorial (Pa.); DEWA = Delaware Water Gap National Recreation Area (Pa. & N.J.); VAFO = Valley Forge National Historical Park (Pa.); HOFU = Hopewell Furnace National Historic Site (Pa.); GETT = Gettysburg National Military Park (Pa.); EISE = Eisenhower National Historic Site (Pa.); ASIS = Assateague Island National Seashore (Md.); APPA = Appalachian National Scenic Trail (Me.).

Figure 1. Virginia big-eared bat, New River Gorge National River, West Virginia.
JOSH JOHNSON, UNIVERSITY OF MARYLAND CENTER FOR ENVIRONMENTAL SCIENCE APPALACHIAN LAB

become entangled in the almost invisible nets, where researchers disentangle them to identify species, and in some surveys record age, sex, body condition; take blood samples; and tag them before releasing them unharmed. Harp nets consist of two frames, each threaded vertically with an array of monofilament lines, and are typically placed over the opening to a cave, mine, or building containing bats. The bats become trapped between the two frames when exiting or entering the structure, where they flutter until they are removed by the researchers.

More interesting is the sonar equipment used to record the echolocation calls of the bats as they forage or swarm near the entrance to their roosts. A bat-detector microphone permits the recording of sounds beyond the reach of the human ear. It captures the sound of the bat activity, which can then be analyzed using computer software. The sonar data are matched with samples in a library of bats calls, and the recorded bat species can be identified. In this way, the presence of species that were not physically captured, but were present, can be ascertained by unique aspects of each species' call.

Several of the parks surveyed provide especially desirable sites for bat colonies. For example, New River Gorge National River has extensive cliff lines, abandoned mines, river and stream corridors, and mature forest, all important for a variety of bats. Allegheny Portage Railroad National Historic Site also has a variety of bat-friendly habitats and structures, and at Delaware Water Gap National Recreation Area, Cold Air Cave remains cold, but not freezing in the winter, providing good hibernation habitat. To protect the bats, researchers recommend placing gates across the portals of such sites to exclude people while allowing the bats to fly in and out unhindered. Knowing which species are resident at, or migrating through, their parks, the natural resource staffs are better able to manage habitat and provide protection appropriate to those bat species.

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Information Crossfile

Public values, climate disruption, and western national parks

"A climate disrupted by human activities poses such sweeping threats to the scenery, natural and cultural resources, and wildlife of the West's national parks that it dwarfs all previous risks to these American treasures," so states the July 2006 report, "Losing Ground: Western National Parks Endangered by Climate Disruption" (Saunders et al. 2006). The authors contend that "a disrupted climate is the single greatest threat to ever face western national parks." Focusing on the effects of climate change in western national parks, this well-documented, peer-reviewed report highlights specific parks with values that will be lost, for instance, the glaciers in Glacier National Park, the tundra in Rocky Mountain National Park, the Joshua trees in Joshua Tree National Park, and the beaches in Golden Gate National Recreation Area (see photos). The report identifies the top 12 western national parks at most risk. In alphabetical order these parks are Bandelier National Monument (New Mexico); Death Valley (California) and Glacier (Montana) national parks; Glen Canyon (Arizona and Utah) and Golden Gate (California) national recreation areas; and Grand Teton (Wyoming), Mesa Verde (Colorado), Mount Rainier (Washington), North Cascades (Washington), Rocky Mountain (Colorado), Yellowstone (Wyoming, Montana, and Idaho), and Yosemite (California) national parks.

The U.S. Geological Survey has judged the beaches and other coastal areas of Golden Gate National Recreation Area (and those at Channel Islands and Olympic national parks, and Point Reyes National Seashore) to be highly vulnerable to sea-level rise resulting from climate change (Saunders 2006). Contributing factors are coastal slope, wave heights, and range of local tides. The vulnerable beaches include heavily visited Baker Beach (left and middle) and Ocean Beach (right). NPS (3)

Though scientists have provided credible warnings about global warming for nearly 30 years, and recent literature confirms a scientific consensus that most of the warming in recent decades can be attributed to human activities (e.g., Houghton et al. [IPCC] 2001, The Presidents of National Science Academies 2005), scientific evidence has not been able to overcome social, economic, or political resistance. Speth (2005) identifies a number of reasons why the current situation in the United States reflects little commitment to climate protection. First, being technical and long term, climate change is difficult to communicate. Second, when results regarding climate disruption are communicated, they only reach a small audience. Journals like *Science* and *Nature* consistently provide newsworthy results regarding climate change. However, as Speth (2005) points out, these results, though often startling in their significance, "rarely if ever, reach beyond a very limited audience." Moreover, the U.S. media, when it does cover a story about climate change, is "afflicted with 'balanceitis,' striving to provide equal coverage to 'the other side of the story' when it deserves little or none at all" (Speth 2005). A comparison with the media internationally shows that "U.S. reports on climate treat the issue as more uncertain, controversial, and theoretical than coverage in other countries" (Speth 2005). Additionally, scientists have been noticeably reluctant to speak out on the subject. Director's award winner for natural resource research, Dan Fagre, a research ecologist for the U.S. Geological Survey at Glacier National Park, is a notable exception (see pages 122–123 in *Natural Resources Year in Review—2005*). Third, economic interests offer stiff resistance to climate protection. According to Speth (2005), the energy industry has skillfully orchestrated advertising campaigns on topics such as opposing the Kyoto Protocol and promoting coal. Finally, the environmental community faces charges of mishandling the climate issue. For instance, the authors of the essay "The Death of Environmentalism" note that environmental leaders are not "articulating a vision of the future commensurate with the magnitude of the crisis" (Shellenberger and Nordhaus 2004). Focusing on technical fixes like hybrid cars and fluorescent light bulbs fails to appeal to the public's values and aspirations.

Now, however, with "Losing Ground," the Rocky Mountain Climate Organization and the Natural Resources Defense Council may appeal to the public's values of natural and cultural resources, wildlife, and enjoyment of national parks. These values are at risk from the loss of glaciers and snowfields, beaches, historical and archaeological sites, and recreational opportunities such as boating, fishing, and winter activities. Additionally, changes in vegetation; wildlife extinction; park closures due to fire; intolerable heat; and overcrowding at cooler, higher elevations will tax such values.

In 2003, with the support of the U.S. Environmental Protection Agency, the National Park Service began an effort to help itself become more "climate friendly." The Climate Friendly Parks pilot program was started in response to the president's February 2002 call for voluntary action on climate change. The Climate Friendly Parks program has held four workshops: in June 2003 for Gateway National Recreation Area (New York), in December 2003 for Glacier National Park (Montana), in May 2004 for Zion National Park (Utah), and in June 2005 for Everglades National Park (Florida). However, Saunders et al. (2005) seems to be prodding the National Park Service to take further steps and realize its potential to help significantly reduce the build-up of greenhouse gases. As Michael Soukup, associate director for Natural Resource Stewardship and Science, stated on 17 July 2006 in *The Billings Gazette*, the National Park Service is "a very small agency with a potentially high impact."

The timing for action seems to be now for at least two reasons. First, according to the presidents of national science academies from the G8 countries, Brazil, China, and India, "action taken now . . . will lessen the magnitude and rate of climate change." Also, "failure to implement significant reductions in net greenhouse emissions now will make the job much harder in the future" (The Presidents of National Science Academies 2005). Second, studies show that people today will be altruistic about protecting the climate. Milinski et al. (2006) reveals that people reward others' contributions to sustaining the climate (with contributions of their own to a "climate fund") when the subjects were allowed to make their contributions in public, as compared to anonymous investments. In addition, Milinski et al. (2006) found that "expert information about the state of the global climate enhanced human altruistic motivation." These results point to a gap in public policy, upon which climate policy makers, and potentially the National Park Service, may be able to capitalize, that is, "designing strategies to improve the social reputation of people investing in climate protection" (Milinski et al. 2006) and providing the public with sound scientific information and legitimate scientific analysis.

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—Katie KellerLynn

CIRMOUNT: Helping resource managers plan for the effects of climate change

In July 2006 the Consortium for Integrated Climate Research in Western Mountains (CIRMOUNT) released the report, "Mapping New Terrain: Climate Change and America's West" (CIRMOUNT Committee 2006). Officially established in 2004 during its Mountain Climate Sciences Symposium at Lake Tahoe, California, CIRMOUNT is a collaboration of ecologists and physical scientists who are researching mountain climate and ecosystems in western North America. Constance Millar, cochair of CIRMOUNT, describes the organization as "a grass-roots consortium, without central funding," whose advancement is a result of the "collective projects and progress of consortium scientists working in their own units." A core group of 15 scientists drives CIRMOUNT's activities and encourages projects that will help the consortium meet its goals, which are aligned with those of the U.S. Federal Climate Change Program (see http://www.climatescience.gov). As such, CIRMOUNT has dedicated itself to developing a forum for responding to society as it grapples with the effects of climate change in mountain ecosystems. In addition, the Mountain Research Initiative—an international, multidisciplinary scientific organization that addresses global change issues in mountainous regions around the world—has endorsed CIRMOUNT as a regional pilot project (see http://mri.scnatweb.ch).

CIRMOUNT has dedicated itself to developing a forum for responding to society as it grapples with the effects of climate change in mountain ecosystems.

Though society's recognition of climate change has been slow, and "grappling" has only just begun, CIRMOUNT is plowing ahead as it seeks to identify critical climate change issues facing western North America. Through its six work groups, collaboration among other scientific programs and organizations, and a biennial science conference (MTNCLIM), CIRMOUNT is developing priorities for action to address climate-driven issues such as water supply, forest dieback, wildfire, the urban-wildland interface, biodiversity, and wildlife. The six task-oriented work groups are (1) Mountain Climate Network (MONET), which coordinates a network of monitoring stations; (2) Mountain-Based Hydrologic Observations (HO), which provides consistency in monitoring water resources and interactions between hydrology and climate; (3) Mountain Ecosystem Response to Climate, which encourages scientific knowledge of the effects of climate change on ecosystems, in particular incorporating this information into planning and conservation; (4) International Relations, which promotes CIRMOUNT activities worldwide; (5) North American GLORIA (global observation research initiative in alpine environments), which monitors alpine plant response to climate change using international protocols; and (6) Paleoclimatic Archives for Resource Management, which provides access and applications of paleoclimatic and paleoecologic data for a range of users, including resource managers.

As "Mapping New Terrain: Climate Change and America's West," points out, "Climate change has been widely overlooked in mountain land-use planning and natural-resource policy." In an effort to remedy this situation, each CIRMOUNT work group has projects with applications in resource management; moreover, consortium participants encourage natural resource managers, resource program managers, and resource policy makers to join the dialog about the application of science in resource management. For example, Stephenson et al. (2006) highlights the Western Mountain Initiative in which CIRMOUNT plays a key role in predicting responses of western mountain ecosystems to climatic variability and change. In addition, various climate centers compile and provide data for National Park Service use. The Western Regional Climate Center compiles all the information available on climate monitoring for the national parks. These stations may be accessed in real-time at http://www. wrcc.dri.edu/. Moreover, the California Climate Change Center is installing long-term monitoring stations, several of which are in national parks (e.g., Yosemite National Park and Devils Postpile National Monument).

The cochairs of the consortium encourage all those interested in mountain climate research, including park managers, to participate. According to Millar, "We have a listserv; [park managers] can join work groups, come to conferences, [and] become involved in any of the management-related projects." For more information contact Constance Millar (USDA Forest Service, Pacific Southwest Research Station) at 510-559-6435 or cmillar@fs.fed.us.

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— *Katie KellerLynn*

A combination of Sherman and Longworth traps diminishes overall error and bias in small-mammal inventories

Sherman (H. B. Sherman, Inc., Tallahassee, Florida) and Longworth (Penlon Ltd., Oxford, U.K.) live traps are widely used in small-mammal inventories. Nevertheless, as Anthony et al. (2005) points out, "few studies have directly compared the effectiveness of these two popular models." Both Sherman and Longworth traps are lightweight and resemble aluminum boxes. Some styles of Sherman traps fold, while the Longworth trap has an entrance tunnel that pushes in for storage. Some users find this feature preferable because "the separate tunnel and nest box permit the addition of food and cotton without being concerned about jamming the trigger, as with Sherman traps" (*Shrew Talk* 1(9), 19 July 1997, http://members.vienna.at/shrew/shrewtalk=1-09.html, accessed 11 January 2007). Each brand has a lever that trips as the animal enters the chamber, closing the trap door. The 2005 study by Anthony and others also deployed pitfall traps, which are generally believed to be more effective in catching small shrews than live traps, though Anthony et al. (2005) did not find this to be a valid assumption, particularly in the absence of drift fences. This fencing intercepts the movements of animals and guides them into traps, generally increasing capture rates (Corn 1994). For this study, investigators dug pitfall traps, consisting of two #10 cans (36 cm x 15 cm [14" x 5.9"]) duct-taped together. At each of 25 stations, investigators laid out a combination of pitfall traps and three other styles of traps at each of 25 stations: Longworth traps (13.8 cm x 6.4 cm x 8.4 cm [5.4" x 2.5" x 3.3"]), small non-folding Sherman traps (17.0 cm x 5.4 cm x 6.5 cm [6.7" x 2.1" x 2.6"]), and large folding Sherman traps (23.0 cm x 7.7 cm x 9.1 cm [9.1" x 3.0" x 3.6"]). Small Sherman traps caught the most animals during this study; hence, the results indicate that trap-size dimensions did not present an obstacle to the species trapped during this study. Anthony et al. (2005) also discusses considerations such as "species-specific differences in capture rates," that is, particular traps preferentially captured certain species (e.g., Longworth traps were the most effective in capturing long-tailed shrews).

Researchers conducted this two-year (1996–1997) study in 12 grassland preserves in southern Wisconsin. Traps were pre-baited with 25-gram (0.88 oz) bags of peanut butter and left open for two days preceding the survey; trapping occurred over four consecutive nights. Investigators checked the traps once each evening and once each morning. However, when temperatures exceeded 27°C (81°F), they shut the traps (presumably to avoid animal mortality). Hence, for consistency, researchers analyzed only nocturnal data, which included the capture of nine different species, six of which were quantitatively sufficient for statistical analysis. These six species were long-tailed shrew *(Sorex* spp*.)*, short-tailed shrew *(Blarina brevicauda)*, western harvest mouse *(Reithrodonomys megalotis)*, white-footed and prairie deer mice *(Peromyscus* spp*.)*, meadow vole *(Microtus pennsylvanicus)*, and meadow jumping mouse *(Zapus hudsonius)*. Researchers made no distinction between white-footed mice *(Peromyscus leucopus)* and prairie deer mice *(Peromyscus maniculatus)* and combined masked shrew *(Sorex cinereus)* and pygmy shrew *(Sorex hoyi)* as long-tailed shrew because discrimination in the field of these species is difficult to impossible.

Long-tailed shrews made up the bulk of all captures, and the majority of trap deaths. For all species, trap mortality was lowest in large Sherman traps: 0% in the first year of the study, and 9.1% in the second year. In the second year of the study, researchers introduced new Sherman traps and capture rates increased with these traps. The difference in capture success may be a result of age and wear of the Sherman traps used. Hence, trap age is likely an important consideration in small-mammal inventories and may "lead to

Trap age is likely an important consideration in small-mammal inventories and may "lead to potentially biased estimates of species capture rates."

potentially biased estimates of species capture rates." Though the researchers tested each trap for functional reliability, the Sherman traps used in the first year had already been used for several seasons. The Longworth traps used were approximately 30 years old, so any differences in capture success in these traps between study years were negligible.

In addition to the significance of trap age, Anthony et al. (2005) concludes that Longworth and Sherman traps used in combination can diminish overall sampling error and yield less biased estimates of species composition than either trap type alone. This conclusion is similar to the findings of past comparisons (e.g., Kalko and Handley 1993; McComb et al. 1991) of live traps, snap traps, and pitfall traps, which suggest that "a combination of different traps is the best means for assessing overall composition and structure of small-mammal communities."

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—*Katie KellerLynn*

Reducing diving impacts on coral reefs

The National Park System is home to many of North America's coral reefs, which are environmentally sensitive, ecologically diverse, and extremely popular. In Florida, reef destinations include Biscayne and Dry Tortugas national parks. The Virgin Islands host several units with coral reefs: Buck Island Reef National Monument, Virgin Islands National Park, Virgin Islands Coral Reef National Monument, and Salt River Bay National Historical Park and Ecological Preserve. War-In-The-Pacific National Historical Park is in Guam, and National Park of American Samoa is in American Samoa. Parks in Hawaii with coral reefs are Kalaupapa and Kaloko-Honokohau national historical parks.

Web sites tout snorkeling as "the best way to become familiar with the park's underwater world and all its resources" (e.g., http://www.nps.gov/viis/snorkeling.htm), and all National Park System units with coral reefs allow either scuba diving or snorkeling, or both. Many parks provide concessions for such activities.

As the ocean's equivalent of rainforests, coral reefs are home to 25% of all marine species, so their popularity is no surprise. However, according to the USGS Coastal and Marine Geology Program, many of these fascinating undersea worlds will be destroyed or significantly damaged in the next 20 years (http://coralreefs.wr.usgs.gov/). Reefs are in decline globally because of human-caused stresses, in particular pollution from sediment, chemicals, and sewage. Barker and Roberts (2004) documents another stressor, once thought to be benign—scuba divers. As the authors point out, "Minor damage and resuspension of sediment by most divers may seem trivial, but by compounding other reef stresses, they could undermine the resilience of reef ecosystems." In addition, studies have shown that pathogens or other invading organisms are more likely to infect damaged corals, which have a higher risk of mortality than undamaged colonies (Hall 2001). Though damage varies depending on the types of corals present, signs of damage from scuba divers include broken coral fragments, and dead, reattached, and abraded corals.

In an attempt to quantify damage and seek ways to reduce it, Barker and Roberts (2004) documents observations of 353 divers over 26 weeks during two periods—high and low tourist season. As incognito divers, investigators recorded information about 12 independent variables; multiple regression analysis using these variables confirmed that dive type, photography, and intervention status contributed most strongly to explaining contact rate (Barker and Roberts 2004). Dive leaders were aware of the study but were asked to not publicize the information. If a visitor inquired about an observer's note taking during a dive, they were told that researchers were collecting data about fish and corals for the Soufrière Marine Management Area, Saint Lucia, in the Caribbean, where the study took place.

Before the dive, investigators randomly selected divers to be observed; targeted divers included photographers and non-photographers, men and women, first-day divers and second-day (or more) divers, and both cruise-ship and hotel visitors. During the dive, investigators recorded each contact and the number of minutes into the dive at which the contact occurred, what part of the diver was involved in the contact, whether the contact was intentional or not, what part of the reef was affected, and the consequence of the contact (i.e., minor damage [touch or scrape], major damage [breakage], and suspension of sediment).

Results showed that the majority of divers (73.9%) did make contact with the reef, with the greatest number of contacts occurring during the first 10 minutes of the dive. Most of the contacts were unintentional (81.2%) and caused minor damage (79.8%), though a small proportion (4.1%) caused major damage. Nearly half of the contacts (49.0%) resulted in suspension of sediment. By far the most common type of contact was fin kicks (81.4%), followed by touching and holding with hands (10.1%). Night dives had more than double the contact rate compared to day dives, which is a conservative estimate because reduced visibility limited the ability of the researchers to make observations. Moreover, more contacts were made during dives that originated from shore (97.9%) than dives where entry was from boats (65.0%). Investigators surmised that this was largely because divers swam across a sandy, shallow area at the beginning and end of the shore dives. The authors suggest that to avoid this particular contact, managers could place buoys to mark where divers should begin descending and ascending.

By far the most common type of contact was fin kicks....

Another significant outcome of the study was the realization that photographers contacted the reef much more frequently that non-camera users, with "specialist" and "non-specialist" photographers (determined by the type of equipment used) being equally damaging. On average during a 10-minute period, photographers caused 3.8 contacts and 0.4 breaks as compared to divers without cameras causing 1.1 contacts and 0.04 breaks. Contact by camera users typically occurred as photographers steadied themselves by holding onto and kneeling on the reef to take pictures.

As observed during this study, the primary means for reducing damage was intervention by dive leaders at the time of contact. This reduced average rates from 11.6 to 2.4 contacts per 40-minute dive. As part of the study, dive leaders included a statement in pre-dive briefings about not contacting the reef; this had no effect on contact rate. Other studies have shown that intensive briefings—45-minute sessions that cover reef biology, damage caused by divers, the difference between reef cover and non-living substrate to illustrate areas that could be touched safely, and the concept of protected areas—followed by in-water demonstrations decreased damage during dives (Medio et al. 1997); nevertheless, this type of education program is rare. Barker and Roberts (2004) found that pre-dive briefings typically last only a few minutes and often do not include how to avoid damaging reefs. Hence, the study concludes that ensuring that dive leaders intervene underwater, as well as lead by example in keeping fins and equipment clear of the reef will reduce diver damage. Additionally, extra vigilance at the beginning of dives, on night dives, and toward camera users will result in substantial reductions in damage to coral reefs.

The primary means for reducing damage was intervention by dive leaders at the time of contact.

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—Katie KellerLynn

Regenerating the historic forest at Gettysburg National Military Park

One of the mission goals of Gettysburg National Military Park (Pennsylvania) is to protect, rehabilitate, and maintain in good condition the landscapes, buildings, monuments, structures, archaeological sites, artifacts, and archives that are significant to the outcome and commemoration of the Battle of Gettysburg. In the 1980s, park staff observed that an important component of the landscape—the woodlots—did not represent the 1863 historical condition of the forest at Gettysburg, detracting from the authenticity of the interpretation of the historic battle.

Small-diameter trees, especially oaks and hickories, were so few that the regeneration of these species in the woodlots was in doubt. Three factors were considered to be responsible for the low tree seedling and sapling densities: (1) white-tailed deer were intensively browsing desirable native seedlings, threatening forest sustainability and species composition; (2) nonnative plants were invading the woodlots and outcompeting native plant species; and (3) the overstory canopy had grown closed, limiting the development of understory trees. (Historically the woodlots were heavily exploited to supply firewood and lumber, leaving openings in the canopy where sunlight penetrated.)

Park managers believed that mitigating these factors would achieve the goal of restoring the woodlots. In order to match the vegetation density of the 1863 woodlots, the park targeted a 60% stocking level, meaning that only 60% of the overstory canopy would be closed.

In 1986, scientists from Pennsylvania State University and Elizabethtown College initiated long-term inventories of woodlot vegetation (see Niewinski et al. 2006). Two additional objectives were to determine quantitatively the browsing impact of deer, and to measure understory response to openings in the canopy.

In 1995, the deer population at the park had reached 325 deer per forested square mile (125 per km^2). Staff then initiated the White-tailed Deer Management Program to reduce the population to 25 deer per forested square mile (10 per km^2), a size calculated to allow the forest to regenerate and achieve the stocking goal. When the study concluded in 2002, deer density had been reduced to 49 deer per forested square mile (19 per km^2).

Initially, investigators set up study plots in pairs, fenced and unfenced. In 1990, they added several more unfenced plots to compare vegetation status at that time with changes that might occur after the deer management program was instituted. Finally, in 1992, they established canopy treatment plots to evaluate the understory response to openings in the overstory. In the control plots, the closed canopy was not altered; in the second treatment, 60% of the canopy was left standing; and in the third treatment, all overstory trees were removed.

From 1986 to 2002, investigators repeatedly inventoried seedlings and saplings of tree and shrub species for density and diversity, and inventoried herbaceous plants for diversity and coverage. They also recorded the presence and abundance of nonnative species.

Investigators compared data from 2002 to that from previous inventories, 1996 in particular, to evaluate the effects of reduced foraging by white-tailed deer and various light levels on the development of understory vegetation. Results were not consistent among the study plots, but overall, the data enabled the researchers to discern clear trends that suggest that deer reduction is allowing the forest to regenerate and the park's woodlot stocking goals to be achieved.

In the canopy treatment plots, seedling tree densities increased from 1996 to 2002, exceeding the stocking-level goals. The closed and partially open canopy treatments showed the greatest seedling tree densities in 2002. Sapling tree densities also improved in those plots between 1996 and 2002, but were still substantially below the stocking-level goal. The reason for the lower sapling tree densities may be a combination of continued browsing by deer (still more numerous than the park's goal), intense competition among shrub species, and light restrictions. In the completely open canopy, nonnative shrubs increased because of their unpalatability to deer and rapid growth.

The research suggested that, as of the last inventory in 2002, there was good potential for a healthy diversity and density of native species that will recreate the historic 1863 woodlots. The researchers recommended that park managers (1) continue to implement the deer management program and adjust the goal as future monitoring indicates; (2) continue to control invasive, nonnative plant species; (3) create openings in the canopy to allow tree seedlings to thrive and mature; (4) develop a plan to provide additional small openings in the canopy where vigorous seedlings are plentiful, giving them a competitive advantage over shrubs and herbaceous vegetation; and (5) monitor periodically for changes in plant density and diversity.

Since the research was completed, park managers have succeeded in reducing the herd to 24 deer per forested square mile (10 per km^2), and they continue to actively maintain that number. In about half of the acreage, they are also gradually bringing the canopy to the 60% stocking level; rapid canopy reduction can cause trees to blow down. Currently they have reduced the canopy to 80% stocking level and plan to wait another 10 years before reducing it to the 60% stocking-level goal.

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—Betsie Blumberg

Values and Challenges in Urban Ecology

Fourteen "vestiges of greater natural landscapes" punctuate the metropolitan area of Washington, D.C. These so-called remnant parks in the National Capital Region protect significant natural resources, which are threatened daily by the aftermath of human development. The booklet, *Values and Challenges in Urban Ecology*, epitomizes these parks: small in scale, lovely to behold, and brimming with information forewarning the effects of urban growth. Under the guidance of the Urban Ecology Research Learning Alliance—the research leaning center for the National Capital Region—students from the Department of Art at Shepherd University, West Virginia, designed this graphically pleasing publication (see photo). Researchers and resource managers from parks, universities, environmental companies, and the U.S. Geological Survey contributed material, which staff at the Center for Urban Ecology edited. The seven science stories highlighted in this booklet range from the endangered habitat of tiny, subterranean, shrimp-like amphipods to the all-too-pervasive impervious surfaces that accompany urbanization. The topics of four of these stories have been reported in past issues of *Natural Resource Year in Review*: Wells and Ingram (2004), Gorsira (2005), Noojibail (2005), and

Orr (2006). However, all of the studies reported in this booklet are fresh and engaging, and many propose future research based on the presented findings.

This publication inspires thoughts of scientific and outreach possibilities. Consider some examples. First, not only is obtaining genetic information crucial for management of brook trout in Catoctin Mountain Park, Maryland (e.g., expanding the range of existing populations or restoring brook trout after an environmental disaster), studying DNA variation has revealed a series of phylogeographic breaks that correspond to major drainages and may indicate local (or regional) adaptive significance and diverging evolutionary pathways. A present-day example of evolution at work in the National Capital Region, these trout are like Darwin's finches. Second, historical data used to restore the wetland area of Stuart's Hill in Manassas National Battlefield Park, Virginia, hearken back to Civil War history. The same maps that helped restore wetlands in 2004 helped clear Major General Fitz John Porter's name during his retrial in 1878. Researchers also used aerial photos from the 1930s and a developer's survey from 1988 during restoration. Third, an investigator used data compiled in 2004 from satellite images, which show impervious surfaces, as a proxy for estimating the health of watersheds in parts of Maryland, Virginia, West Virginia, and the District of Columbia. The hypothesis is the greater the percentage of impervious surface area, the poorer the watershed condition. Data from water-quality monitoring in 2006 will quantify this relationship. Fourth, the story about odonates described in the booklet makes readers remember the meaning of "odonate"—dragonflies and damselflies. A single researcher meticulously conducted an intensive inventory of odonates throughout the Potomac River corridor. Though Richard Orr (Versar, Inc., Columbia, Maryland) had the assistance of 23 volunteers, the identification of 101 species—45 of which have conservation importance due to rarity—and the discovery of the Potomac snaketail (a new species of *Ophiogomphus*) is impressive, to say the least.

As reported in this publication, "Understanding the complex working of urban ecosystems relies on multidisciplinary approaches." The Center for Urban Ecology, for which this booklet was produced, houses a team of scientists that addresses park and regional needs through programs including air resources, ecology, exotic plants, geology and soils, horticultural landscapes, inventory and monitoring, pest management, rare species, vegetation, water resources, and wildlife. The Chesapeake Watershed Cooperative Ecosystem Studies Unit, also part of the center, facilitates collaboration among the center's team, outside researchers, and other governmental entities. As part of this team, the Urban Ecology Research Learning Alliance supports these research efforts and communicates their results; *Values and Challenges in Urban Ecology* is a notable example.

Copies of *Values and Challenges in Urban Ecology* may be obtained through Giselle Mora-Bourgeois, the science education coordinator at the Center for Urban Ecology. She can be reached at 202-342-1443 ext. 220 or giselle_mora-bourgeois@nps.gov.

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—Katie KellerLynn

IMPACTS OF PATH SURFACES ON SURROUNDING VEGETATION

Walking down the Longs Peak Trail in Rocky Mountain National Park (Colorado) near the appropriately named Granite Pass, I looked at the path and thought, "This is not granite. Could it be volcanic tuff or are these flat pieces of cement?" Having scrambled over 1.4-billion-year-old Silver Plume Granite for most of the day, the path's surface seemed peculiar. However, short of a Feng Shui discomfort in the 10th mile of the day with another five miles ahead, I dismissed the thought—until now. Reading Godefroid and Koedam (2004) made me recall this experience. I suspect I am neither alone in my thought nor is Rocky Mountain National Park the only park to have exotic surfaces. For instance, this study in central Belgium investigates an acidic beech forest that hosts a dense network of roads and paths with varying surface materials. Constructing paths with foreign materials is common on a global scale, and the lessons learned from this study could be applied broadly.

The investigators set up 50 sampling sites—10-meter-(33') belt transects divided into 10 rectangular quadrants (10 m x 1 m [33' x 39"]). All the sites had the same soil type, topography, overstory species, and traffic intensity; hence, the variable was path surface. Investigators considered five types of surfaces: asphalt, cobblestone, dolomite, non-surfaced (native soil), and sand. Though the forest has concrete paths, these did not meet the prerequisite for selection. Additionally, in order to include a broad range of soil compaction values, investigators selected stands of trees of many different ages, as soil compaction and stand age have a positive correlation. The construction phase of paths accounts for compaction of both sides of the path, the disappearance of the most vulnerable species, and the development of plants adapted to this kind of disturbance (Godefroid and Koedam 2004).

Analysis of the 500 plots shows that path surfaces influence surrounding plant composition up to 10 meters (33') from the path: plant traits and soil compaction were driving factors in the first 3 to 4 meters (10' to 13'); soil reaction and soil nitrogen affected the remaining distance.

Path surfaces influence surrounding plant composition up to 10 meters from the path.

Additionally, the pattern of vegetation shows plant preferences for particular surfaces. The study documents the following results: Spreading woodfern (*Dryopteris dilatata*) shows a strong bias for stands associated with non-surfaced paths. Small balsam (*Impatiens parviflora*), yellow archangel (*Lamium galeobdolon*), and stinging nettle (*Urtica dioica*) are more frequent in the vicinity of cobblestone. The presence of field forget-me-nots (*Myosotis arvensis*), common plantain (*Plantago major*), and gypsywort (*Lycopus europaeus*) seems to be correlated to asphalt paths. Near the sand sample quadrant the close positioning of common gypsywort (*Veronica officinalis*) and pill sedge (*Carex pilulifera*) indicates that these species have a strong preference for this surface.

The surface with the most forest species was cobblestone. Moreover, it had the highest number of stress-tolerant (forest) species, but also the highest number of competitive and stress-tolerant ruderals—vegetation that commonly grows in disturbed areas. Bare soil paths had the most disturbance species but also the most competitor (forest) species. Dolomite was responsible for the disappearance of nitrogen-demanding species. It also had the most short-term species (seed bank persistence between one and five years) and abundant ruderals. Sand had the most long-term species (seed bank persistence greater than five years). Asphalt had abundant ruderals and the highest number of transient species (seed bank persistence less than one year).

In order to conserve ecological processes and minimize the spread of plants that threatens optimal development of forest vegetation, the authors recommend that efforts be made "to limit the use of the most detrimental surfacing materials," in this case asphalt and dolomite. Generally speaking, however, the presence of a path increases the number of ruderal species, disturbance indicator species, nitrogen-demanding species, and species that indicate chemically basic conditions. Hence, creating paths promotes a so-called "edge effect" where internal edges in the forest make its functional interior area smaller than its actual area. According to a previous study by the same authors, Godefroid and Koeman (2003), this effect "will likely enhance the spread of opportunistic species and might be a threat for conserving woodland flora."

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—*Katie KellerLynn*

Where the buffalo roam:

Figure 1. Bison in Wind Cave National Park, South Dakota.
HARGREAVESPHOTO.COM

THE ROLE OF HISTORY AND GENETICS IN THE CONSERVATION OF BISON ON U.S. FEDERAL LANDS

By Natalie D. Halbert, Peter J. P. Gogan, Ronald Hiebert, and James N. Derr

History of bison

As an emblem of the Great Plains, American Indians, and wildlife conservation, the American bison (*Bison bison*) is one of the most visible and well-known of wildlife species in North America (fig. 1). Species of the genus *Bison* originally entered the continent via the Bering land bridge from northern Eurasia in the Illinoian glacial period of the Pleistocene epoch (125,000–500,000 years ago). Bison are the largest species in North America to have survived the late Pleistocene–early Holocene megafauna extinction period (around 9,000–11,000 years ago), but likely experienced a dramatic population reduction triggered by environmental changes and increased human hunting pressures around this time (Dary 1989; McDonald 1981). The modern American bison species (*Bison bison*) emerged and expanded across the grasslands of North America around 4,000–5,000 years ago (McDonald 1981).

As the major grazer of the continent, bison populations ranged from central Mexico to northern Canada and nearly from the east to west coasts (fig. 2; McDonald 1981), with 25–40 million bison estimated to have roamed the Great Plains prior to the 19th century (Flores 1991; McHugh 1972; Shaw 1995).

By the 1820s, bison in North America were already in a state of continuous decline, especially in the South and East (Flores 1991; Garretson 1938). Evidence on many fronts indicates the initial decline was due to both natural and anthropogenic (human-induced) forces (Flores 1991; Isenberg 2000). For example, the introduction of nonnative animal species led to increased hunting efficiency by aboriginal peoples with the proliferation of the horse culture, spread of exotic diseases (e.g., tuberculosis and brucellosis from cattle), and competition for grazing and water sources with growing populations of cattle, horses, and sheep. Natural pressures including fire, predation by wolves, and severe weather events such as droughts, floods, and blizzards also served to limit historical bison population sizes (Isenberg 2000). Uncontrolled hide hunting by both aboriginal and Euro-American hunters, facilitated by advances in firearms and transcontinental rail transportation, advanced the rapid decline leading to the well-documented, precipitous population crash of the late 1800s (Coder 1975; Garretson 1938). A preference for young female bison hides likely added to the population decline by disrupting herd social structure and natality (birth) rates. Fewer than 1,000 American bison—including both the plains and wood bison types—existed in the world by the late 1880s, and the species appeared to be at risk of extinction (Coder 1975; Soper 1941). The timely formation of six captive herds from 1873 to 1904 by private individuals and governmental protection of two remnant wild herds in the United States (Yellowstone National Park, established in 1872) and Canada (Wood Buffalo National Park, federally protected from 1893, park established in 1922) effectively served to save the species from extinction (table 1, page 25; locations indicated on fig. 2). The individuals involved in the early bison conservation movement were primarily cattle ranchers concerned with the disappearance of large, free-roaming bison herds. For example, the Texas cattle rancher Charles Goodnight (fig. 3, page 24), at the behest of his wife (Haley 1949), captured bison in the panhandle of Texas during the late 1870s and early 1880s to form a small captive herd. From these few herds, a combined total of fewer than 500 bison served as the foundation stock from which all bison in existence today are derived (Coder 1975; Soper 1941).

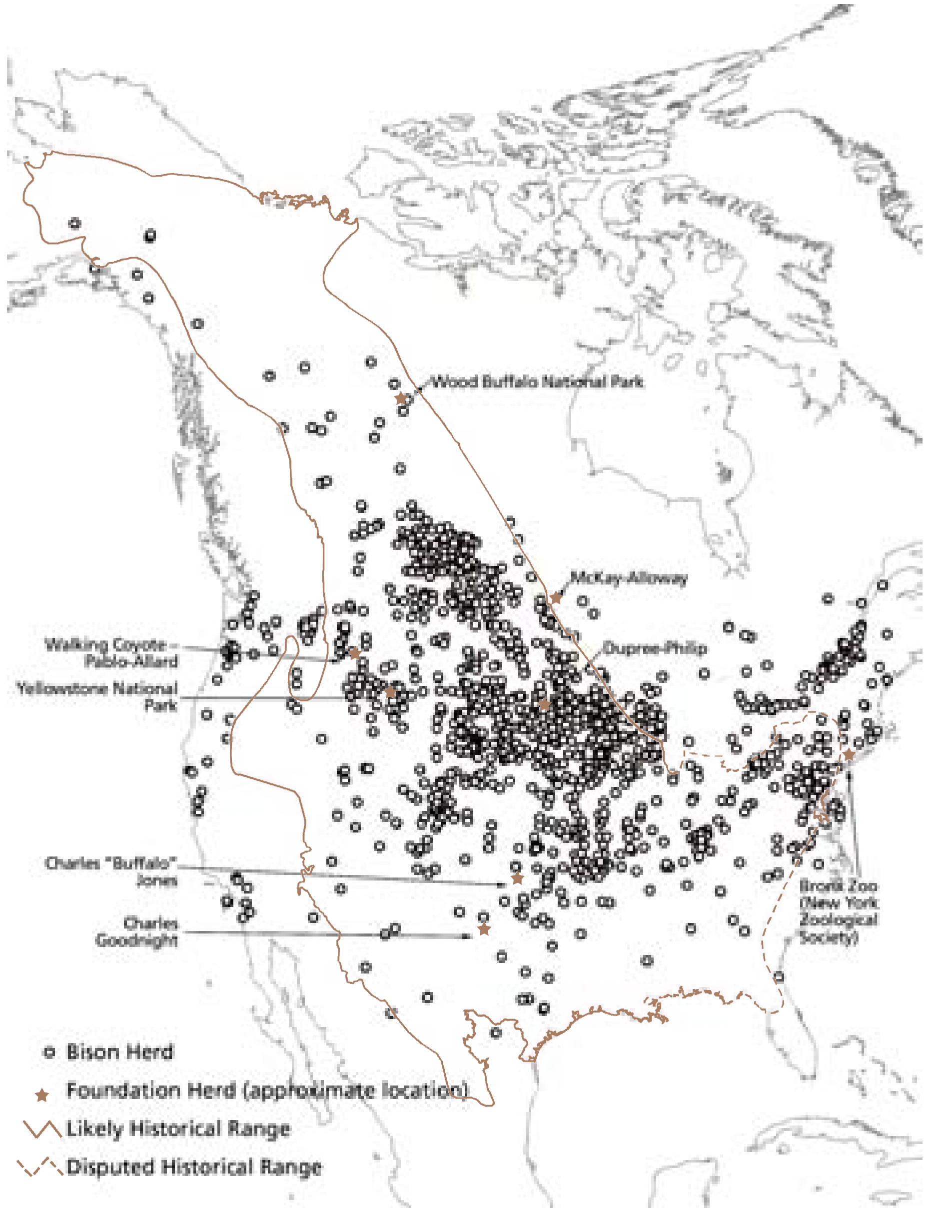

Figure 2. Historical distribution of Bison bison, with locations of foundation herds indicated (see table 1 for foundation herd histories). WILDLIFE CONSERVATION SOCIETY

Fewer than 500 bison served as the foundation stock from which all bison in existence today are derived.

Establishment of federal bison herds

Despite the significant population crash experienced in the late 1880s, bison in captivity thrived and by the turn of the 20th century, surplus bison were being sold off by private owners (Coder 1975). In contrast, the bison herd in Yellowstone National Park, representing the only continuously wild herd in the United States, was declining during this period due to unabated poaching; by 1902 only 30–50 bison persisted in the park (Garretson 1938; Meagher 1973). A critical shift in the bison conservation movement would occur, however, with new legislation in the United States and Canada providing for the protection of wildlife and the formation of additional federal bison herds (Coder 1975). The famous naturalist, William Hornaday, and the American Bison Society, founded in 1905, were instrumental in lobbying the U.S. government for such protective legislation and in procuring bison through the New York Zoological Park (see table 1) to establish new federal herds. At present, approximately 8,500 bison are maintained in five units administered by the National Park Service (NPS) and six units administered by the U.S. Fish and Wildlife Service (USFWS) (table 2). The bison in these 11 herds were derived almost exclusively from the 6 foundation herds and the continuously wild herd in Yellowstone National Park and, therefore, serve as an important reservoir of bison germplasm (genetic content).

Figure 3. The famous Texas cattle rancher Charles Goodnight, who captured wild bison in the panhandle of the state to form one of the six foundation herds (see table 1) from which many extant bison are derived. In 1902, Goodnight gave three bison bulls to the U.S. federal government to supplement the small, wild herd in Yellowstone National Park (see table 2).

PANHANDLE-PLAINS HISTORICAL MUSEUM AND THE TEXAS STATE BISON HERD ARCHIVE PROJECT

Need for genetic information for bison management

The U.S. Department of the Interior (DOI) Bison Conservation Management Working Group has met annually since 1997 to gather and share information on bison management techniques, policy issues, animal health, genetics, and demographics. Early on, the group recognized the need for genetic information to guide management and specifically wanted to know: (1) the present levels and patterns of genetic variation within and among herds; (2) if it is more appropriate to manage DOI bison herds as separate populations or as a meta-population; (3) the effects of various culling practices on the maintenance of genetic variation; and (4) levels of domestic cattle (*Bos taurus*) introgression (introduction of foreign DNA fragments into a genome) in the DOI bison herds.

With funding from the U.S. Geological Survey Natural Resource Preservation Program and the U.S. Fish and Wildlife Service, a cooperative project was initiated with Texas A&M University. A summary of the results of this project and management implications follows.

Genetic architecture of bison herds

Knowledge of the genetic architecture of federal bison herds is critical to proper management, long-term maintenance of genetic diversity (that is, for the next 100+ years), and species conservation. For instance, genetic technologies can be used to assess the effects of the historic 19th century population crash (genetic bottleneck) and foundation of herds with few individuals (founder effect), levels of inbreeding and diversity in herds, subpopulation structure within herds (nonrandom mating), and genetic relationships among herds. Such information is of great value to managers in determining appropriate herd sizes, sex ratios, and culling strategies.

To address these issues, polymorphic DNA markers—those having more than one allele or “form” of a gene/DNA sequence—are commonly employed to obtain genotypic information on individuals from populations. One such polymorphic marker is called a microsatellite, which is a type of simple sequence repeat (SSR). Microsatellites have several advantages in population genetic studies in that they are relatively inexpensive to use, simple and reliable to score (i.e., obtain genotypes), highly polymorphic, and abundant throughout the genomes of mammals.

Using a panel of 49 microsatellites dispersed throughout the bison genome, we recently completed an evaluation of the genetic structure of the 11 U.S. federal bison herds. (For complete study details, see Halbert (2003); Sully’s Hill National Game Preserve herd data is from

Halbert and Derr, unpublished data.) Blood, hair, or tissue samples collected by DOI personnel from 2,260 individual bison were shipped to Texas A&M University for DNA isolation and genetic evaluation. From these analyses we identified differences among herds in the average number of alleles per microsatellite (a measure of diversity) and calculated an average across all herds of 4.36 and a range from 4.96 (National Bison Range herd) to 3.55 (Theodore Roosevelt National Park, north unit herd) alleles per microsatellite. Herds also differed in levels of heterozygosity (an indicator of the breeding history of a herd), with an average across all herds of 59.1% and range from 65.7% (Wind Cave National Park herd) to 51.9% (Theodore Roosevelt National Park, north unit herd) heterozogosity. In general, higher levels of both heterozygosity and genetic diversity (alleles per microsatellite) are desirable, as these measures correlate with population stability and viability. The U.S. federal bison herds appear to have relatively high levels of both heterozygosity and genetic diversity, especially considering the significant population bottleneck experienced in the late 1800s and small numbers of founders used to establish the herds. In comparison, the Texas State Bison Herd, which is directly descended from the original Goodnight herd (table 1) and has remained a small, closed population for many generations, has an average of 2.61 alleles/marker and 38.5% heterozygosity (Halbert et al. 2004). As is often found in populations suffering from low levels of genetic diversity, the Texas State Bison Herd has a history of inbreeding, low natality rates, and high juvenile mortality rates compared with other bison herds (Halbert et al. 2005a).

The genotypic information obtained in this study was used to evaluate relationships among herds (fig. 4, page 27). While some herds are closely related, such as those in Fort Niobrara National Wildlife Refuge, Badlands National Park, and Theodore Roosevelt National Park (south and north unit herds), others are more distantly related, such as those in Wichita Mountains National Wildlife Refuge and Grand Teton National Park. Overall, the identified genetic relationships follow closely the history of establishment of these herds (table 2, page 26). For example, the Wichita Mountains National Wildlife Refuge and Wind Cave National Park herds share a historical link through their establishment (at least in part) from New York Zoological Park herd bison (table 2), and the genetic data indicate that this relationship persists, as the two modern derivatives of these herds are more closely related to each other than either is to any other herd examined (fig. 4). As another example, the Badlands National Park and Theodore Roosevelt National Park north unit herds were both established with bison from the south unit herd of Theodore Roosevelt National Park, which was in turn derived from Fort Niobrara National Wildlife Refuge stock (table 2); this relationship is also evident based on the genetic data (fig. 4).

In other cases, genetic analyses shed new light on the relative contributions of various founder sources. For instance, the Grand Teton National Park herd was originally established with bison from Yellowstone National

Table 1. Captive bison herds providing founding stock for U.S. and Canadian federal herds

Herd	Source	Year	Number of bison
James McKay-Charles Alloway	Saskatchewan	1873–1874	5
Charles Goodnight	Texas	1878	5
Frederick Dupree	Montana	1882	6–7
Michel Pablo-Charles Allard	Montana	1879	4[a]
	Jones herd	1893	44
Charles Jones	Texas	1886–1889	56
	McKay-Alloway herd (through Samuel Bedson)	1888	86
	Kansas, Nebraska (various)	unknown, prior to 1893	10
New York Zoological Park[b]	Nebraska	1888	2
	South Dakota	1889	4
	Pablo-Allard herd	1897	3
	Mix[c]	1904	4

Source: Derived from Coder 1975, Garretson 1938, and Seton 1937.

Note: Wild bison captured within their native range were used as initial stock for each captive herd and were later pivotal in providing founding stock for U.S. and Canadian federal herds. In addition to these herds, remnant wild herds existed in Yellowstone National Park (reaching a low of 30–50 bison in 1902; Garretson 1938; Meagher 1973) and the area now protected as Wood Buffalo National Park (with a low of 300 bison around 1891; Soper 1941).

[a] Wild bison originally captured by Walking Coyote (Samuel Wells), a Pend d'Oreille Indian in 1879; the herd grew and 12 head were sold to Pablo and Allard in 1883.

[b] Herd formation largely due to efforts of William Hornaday and the American Bison Society (Coder 1975).

[c] Derived from Wyoming, Manitoba, and the Jones herd.

Park in 1948. In 1963, the infectious disease brucellosis was discovered in the herd and all 13 adults were killed (National Park Service 1996). To the remaining 4 yearlings and 5 calves, 12 adult (6 male and 6 female) bison from the Theodore Roosevelt National Park south unit herd were added in 1964 (National Park Service 1996). The modern Grand Teton National Park herd appears to be more closely related to the Theodore Roosevelt National Park south unit herd than the Yellowstone National Park herd (fig. 4), most likely as a result of preferential breeding for a number of years by the adult Theodore Roosevelt National Park south unit bison while the herd was small. Genetic drift, or random changes in allele frequencies, which is especially powerful in small populations, might also have played a part in shaping the modern genetic structure of the Grand Teton National Park herd. Regardless, the genetic data in this case reveal relationships not clearly apparent from herd history alone.

A common concern in wildlife management is inbreeding, which can lead to decreased heterozygosity, adaptive response (ability of a population to adapt to environmental changes), and population viability (Franklin 1980). Indeed, the history of formation of these herds from a handful of individuals (table 2) and continued maintenance of federal bison in relatively small (with the

Table 2. Establishment of U.S. federal bison herds

Herd	Location	Year	Founding Stock Number – Source[a]
Badlands NP	South Dakota	1963	3 – Fort Niobrara NWR; 50 – Theodore Roosevelt NP south unit
		1983	20 – Colorado National Monument (unknown origin)
Fort Niobrara NWR	Nebraska	1913	6 – private ranch, Nebraska; 2 – Yellowstone NP
		1935	4 – Custer State Park, South Dakota
		1937	4 – Custer State Park, South Dakota
		1952	5 – National Bison Range
Grand Teton NP	Wyoming	1948	20 – Yellowstone NP
		1964	12 – Theodore Roosevelt NP
National Bison Range	Montana	1908	1 – Goodnight herd; 3 – Corbin (McKay-Alloway); 34 – Conrad (Pablo
		1939	2 – 7-Up Ranch (unknown origin)
		1952	4 – Fort Niobrara NWR
		1953	2 – Yellowstone NP
		1984	4 – Maxwell State Game Refuge, Kansas (Jones)
Neal Smith NWR	Iowa	1996	8 – Fort Niobrara NWR; 8 – Wichita Mountains NWR
		1997	6 – Fort Niobrara NWR; 8 – National Bison Range
		1998	3 – Fort Niobrara NWR
Sully's Hill National GamePreserve[b]	North Dakota	1919	6 – Portland City Park, Oregon (unknown origin)
		1932	1 – Wind Cave NP
		1941–1979	7 – Fort Niobrara NWR
		1987	3 – National Bison Range
		1994–1997	2 – Theodore Roosevelt NP
Theodore Roosevelt NP[c]	North Dakota	1956	29 – Fort Niobrara NWR to found Theodore Roosevelt south unit herd
		[1962]	[20 – Theodore Roosevelt south unit bison to establish north unit herd]
Wichita Mountains NWR	Oklahoma	1907	15 – New York Zoological Park
		1940	2 – Fort Niobrara NWR
Wind Cave NP	South Dakota	1913	14 – New York Zoological Park
		1916	6 – Yellowstone NP
Yellowstone NP	Wyoming, Idaho, Montana	1902	approximately 30 indigenous; 18 – Pablo-Allard herd; 3 – Goodnight herd

Source: Halbert and Derr 2007; copyright 2007 by the America Genetic Association.
[a]See table 1 for description of six foundation herds.
[b]History of introductions provided by C. Dixon, personal communication.
[c]Theodore Roosevelt National Park hosts two herds: south unit and north unit.

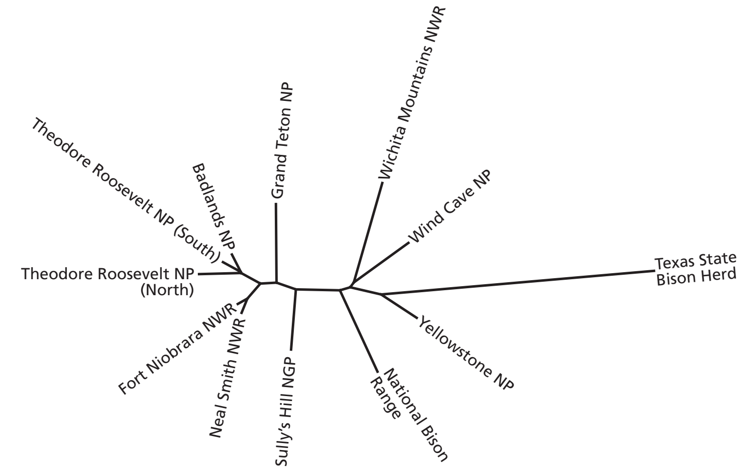

Figure 4. Genetic relationship tree based on 49 polymorphic microsatellites. Populations and sample sizes indicated in table 2. Figure derived from DS genetic distances (Nei 1972), which is based on the infinite alleles model of evolution. Branch lengths correlate with the amount of genetic similarity identified between herds.

exception of Yellowstone National Park), closed herds (table 3) would suggest that inbreeding may be adversely impacting the genetic architecture and trajectory of these herds. However, the genetic data described herein do not indicate inbreeding (Halbert 2003), and phenotypic indicators of inbreeding depression (e.g., decreased birth rates, abnormal physical characteristics, increased mortality) have not been observed in these herds. Although genetic data from pre-bottleneck bison herds are currently not available to make direct measurements of changes in genetic diversity over time, these herds appear to have maintained moderate levels of genetic diversity despite the bottleneck event of the late 1800s and subsequent small founding population sizes. In fact, compared with cattle and related species, bison in general appear to have levels of genetic diversity and heterozygosity similar to other nondomesticated bovids (e.g., MacHugh et al. 1997; Navani et al. 2002; Rendo et al. 2004).

The genetic data ... do not indicate inbreeding.

Historical—and in some private herds, recent—hybridization between bison and their close relative, domestic cattle, has complicated bison conservation efforts due to introgression of domestic cattle DNA into the bison genome. The two species do not naturally interbreed, and, in fact, viable first-generation hybrids are somewhat difficult to produce (Boyd 1914; Goodnight 1914). However, most of the people involved in saving bison from near-extinction in the 1880s were cattle ranchers interested in producing hardier breeds of cattle. Various records of successful attempts by ranchers to hybridize the two species exist (e.g., Coder 1975; Jones 1907), and the remnants of these crosses are evident today. Domestic cattle DNA has been detected in both the mitochondrial (Polziehn et al. 1995; Ward et al. 1999) and nuclear (Halbert and Derr 2007; Halbert et al. 2005b) genomes of bison in state, federal, and private herds in the United States. In U.S. federal bison herds, levels of detected introgression are low, and probably constitute less than 1% of the total nuclear DNA (Halbert and Derr 2007). No evidence of introgression has been detected in the Yellowstone and Wind Cave national park herds, where several hundred bison have been tested (Halbert and Derr 2007). Conversely, some private and state herds have substantially higher levels of introgression, with up to 100% of the bison in one private herd harboring domestic cattle mitochondrial DNA (Halbert and Derr, unpublished data).

Table 3. Nuclear microsatellite sampling regimen for federal bison herds

Population	Collection year(s)	Census[a]	Total sampled
Badlands NP	2002	875	312
Fort Niobrara NWR	2001–2002	380	167
Grand Teton NP	1999–2000	600	39
National Bison Range	1999–2002	350	152
Neal Smith NWR	2001	63	49
Sully's Hill National Game Preserve	2004	35	31
Theodore Roosevelt National Park, north unit	2000	312	270
Theodore Roosevelt National Park, south unit	2001	371	324
Wichita Mountains NWR	1999, 2002	600	35
Wind Cave National Park	1999–2001	350	293
Yellowstone National Park	1997, 1999–2002	3,000	488
Sum		6,936	2,160

Note: A total of 2,160 bison were scored for 49 nuclear microsatellites.
[a]Approximate census population size, as estimated by individual herd managers. When possible, estimates are given of total census population size at time of collection for this study (or average across collection years).

Implications for future management

The human-aided recovery of bison from the brink of extermination in the late 1800s is among the first and best known conservation success stories. With more than 500,000 American bison in the world today, the recovery of the species would indeed seem secure. However, only 5% of these bison are in conservation herds (maintained by federal, state, or private conservation groups); all other bison are maintained on private ranches (Boyd 2003). While some ranchers with private bison herds are interested in and committed to conservation, others raise bison as semidomesticated livestock subjected to intensive management, handling, herd structure manipulation, and artificial selection. Artificial selection on phenotypes (traits), such as weight or hump size, effectively selects for or against alleles at one or more genes in the genome that control the trait; this type of selection leads to changes in the genetic architecture of a herd that are difficult to predict, alter the genome (in many cases irreversibly) from its "natural" state, and can lead to reduced fitness due to decreased genetic variation or inadvertent selection on nearby "fitness-related" genes. Arguably, therefore, the primary—though possibly not exclusive—burden of the long-term preservation of bison as a distinct species falls on the managers of conservation herds. Before a complete picture of the modern bison germplasm can be understood and most effectively conserved, however, further evaluation using methods such as those presented here is needed to assess the genetic architecture of several conservation herds in both the United States and Canada for which such information is poorly understood or altogether unknown.

The current and future management of U.S. federal bison herds has been debated and scrutinized from many perspectives. As is the case with many other wildlife species, anthropogenic changes to the environment and landscape have forced the primary existence of bison into fragmented herds of relatively small size (<1,000 individuals). Small populations are prone to losses of genetic diversity, or genetic erosion, which in turn can lead to decreased fitness and adaptive response. Migration among populations is the principle process that can counteract genetic erosion. For modern bison, opportunities for natural migration do not exist. Movement of bison among herds only occurs artificially. Extreme caution must be practiced when moving animals in this way, however, to prevent the inadvertent transmission of disease and further dilution of the bison genome with introgressed domestic cattle DNA.

Small populations are prone to losses of genetic diversity, or genetic erosion, which in turn can lead to decreased fitness and adaptive response.

Probably the most pressing genetic issue facing U.S. federal bison herd management today is the general need for increased herd sizes. Recent simulation modeling based on the genetic data presented herein indicates that effective population sizes of at least 1,000 individuals are necessary for the long-term maintenance of both genetic diversity and heterozygosity (Gross and Wang 2005). Effective population sizes reflect the effective number of breeding individuals and are generally only a fraction of the census population sizes. A "population" need not be contiguous, and several herds from the same genetic stock might be considered in the effective population size calculation. In fact, the creation and maintenance of such herds is recommended to prevent genetic erosion and decrease chances of catastrophe (e.g., devastating disease, flood, fire) leading to the loss of irreplaceable germplasm. The Yellowstone National Park herd is the only U.S. federal herd that likely meets the effective population size criteria directly, although the continued presence of brucellosis in the herd greatly complicates efforts to create satellite herds outside of the park boundaries. The Fort Niobrara National Wildlife Refuge herd and direct satellite herds in Theodore Roosevelt National Park (south and north units) combined likely also meet the effective population size criteria. The establishment and proper management of disease-free satellite herds from various U.S. federal bison herds, especially those with unique lineages and no historic or genetic evidence of introgression (e.g., Wind Cave and Yellowstone National Park herds), will serve to not only decrease genetic erosion, but also support long-term species conservation efforts.

More genetic information has been gathered, analyzed, and utilized for the study and conservation of American bison than for any other wildlife species. Collectively, genetic technologies have given us a detailed snapshot of the current architecture of both public and, to a lesser degree, private bison herds. Conservation herd data gaps still exist, especially with regard to largely unexamined herds (e.g., private conservation herds, Canadian public herds) and to intrapopulation dynamics (e.g., subpopulation division, effects of age and sex structure on genetic diversity). The long-term preservation of the bison genome will depend upon the responsible use of available data in the management of conservation herds. Like bison, many other species currently exist in fragmented populations, in limited habitats, and with continuous anthropogenic pressures. Genetic technologies such as those described here should be considered in the assessment of population structure and relationships as tools to assist management efforts and promote long-term species conservation.

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The ecological future of North American bison

By Michael A. Soukup

Editor's Note: Following are remarks of Mike Soukup, NPS associate director for Natural Resource Stewardship and Science, on the occasion of the Wildlife Conservation Society meeting on the ecological future of North American bison, held in Denver, Colorado, 23 October 2006. His address rounds out the discussion of bison management in North America by sharing a context for the scientific findings of our cover article on the history and genetics of federal bison herds and examining several other important and interrelated management considerations.

Bull bison, Yellowstone National Park, Wyoming. COPYRIGHT DAN NG

Bison as symbol

Few symbols, and no other animal, are so associated with our national parks as the American bison. These great beasts were amidst the geysers of Yellowstone and an integral part of the vista that inspired creation of the first national park in 1872.

It is part of our emblem to this day. It is on the arrowhead of every National Park Service employee uniform, and at the entrance of every national park unit. The bison is the emblem for the Department of the Interior—suggesting that the bison also has a claim on the vast lands of the Bureau of Land Management and the U.S. Fish and Wildlife Service. At least two states feature the bison on their new state quarters (Kansas and North Dakota). It is part of the psyche of generations of Americans, especially as their daily lives were more circumscribed in suburbs and cities, that it is their birthright to see wild bison in a wild setting. Indeed it is the Park Service mission to fulfill that need. And for many more generations bison have been central to the culture of many Native Americans.

The reason that I was delighted to accept your invitation and join you for this meeting is that my responsibility in the National Park Service, as the associate director for Natural Resource Stewardship and Science, is to ensure that the bison and the processes under which it evolved are both understood and not lost to future generations. We are justly proud of our long record of sponsoring observations and studies that provide understanding of the bison in its natural habitat. The process part—that's the rub—as you well know. Our task is not simply to provide herds of bison for viewing at a safe distance, on a visit to Yellowstone, or Badlands, or Theodore Roosevelt national parks. That would seem simple enough. But we must keep some part of the nation's bison wild, subject to the same selection pressures that made the animal—that is our real challenge.

Our task is not simply to provide herds of bison for viewing at a safe distance.... We must keep some part of the nation's bison wild, subject to the same selection pressures that made the animal—that is our real challenge.

I want to spend my few minutes here on how we must face that challenge on three fronts: providing a National Park Service perspective on genetics, disease, and behavior of bison. And underlying both our understanding and our management practices in all of these fields is the issue of boundaries. The idea of discrete boundaries has been clearly drawn for the National Park Service by the Congress. (Congress has had less success impressing this upon the bison.) Bison once roamed freely across the western landscape, and evolved without regard to boundaries. That hasn't changed. Our vision for the future must realize and address that reality.

Genetics

Thanks to the breakthrough in molecular genetics we know a great deal about the genetics of the NPS bison herds. They are not all equal from a genetic value. Some like the Yellowstone and Wind Cave herds, by good fortune of how they were saved or how they were collected, have significantly more variation. (Genetic studies are very recent, and were jointly supported by the U.S. Geological Survey, National Park Service, and National Science Foundation.)

Some herds have significantly less variation, but they contain genetic differences that are important to bison conservation and recovery. But some herds have too much variation; that is, they have genes that show they descend from historical crosses between *Bison* and *Bos*—between bison and domestic cattle.

Before we think about what we can do with this knowledge, it is worth remembering how we have it. The enzyme that allows us to identify these DNA markers through the process of polymerase chain reaction (PCR) originally came from a thermophylic bacterium found in the Yellowstone hot springs. And we have access to so many polymorphic markers because of the work of Drs. Natalie Halbert and Jim Derr (Texas A&M University) precisely because of the close relation between bison and cattle, and the gene map being developed for domestic cattle.

It is not enough to know where the significant variation in our bison herds resides; we must know what it takes to maintain it. This we get from the modelers—those who can look at what we have in the genetics, life history, and ecology of the bison and tell us what we need. The National Park Service was fortunate to hire one of the best ecological modelers in the business, John Gross. These models make clear that to maintain genetic variation you need to have large herds—herds numbering in the many hundreds, or better yet, thousands.

For some small parks, the only way to achieve a sustainable population size is to manage herds at a broader scale, by moving bison between herds. But we can't do that today because of disease. The silver lining is we're lucky that we didn't do this in the past because we didn't really understand the genetics.

Disease

The National Park Service is now collaborating with the U.S. Department of Agriculture and the states of Idaho, Montana, and Wyoming to continue long-term planning processes for the eventual elimination of brucellosis from Greater Yellowstone Area bison and elk.

Why? Because just as it is troubling for us to be shooting bison that turn up in national parks because there is reason to suspect they carry cattle genes, so it is bad news to shoot bison that roam outside of national parks because they could be brucellosis carriers.

We need veterinary medical breakthroughs to remove these barriers. So the National Park Service is instigating research "for more effective vaccines, more effective vaccine delivery techniques for free-ranging wildlife, and better diagnostic techniques for identifying infection in live animals—all are priority research and development needs." That is our commitment, as Mary Bomar, the new director of the National Park Service, pledged to Senator Thomas in her confirmation hearings.

Behavior

A visitor to Hayden Valley in August is likely to get stopped by bison rutting on the road. Recently more than 2,000 bison from Yellowstone gathered with the snorting, and dust rolling, and hundreds of massive bulls competing for mates. This spectacle—this process—is one of the selection factors that influenced bison survival for eons.

Less often seen, but now well documented by biologists working year-round in Yellowstone is increasing predation by wolves on bison. Molly's Pack in Pelican Valley has lived on bison in winter, and three years ago a second pack formed in Hayden Valley makes bison its exclusive winter diet. At least two other packs also make bison part of their diet. Hunting bison with fang and claw is especially dangerous because, unlike elk, bison stand their ground. There is an innate elegance in natural systems where predator and prey constantly test each other's mettle, and each other's fitness, as they vie for survival. One of the many positive aspects of wolf restoration to Yellowstone National Park is a strong, wild bison that can match any future vision we have for this species.

Selection pressures on commercial bison are obviously quite different, where competition between bulls may be secondary to weight gain, and good behavior may be docility rather than avoiding predation by wolf packs. (I think of wild animals as the pros, and domestic animals as the couch potatoes.)

So the behavioral and genetic differences between domestic and wild bison are likely to increase this century, even as we blur those distinctions in the public perception. Bison on the plains can help sell bison in the market, but they are not the same.

Wild bison for the future

Which brings me back to this matter of boundaries. We in the National Park Service must be diligent in observing our boundaries. But bison are notorious in their disrespect for fences and other human-defined boundaries. As we treat them as more than symbols of the wide-open West, as we learn more about them, we can change some of our practices as well. I am confident we can do this. We began a pilot project a couple of years ago in the Southeast called the Seamless Network of Parks, which seeks common, biologically based, management practices regardless of the blend of federal and state agency lands. Perhaps one day, wild bison will freely graze the public lands set aside as bison habitat.

Our vision for the future of bison should be great herds that roam across vast expanses without detecting agency jurisdictions. Accomplishing this will take better cooperation on public lands. Strong partnerships with private landowners can make this vision a reality. We could have bison conservation areas, as we do now for bears in the Rocky Mountains. Perhaps some day bison conservation lands can be connected as corridors so that bison can move freely, and gene frequencies will not need to be managed by trucking bison from place to place. Genetically true bison that increase in these areas can provide for disease-free replenishment of bison herds whenever opportunities arise in their former native home range.

The National Park Service has and will continue to support restoration of bison as an important part of the heritage of North American cultures, and as a key species in North American ecosystems. This workshop is a key step toward achieving a common vision of restoration of bison in North America.

With a wide-reaching vision, the time could come when bison also have a visible role in the daily lives of many more Americans in the West. In some places bison will be hunted by wolves, in some places by humans, but keeping them wild will be the principle that drives decisions. If we can do that, we all will be keeping faith with those who saved these great animals from extinction. Our part is to ensure that bison have not just survived, but remain an authentic part of our heritage.

BUFFELGRASS FUEL LOADS IN SAGUARO NATIONAL PARK, ARIZONA, INCREASE FIRE DANGER AND THREATEN NATIVE SPECIES

Saguaro cacti in buffelgrass, Javelina Picnic Area, Saguaro National Park, Arizona. USGS/TODD ESQUE

By Todd C. Esque, Cecil R. Schwalbe, Jessica A. Lissow, Dustin F. Haines, Danielle Foster, and Megan C. Garnett

Historically, patchy fuels and sparse vegetation have limited individual fires to small areas in the hot deserts of North America, including the Sonoran Desert (Humphrey 1974; Schmid and Rogers 1988). Most Sonoran Desert vegetation is not adapted to fire and some important endemic plant species are vulnerable to recurring fire (Thomas and Goodson 1992; Wilson et al. 1994; McAuliffe 1995). Two species found in the Sonoran Desert, the saguaro cactus (*Carnegiea gigantea*) and foothill palo verde tree (*Cercidium microphyllum*), are very susceptible to wildfire (McLaughlin and Bowers 1982; Rogers 1985; Esque et al. 2004). Exotic grass invasions in desert regions can change the fire regime by providing fuel for fire where fire was once rare. In this article we describe how an invasive exotic plant—buffelgrass (*Pennisetum ciliare*)—is a management problem in the borderlands between the United States and Mexico. We also report the results of our study of buffelgrass fuel loads on two sites in Saguaro National Park, Arizona, and discuss management implications of buffelgrass-related fire risks.

Buffelgrass fire cycle

Buffelgrass, a perennial grass native to Africa and Asia, was introduced to Australia, North America, South America, Caribbean islands, Hawaii, and some Pacific and Indian Ocean islands (Martin 2000) to increase forage production for livestock (figs. 1, 2a, and 2b). It was selected because of its ability to thrive over a wide range of annual precipitation (8–49 in or 200–1,250 mm) on shallow, marginally fertile soils and in high temperatures (Cox et al. 1988). In the Sonoran Desert, buffelgrass has escaped areas of cultivation and invaded riparian areas, roadsides, urban fringes, and wildlands (Búrquez-Montijo et al. 2002). Most cultivated stands of buffelgrass in central Sonora (Mexico) have burned at least once, if not many times, in the last 20 years (Búrquez-Montijo et al. 2002). While most Sonoran Desert plant species are not fire adapted, buffelgrass grows vigorously after a fire (Hamilton and Scifres 1982; Mayeux and Hamilton 1983; Hamilton 1985; Rutman and Dickson 2002). A grass/fire cycle (D'Antonio and Vitousek 1992) can be initiated by exotic grasses such as buffelgrass, whose productivity is enhanced by

Figure 1. A perennial grass from Africa, buffelgrass (beige tufts) was introduced to different regions of the world for livestock forage. In the Sonoran Desert it has invaded wildlands, increasing fuel loads and the susceptibility of natural areas to fire, and threatening protected species. USGS/TODD ESQUE

fire adaptations that increase fuel loads and fire intensities. The cycle is complete as high fire mortality to native plants further advances buffelgrass proliferation and results in a more frequent and intense fire regime.

Natural areas at risk from buffelgrass and the threat of fire include Saguaro National Park, Organ Pipe Cactus National Monument, and Ironwood Forest National Monument in Arizona; and Big Bend National Park, Santa Ana National Wildlife Refuge (NWR), Lower Rio Grande Valley NWR, and Laguna Atascosa NWR in Texas. The addition of frequent fire as a new process in these systems puts protected ecological communities and species at risk because hydrology and community composition, structure, and function may be drastically altered. This can cause losses of both rare and protected species by the direct effects of fire, and possibly more consequential, the loss of these rare and critical habitats by their alteration. For example, desert tortoises (*Gopherus agassizii*) and giant saguaro cactus at Saguaro National Park can be killed outright by fire and may be negatively impacted by habitat changes from fire (Brooks and Esque 2002; Esque et al. 2003). The thornscrub forest protected at southern Texas national wildlife refuges provides biologically diverse habitat for jaguarundis (*Herpailurus yaguarondi cacomitli*) and ocelots (*Leopardus pardalis*). When buffelgrass burns, the thornscrub forest is converted to less structurally diverse grasslands and may change habitat use by these endangered cats. In Big Bend National Park the endangered Chisos Mountains hedgehog cactus (*Echinocereus chisosensis*, fig. 3) is susceptible to buffelgrass fires. In the Lower Rio Grande Valley, buffelgrass invasion is considered to be a serious threat to three federally endangered endemic plants that are protected by the U.S. Fish and Wildlife Service: Walker's manioc (*Manihot walkerea*), Zapata bladderpod (*Physaria thamnophila*), and border ayenia (*Ayenia limitaris*).

Figure 3. Hedgehog cactus (*Echinocereus chisosensis*) in a patch of buffelgrass at Big Bend National Park. Hedgehog cactus is susceptible to fire carried by buffelgrass biomass. USGS/TODD ESQUE

Data on buffelgrass fuel loads in infested wildlands are not previously available. Wildfires fueled by red brome (*Bromus madritensis*), another exotic species, have occurred in desertscrub habitats in southern Arizona, including Saguaro National Park (Esque and Schwalbe 2002). The Mother's Day fire in 1994, for example, consumed 340 acres (138 ha) of Arizona Upland desertscrub, after which 24% of saguaros and 73% of palo verdes had died by 2000 (Esque et al. 2004). Since fuel loads from perennial buffelgrass have the potential to be considerably higher than those from exotic annual grasses, fires in buffelgrass likely would have longer flame lengths, more rapid rates of spread, higher temperatures, and higher mortalities of native flora and fauna.

Researchers and land managers throughout the U.S.-Mexico borderlands have reported an urgent need for control methods for buffelgrass infestations because these infestations put sensitive native species and entire natural systems at risk. To meet this goal, the U.S. Geological Survey and the University of Arizona are working with Saguaro National Park to determine the physical and ecological characteristics of buffelgrass infestations, including fuel loads, and to compare commonly used buffelgrass eradication techniques. Buffelgrass, first found along the roadsides of Saguaro National Park in 1993, has expanded into dry washes and rocky slopes of the backcountry. Concern about buffelgrass throughout Arizona has led to the addition of buffelgrass to the state list of noxious weeds (Arizona Department of Agriculture 2006).

These infestations put sensitive native species and entire natural systems at risk.

Figures 2a (left) and 2b (right). Nonnative buffelgrass (*Pennisetum ciliare*) shown in detail. 2a shows a mature tussock; 2b a young tussock going to seed. USGS/TODD ESQUE

Study location and methods

To examine wildfire potential in areas infested with buffelgrass, in 2003 we began investigation of two areas of Saguaro National Park infested with buffelgrass: Panther Peak and Javelina Picnic Area. The two sites differ in geological parent material but are similar in aspect, and both are located on steep hillsides. We placed experimental plots in continuous stands of buffelgrass within these areas as part of a larger research project comparing control methods for buffelgrass.

Fires in buffelgrass likely would have longer flame lengths, more rapid rates of spread, higher temperatures, and higher mortalities of native flora.

We measured buffelgrass production in June of 2003 on 14 plots (4 at Javelina Picnic Area and 10 at Panther Peak), where buffelgrass was manually pulled from the ground. All plots were 10 x 10 m (~33 x 33 ft) in area. To estimate standing fuel loads, all of the buffelgrass was harvested from study plots by pulling it up by hand. Soil was removed by shaking and hitting the roots against rocks to the greatest extent possible. All of the grass was placed in plastic trash bags and weighed fresh to the nearest gram immediately. In the laboratory, individual plants were selected to represent the sizes of plants growing on the plots. Shoots were separated from roots and weighed separately to provide an estimate of the shoot-to-root ratio. Then samples were oven-dried to constant temperature to estimate moisture content of the buffelgrass plants. These data were used to provide estimates of the total amount of dry buffelgrass on each study plot and then extrapolated to estimate production as the average kilograms per hectare (lb/ac) plus or minus one standard error from the mean (± 1SE).

Results and discussion

The average amount of buffelgrass estimated on four plots at Javelina Picnic Area, and measured as dry aboveground mass, was 2,828 kg/ha ± 335 1SE (2,523 lb/ac ± 298 1SE), and at Panther Peak was 2,480 kg/ha ± 227 1SE (2,213 lb/ac ± 202 1SE). During the study, sites received less than 267 mm (10.5 in) of rain annually (National Oceanic Atmospheric Administration, 2002, 2003, 2004). The buffelgrass measured in June was very dry with only 3.6% water present in the samples on the plots.

Production estimates reported here are well above the minimum amount required to carry fire in arid areas. Furthermore, the fuel loads found in this study, along with the occurrence of fires fueled by buffelgrass in suburban areas of Arizona, Sonora (McNamee 1996; Búrquez-Montijo et al. 2002), and Texas, leave no doubt regarding the ability of buffelgrass to carry fire in infested wildlands of the Sonoran Desert (fig. 4).

The fuel loads we measured in Saguaro National Park are large enough to carry wildfire and present a threat to the resources managed by the park. The buffelgrass fuel loads on our study plots were found to be high in comparison to fine fuels from annuals (native and exotics combined) in desert biomes of North America, which range from zero to more than 700 kg/ha (624.9 lb/ac) (Beatley 1969; Halvorson and Patten 1975; Hunter 1991; Brooks et al. 2003; Esque and Schwalbe 2002). A minimum of 1,680 kg/ha (1,498 lb/ac) is required for American grasslands to burn and 3,000 kg/ha (2,677 lb/ac) of fuel is necessary for fire to carry in moist African savannas (van Wilgen and Scholes 1997; Hély et al. 2003; Stevens 2004), but it takes as little as 500 to1,000 kg/ha (446 to 892 lb/ac) of fuel for fire to carry in arid areas of Africa (van Wilgen and Scholes 1997). For comparison, we measured potential fuels on previously burned (at least one growth season after fires) and unburned sites at Saguaro National Park and found that red brome comprised about 43% of the fine fuels of annual plants and ranged between 0.25 and 2.3 kg/ha (0.22 to 2.05 lbs/ac) on previously burned and unburned sites, respectively.

Figure 4. An infested control plot at the Javelina Picnic Area study site at Saguaro National Park illustrates the large fuel load created by buffelgrass. USGS biologists estimate the total standing biomass of buffelgrass. USGS/TODD ESQUE

Other reasons for concern

Though some Sonoran Desert plants show the ability to regenerate or re-sprout after a fire (Wilson et al. 1994), many species do not. Regrowth from seed may require 20 years or more for a return to pre-fire vegetative cover conditions and an order of magnitude more than that to replace mature saguaro stands assuming the sites do not burn again during recovery (Rogers and Steele 1980; McLaughlin and Bowers 1982; Cave and Patten 1984; Esque and Schwalbe 2002). In contrast, buffelgrass can re-sprout quickly after a fire and may outcompete native plant species or even replace them. Buffelgrass encourages a fire cycle, which desert plants and animals are not adapted to. An increase in fire occurrence could lead to local extirpations of long-lived species like the saguaro, palo verde, and desert tortoise (fig. 5). Therefore, if buffelgrass persists in natural areas and continues to spread, these areas could convert from saguaro and palo verde desertscrub into grassy mesquite (*Prosopis* spp.) and acacia (*Acacia* spp.) savannas, similar in structure to the native areas of buffelgrass and, since North American Sonoran Desert plants are not adapted to fire, such a trend might lead to biological impoverishment similar to that observed where the exotic cheatgrass (*Bromus tectorum* L.) has degraded Great Basin Desert biomes (Billings 1990).

Figure 5. With the encroachment of buffelgrass, an increase in fire could follow, resulting in local extirpation of desert tortoises, like this one.

USGS/TODD ESQUE

High fuel loads from buffelgrass in otherwise undisturbed wildlands and the threat of subsequent fires illustrates the need for more information on these infestations and possible methods to control them. Based on current observations 1% of the desertscrub plant community at Saguaro National Park is infested with buffelgrass and those patches have the potential to grow rapidly, having more than doubled in area over the last four years (Danielle Foster, National Park Service, unpublished data). Land managers and scientists share a growing concern not only with buffelgrass but also with other exotic perennial grasses in the southwestern United States, such as fountaingrass (*Pennisetum setaceum*), which present similar threats from invasion and subsequent fire (Williams and Baruch 2000).

Although the general distribution of buffelgrass within national parks and ecological reserves in the United States and Mexico is known, the associated risks of fire in the urban-wildland interface, the threats to rare and protected species, and changes in biotic communities are not well documented. This information gap is hindering land managers in developing strategies to control this invasive species, as it is difficult to select areas in which to concentrate efforts without first knowing the extent of the problem.

Buffelgrass will continue to be a fire risk in urban areas and wildlands throughout its range in the United States and Mexico until comprehensive control strategies are developed and successfully implemented. The National Park Service, U.S. Geological Survey, and the University of Arizona have entered into a partnership to provide partial solutions to the buffelgrass problem. A research project has been developed to study the most cost-effective way to control buffelgrass with techniques that are allowable in national parks in addition to analyzing the costs and benefits of such activities both financially and environmentally. Preliminary information from this study was used to develop an integrated pest management plan at Saguaro National Park that included limited use of herbicides where necessary. The work initiated at Saguaro National Park has been expanded into surrounding natural areas and vacant lots in Pima County surrounding the national park. Local experts feel that the expanded control efforts are necessary for the removal of this invasive exotic grass. The methods employed to control buffelgrass appear to be effective on the patches where control measures have been applied. However, success depends on reducing the probability of re-invasion from nearby patches both on and off of parklands.

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VERP, LAC, VIM, VAMP:

A database that compiles user-capacity indicators and standards on the Web

By Michael Rees, Kerri Cahill, Matthew Safford, and Heather Rice

Background

User capacity, previously referred to as visitor capacity or carrying capacity, came to the forefront of public land planning in the 1970s. Concern over rising visitation in parks and the accompanying impacts on resources and visitor experiences led the National Park Service to focus increasing attention on user capacity. In 1992 the National Park Service began developing a visitor experience and resource protection (VERP) framework to address user capacities in the National Park System (Hof et al. 1994). The VERP framework has subsequently been applied in national parks across the country, including Acadia (Maine), Isle Royale (Michigan), Arches (Utah), Yosemite (California), and Haleakala (Hawaii) (fig. 1).

Although many people think of user capacity as a maximum number of people (i.e., a limit) for a given area, the concept is much more complex. Research has shown that user capacity cannot be measured simply as a number of people because impacts to desired resource conditions and visitor experiences are often related to a variety of factors that include not only the number of people but also types of activities, where people go, what kind of impacts they leave behind, what type of resources are in the area, and the level of management presence. In an attempt to acknowledge these variables, the National Park Service defines user capacity as the types and levels of public use that can be accommodated while sustaining the desired resource and social conditions that complement the purpose of the park.

Research has shown that user capacity cannot be measured simply as a number of people.

The premise behind VERP, and almost all of the other user-capacity management approaches (e.g., limits of acceptable change [LAC], visitor impact management [VIM], and visitor activities management process [VAMP]), is that with any use comes some level of impact that must be accepted. Furthermore, the public land management agency is responsible for determining what level of impact is acceptable and what actions are needed to keep impacts within acceptable limits. As such, user capacity frameworks incorporate the following key elements:

1. Identifying desired resource and social conditions for each area (management zone) of the park
2. Setting resource and social indicators (specific, measurable variables that will be monitored) and standards (a management decision about the minimum acceptable conditions for the indicators) for each zone
3. Monitoring the indicators to measure success in achieving and maintaining the desired resource conditions and visitor experiences
4. Taking management action when resource or social conditions are "out of standard" or are deteriorating and likely to become "out of standard"

Indicators and standards for user capacity may be part of many different types of plans including general management plans, comprehensive conservation plans, resource management plans, river plans (fig. 2), wilderness plans, trail plans, and visitor use management plans.

Figure 1. The National Park Service is developing a commercial services plan at Haleakala National Park (Hawaii) that will include user capacity indicators and standards. This scene depicts a popular park activity: enjoying sunrise from the summit of Haleakala volcano. Indicators and standards will help park staff manage heavy-use areas and commercial services such as bike and horseback-riding tours. USGS/JEFF MARION

Developing the database

In summer 2005, a team of NPS employees from the Denver Service Center, Alaska Regional Office, and Washington Office began developing a database of visitor impact–related indicators and standards. The purpose of the database is to compile and share existing information about indicators and standards that various land management plans and literature sources have used or suggested for monitoring user capacity. The NPS team developed the database as a tool to assist with the selection of indicators and standards. For example, when managers are trying to develop indicators and standards for an area, considering indicators and standards already suggested or selected for other areas with similar resources, use patterns, or visitor-use issues may be beneficial; however, managers must recognize that adopting the exact standard selected for another area may not be appropriate as standards should be based on the desired conditions of each area. Many other resources are available to managers who are developing indicators and standards, so this database is not the sole source of information. The database only addresses recreational impacts that have related indicators and standards in some type of plan or in the literature. Nevertheless, the database has collected information about indicators and standards developed by public land management agencies and the research community, including those from approved draft or final plans developed by the National Park Service (NPS), USDA Forest Service (USFS), and the Bureau of Land Management (BLM). All of these indicators and standards have been vetted through a planning process. Some indicators suggested or tested in research studies, though not put through a planning process, are also part of the database.

As of July 2006, more than 250 entries had been made into the database. However, the database is not exhaustive of all possible sources. It is a tool that can be continually updated with indicators and standards as they are collected from existing sources or are developed during new planning or research efforts.

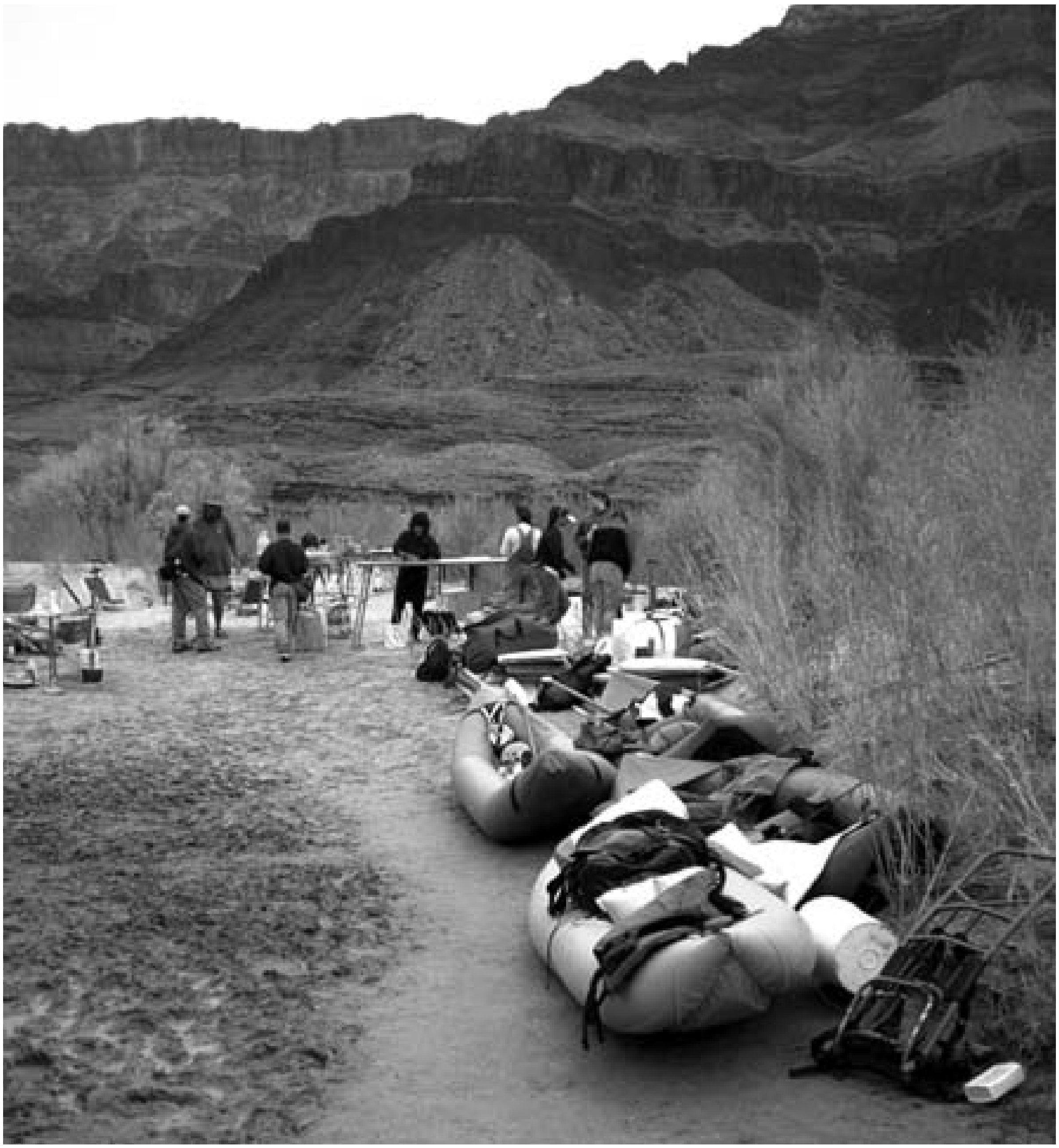

Figure 2. User capacity–related indicators and standards, including impacts to campsites, have been part of planning and management of the Colorado River in Grand Canyon National Park (Arizona) for many years. The Colorado River Management Plan (November 2005) includes a revised set of user capacity indicators and standards that will be implemented over the lifespan of the plan. USGS/JEFF MARION

Database structure

Table 1 shows a simplified version of three examples from the database. The examples, taken from National Park Service, Bureau of Land Management, and USDA Forest Service plans, show only the indicators and standards. However, the actual database has other fields, for example, sources of information for further inquiry. In addition, some fields are intended to allow the user to search various topics of interest and identify related indicators and possibly standards (if provided). For instance, users can search the database for indicators and standards related to topics such as loss of vegetation, vandalism of archaeological sites, and visitor-use volume/density. Furthermore, users can search the database for indicators and standards applicable to certain types of settings such as wilderness and backcountry areas, rivers, and developed areas. However, although many types of settings occur in parks, the database only includes settings for which the team found reported indicators and standards. Finally, users can search the database for indicators and standards related to types of facilities such as campsites, trails, roads, boat docks, and transit facilities.

For each indicator and standard entry, the following information is provided in the database (as available):

- Agency
- Unit (name of the public land management area)
- Type of document (e.g., approved plan, draft plan, or study)
- Name and date of document
- General issue category (general query field for major topics, e.g., "vegetation")
- Secondary issue category (general query field for more specific subtopic relating to "general issue category," e.g., "removal/loss of vegetation")
- Setting/resource type
- Facility/site
- Any additional clarification of the indicator or standard that might be helpful (e.g., suggestions for clarification of terms or units of measurement)
- General comments (e.g., notes on the application of the indicator, other applicable standards to different zones, or more information on the source or implementation of the indicator)

Using the database

Hosted by the Denver Service Center, the user capacity indicator and standards database is available at http://usercapacity.nps.gov. The database is read-only, searchable, and provides a user's guide, which should be read by first-time users (click on "Help"). For questions about the database, suggestions for changes or additions, or technical problems, users can send an e-mail to usercapacity@nps.gov.

Potential users

Although the database has been operational for NPS users since June 2006—when the Park Planning and Special Studies Division in Washington, D.C., announced it in "Inside NPS"—the authors have not tracked the use of the database. However, a large population of potential users exists, both within and outside the federal government. In addition to park planning teams and park staff, other likely users include other federal land agencies (e.g., USDA Forest Service, Bureau of Land Management, and U.S. Fish and Wildlife Service), state and private land managers, and researchers in educational institutions. The database became publicly available on the Internet in January 2007.

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Table 1. Sample fields of the user-capacity database

Agency	Name of plan	Indicator	Standard
BLM	Mt. Trumbull/Mt. Logan Wilderness Management Plan, 1990	Number of undesignated campsites per 500-acre area (203 ha)	No more than one undesignated campsite per 500-acre area (203 ha)
USFS	Hells Canyon National Recreation Area Comprehensive Management Plan, 2003	Number of human encounters per day on trails	80% probability of not more than one human encounter per day on trails
NPS	Shenandoah National Park Backcountry and Wilderness Management Plan, 1998	Number of informal/user-created trails to campsite	No more than two informal/user-created trails to campsite

Effects of prescribed fire on small mammals inhabiting Spotsylvania Court House Battlefield

By Cheryl Tanner and Gregg Kneipp

Introduction

The primary objective of prescribed burning at Fredericksburg and Spotsylvania County Battlefields Memorial National Military Park (Virginia) is to protect and preserve its cultural resources. Prescribed burning accomplishes this objective by controlling woody vegetation on earthworks and in fields and promoting the growth of native grasses, which are an essential element of the historical scenes. Native grass species include broomsedge (*Andropogon virginicus*), purpletop (*Tridens flavus*), little bluestem (*Schizachyrium scoparium*), poverty grass (*Danthonia spicata*), purple love grass (*Eragrostis spectabilis*), Indian grass (*Sorghastrum nutans*), and switch grass (*Panicum virgatum*). Burning maintains the historical view of the battlefields by suppressing forest succession and invasion of exotic vegetation. Other objectives of prescribed burning are reducing hazardous fuel accumulations around developed areas and along the park boundary, thereby reducing the potential for fire damage to park resources and adjacent lands and minimizing risks to employees, residents, and visitors.

Many studies have examined the effects of fire on small mammals but few have included the eastern harvest mouse (*Reithrodontomys humulis*; fig. 1, page 42), an abundant inhabitant of the fields in the park. The western harvest mouse (*R. megalotis*) and the meadow vole (*Microtus pennsylvanicus*; fig. 2, page 42), however, have received greater attention. Fire-related mortality among both *R. humulis* and *R. megalotis* adults has been documented as has that of nesting *R. megalotis*, which are particularly susceptible because of immobility (Erwin and Stasiak 1979). We assumed similarities between both species of harvest mouse. The extent of mortality depends upon the seasonal timing and intensity of the fire (Smith 2000; USDA Forest Service 2002). When nestlings are present, immobile *R. megalotis* pups suffer high mortality (Erwin and Stasiak 1979) because their nests are aboveground (Linzey 1998). Adult small mammals, including meadow voles and western harvest mice, often seek refuge in underground burrows to escape the heat of the fire. However, sometimes they cannot outrun or otherwise escape the heat and flames (Smith 2000; USDA Forest Service 2002; U.S. Geological Survey 2006). Western harvest mice generally remain in the habitat after the burn or quickly recolonize (U.S. Geological Survey 2006). Meadow voles, however, quickly vacate the burned area because of lack of cover and food. Moreover, peak densities of *M. pennsylvanicus* are not achieved until vegetation has regenerated enough to provide sufficient habitat requirements, typically two to five years after burning (Murphy et al. 2006; USDA Forest Service 2002; U.S. Geological Survey 2006). Though mortality is occasionally documented, the greatest impact to population densities of grassland small mammals is attributed not to direct mortality from the

Many studies have examined the effects of fire on small mammals but few have included the eastern harvest mouse.

Figure 1. An eastern harvest mouse is released after capture into the charred remains of its habitat at the McCoull House site in Spotsylvania Court House Battlefield.
NPS/CHERYL TANNER

Figure 2. Seeing a meadow vole, the species most affected by the prescribed fires at Fredericksburg and Spotsylvania National Military Park, has been a rare occurrence since prescribed burning began in 2004.
NATIONAL BIOLOGICAL INFORMATION INFRASTRUCTURE/JOHN J. MOSESSO

fire but to the relatively short-term (but significant) impact of habitat modification (USDA Forest Service 2002; U.S. Geological Survey 2006). The burning of vegetation removes the vital cover required for predator avoidance, destroys thick grasses through which small mammals construct their "runways" or travel corridors and build their nests, and affects food supplies.

Natural Resource Manager Gregg Kneipp began the use of prescribed grassland fires in Spotsylvania Court House Battlefield—one of four major battlefields preserved in the park—in February 2004. In accordance with the National Park Service's Inventory and Monitoring Program, investigators coincidently initiated a mammal inventory two days after the first annual burn. Under a cooperative agreement between Frostburg State University (Maryland) and the National Park Service, graduate students conducted the inventory over the next two years, which included several trapping sessions in the burned fields. However, because neither of these efforts focused on how the fire affected movement and mortality of the park's grassland residents, Kneipp initiated a pilot study before the third annual burn, which occurred on 28 April 2006 (fig. 3). The purpose of the pilot study was to investigate the effects of fire on small mammals. The small mammals under investigation in this study were species that had been discovered during previous research in these fields.

Though protecting and preserving cultural resources is the primary objective, knowing about the mortality and migration patterns of small mammals between open fields and forested areas during prescribed burns will provide valuable information concerning the ongoing management of these open fields. Using these research results park managers will be able to modify management practices for the benefit of both the cultural and natural resources in the park.

Methods

Sherman live traps were deployed at regular intervals (10 m [33']) in grids (3 m x 15m [9.8' x 49']) in two fields (McCoull House and Upton) for eight days before and eight days after the burn to monitor mortality and movement. Grid formations were used to facilitate calculations of population parameters (i.e., abundance, density, and movement distances), which are based on area. By contrast, transects do not allow for such accurate calculations because of their lack of effective area. However, traps were also placed in two transects 10 meters apart in the surrounding forest edges to document movement out of the field and into the adjacent forests. Traps were baited with a mixture of peanut butter, bird seed, and oats and checked at least once per day, depending on weather and capture trends. Before release, captured individuals were marked for recognition upon recapture. The demographic variables of age, sex, reproductive status, and weight of these mammals were recorded as was trap location for each capture in an attempt to measure movement distances.

Results

The only species of small mammal captured in fields during the 2006 study was the eastern harvest mouse. These animals were documented both before and after the burns in both fields but never in the forest edges, which indicates no movement out of the habitat. Data were insufficient to analyze pre- and post-movement distances, which would have been useful in determining how far species were forced to travel in order to find the resources necessary for their survival after habitat alteration. If mortality occurred, it was low, at least among non-nesting individuals. Because eastern harvest mice build their nests of grass aboveground, any young in these nests could have perished. Partially charred empty nests (fig. 4, page 44) were found after the fires, which indicate that they were either empty before the fire or exposed and depredated afterwards. Half of the mobile individuals caught before the burn were also caught after the burn in both fields (after/before: 4/8 and 1/2), indicating survival. Evidence of survival was also documented by 16 captures of new individuals in both fields after the burns, presumably in search of food in the absence or reduction of their normal forage. Upon release from capture, some harvest mice were observed entering underground burrows, which is likely how they survived the fire. Other factors that may have contributed to survival include the patchiness and relatively low intensity of the

Figure 3. A member of the prescribed-burn team, Rocky Schroeder (Prince William Forest Park), ignites the McCoull House site in Spotsylvania Court House Battlefield. NPS/GREGG KNEIPP

burn. Harvest mice were also documented after the Upton burns in previous years, which suggests that the population has survived three fires. Because very little fire research has addressed the effects on eastern harvest mice, this is valuable information.

Meadow voles weigh about 70g (2.5 oz) and require heavy cover and thick grasses for runway construction (Linzey 1998). Only two meadow voles were captured (in different fields) during the inventory of February 2004. The individuals were trapped on day 3 and day 8 after this first annual burn. Subsequent trapping in these particular fields has documented no meadow voles since that time. The presence of at least one vole in each burned field in 2004, the presence of elaborate and heavily used runway systems observable immediately after the 2004 fire, and the absence of the species ever since suggests that meadow voles were present and most likely abundant before the fire. These data suggest a reluctance of the species to return. Capture of one individual in a small, unburned portion of the 2006 McCoull House site, together with the absence of the species in burned areas, suggest that the annual removal of vegetation by fire most likely prevents the meadow vole population from rebounding in these fields. By contrast, eastern harvest mice, which are much smaller (average adult is 11g [0.4 oz]) and do not depend on runways, are less affected. The lone meadow vole from the unburned McCoull site may indicate either a very small remnant population from before the burns or the attempted return of the species to the fields. However, the latter does not seem likely due to the recent annual elimination of their habitat.

The annual removal of vegetation by fire most likely prevents the meadow vole population from rebounding in these fields.

Factors that may have contributed to survival [of the eastern harvest mouse] include the patchiness and relatively low intensity of the burn.

The white-footed mouse (*Peromyscus leucopus*; fig. 5) was the only species found in the forest edges. Fewer individuals were captured after the burn than before (3/10 and 6/12); however, because none were caught in the burned fields, mortality is not suspected. In addition, many traps in the forest edge were habitually closed by raccoons, thereby preventing entry by mice. On a side note, traps on the forest edge led to the unexpected but exciting incidental capture of a southern flying squirrel (*Glaucomys volans*), the first to be documented in the park.

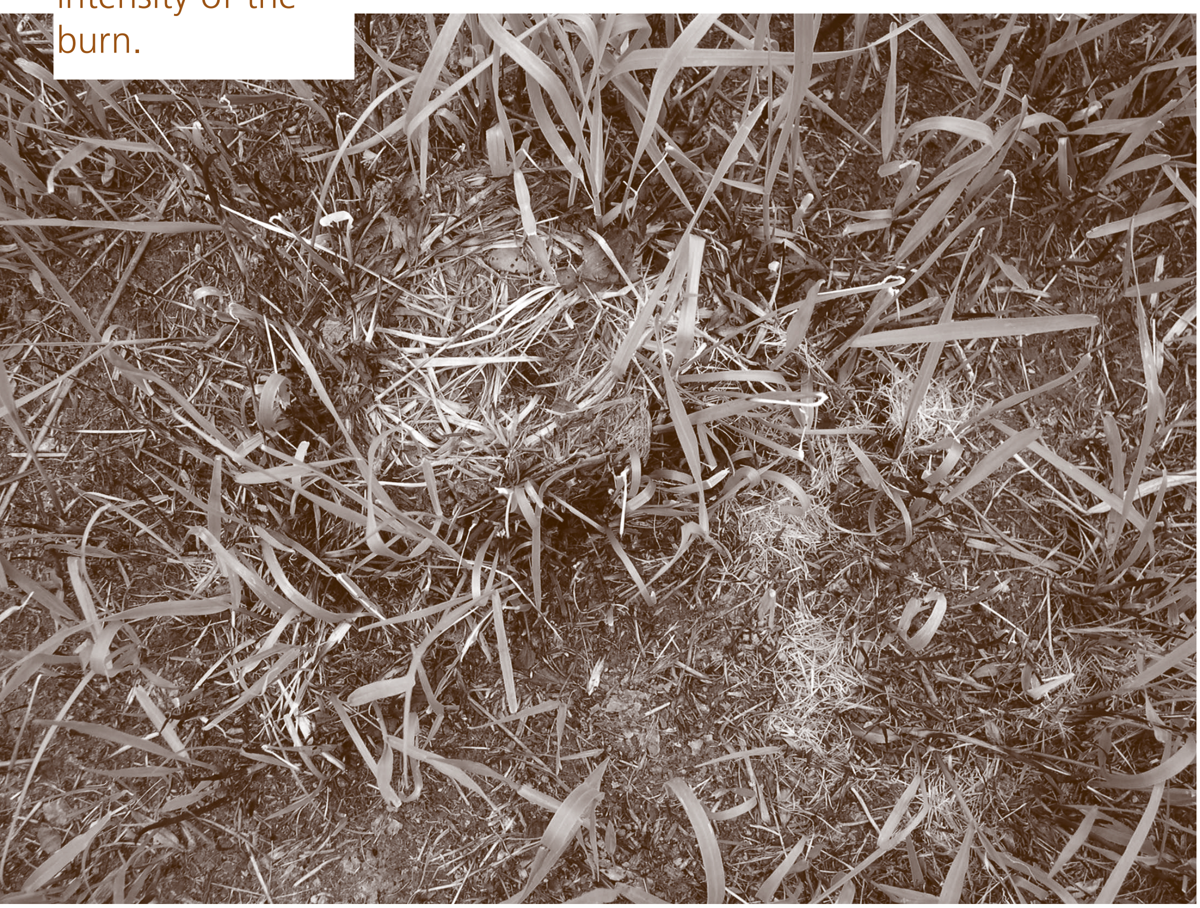

Figure 4. Several weeks after the 2006 prescribed burn, investigators located the partially charred remains of an eastern harvest mouse nest. NPS/CHERYL TANNER

Conclusions

In summary, the eastern harvest mouse population survived the fires and remained in its habitat. The meadow vole population disappeared after the first annual burn and has yet to recover three years later, probably as a result of persistent habitat modification. Forest-dwelling, white-footed mice seem unaffected by the grassland fires. Plans are to continue monitoring the effects of fire on small mammals during subsequent prescribed burns in order to elucidate any trends. Once fire has reduced woody vegetation in the fields, which is the primary objective, a two-to-three-year rotation in prescribed fire management will be implemented to reduce the effects on meadow voles. In the rotation, some fields would be burned in any given year while other contiguous fields would not. Hence, the unburned fields may provide the habitat necessary to sustain the local population; that is, voles from the burned fields could potentially relocate to the unburned areas that have had time to partially regenerate the cover necessary for survival.

Figure 5. White-footed mouse. NPS/CHERYL TANNER

Future research suggestions

Because insufficient capture data precluded the ability to statistically analyze movement distances before and after the fires, we suggest conducting a similar study over a longer period of time. We cannot determine movement distances without a sufficient number of individual recaptures. Also, the question arises as to where meadow voles go after the fire. A radiotelemetry study could determine movement patterns and refugia used after the loss of their habitat.

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An assessment of significant visitor experiences and preferences

in Kennecott National Historic Landmark

By Stephen C. Taylor, Peter J. Fix, and Megan Richotte

Figure 1. Rugged wilderness terrain and vast glaciers typify Wrangell-St. Elias National Park and Preserve: Mt. Blackburn viewed from near the town of McCarthy (left), McCarthy Creek sunset (middle), and Root (foreground) and Kennicott (background) glaciers separated by Donoho Peak. COPYRIGHT STEVE TAYLOR (3)

Introduction

At 13 million acres (53 million ha), Wrangell-St. Elias National Park and Preserve in south-central Alaska is the largest unit in the National Park System. The park, established in 1980, contains many of North America's largest mountain peaks and is known for its vast glaciers and rugged, remote wilderness (fig. 1). The park also contains the historic copper-mining town of Kennecott, which lies near the foot of the Kennicott[1] Glacier (fig. 2). The high-grade copper ore extracted from the Kennicott Valley was in great demand in the early 20th century: copper wire was needed to develop the electrical grid, and brass was used for steam-engine components and wartime munitions. As a result, Kennecott was a booming town during this period. However, upon depletion of the copper reserves, the town was quickly abandoned. More recently legislators, land managers, and the public have recognized the historic value of the mill town; as a result, in 1978 Kennecott became a national historic landmark. In 1998 the National Park Service purchased a large portion of the Kennecott mine property and structures (Gilbert et al. 2001). The structures, which date back to the early 1900s, are in various states of disrepair (figs. 3 and 4, page 48). Following the purchase, the National Park Service initiated a management plan for Kennecott and began historic preservation of the mill town's buildings to provide future generations the benefit of experiencing Kennecott's extraordinary mining history.

To better accommodate future visitors, park managers are in the process of developing an alternative transportation plan [which includes an interpretive component] for the Kennicott Valley.

Concurrent with this stabilization and rehabilitation effort, visitation in 2010 is projected to reflect a 20% increase over 2000 visitation statistics (National Park Service 2003). The expected trend is partly due to improved access to Kennecott and the Kennicott Valley. Improved access might entice a broader range of visitors. In years past, reaching Kennecott entailed driving the 60-mile (97 km), unpaved McCarthy Road, which is notorious for flat tires, and, upon reaching the end of the road, required crossing the Kennicott River by a suspended handcart and traversing a 5-mile (8 km) stretch of road by foot, bicycle, or shuttle. In 1997 a foot bridge spanning the Kennicott River replaced the adventurous handcart crossing. Also, the Alaska Department of Transportation and Public Facilities, which maintains the McCarthy Road, is considering upgrading the road (National Park Service 2006).

Access changes may not be the only factor contributing to future growth in visitation: a federally funded program, administered by the Alaska Travel Industry Association, designed to promote visitation to lesser visited parks such as Wrangell-St. Elias is being implemented (Ahern 2005; Bradner 2005). To better accommodate future visitors, park managers are in the process of developing an alternative transportation plan for the Kennicott Valley. The plan will include an interpretation component for historic Kennecott. Previous management documents call for stabilizing and preventing deterioration rather than fully restoring the mill town's buildings (Gilbert et al. 2001). However, park managers have yet to determine the types of supporting facilities and mechanisms for interpretation at Kennecott. While information exists regarding backcountry uses of park resources (Glaspell and Watson 2003), park managers were without information regarding visitors to developed areas such as Kennecott. They felt it

[1] "Kennecott" (mill town) is spelled differently than "Kennicott" valley, river, and glacier.

would be difficult to generate a viable plan without first knowing visitor preferences and expectations for Kennecott. Based on anecdotal evidence of visitor preferences with regards to development and information needs, park managers posed four questions:

- What are the significant visitor experiences?
- How can the significant visitor experiences inform us about what types of interpretation to provide (e.g., wayside exhibits, audio, or publications)?
- What does the visitor think is the significance of Kennecott?
- How do people get information about Kennecott prior to arriving?

This study responded to management needs by gathering baseline information on these questions. In this article, we focus on the first three questions. The study design assumed that visitors would differ in how they would like to see the mill town managed: some may desire restoration of the mill town with interactive interpretive facilities; others may feel such development detracts from the historic nature of the town and would prefer the solitude and stillness of its current "ghost town" state. The intent of the study was to identify current visitor demographics and trip characteristics and present these data in a format allowing managers the ability to predict how changes, such as improved access, might impact current visitors, and replicate the study in the future to assess whether visitor composition has changed.

This study responded to management needs by gathering baseline information [about visitor preferences].

Following the principles of "experience based management" (Manfredo et al. 2002), we hypothesized that discrete visitor groups or "experience types" would have differing reasons (i.e., motivations) for visiting Kennecott, preferences for facility development and management, and information needs. Experience types define the target audiences for different kinds of interpretation and the appropriate medium for providing such interpretation.

Following the principles of "experience based management"…we hypothesized that discrete visitor groups or "experience types" would have differing reasons (i.e., motivations) for visiting Kennecott.

Figure 2. Wrangell-St. Elias National Park and Preserve is known for its vast glaciers and rugged terrain. Here, visitors take a hike on the Root Glacier near the historic mill town of Kennecott. COPYRIGHT PETER FIX

Figure 3. The former train depot in Kennecott currently serves as a temporary visitor center. COPYRIGHT STEVE TAYLOR

Figure 4. The mill building stands prominently on the hillside in Kennecott. The National Park Service has deemed this building a high priority for stabilization. COPYRIGHT STEVE TAYLOR

Methods

To gather data on visitors and measure their motivations, we designed a four-page survey, which park staff administered on-site. We hypothesized eight motivations would be relevant to visitors to the Kennecott mill town and surrounding Kennicott Valley. Respondents were asked to rate the importance of 18 statements representing the eight motivations (two to three statements per motivation) (table 1) using a scale ranging from 1 (not at all important) to 5 (extremely important). The first step in analyzing the data consisted of checking the reliability of the statements. Reliability, measured by "alpha," is a gauge of the consistency in which respondents rate the two or three statements relating to a particular motivation.

Next, using a scale that ranged from 1 (strongly detracts from my experience) to 5 (strongly adds to my experience), with the center point (3) designating neutrality towards the management option, we gathered data regarding the impact that six hypothetical management options would have on visitor experiences. The six management options were (1) further stabilization of existing

Table 1. Hypothesized reasons and survey results of visitors to Kennecott mill town

Motivation	Statement	Mean	Reliability (alpha)
Exercise			0.945
	To get exercise	3.69	
	To feel good after being physically active	3.84	
Family/Companionship[1]			0.740
	To be with family	2.94	
	To bring your family close together	2.41	
	To be with friends	2.76	
	To be with others who enjoy the same things you do	3.19	
Learning			0.827
	To learn more about nature	3.47	
	To learn about the ecology of the area	3.59	
Nature			0.826
	To enjoy the sounds and smells of nature	4.15	
	To observe wildlife	3.91	
	To be in a natural setting	4.29	
Solitude			0.860
	To experience tranquility	3.82	
	To be away from crowds of people	3.86	
	To experience natural quiet	4.07	
History			0.845
	To be in a historical setting	3.85	
	To learn about the history of the area	3.97	
Creativity[2]			0.521
	To do something creative such as paint, sketch, or photograph	2.54	
	To gain a new perspective on life	2.65	

[1]Originally separate motivations—family and companionship are closely related and exhibited higher reliability when combined.
[2]Not included in the analysis because statements had low reliability (i.e., respondents did not answer two statements consistently).

historic structures, (2) an opportunity to explore the inside of more mill buildings, (3) an opportunity to explore the outside of more mill buildings, (4) the addition of signs and exhibits in Kennecott to explain its historical significance, (5) a headphone audio-guided tour of the mill town, and (6) a film telling the history of the Kennicott Valley. We take these statements to be indicative of preferences for management options.

In addition to motivations and preferences, we included questions regarding trip characteristics, activity participation, demographics, and the importance and quality of interpretation. Park staff conducted the survey from 11 June through 6 September 2004. During randomly selected time blocks, the survey administrator contacted every third visitor leaving the mill town who appeared to be over the age of 18 years; those over 18 were asked to complete the survey.

We grouped respondents into experience types using a K-means cluster analysis; this technique forms groups based on similar response patterns, in this case respondents' reported motivations. However, cluster analysis does not provide a definitive assessment of the correct number of groups to use for analysis, but the suitability of a cluster analysis can be judged by the F values for each input (F values are calculated as the ratio of variation between groups to the variation within groups for each input, in this case, each motivation). We ran trials of three, four, five, and six groups. We then linked experience types to preferences and investigated how, if at all, preferences among experience types differed.

Results

Of the 351 visitors contacted, 233 agreed to complete the survey, resulting in a response rate of 66.38%. We believe the lower than expected response rate (we expected approximately 75.00% to 80.00%) is due, in part, to visitors pressed for time to catch a shuttle that runs the 5 miles (8 km) between Kennecott and the Kennicott River. Non-response tests did not reveal any differences in gender, prior visitation, time of visit, number of people in their group, number of children present, and the preference towards further building stabilization. The lack of response on some of the questions resulted in a final sample size of 206 respondents. Based upon the sample design, the margin of error for this study is ±7.80% at the 95.00% level of confidence.

Employing a minimum alpha score of 0.7 to indicate acceptable reliability, the analysis identified seven of the eight motivations as being reliable (see table 1); creativity resulted in unreliable responses. The family and companionship motivations exhibited a higher reliability when combined leading us to conclude the two closely related motivations represented a social need. Individual statement scores within each motivation were averaged together by respondent to obtain a score for each motivation. These scores were then used in the cluster analysis procedure.

A cluster solution with five experience types best fit the data based on the F values for each motivation (exercise F = 74.15; family/companionship F = 18.82; learning F = 32.94; nature F = 34.79; solitude F = 25.39; history F = 100.22). The following descriptions outline each of the five experience types and provide an indication of each group's significant experiences. For descriptive purposes only, we associated names with each experience type based on important motivations and activity participation.

Experience Type 1—"Outdoor enthusiast" (16.02% of respondents)

Nature, exercise, and solitude were the three dominant motivations for this group. Learning scores were also quite high. This group had the highest percentage of backpackers, hikers, mountaineers, and climbers. While the majority within each of the other four groups rated history as their primary subject of interest, only 14.81% of Type 1 visitors noted history as their primary subject of interest. Type 1 visitors had a relatively high portion who stayed in the Kennecott Valley longer than two weeks.

Experience Type 2—"Multiple experience visitor" (31.55%)

These visitors ranked at the top of all six motivations (i.e., nature, learning, exercise, family/companionship, solitude, and history), illustrating that multiple aspects of the park are quite important to them. These visitors had high participation rates in exploring the mill town (82.81%), hiking (76.56%), nature walks (57.81%), and wildlife viewing (53.13%). Similar to the Type 1 visitors, this group tended to stay in the Kennicott Valley for longer periods than Type 3, 4, and 5 visitors.

Experience Type 3—"Non-interpretive historian day visitor" (22.33%)

History was the primary motivator for this group; solitude, exercise, and learning were rated with relative lower importance. Type 3 visitors had lower participation rates in backpacking, hiking, wildlife viewing, and nature walks than the other groups. Exploring the mill town was a very popular activity for this group (82.61%). Finally, this group had the shortest length of stay in the Kennicott Valley with 42.22% staying only one day.

Experience Type 4—"Generalist" (10.19%)

Type 4 visitors generally listed moderate importance for the six motivations; no motivation stood out as highly important. They were interested in sightseeing, wildlife viewing, fishing, camping, and nature walks. Exploring the mill town and attending interpretive programs were not high priorities. Type 4 visitors were primarily interested in the subjects of history (60.00%) and geology (25.00%).

Experience Type 5—"Interpretive-focused mill town visitor" (19.90%)

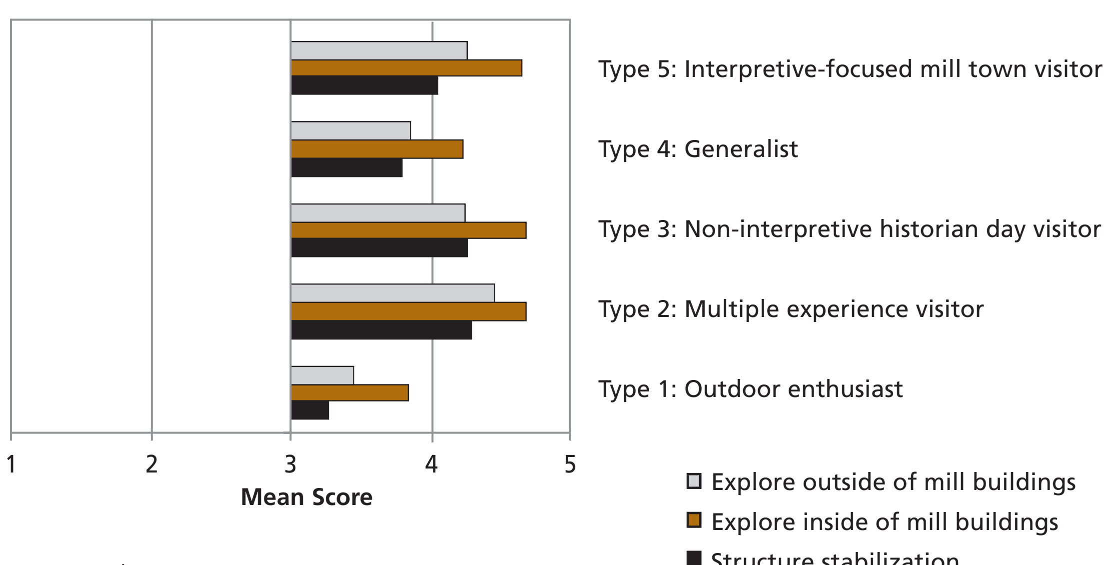
This group was highly motivated by history, nature, and solitude to visit the park. Exercise and family/companionship were of very low importance to them. They had the highest participation rates in interpretive programs (41.46%) and exploring the mill town (85.37%) of all five groups. Sightseeing, wildlife viewing, and hiking were other popular activities for this group. Backpacking was uncommon among Type 5 visitors. The historical nature of the park was very important to this group: 41.67% listed exploring the mill town as their primary activity, and 70.59% rated history as the subject of most interest.

Preferences for Management Options

Of the six management options, three represented actions regarding facility development in Kennecott. All five experience types showed support for these management options (fig. 5). However there was an apparent lower rating of "further stabilization of the mill buildings" than the "opportunity to explore the inside of more mill buildings." Taking into account the park's current strategy to ensure visitor safety by stabilizing buildings prior to opening them for exploration, we decided to further investigate these incongruous results by comparing the means of these two management options within each group. All groups except Type 4 ("generalist") showed, on average, lower support for building stabilization than for exploring inside buildings (P =.088 for Type 4 and P <.001 all other groups). It is likely that many visitors were strongly in favor of more opportunities to explore inside the buildings because at the time the study was conducted, the old mill building was virtually the only structure open to the public. The old hospital, which has been partially washed away by the nearby National Creek, was also open to the public for exploration, although it is located off the main path and is well hidden by a stand of dense brush. Visitors were not able to freely explore the mill building; access was limited to a fee-based, guided walking tour. The results suggest that visitors may not have associated the dangerous state of disrepair of many of the buildings with access into the buildings. An education program illustrating how further stabilization of the mill buildings could lead to more exploration opportunities might increase visitor awareness of the necessity of the stabilization process.

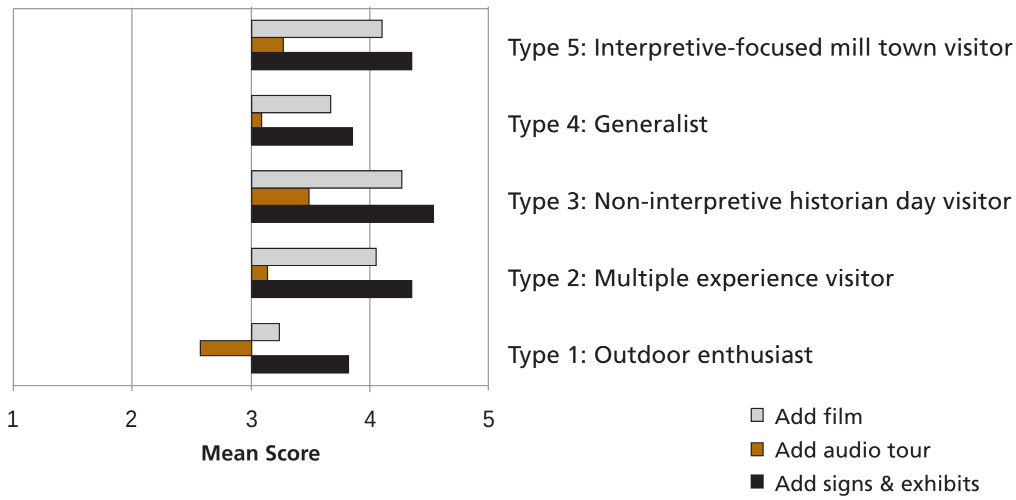
The other three management options involved information services or products to increase the quality of visitor experiences. All five experience types supported the addition of signs and exhibits in Kennecott and a film about site history (fig. 6, page 52). Alternatively, no group felt strongly for or against the addition of audio guided tours. Type 1 visitors ("outdoor enthusiasts") felt the addition of an audio guided tour of the mill town would detract, albeit slightly, from their experience. One possible explanation is that Type 1 visitors value the Kennicott Valley for its wilderness recreation opportunity over its historical aspect and might see audio guided tours as unwanted commercialization or technology that does not fit the wilderness setting. The addition of signs and exhibits at Kennecott appears to be an alternative that visitors find less intrusive to their experience (fig. 6). Hence, park managers striving to provide high quality experiences for all visitors might consider erecting signs and exhibits in the mill town rather than providing an audio guided tour.

Figure 5. Preference scores for facility development options by experience type



Response scale:
1 = Strongly detracts from experience, 3 = Neutral, 5 = Strongly adds to experience

Figure 6. Preference scores for interpretation options by experience type



Response scale: 1 = Strongly detracts from experience, 3 = Neutral, 5 = Strongly adds to experience

Discussion

Identifying important reasons for visiting a park, choices of activities in which to participate, and preferences for site development and management has utility for planning decisions in several ways. First, it can provide an understanding of how different visitor types may react to potential or proposed management actions. When addressing a resource concern, park managers can analyze various options to identify which alternative will be most acceptable to all groups. Second, the technique can provide guidance for how to best match facilities to the needs of visitors. Often, the types of experiences desired by visitors can help determine the appropriate facilities to provide. For example, those seeking to learn about the history of an area may feel that an audio guided information service is an acceptable method to satisfy their desired experience. By contrast, those seeking to truly "experience" history might object to such a service, citing that it would detract from the historical setting.

The research techniques used in this study are applicable in any park setting where multiple user groups seek different significant experiences. In a given setting, experience types will likely differ in character based upon the prominent resources of the park. For example, if we conducted a similar study of visitors to Denali National Park—a park famous for its abundant wildlife—we would expect a group more strongly motivated by outcomes associated with wildlife viewing to emerge from that data. Finally, including a comprehensive set of questions to quantify motivations for visiting a particular setting provides an extremely important basis for identifying visitor groups.

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Speedy conversion of science into management at Rocky Mountain National Park

By
Terry Terrell
and
Judy Visty

Applying science to park management at Rocky Mountain National Park, Colorado, happens quickly, sometimes the same day staff becomes aware of research results. Generally speaking, Natural Resource Challenge programs and universities are working together to develop and apply science-based management information throughout the National Park System; the following examples from Rocky Mountain National Park demonstrate that inserting good science into park practices does not need to take years.

Figure 1. Native penstemon species are very important to the biodiversity of Rocky Mountain National Park. This beardless sidebells penstemon (*P. virgatus*) is common throughout most of the park at mid-summer, while Harbour's beardtongue (not pictured) is rare. Both species are threatened by invasive, nonnative Dalmatian toadflax (page 54). NPS

Using a biocontrol to fight exotic species

Some species of native penstemon (e.g., *Penstemon virgatus* and *P. whippleanus*, fig. 1) are among the most common wildflowers in Rocky Mountain National Park. By contrast, the endemic Harbour's beardtongue (*P. harbourii*) is listed as vulnerable by NatureServe, a nonprofit conservation organization and leading source of information about rare and endangered species and threatened ecosystems. These flowering plants, in addition to making significant contributions to visitor enjoyment, are important to park biodiversity. The exotic invasive species Dalmatian toadflax

(*Linaria genistifolia* spp. *dalmatica*, fig. 2) and yellow toadflax (*L. vulgaris*) are threatening native penstemon. Though biocontrols such as *Calophasia lunala* (a leaf- and flower-eating moth), *Eteobalea intermediella* (a root-boring moth), and *Mecinus janthinus* (a stem-boring weevil) are available to fight these pest species, until recently park staff did not know what the impact of such controls would be on the native penstemon population in Rocky Mountain National Park. In particular, as members of the same plant family Scrophulariaceae (figwort), toadflaxes are closely related to native penstemon, suggesting that predators of one may also attack the other. A disastrous outcome would be introducing a biocontrol that attacked both native penstemon and nonnative toadflax.

In order to test the host specificity of the biocontrol organisms in a controlled location, the Continental Divide Research Learning Center, Rocky Mountain Cooperative Ecosystem Studies Unit, and University of Colorado–Boulder provided cooperative funding for graduate student Nehalem Breiter to use penstemon salvaged from the recent widening of Bear Lake Road, a main transportation corridor in the park (fig. 3). Breiter placed the salvaged plants in a greenhouse environment at an off-park location and exposed them to the biocontrol insects. This study determined that the biocontrol organisms did not attack native penstemon. Because the park's invasive species management plan permits the use of biocontrols when proven not to threaten native biodiversity, park resource managers approved the use of the stem-boring weevil within one week of receiving the researcher's final report (Breiter 2005).

Changing prescribed burning practices to preserve rare communities

Researchers from the University of Northern Colorado reported that at the current level of ungulate herbivory (as many as 3,500 elk inhabit the park and Estes Valley during the summer—a historical high), prescribed burns in shrub communities prevented the regeneration of the globally rare steppe shrub communities in the park (Nesvacil 2003). Additionally, as lands east of the Continental Divide undergo rapid development in Colorado, shrublands, which are primary habitat for nine species of birds, are being lost. Graduate student Kelly Nesvacil presented these findings at a staff seminar. Park resource and fire managers met immediately after the presentation and changed prescribed burning practices in order to protect shrub communities in the park.

Closing backcountry campsite to protect threatened species

The boreal toad (*Bufo borealis*), like many amphibian species, has suffered dramatic declines in the last decade and is a threatened species in Colorado. The same day that a researcher from the U.S. Geological Survey (USGS), Erin Muths, discovered the toads spawning in a pond adjacent to a backcountry campsite, park managers closed the campsite and relocated campers; thereby, disturbance to the pond and adjoining areas was limited.

> Park staff did not know what the impact of [bio]controls would be on the native penstemon population.

Figure 2. As a result of research at the University of Colorado–Boulder, Rocky Mountain National Park now has a biological control available to fight Dalmatian toadflax, pictured here.

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Figure 3. Researchers used samples of native penstemon species salvaged from the widening of Bear Lake Road in Rocky Mountain National Park in 2004–2005 to test biocontrol insects for host specificity.

NPS

Testing for mercury in fish

During air-quality studies, USGS researchers detected mercury in snowpack adjacent to remote, high-elevation lakes in the park. These results sparked curiosity as to whether investigators had ever analyzed fish in Rocky Mountain National Park for mercury. A search of records turned up previous analysis of fish tissue in 1999 (U.S. Geological Survey, D. P. Krabbenhoft, personal communication, January 2004) that showed total mercury wet-weight concentrations averaging between 0.01 and 0.12 parts per million (ppm). However, individual trout had concentrations as high as 0.15 ppm, that is, about half the amount of EPA guidelines (i.e., 0.3 ppm) for mercury in fish tissue intended for human consumption. Because some lakes receive more precipitation and the surrounding topography favors drainage into some lakes, potentially more mercury is deposited; therefore biologists surmised that fish with higher concentrations of toxic methyl mercury might be present in park waters. The 1999 analysis report and follow-up discussion triggered a rapid collaborative effort among the U.S. Fish and Wildlife Service, U.S. Geological Survey, and park staff to conduct systematic fish surveys. Analysis of tissue did not identify any fish that exceeded consumption guidelines; hence, park managers have not issued any mercury advisories. Nevertheless, scientists are continuing analysis to determine general patterns regarding mercury accumulation in high-elevation lakes.

Removing deer with chronic wasting disease

Researchers from the Colorado Division of Wildlife and park staff have been using tonsillar biopsies since 2002 to test for chronic wasting disease in deer. They collar tested animals and remove from the herd the deer that test positive. Chronic wasting disease, like mad-cow disease, is caused by abnormal proteins called prions. Although studies do not indicate that the disease can be transmitted to humans, eating meat from infected animals is not recommended. The National Park Service classifies the disease as nonnative, and park staff is cooperating with the State of Colorado in limiting its spread. Preliminary results indicate this "test and cull" method may be helping to reduce prevalence of the disease among mule deer in the Estes Park–Rocky Mountain National Park herd. However, investigators will not complete the study until spring 2007 (Colorado State University, M. K. Watry, personal communication, December 2005).

In a related study, data from collared animals also revealed that migrant deer may play a more significant role in spreading the disease than dispersing deer, at least in north-central Colorado. For example, about half of the mule deer that winter in the Estes Park area (adjacent to the national park) migrated from winter to summer range, but only 2% actually dispersed (left the area and did not return) (Conner and Miller 2004).

Results from both the ongoing "test and cull" and deer-movement studies have provided information that is useful in predicting the likely spread of chronic wasting disease and perhaps controlling local outbreaks where they occur.

Facilitating management actions

During the often frenetic, day-to-day operations in parks, research reports may come in and get filed without receiving the attention needed to turn results into action. At Rocky Mountain National Park, staff uses several mechanisms to ensure that research informs decision making.

A park staff member serves as a project shepherd, making a special point to be involved throughout the duration of a study and taking necessary post-project action.

An informal presentation brings key people together to discuss results with the researcher. This is especially valuable when the project investigator is a graduate student who may be moving out of the area.

Sometimes the research partner personally requests a management action such as the closure of an area to visitors. Having a designated point of contact for researchers helps ensure that recommendations are addressed and appropriate action can be taken.

Having a designated point of contact for researchers helps ensure that recommendations are addressed and appropriate action can be taken.

Now that investigators' annual reports (https://science1.nature.nps.gov/research/ ac/ ResearchIndex) can be exported into file formats that are easy to share electronically (e.g., PDF), staff entering these reports into the system can forward concise documents to other interested staff. This approach is very helpful in providing a manageable amount of information about multiple projects.

Rocky Mountain National Park hosts a biennial research conference during a relatively quiet time of the year, thereby encouraging staff participation. The conference focuses attention on project results and is also a forum for sharing science-based information with the public and media, alerting stakeholders to the need for management action.

The park's electronic morning report includes research report citations along with information about obtaining the full report (e.g., in the park's library).

Based on the number of research permits issued at Rocky Mountain National Park, the park's research program has nearly doubled over the last six years. Founded in 2001 as part of the Natural Resource Challenge, the Continental Divide Research Learning Center, hosted in Rocky Mountain National Park, handles the task of improving information transfer of research results. Research learning center staff has found that using the aforementioned routes to share information is extremely useful. Many parks have these types of communication mechanisms already in place. Hence, ensuring that critical research results turn into swift, beneficial actions may be as simple and feasible as coordinating and applying these already established communication strategies.

The Continental Divide Research Learning Center … handles the task of improving information transfer of research results.

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Using tree-ring dating
in hedgerow management at Homestead National Monument of America

By Richard K. Sutton

A few minutes past midnight on New Year's Day 1863, when the Homestead Act of 1862 took effect, Daniel Freeman filed one of the first claims at the Brownville, Nebraska, Land Office (Land and Community Associates 2000). He wisely selected his 160-acre plot, which is now part of Homestead National Monument of America, for its wood and water—resources often lacking on the prairie (Dale 1948). However, the wooded banks along Cub Creek, west of Beatrice, Nebraska, did not have enough timber for all his needs (e.g., buildings, fuel, and wooden fences). Hence, Freeman, like so many prairie settlers (Baltensperger 1987), adopted hedge culture as a way to demarcate property boundaries, control livestock, block wind, and provide fuel wood and fence posts (Hewes and Jung 1981). The historic Osage-orange (*Maclura pomifera*) hedgerow planted by Daniel Freeman is one of the few structures left from the time of his original land claim (Sutton 2005). One-half mile (805 m) of Osage-orange lines the southern boundary of Homestead National Monument of America and creates a backdrop to the nation's second oldest tallgrass prairie restoration (fig. 1). Managed by the National Park Service, the 244-acre (99 ha) national monument celebrates and preserves the history of settlement of the Great Plains during the era of the Homestead Act (1863–1986).

> Many prairie settlers … adopted hedge culture as a way to demarcate property boundaries, control livestock, block wind, and provide fuel wood and fence posts.

Earlier settlement of the Prairie Peninsula in Illinois had spawned the use of hedges featuring Osage-orange (fig. 2, page 58). This tough, thorny tree was collected by Lewis and Clark near St. Louis, Missouri, but was more common to northeastern and southwestern Arkansas, northwestern Louisiana, and southeastern Oklahoma. Touted by pioneer planters in Illinois, Osage-orange grew quickly on dry, windy sites and responded to hedging in which sprouts are encouraged then pruned and woven into an impenetrable barrier using a technique called plashing (Overman 1858). Billed as a plant to make "horse-high, bull-strong, and pig-tight" hedges, the likeness of Osage-orange to the barbed wire of the 1880s in Illinois—where it was invented, patented, and manufactured—is no mere coincidence. Ironically, many Osage-orange hedgerows continue to provide rot-resistant posts onto which barbed wire is strung.

Park managers speculate that the age of the hedgerow at the national monument is about 135 years old. However, the original planting date is unknown, as are Freeman's actual uses and management of the hedge. The surmised age of the hedge suggests that the hedgerow trees may be reaching the end of their lifespan, though at least one Osage-orange specimen in Virginia, growing more than 1,000 miles (1,609 km) from its native range, is thought to be more than 300 years old. Loss or decline of the hedgerow represents an unacceptable historical and visual impact to the

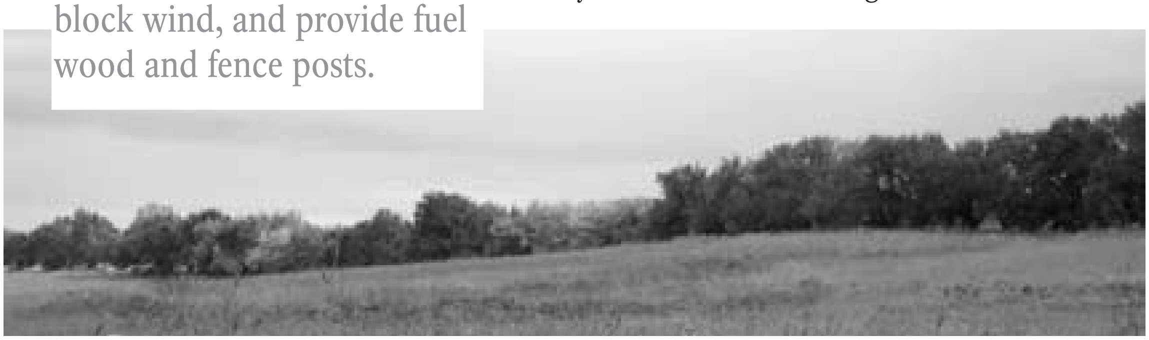

Figure 1. Osage-orange hedgerow provides a historically significant backdrop for the tallgrass prairie restoration efforts at Homestead National Monument of America.

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site and runs counter to the management policy to preserve and interpret these homestead resources for future generations. Hedgerows still grow nearby, but each year brings losses as a result of widening of roads and fields by county road engineers and farmers who covet the space that hedges occupy in the rural landscape (Sutton 1985).

Loss or decline of the hedgerow … runs counter to the management policy that is to preserve and interpret these homestead resources for future generations.

Based on recommendations of a cultural landscape report (Land and Community Associates 2000) and to verify the age of the hedgerow for the purpose of interpretation and cultural resource management, park managers contracted the University of Nebraska–Lincoln to study and draft a plan that (1) reviewed and analyzed the recommendations in the cultural landscape report; (2) focused on preserving the historic hedgerow's structure; (3) inventoried individual plants in the hedgerow to ascertain their condition, size, age, and location; (4) proposed a tree monitoring protocol and timetable; and (5) examined impacts of adjacent land use. The study recommended procedures, practices, and scheduling of hedgerow maintenance and proposed alternatives that addressed ecological and sustainable management. The study also identified potential interpretation of the hedgerow and opportunities for its connection to a proposed new heritage center.

The study recommended procedures, practices, and scheduling of hedgerow maintenance and proposed alternatives that addressed ecological and sustainable management.

Figure 2. Prairie settlers used the thorny Osage-orange for live fencing, posts, and fuel. Pawnee and Omaha-Ponca prized it for bows (bois d'arc), arrows, and war clubs. Though inedible to humans, squirrels eat the fruit, and deer browse the leaves and young shoots until deterred by thorny stems. COPYRIGHT RICHARD K. SUTTON

Methodology

The researcher selected tree coring and dendrochronology as the methodology to address park management needs. The difference in seasonal growth of most woody plants leaves a concentric pattern of annual tree rings, which can be counted to determine the specimen's age. Dendrochronologists have conducted tree-ring dating for about 80 years, during which time the method has developed into a sophisticated archaeological and ecological tool (Stokes and Smiley 1968) that reveals general precipitation and temperature trends (Briffa et al. 2002), periods of drought (Dean 2001), and fire histories (Allen et al. 1995; Swetnam et al. 1999).

During the inventory of individual plants in the hedgerow, the researcher selected several large-diameter specimens, which likely represented some of the oldest trees. Six trees were sampled with a 12-inch increment borer. The use of the borer causes no harm to the tree because growth of the tree's cambium layer closes in the small-diameter hole within a year or two. However, one mishap occurred while taking sample 3: the bore tube snapped off inside the tree abruptly concluding sampling. Osage-orange wood, even when green, is extremely hard, and this contributed to the damaged bore tube. The large diameters of the sample trees coupled with the difficulty of tapping all the way to the trees' center piths led to incomplete (but useable) core samples.

After extraction, core samples were dried and glued into grooves cut into blocks of wood (fig. 3). The blocks/cores were then sanded with very fine sandpaper to reveal the annual growth rings. To make the best estimates of tree age, each growth ring was measured, and dated backward from 2004, the year of sampling. Counting and measuring was done on 600 dpi (dots per inch) scanned images of each sanded core. Ring width was averaged for the sample and used to extrapolate and predict the number of annual rings that would lead to the center of each sample tree. This method does have some problems: trees have a growth curve that may be faster in young trees; that is, the young growth rings tend to be larger than the older ones. The estimate did not account for this and represents a straight line rather than an S-shaped growth curve.

Results

Each sample was analyzed with a test of homogeneity of variances using Bartlett's test (SAS 1985). A common scientific practice to establish a rough estimate of a tree's age is dividing half of a tree's diameter by the average

Figure 3. The researcher analyzed five cores from large Osage-orange specimens to estimate the age of the hedgerow. Coring of sample 3 ended abruptly when the bore tube snapped off in the hard Osage-orange wood. COPYRIGHT RICHARD K. SUTTON

yearly ring width then subtracting that number from the year of sampling. The mean tree-ring size was not significantly different across samples ($P > .895$), so the tree-ring widths were pooled and used for calculating age estimates (table 1). The pooled tree-ring width mean was 0.1688 inches (4.29 mm). The mean width of the annual rings of sample 1 was 0.1688 inches (4.29 mm); for sample 2, the mean width was 0.1776 inches (4.51 mm). The mishap during coring of sample 3 resulted in no data. For sample 4, the mean width was 0.1768 inches (4.49 mm), 0.1776 inches (4.51 mm) for sample 5, and 0.1692 inches (4.30 mm) for sample 6.

Interpretation

The core samples establish that the sampled trees postdate the original plantings of Osage-orange (table 1). Simply put, the present hedgerow consists of at least second-growth stump sprouts. This interpretation is supported by NPS photos taken in the early 1940s, which show thin, short wisps of suckering Osage-orange trees in a spindly hedge with large gaps (fig. 4, page 60). The data suggest that all or some sections of the hedge were cut for fence posts just prior to the National Park Service acquiring the land in 1936. This interpretation corresponds to the practice of harvesting trees during the Great Depression, which was common in Gage County, where the national monument is located.

At several places in the hedgerow, large Osage-orange trunks spring from the periphery of old stumps (fig. 5, page 60). The larger of these stumps range from 1.5 feet to 2.0 feet (0.5 m to 0.6 m) in diameter, which is about the size of the larger live trunks within the hedge, which sprouted between 1934 and 1938 (table 1). The stumps are most likely the remnants of Freeman's original Osage-orange plantings. Because Osage-orange wood is rot resistant, stumps may have survived many years past harvest. The only method to examine the stump's age would require digging out the stump and carefully sawing a section through it. This destructive sampling would not be easy because Osage-orange wood of that age would resist most saws. Furthermore, digging out a stump would damage the stump's roots and the intertwined roots of neighboring trees, which are most likely alive with the potential to resprout and should be preserved.

Application to management plan

The hedgerow is a significant social, historical, and cultural feature at Homestead National Monument of America. Settlers adapted and adopted plants, animals, technology, and social systems to survive and prosper on the Great Plains. Osage-orange hedgerows are one of the best examples of the integration of all of these accommodations. Though "historical," that is representing a moment in time, hedgerows cannot simply be preserved in a static state but must also be managed as a dynamic,

Table 1. Estimated ages of selected Osage-orange stems at Homestead National Monument of America

Tree	Diameter / 2 inches (mm)[1]	Estimated date of sprouting[2]	Age in 2004
Sample 1	11.64 (295.66)	1935	69
Sample 2	11.82 (300.23)	1934	70
Sample 3	No data		
Sample 4	11.12 (282.45)	1938	66
Sample 5	8.64 (219.46)	1953	51
Sample 6	8.10 (205.74)	1956	48

[1]Rounded to nearest 100th.

[2]Based on pooled tree-ring width (0.1688 inches [4.29 mm]).

living resource. Individual trees are managed to bring about the favorable growth, development, visual character, and interpretation of the hedge. The hedgerow serves as wildlife habitat and a corridor, connecting bottomland and upland, and provides erosion and wind control. These are benefits that most often fall under the province of natural resource management. In this case, the hedgerow serves multiple purposes and functions: it is part of a cultural landscape requiring natural resource management to preserve and science to understand.

Because Osage-orange is not a native plant, like those found in the monument's woodlands and prairies, the hedgerow's cultural and historical status assumes the primary reason for its management. The hedgerow planting is next to a prairie restoration area (not unplowed native prairie). To the south of the hedge is crop ground that has been in production since at least the time of Freeman's homestead. Osage-orange is not reproducing at a problematic rate, and neighbors of Homestead National Monument of America do not consider it a pest. In actuality, natural resource managers have a bigger problem with native wild plum (*Prunus americana*) and native smooth sumac (*Rhus glabra*) invading the prairie than with Osage-orange. Recently the Friends of the Homestead National Monument of America were instrumental in gaining funds for the purchase of a conservation easement along the south side of the Osage-orange hedgerow. This will allow control of the invasive, native eastern redcedar (*Juniperus virginiana*) now growing there and obviate hedge management difficulties.

The management plan recommends that the hedgerow be managed in permanently marked "units." Because harvesting has occurred in the hedgerow in the past, most likely in clear-cut sections (see fig. 4), use of sectional clear-cuts as management units would not be contrary to the historic scene. Moreover, dividing the hedgerow into management units would bring flexibility to planning yearly work and help identify and prioritize the uses, locations, and timing of hedging activities. The management plan proposes three spatial and temporal schemes for the preservation, rehabilitation, and scheduled maintenance of the historic hedgerow:

Scheme 1: Infill and rejuvenate

The simplest and most straightforward scheme for managing the hedgerow would be to propagate specimens and replant to fill its gaps, cut and rejuvenate certain key plants, and allow the hedge plants to continue growing and become trees. This management technique is now used with most hedgerows in southeastern Nebraska and eastern Kansas. While relatively simple to accomplish and less labor intensive over the long term,

The hedgerow serves as wildlife habitat and a corridor, connecting bottomland and upland, and provides erosion and wind control.

Figure 4. The National Park Service purchased Daniel Freeman's homestead in 1936. In 1941, when this photo was taken, the Osage-orange hedgerow was spindly and full of gaps. The lower, shrubby vegetation to the left of the largest gap (near the center of the photo) shows regrowth after cutting for posts several years earlier. NPS

Figure 5. The Osage-orange hedgerow at Homestead National Monument of America is a multifunctional resource with primarily cultural but also ecological values. The stump in the photo represents Freeman's original planting and serves as evidence of past harvesting activities. The tree trunks, which postdate the stump, represent sprouting that occurred around the time of the Great Depression, prior to NPS purchase of the site. COPYRIGHT RICHARD K. SUTTON

this scheme misses the opportunity to depict and interpret the hedgerow as a historic structure in the context of Freeman's homestead in particular and many eastern Great Plains homesteads in general.

Scheme 2: Mimic 1870s management techniques

One possible way to address the need for interpretation and facilitate long-term management of the hedgerow would be to follow Scheme 1 for most of its length, but establish a section of hedge using 19th century techniques of cutting, pruning, and plashing near the new homestead heritage center.

Scheme 3: Integrate management and expand interpretation

A more ambitious plan would be to focus a portion of the proposed homestead heritage center's interpretive space and adjacent landscape on the theme of hedgerows and their suitability to settling the eastern Great Plains. Scheme 3 would be in addition to Scheme 2.

Because Osage-orange will resprout after cutting, management units of the hedgerow can be cut and the harvested trees readily sold for posts. This sustainable harvesting is in keeping with previous techniques of management by the Freeman family during the Great Depression (see fig. 4). Also, such management techniques of Osage-orange hedgerows are in keeping with active interpretation in a living history setting.

Summary

The management plan for the Osage-orange hedgerow at Homestead National Monument of America incorporates a blend of natural and cultural resource considerations, where natural resource management can help achieve cultural goals. Ascertaining the age and growth rate for the hedgerow allowed the researcher to propose a dynamic rehabilitation and management plan that can be interpreted to the public. Such interpretation is important in explaining that Osage-orange hedgerows had a distinctive place in the 19th and 20th century agricultural landscape of the Great Plains, while still providing aesthetic, ecological, and economic benefits in the 21st century.

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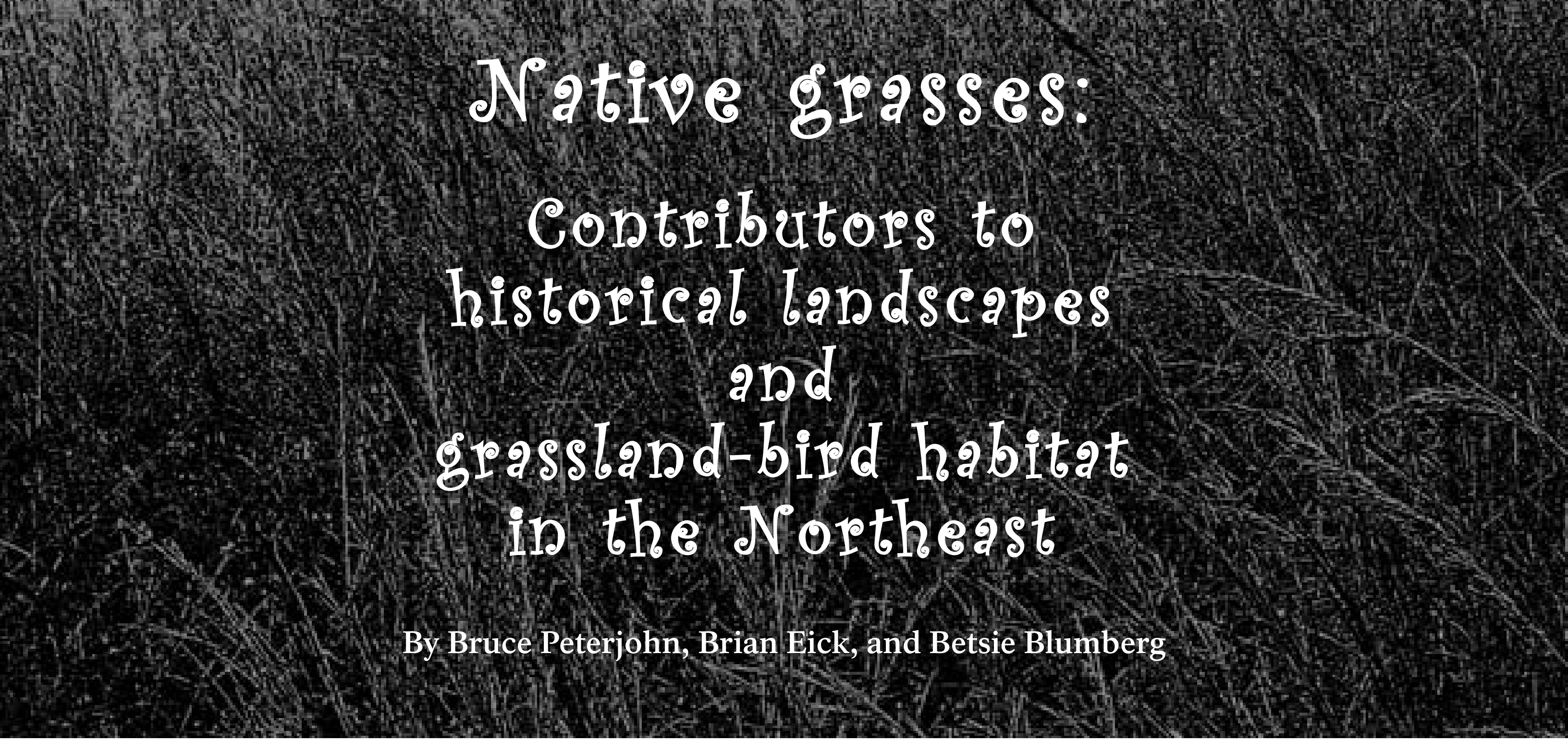

Native grasses:

Contributors to historical landscapes and grassland-bird habitat in the Northeast

By Bruce Peterjohn, Brian Eick, and Betsie Blumberg

As many national parks in the Northeast pursue their missions of re-creating open landscapes where important historical events took place, managers are using native grasses to replace forests that grew up on these sites in the 20th century and to restore open spaces now occupied by nonnative, cool-season grasses. This initiative reflects National Park Service (NPS) policy to restore native species and has ramifications for wildlife, particularly grassland birds.

By the mid-1800s, the once-dominant forests that covered much of the eastern United States had been converted to agriculture. Farming practices, particularly in the southern states, quickly depleted the land of nutrients. These worn-out fields were left fallow or used as pasture as new land was opened for farming. By the 1860s in the eastern United States, the landscape was typically a mosaic of crops, pasture, orchards, woodlots, and abandoned fields. The abandoned fields began the slow succession to forest, often being first colonized by native, warm-season grasses such as broomsedge (*Andropogon virginicus*), purpletop (*Tridens flavus* var. *flavus)*, Indiangrass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparium* var. *scoparium*), and big bluestem (*Andropogon gerardii*). These types of grasses grow in clumps or bunches, never forming a blanket of turf, and put down long taproots, penetrating at least 6 feet (1.8 m) into the subsoil. The long roots reach needed nutrients and water, making the grasses drought tolerant and helping rebuild the soil. Many species of grassland birds thrived in this landscape of small farming fields and abundant fallow ground.

Changes in agriculture following World War II, such as the introduction of large-scale crop production, and use of turf-producing, nonnative, cool-season grasses, particularly cultivars of fescue such as Kentucky-31, began altering the agricultural landscape. Habitat conversion and intensification of agricultural practices probably led to the decline of many grassland birds (Trocki and Paton 2005). Use of fescue for hay and pastures also greatly reduced wildlife habitat. These changes also took place in many historical park units where agriculture has been used as a land management tool. In many parks, the agricultural lands no longer reflected the mosaic landscape of the 1800s.

Re-creating native grassland habitat

At Appomattox Court House National Historical Park in Virginia, Natural Resource Manager Brian Eick has been converting 70 acres (28ha) of fescue fields into native, warm-season grasses. Worn-out tobacco fields

Planting warm-season grasses ... creates an ecologically viable habitat for wildlife that is representative of the historical scene.

dotted the scene in Virginia in the 1860s, and although planting warm-season grasses does not fully re-create this particular landscape, it creates an ecologically viable habitat for wildlife that suggests the historical scene.

The experiment entails learning how to successfully plant and sustain native grasses and then working with local farmers to maintain the fields through the park's agricultural leasing program. Like many historical parks in the Northeast, Appomattox Court House has been using agricultural leasing since the 1940s as a tool to maintain a historical, rural character of the landscape. This program also enables local farmers to cultivate park land in exchange for services or payment. Over time, however, local farmers stopped planting the fields in crops that were grown historically, such as corn and wheat. Instead, to compete in the modern agricultural market, they increased the use of nonnative, cool-season grasses for beef production. As a result, the cultural landscape of the park began to resemble modern agricultural land.

Park staff has tried several techniques to establish and manage native, warm-season grasses. They started by treating existing turf with herbicide (fig. 1). Because the native grass seed is "bearded" and will not slide through standard equipment, staff borrowed a special seed drill from the Virginia Department of Game and Inland Fisheries to plant the seed (fig. 2). They found that the germination rate improved if existing thatch was removed, promoting good contact between seed and soil. Park staff employed disking before planting and found that it yielded good results (fig. 3a, page 64). Establishing these grasses takes a few years (figs. 3b and 3c, pages 64–65), so staff used mechanical and chemical means to control broadleaf weeds, vines, woody plants, and invasive, nonnative plants. These grasses are harvested only once a year, in early August, rather than twice, in late May and late September, as are cool-season grasses (fig. 3d, page 65). The late-summer timing of the hay harvest allows nesting birds to fledge their young. In the historic village area, park staff created a mosaic of fields, some in warm-season grasses, and others in fescues. Because of the different harvest time periods, the park is able to re-create a partial impression of the smaller fields of the past. The park is working to create a volunteer bird monitoring program to compare the two field types in terms of providing bird nesting and wintering habitat.

The late-summer timing of the hay harvest [at Appomattox Court House] allows nesting birds to fledge their young.

At Valley Forge National Historical Park in Pennsylvania, no agricultural leasing program has been implemented; however, starting in the 1990s, park staff converted 925 acres (374 ha) of lawn to native grasses. Here, monthly mowing was simply stopped and the native seed in the soil germinated and grew. About 35% of the vegetation in the meadows is nonnative. Park Ecologist Margaret Carfioli reports that the meadows are mowed once a year to keep them from reverting to forest, and the emerging woody saplings are controlled to some extent by deer browsing. Burning the meadows periodically would also keep them open, but this can not be done at Valley Forge, which is situated in a densely developed area.

Figure 1. Resource managers at Appomattox Courthouse National Historical Park, Virginia, have converted approximately 70 acres (28 ha) of nonnative grasses to native, warm-season species. The process began by treating the nonnative grasses with herbicide in preparation for planting native species. NPS/BRIAN EICK

Figure 2. In order to plant the "bearded," native, warm-season grasses, park staff at Appomattox Court House used a special seed drill from the Virginia Department of Game and Inland Fisheries, which allowed the seeds to slide through. Seeds of this type get caught in standard equipment. NPS/BRIAN EICK

At Petersburg National Battlefield in Virginia, Resource Management Specialist Dave Schockley found native, warm-season grasses to be a poor choice to replace trees removed from fortifications. The old trees that had covered the earthworks since the Civil War were falling over and damaging the historic ruins as their roots lifted out of the earth. Covering the bare slopes quickly when the trees were gone was necessary to protect the earthworks from erosion. Park staff planted six test plots in native grasses but found that their slow rate of establishment and spotty coverage did not provide adequate erosion control. Instead they planted a blend of fescues.

Native grasses for grassland birds

An important benefit of meadows and fields of native, warm-season grasses is that they provide habitat for ground-nesting birds. The status of grassland birds has become an increasingly important conservation issue because they are suffering the most consistent population declines of any group of North American birds (Peterjohn and Sauer 1999). The conversion of grasslands into other habitats is largely responsible for these declines, but other factors may include habitat fragmentation and unfavorable mowing regimes (Vickery et al. 1999). The plight of grassland birds has heightened awareness of the need for concerted conservation actions to reverse these seriously declining population trends.

The plight of grassland birds has heightened awareness of the need for concerted conservation actions to reverse these seriously declining population trends.

In 2005 the National Park Service partnered with the U.S. Geological Survey (USGS) Patuxent Wildlife Research Center to initiate a project exploring the potential of cultural parks to support significant breeding communities of grassland birds. This required inventorying grassland habitats to determine the composition and abundance of the grassland bird communities. The objective was not to examine the effects of specific management actions on grassland birds in these parks, but rather to provide recommendations to the parks on how they could modify their management practices to the benefit of grassland birds. The best management for birds would reduce the value of agricultural leases for farmers, which would also mean reduced income to the parks. But when opportunities arise for the parks to provide better management for grassland birds, the park staff now has better information to allow them to make informed decisions.

The objective [of the study] was … to provide recommendations to the parks on how they could modify their management practices to the benefit of grassland birds.

This project involved four parks in the Northeast that have extensive grasslands: Antietam and Monocacy national battlefields in Maryland, Gettysburg National Military Park in Pennsylvania, and Manassas National Battlefield Park in Virginia. Each of these parks maintains grasslands for interpretation of historic events. The grasslands within the parks vary in size from nearly 2,000 acres (810 ha) at Gettysburg to less than 100 acres (40 ha) at Monocacy.

Findings and discussion

The four test parks support differing compositions of grassland bird communities. Antietam supports the greatest densities of grassland birds. Gettysburg hosts a sizable population of bobolinks (*Dolichonyx oryzivorus*), a World Conservation Union threatened species (fig. 4). A breeding pair of Henslow's sparrows (*Ammodramus henslowii*)

Figure 3a (facing page, left). At Appomattox Court House, after disking the field, park staff sowed native, warm-season grasses. This practice improved germination by removing a cover of thatch. In spring of the first year (fig. 3b, facing page, right), the native grasses had germinated and begun to grow. In fall of the first year (fig. 3c, above left), the grasses had gone to seed. After two growing seasons (fig. 3d, above right) the grasses are well enough established to be cut the following year. Mowing is now delayed under the new management regime until mid-July or later, allowing nesting birds to finish brooding. NPS/BRIAN EICK (4)

Figure 4. Gettysburg National Military Park in Pennsylvania hosts a sizable population of bobolink, a grassland bird species listed as threatened by the World Conservation Union. Four national parks involved in grassland bird habitat enhancement support differing compositions of grassland-bird communities, with Antietam National Battlefield in Maryland hosting the greatest densities of grassland birds. USFWS/S. MASLOWSKI

inhabits a warm-season grassland at Manassas—a big surprise to USGS investigators. These sparrows prefer mature grasslands with dense vegetative cover and thick litter layers. Very few Henslow's sparrows have been documented in the greater Washington, D.C., area in recent years. Breeding population estimates developed for grassland birds in each park serve as a baseline useful for establishing goals for restoration efforts (table 1).

Table 1. Estimated populations of territorial male grassland birds in four northeastern cultural national park units

Species	Antietam	Gettysburg	Manassas	Monocacy
Vesper sparrow	8			
Savannah sparrow	~~9~~	9		1
Grasshopper sparrow	28	29	29	11
Henslow's sparrow	~~1~~		1	
Bobolink	~~74~~	74		1
Eastern meadowlark	14	48	33	

Several interesting patterns of occurrence were evident during these grassland bird surveys. In Gettysburg where mowing is delayed until July, grassland birds were largely restricted to NPS-managed fields that support more diverse grassland communities. Leased hayfields were composed of dense monocultures and supported few grassland birds. In the other parks where mowing began in late May, grassland birds generally abandoned fields after they were mowed. Evidence of successful reproduction was evident only in fields that remained unmowed through June.

In … parks where mowing began in late May, grassland birds generally abandoned fields after they were mowed.

As expected, breeding grassland birds preferred the largest contiguous habitats in every park, avoiding smaller fields less than 24 acres (10 ha) in size.

Breeding grassland birds preferred the largest contiguous habitats in every park, avoiding smaller fields less than 24 acres (10 ha) in size.

Preliminary results indicate that grassland management practices can be adapted to benefit breeding bird communities in these habitats. Regulating mowing and haying activities until after July 15 will allow for improved reproductive success resulting in population increases. Grassland birds avoid dense monocultures (areas where only one species grows) of grasses (Norment et al. 1999), so replacing these homogenous areas with mixed-grasses will increase the amount of suitable habitat. In addition, proactive grassland management through the use of prescribed burns, regular mowing, and/or periodic disking to create young and mature, mixed-species grasslands will support a more diverse grassland-bird community. Increasing the size of contiguous grassland habitats would also benefit breeding grassland birds.

With proper management of native grasses, cultural parks in the Northeast can cultivate an environment reminiscent of the past landscapes common in this region in the 18th and 19th centuries, while providing habitat with the potential to support source populations for most grassland birds. These efforts could contribute to the recovery of regional populations that flourished here during that era.

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IMPORTANCE OF TRAP TYPE

for the detection and conservation of small mammals

By Samantha A. Sedivec and Howard P. Whidden

Introduction

The loss and degradation of habitat poses the single greatest threat to imperiled species in the United States (Wilcove et al. 1998). Limited availability of conservation resources requires conservationists to prioritize areas for protection, and as a result they face the urgent task of determining the geographic distributions of imperiled taxa (Groom et al. 2006). For many rare small mammals, however, such distributional data are incomplete and additional inventories are warranted if their critical habitats are to be identified and preserved.

> Multiple sampling techniques and protocols are often necessary for a comprehensive mammal inventory.

The literature thoroughly documents trap type as an important variable in the capture of small mammals (e.g., Sealander and James 1958; Wiener and Smith 1972; Kalko and Handley 1993; Kirkland and Sheppard 1994; Francl et al. 2002; Umetsu et al. 2006). A number of factors may predispose a species to be captured more often in one trap type than another, including body size and behavior. For example, some shrews may be too small to engage the trigger mechanism of a typical live trap, whereas saltatory species (those adapted for jumping or hopping) such as jumping mice may be reluctant to enter the confined space of a live trap. Consequently, multiple sampling techniques and protocols are often necessary for a comprehensive mammal inventory (Jones et al. 1996).

Study

We conducted an inventory of small mammals along the Appalachian National Scenic Trail corridor in Pennsylvania, New Jersey, New York, and Connecticut. The Appalachian National Scenic Trail is a unit of the National Park System that passes through 14 states. The width of the trail corridor varies, but it averages 1,000 feet (305 m). Our primary goal was to acquire baseline data on the distributions of eight target taxa (species or subspecies) listed by NatureServe as critically imperiled, imperiled, or vulnerable in the four states we studied (NatureServe 2004; see table 1). We used NatureServe Explorer to identify target taxa because it provided a consistent ranking system for the different states and it was the most reliable and readily available source; none of our target taxa were federally listed as threatened or endangered. A secondary objective was to inventory all small mammals present in the study area. To obtain a comprehensive inventory, we used a combination of Sherman live traps, Museum Special snap traps, and pitfall traps (fig. 1). Our study design allowed us to compare the effectiveness of these different trap types for documenting the presence of small mammal populations along the Appalachian Trail.

Methods

We reviewed the literature to identify known distributions and preferred habitats for each of our target species, many of which are habitat specialists. We then developed a GIS project that included National Land Cover data (Multi-Resolution Land Characteristics Consortium), National Wetlands Inventory data (U.S. Fish and Wildlife Service), topographic maps, and orthophotos (aerial photos corrected for the effects of tilt and relief). We used this approach to identify more than 100 potential study sites that appeared to provide suitable habitat for our target species, including boggy wet meadows and areas of moist wooded talus. Subsequent field checking allowed us to reduce this list to 33 sites for sampling (fig. 2).

Table 1. Species targeted for inventory along the Appalachian National Scenic Trail in Pennsylvania, New Jersey, New York, and Connecticut

Common Name	Scientific Name	PA Rank	NJ Rank	NY Rank	CT Rank
Long-tailed shrew	*Sorex dispar*	S3	S1	S4	–
Maryland shrew	*Sorex fontinalis*	S3S4	–	–	–
Water shrew	*Sorex palustris*	SNR	SU	S4	S3S4
Least shrew	*Cryptotis parva*	S1	SU	SH	S1
Kittatinny red-backed vole	*Clethrionomys gapperi rupicola*	S3	–	–	–
Southern bog lemming	*Synaptomys cooperi*	S4	S2	S4	S3
Rock vole	*Microtus chrotorrhinus*	S2	–	S4	–
Deer mouse	*Peromyscus maniculatus*	S5	SU	S5	S3

Note: Data on state ranks from NatureServe (2004).
State rarity rank codes: S1 = Critically Imperiled; S2 = Imperiled; S3 = Vulnerable; S4 = Apparently Secure; S5 = Secure; SH = Possibly Extirpated; SNR = Not Yet Ranked; SU = Under Review; – = not listed as present.


Figure 1. The researchers used three trap types in this inventory. The left photo shows a trapping station with Sherman live trap (at left) and Museum Special snap trap (at right); the right photo shows a pitfall array with drift fence, after Handley and Varn (1994). Sherman live traps generally catch animals alive so they can be released whereas Museum Special snap traps are lethal. Animals can be released alive from pitfall traps if the traps are checked frequently enough. HOWARD P. WHIDDEN (LEFT), SAMANTHA A. SEDIVEC (RIGHT)

We used traplines of Sherman live traps and Museum Special snap traps as the main inventory technique to document small mammals at all sites. At each study site, the two trap types were baited with a mixture of peanut butter and rolled oats and placed together in pairs at 40 stations along a transect for four consecutive nights. In addition, pitfall traps were installed at 13 sites, either as terrestrial arrays following the recommendations of Handley and Varn (1994) or as lines targeted at water shrews following the recommendations of the Resources Inventory Committee (1998).

We used a Wilcoxon test for matched pairs to compare the effectiveness of Sherman live traps to Museum Special snap traps for capturing small mammals. Pie charts were used to compare trap efficacy of the three sampling techniques based on trap-nights of effort (fig. 3, page 70). Capture rates for the two types of pitfall arrays were similar, and because we had limited numbers of total pitfall trap nights we lumped the terrestrial pitfalls and streamside pitfalls for this comparison.

Results

We recorded 11,182 total trap nights and captured 318 small mammals, including 9 total species and 4 of our target taxa (table 2, page 70). We captured four of our target taxa in the Museum Special snap traps (Maryland shrew, water shrew, southern bog lemming, and Kittatinny red-backed vole), whereas only one target taxon was captured in the Sherman live traps (Kittatinny red-backed vole). Museum Special snap traps were significantly more effective than Sherman live traps (227 vs. 67 total captures) for capturing small mammals in general ($T = 16$, $P < 0.001$, Wilcoxon's test for matched pairs). Pitfall traps were five times more effective at capturing shrews in the genus *Sorex* than the other trap types on a per-trap-night basis (fig. 3). Furthermore, the pitfall traps successfully captured both red-backed voles and woodland jumping mice.

Figure 2. Map of project area and locations of 33 sites sampled along the Appalachian National Scenic Trail from May 2005 to February 2006.

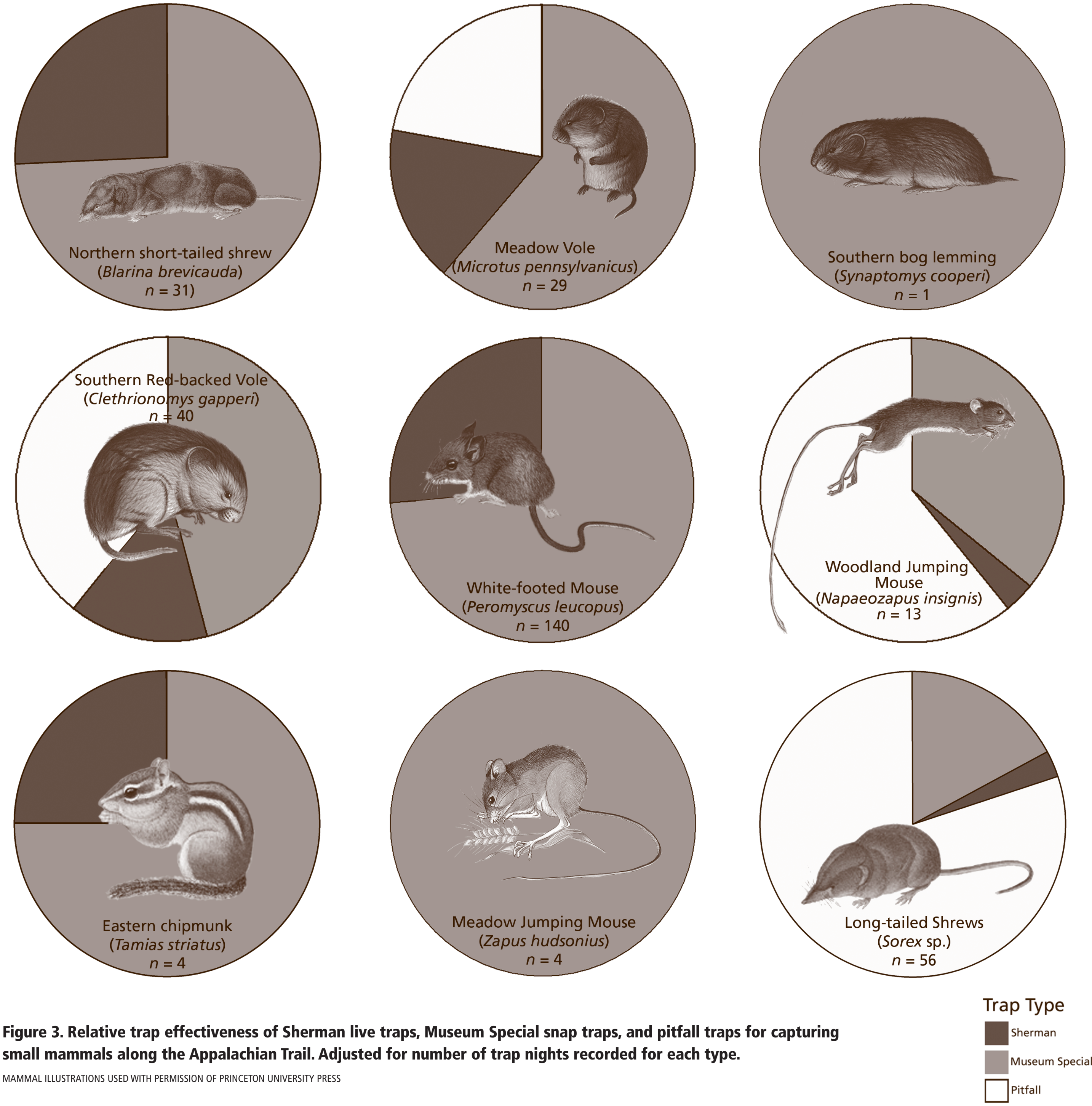

Figure 3. Relative trap effectiveness of Sherman live traps, Museum Special snap traps, and pitfall traps for capturing small mammals along the Appalachian Trail. Adjusted for number of trap nights recorded for each type.

MAMMAL ILLUSTRATIONS USED WITH PERMISSION OF PRINCETON UNIVERSITY PRESS

Table 2. Number of small mammals documented using three trap types: live traps, snap traps, and pitfall traps

Trap Type	Trap Nights	*Sorex* sp.[a]	*Blarina brevicauda*	*Microtus pennsylvanicus*	*Clethrionomys gapperi*	*Peromyscus leucopus*	*Zapus hudsonius*	*Napaeozapus insignis*	*Tamias striatus*	*Synaptomys cooperi*	Total
Museum Special	5,280	33[b]	23	22	28[c]	103	4	10	3	1	227
Sherman	5,280	5	8	6	9[d]	37	0	1	1	0	67
Pitfall	622	18	0	1	3	0	0	2	0	0	24
Total	11,182	56	31	29	40	140	4	13	4	1	318

[a]Includes *S. cinereus*, *S. fontinalis*, *S. fumeus*, and *S. palustris*.
[b]Includes 1 specimen of *S. fontinalis* and 1 specimen of *S. palustris*.
[c]Includes 2 specimens of *C. g. rupicola*.
[d]Includes 1 specimen of *C. g. rupicola*.

Discussion

Proper management of rare and declining species requires knowledge of their distributions and habitat preferences. Our results suggest that Museum Special snap traps and pitfall traps are more effective than live traps for documenting some species of small mammals. Park personnel and other land managers may be reluctant to conduct inventories that involve the killing of small mammals. However, accurate distributional data are necessary for conservation efforts, and the importance of obtaining these data with a minimum of time and effort must be balanced against the sacrifice of some animals. By removing our traps after capture of a target species, we never collected more than one individual of a target species at a site. Such judicious inventory trapping will likely have minimal impact on the populations of target species, and may provide the data needed to manage these populations.

A further consideration is that some at-risk small mammals are difficult to identify in the field (e.g., Maryland shrew and long-tailed shrew), and a definitive identification of some taxa may require laboratory examination of the skull and teeth. In addition, vouchers (specimens retained for documentation) obtained through trapping provide a permanent record of a taxon's presence, and can always be examined by future researchers if the identification or taxonomic status of a specimen is ever in doubt.

Conservationists, park managers, and policy makers are often faced with the difficult task of prioritizing areas for the protection of imperiled species. Our data reaffirm the importance of using multiple trap types for comprehensive and efficient inventories of small mammals. Inventories that rely solely on live traps may fail to identify at-risk populations or may require substantially greater trapping effort to document these populations. It is our hope that these results will help inform the design of future small mammal inventories and thereby assist conservation efforts aimed at protecting small mammal populations.

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Workforce succession and training needs among National Park Service program managers

By William E. Hammitt, Lisa K. Machnik, Ellen D. Rodgers, and Brett A. Wright

Workforce succession—the dynamic change that occurs with the personnel and management of any institution—is an ongoing process that varies in both character and rate. Like natural succession, certain events and forces can initiate more dramatic types and rates of change in workforce succession than is normal. Retirement can be such an event and force. As the American population ages, so does its workforce. The baby boomer generation, born between 1946 and 1964, is preparing to retire and agencies and institutions must be concerned with who will replace those leaving the workforce. The National Park Service (NPS) is not immune to this successional event: it too must be cognizant of the dynamics of its workforce relative to the recruitment, training, and transfer of bureau knowledge during periods of employee and management succession. During employee succession certain questions become more pertinent: From what ranks will replacements come? Will they come from within the bureau, or should they be recruited from other institutions? What competencies are needed within the new workforce? What training will be needed in order to step into existing positions? How will bureau "heritage and tradition" be maintained as large numbers of senior personnel exit the workforce? Basically, what will be walking out of the doors of the National Park Service and what should or must be walking through these doors within the next 5–10 years so that competency erosion does not occur?

Our research addresses some of these questions as we investigated the impending retirement/workforce succession of natural resource program managers within the National Park Service. We examined employee perceptions of how prepared they are to perform specific competencies, which the National Park Service identified as pertinent to senior-level job classifications (pay grade GS-12 and higher).

> How will bureau "heritage and tradition" be maintained as large numbers of senior personnel exit the workforce?

The situation

The Natural Resources Stewardship Career Field has been in existence only since 1995 and we were unable to obtain data for retirement rates for the period 1995–2005. However, in a study of federal employee retirement projections for 1999 through 2006, the United States General Accounting Office estimated that approximately 31% of employees of federal agencies became eligible for retirement in 1998. By 2006, according to the report, approximately half of the eligible employees will have retired; a number equivalent to 15% of the 1998 federal agency workforce in question (United States General Accounting Office 2001). This estimate translates into resource management agencies such as the National Park Service facing the loss of experienced personnel, which could present a knowledge drain, potentially leaving these agencies to manage and protect many of the nation's most treasured environmental and natural resources with insufficient numbers of experienced and prepared workers.

Nowack (1994) concludes and we concur that agencies undergoing retirement-related change need to be innovative in their approach toward employee preparation and development. The tradition of *replacement planning* often examines specific positions and identifies strengths and weaknesses, but lacks a comprehensive analysis of knowledge sharing and advancement. By contrast, *succession planning* is more comprehensive and open, with increased identification of critical competencies. As stated in Weston (1996), "If you've done some succession planning, you've done serious thinking about values and management processes that you believe are core to your organization." Still more comprehensive is *succession development*, where linkages are further developed, performance evaluated, and identification and ongoing monitoring of development/training needs are emphasized (Nowack 1994). Both succession planning and succession development contend that developing the talent pool of an agency, sharing knowledge and skills, and consciously and continuously identifying potential training needs will ultimately best serve the mission of an agency. However, at the core of succession planning and development is performance assessment and training development.

National Park Service response

In 1995, the U.S. National Park Service adopted the *NPS Employee Training and Development Strategy*. This strategy was designed to support the intent of the Government Performance and Results Act in that all federal agencies were required to establish clear goals and measure progress toward those goals through intensive performance evaluation. As a result, the National Park Service consolidated approximately 225 occupational specialties into 17 distinct career fields and established a list of "essential" competencies for each. From this exercise came a three-fold training mission statement in 2001, describing the National Park Service's commitment to build and maintain an effective, competency-based system of employee performance evaluation.

Implementing a system to track training effectiveness and developing "an agile workforce that is capable of responding to changing organizational and personnel needs" requires systematic research into issues such as employee retirement and workforce succession (National Park Service 2003). Therefore, the National Park Service initiated a research contract in 2002 (Rodgers 2003) to evaluate the preparation of natural resource management personnel to address prescribed competencies and the need for employee training and development programs. This article highlights findings from the 2002 study, which addresses some of the job performance/competency concerns of NPS senior employees, and further analyzes differences of perceived preparedness among upper-level program managers (i.e., GS-12, GS-13, and GS-14+). The analysis was restricted to GS-12 and higher-level positions because these positions are more multidisciplinary, requiring specific managerial and leadership competencies, than GS-11 and lower-level positions.

Methods

Sample

Participants were drawn from a larger pool of individuals that participated in a needs assessment in 2002 (Rodgers 2003); this study included all classifications of employees in the NPS Natural Resources Stewardship Career Field (sample size [*n*] = 1,243 employees). For our analysis, we used a sub-sample (192 employees) of Advanced Level Natural Resources Program Managers (hereafter referred to as "program managers") closest to retirement. These employees oversee a comprehensive range of activities, including environmental management and natural resources planning within the Natural Resources Stewardship Career Field.

A panel of NPS experts in natural resource management prescribed seven categories of competencies, (i.e., *mega competencies*) for employees in the Natural Resources Stewardship Career Field. Thirty-four *specific competencies* (i.e., knowledge, skills, and abilities) were then prescribed by this same panel for the seven mega competencies of program managers (table 1, pages 74–75).

Survey instrument

We used mail surveys to collect data regarding the competencies prescribed by the National Park Service. Respondents recorded perceptions of their preparedness (at the time of completing the survey) to perform each specific competency task using a seven-point rating scale, ranging from "1 = unprepared" to "7 = fully competent/prepared." Self-reports of employee perceptions of preparedness were used instead of more objective measures (e.g., performance results) because more than 1,000 NPS employees were surveyed in the original 2002 study.

Data collection and response rates

We generated mailing lists for the program managers based on information contained in the Federal Payroll and Personnel System (FPPS). Employees received a cover letter, questionnaire, and self-addressed business reply envelope during summer 2002. Persons who had not responded to the initial mailing received a follow-up letter and second questionnaire approximately four weeks later, requesting the completion and return of the questionnaire as soon as possible. We addressed concerns about confidentiality by assuring that all data would be reported in aggregate, never attributed to any individual. The effective response rate for program managers was 60.9% (*n* = 117).

Data analysis

We analyzed the perceived levels of preparedness to perform job competencies by computing average (mean) ratings and variation in ratings (standard deviations) for each of the 34 specific competencies. We then compared the competency ratings (means) among three sub-groups of program managers, based on GS grade level (i.e., GS-12, GS-13, and GS-14+). We tested the differences in preparedness (means among the three GS grade levels) using analysis of variance (ANOVA).

Verification of preparation ratings

To verify the perceived preparedness ratings for the NPS-generated competencies, we conducted three regional, focus-group interviews with 23 NPS professionals from a total of 11 different national park units. The Washington Office of the National Park Service identified potential interviewees from a representative sample of small and large parks in the West Coast, Rocky Mountains, and Mid-Atlantic regions. The purpose of the focus-group interviews was to validate the perceived preparedness ratings for accuracy and meaningfulness in terms of potential training needs (for additional detail, see Wright et al. 2005).

Results and discussion

Survey respondent characteristics

More than three-quarters (78.4%) of respondents were male, and 93% were white. They ranged in age from 36 to 62 (average = 48.7 years). Respondents had completed an average of 17.5 years of education, with 95.7% holding at least one advanced degree. The average number of years of NPS employment was 17.9, with seven years averaged in the current position. Nearly half were classified as GS-12 (47.8%), followed by GS-13 (31.2%) and GS-14+ (20.0%).

Table 1. Average preparedness ratings of NPS program managers for 34 natural resource management competencies

No.	Competency Description	Average[1]	Standard Deviation[2]
23.	Knowledge/ability recognized by agency/academic peers as leading in the natural resource field.	5.83	1.44
8.	Advanced knowledge of mission, goals, guidelines, policies of NPS, as well as mission/purpose of other agencies, groups, and private industry.	5.75	1.16
9.	Ability to develop innovative solutions, consistent with NPS policy, to complex situations.	5.51	1.06
13.	Ability to provide sound advice to upper-level managers on stewardship/actions at a landscape-level or Service-wide scale.	5.44	1.36
3.	Ability to integrate information across discipline, recognize patterns/draw conclusions, and adapt the results in innovative ways to resolve diverse/complex park resource issues.	5.40	1.24
32.	Ability to manage multiple programs including those in natural resource disciplines outside the field of expertise.	5.34	1.33
27.	Ability to evaluate/synthesize information from diverse/conflicting sources.	5.34	1.33
31.	Ability to develop/oversee innovative programs, involving multiple components/need for careful coordination/sequencing, to address complex/controversial resource management issues.	5.31	1.24
4.	Knowledge of environmental ethics/philosophy applied to natural resource management.	5.30	1.37
22.	Recognized ability to effectively represent the NPS on a multiagency task force to address natural resource issues.	5.30	1.34
2.	In-depth knowledge of ecosystem.	5.22	1.20
7.	Ability to evaluate research reports/scientific publications/diverse agency documents and legislation for applicability to specific natural resource issues/natural resource stewardship.	5.12	1.29
26.	Ability to convey information concerning politicized/controversial issues to potentially hostile audiences.	5.12	1.36
29.	Ability to give oral/written briefings from which decisions are made by high-level agency personnel/Congress.	5.10	1.49
12.	Ability to plan/direct large-scale resource stewardship programs requiring a multi-disciplinary approach/ considerable potential for controversy.	5.07	1.37
14.	Ability to evaluate/synthesize results of relevant scientific studies/develop solutions to complex situations where scientific information, laws, policies, or guidelines may be lacking.	5.05	1.36
30.	Ability to persuade, effectively negotiate/solve problems with diverse individuals and organizations.	5.05	1.31
25.	Recognized ability to integrate representatives of agencies, academic institutions/diverse interest groups into an effective program of cooperation in achieving shared objectives for natural resource stewardship.	5.04	1.19

Preparation to perform competencies

Advanced-level natural resources program managers reported feeling prepared (i.e., average rating 5.0 or higher) for 21 of the 34 competencies (table 1). However, these program managers reported no competencies in which they felt highly prepared (rating near 6.0) or fully prepared (rating near 7.0). The specific competency in which program managers felt most prepared was "recognition by agency/peers as leading in the natural resources field" (number 23). Additionally, program managers felt prepared in policy and stewardship of natural resources management (number 8, 9, and 13; see table 1). Competencies associated with natural resource stewardship, such as those dealing with scientific knowledge (number 2, 3, and 4) and project management (number 31 and 32), also received fairly high preparedness scores (i.e., mean values above 5.20).

The two competencies in which program managers perceived themselves to be least prepared (i.e., means less than 4.0) were "knowledge of case law as it relates to specific natural resource issues"(number 10) and "knowledge of precedent and case law related to planning and compliance" (number 18). The mean for these was 3.94. Other competencies related to law and planning/compliance also received fairly low preparation scores (number 5, 11, 19, and 21). In addition, program managers felt they were unprepared to publish their ideas in journals (number 24). Thus, program managers perceived themselves most prepared to handle tasks concerning natural resources stewardship, scientific knowledge, and project management; and least prepared with duties related to case law, planning and compliance, and publishing in scientific journals.

Table 1 (continued)

No.	Competency Description	Average[1]	Standard Deviation[2]
1.	Mastery of a natural resource discipline/current knowledge of state-of-the-art concepts.	5.03	1.34
34.	Ability to prepare complex/innovative cooperative agreements, MOUs/other agreement instruments.	5.03	1.43
20.	Ability to develop innovative solutions to complex or intractable issues.	5.02	1.26
15.	Ability to take the lead in interagency programs for critical resource protection on a landscape scale that crosses jurisdictional boundaries.	4.97	1.39
17.	Highly developed leadership skills, including skill in effective team-building.	4.94	1.37
6.	Ability to develop/coordinate complex multifaceted programs of research, inventory, monitoring, and resource management.	4.94	1.45
33.	Ability to effectively compete for funding through large-scale partnerships that may include diverse/opposing viewpoints.	4.93	1.45
28.	Ability to write highly complex documents dealing with natural resource issues/technical information.	4.90	1.58
16.	Ability to form effective partnerships with diverse/potentially hostile groups to address complex natural resource issues.	4.89	1.35
19.	Ability to orchestrate the development, completion/implementation of complex strategies/plans, consisting of distinct component parts/sequential actions, addressing complex/controversial actions.	4.82	1.42
5.	Advanced ability to apply scientific approaches/problem-solving techniques to complex natural resource problems, involving long-term/large-scale programs that cross jurisdictional boundaries.	4.71	1.33
21.	Ability to develop/carry out a public involvement program, working with public information personnel as appropriate, for plans that may include complex, controversial issues.	4.68	1.27
11.	Thorough interpretation of existing law/precedent/scientific information, ability to develop new policies, regulations, guidelines, programs, and concepts.	4.46	1.43
24.	Ability to publish syntheses/thought-provoking concepts in journals, recognized as providing leadership in advancing natural resource stewardship.	4.08	1.52
18.	Knowledge of precedent/case law related to planning and compliance.	3.94	1.55
10.	Knowledge of case law as it relates to specific natural resource issues.	3.94	1.54

Note: Competencies abbreviated from original text.
[1]Scale: 1 = unprepared to 7 = fully competent/prepared.
[2]Standard deviations > 1.0 indicate increasing variation in perceived preparedness.

Preparation by GS grade

The perceived preparedness scores also contain considerable variation (i.e., standard deviations above 1.0), which indicates that the program managers varied in how they perceived their individual preparation for the various competencies (see table 1). This variation may be related to several factors, including the GS grade level of employees. For example, a logical assumption is that program managers of GS grades 14 and higher would be more prepared with respect to the specific competencies than GS-12 employees. Preparation among these three GS grade groups might also be expected to differ more for certain competencies than others. For these reasons, we analyzed the preparation scores by GS grade level to see if specific competency preparation differed significantly among the three GS levels examined.

Only six of the 34 competencies show a significant difference ($p \leq 0.10$) in average preparedness among the three GS levels (table 2). In four of the six, preparation increased from GS-12 through GS-14+ grade levels as expected. However, in the other two (number 22 and 25), GS-13 employees perceived themselves least prepared. Although not significantly different, statistically speaking, GS-13 employees had the lowest preparation ratings for seven more of the competencies listed in table 1 (numbers 15, 16, 19, 24, 26, 29, and 30).

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

No.	Competency description	GS-12	GS-13	GS-14+
13.	Ability to provide sound advice to upper-level managers on stewardship/actions at a landscape-level or Service-wide scale.	5.19[a]	5.44[a]	6.04[b]
22.	Recognized ability to effectively represent the NPS on a multiagency task force to address natural resource issues.	5.15[a]	5.09[a]	5.96[b]
23.	Knowledge/ability recognized by agency/academic peers as leading in the natural resource field.	4.61[a]	4.67[a]	5.61[b]
32.	Ability to manage multiple programs including those in natural resource disciplines outside the field of expertise.	5.00[a]	5.64[b]	5.70[b]
25.	Recognized ability to integrate representatives of agencies, academic institutions/diverse interest groups into an effective program of cooperation in achieving shared objectives for natural resource stewardship.	5.02	4.76[a]	5.50[b]
33.	Ability to effectively compete for funding through large-scale partnerships that may include diverse/opposing viewpoints.			

Note: Mean scores with different superscripts are significantly different, LSD $p \leq 0.10$. Fisher's Least Significant Difference (LSD) is a statistical procedure for determining the amount of difference between two mean scores.
[a]Significantly different from mean scores for this competency noted with the superscript *b*.
[b]Significantly different from mean scores for this competency noted with the superscript *a*.

Verification of preparation

Three major findings were gleaned from the focus-group interviews with natural resource professionals. First, the majority of participants agreed that the survey data accurately reflected the relative preparedness of employees to perform prescribed competencies in the management of park resources. Interviewees agreed that adequate preparation in the areas of case law and regulation compliance are ongoing needs within the National Park Service. Secondly, a fairly large percentage of deficiencies (26%) in competency preparedness seemed to be among mid-level program managers at the GS-13 grade. This may be an important finding in terms of training needs because this grade level is the next group of employees logically to ascend to the National Park Service's top management rank (GS-14+). Competency shortfalls needing the most emphasis include law compliance, scientific knowledge, and program leadership. The situation was described by one interviewee as follows:

> Those trained in the classic disciplines typically have had little training in developing leadership and management skills. This presents a dilemma for [the] National Park Service, where employees without the needed technical, scientific background are moving into management positions because those with the scientific backgrounds do not have management skills or training. If not corrected, this practice will continue the tradition of non-science–based management at a critical time in National Park Service workforce succession history.

Finally, during the interviews participants discussed at length the differences between large and small parks. These differences were most evident with Natural Resource Stewardship competencies, particularly in the areas of law and directing large-scale resource stewardship programs. Participants noted that large parks frequently have staffs that concentrate on case law and compliance issues, and also possess multiple resource managers that can specialize in a disciplinary area (e.g., water or wildlife). Small parks, on the other hand, do not have this luxury; staff professionals are more dependent upon the Department of the Interior's Office of the Solicitor for legal advice and required to focus on numerous resources, rather than specialize solely in their area of expertise.

Implications and conclusions

The National Park Service will experience, through approaching retirements, the inevitable loss of essential employee skills, knowledge, and institutional memory. This phenomenon stimulated our study of workforce succession among NPS natural resource managers. The National Park Service must be cognizant of the dynamics of its current and evolving workforce, relative to the recruitment, training, and transfer of agency knowledge, during periods of employee succession. However, concerns over the dynamics of workforce succession in the National Park Service go beyond the impending retirement of its employees. Agency change, employee evolution and development, and the management of institutional heritage are continual processes, and peak retirement events in the process only serve to increase the rate of workforce succession and needs in training.

In terms of competency preparation and training needs, we propose some implications for further consideration. First, program managers perceived themselves as least prepared in the competency areas of case law, planning and compliance, and complex/integrative project management. Second, though our study showed few statistically significant differences (i.e., six) in perceived preparedness among the three GS grades tested, GS-13 employees recorded the lowest ratings in nine of the 34 (26%) competencies compared. Though further research may be needed to refine this outcome, based on our findings, training should first be directed toward GS-13 personnel. This is particularly true if these employees are likely to advance into the GS-14+ grades, handling the most senior-level responsibilities.

Based on our findings, training should first be directed toward GS-13 personnel.

In conclusion, this article reports our findings of the perceived competence of program managers in natural resources, particularly in the context of workforce succession and training needs. One comment during the focus-group interviews captures the essence of what the natural resource management community in the National Park Service faces:

> We should not over-emphasize the retirement aspects of workforce succession. For me, the really important need is the fact that the legal mission of the National Park Service has become more and more complex, and that through the Natural Resource Challenge the National Park Service has greatly increased the number of technical experts in the agency. Many of these people are finding themselves lacking in leadership and management skill needed for their positions and careers. If we are to move this agency toward more scientific management, we need to encourage people with science backgrounds to move into management positions. Thus we will need to look strategically at building these critical skills. This will constitute a fundamental shift in the leadership of this agency, and needs to be identified as a primary issue, if not *the* primary issue, for management succession.

"If we are to move this agency toward more scientific management, we need to encourage people with science backgrounds to move into management positions."

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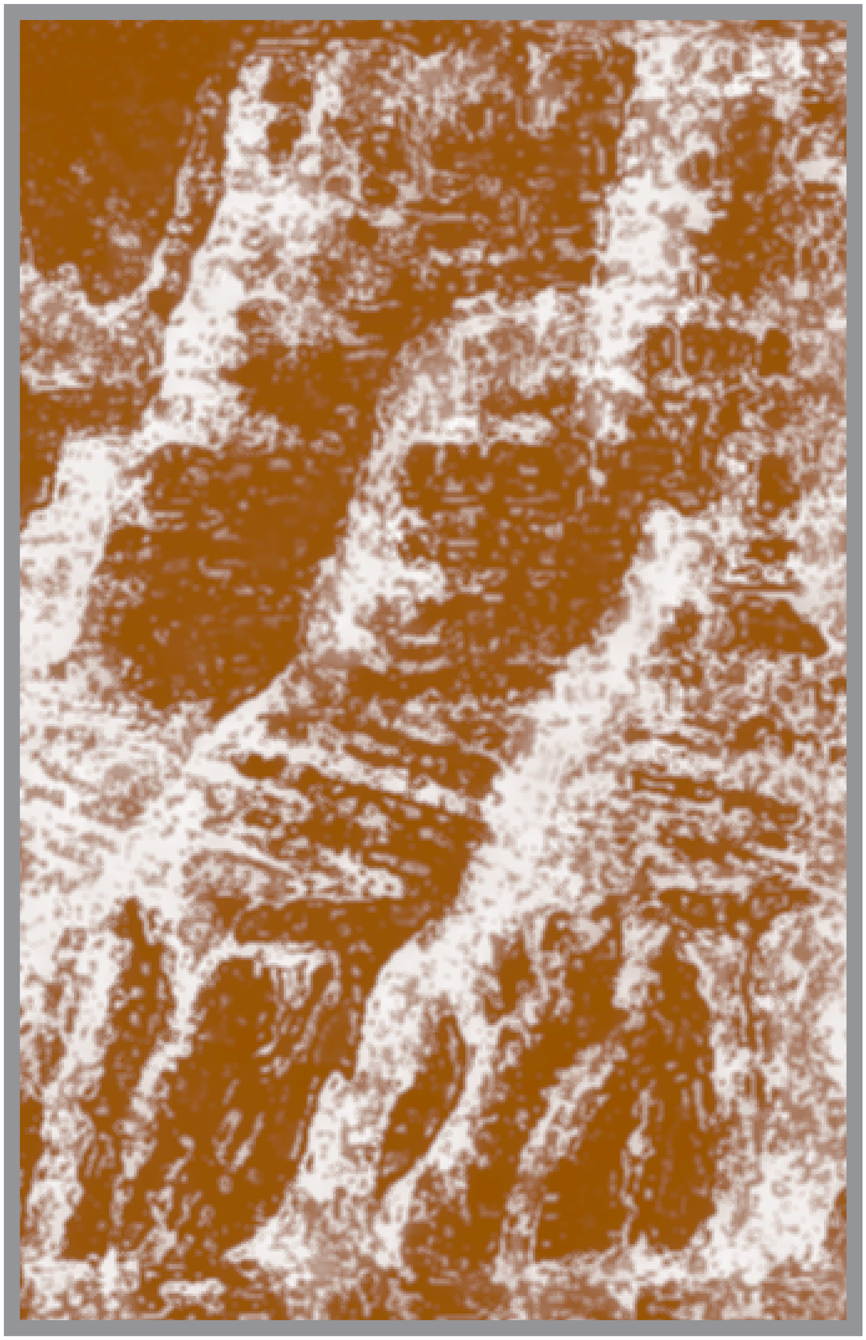
Telling time at Grand Canyon National Park

By Allyson Mathis and Carl Bowman



With one of the clearest exposures of the rock record and a long, diverse geologic history, Grand Canyon is an ideal place to gain a sense of geologic or "deep" time. The oldest rocks exposed in the canyon are ancient, 1,840 million years old. Conversely, the canyon itself is geologically young, having been carved in the last 6 million years. Even younger deposits, including ice age fossils in caves, 1,000 year-old lava flows in the western canyon, and recently deposited debris flows, bring Grand Canyon's geologic record to the present.

Understanding the park's natural resources is undeniably intertwined with its geologic history; therefore, telling geologic time is an important part of the interpretive efforts at Grand Canyon National Park (Arizona). An appreciation of geologic time places geologic topics such as geomorphology, the origin and evolution of the Colorado River, stratigraphy, historical geology, and paleontology in context. Unfortunately, telling geologic time is a mystery to visitors and park staff without backgrounds in Earth science. Naturally a non-geoscientist may wonder, "How do you know that?" when a geologist or interpreter says "That rock formed 270 million years ago." To add to the confusion, both technical and popular literature report a wide variety of numeric ages for Grand Canyon rocks. For example, one publication may say that the Kaibab Formation is 270 million years old, while another says 255 million years old. The same inconsistencies arise for the other rock units in the park. At best, readers are left wondering which are the correct (or "best") ages and why. At worst, they may discount the scientific processes used to measure deep time.

When one's objective is simply to learn how old a rock layer is, sorting through the subdivisions of geologic periods, the scientific names of microscopic index fossils (diagnostic assemblages of past life), and the nuances of radiometric dating techniques is very confusing. Moreover, most non-geoscientists will not find a description of the Kaibab Formation as Leonardian or Roadian (stages) meaningful. However, they will be able to comprehend the numeric value of 270 million years (at least to the degree that geologic time is understandable). Therefore, numeric ages are essential when interpreters and resource managers communicate geology to the public and to one another. However, finding such numbers in the scientific literature is not easy. Unless researchers used absolute-dating techniques in a study, only the relative geologic age (i.e., period, epoch, or stage) of a rock unit is usually reported. Moreover, the scientific papers that do publish absolute age determinations are not always clear about the geologic significance of these dates.

Given the inconsistencies in reported numeric ages for Grand Canyon rocks and the difficulty in determining their ages, we reviewed the technical literature and consulted with researchers to compile the "best" ages of Grand Canyon rocks. By "best" we mean the most accurate and precise ages, given the parameters of geologic dating techniques and available information from the rock record. The primary audiences for this work were interpreters (including NPS rangers, commercial guides, authors, and publishers) and resource managers. The goal was to develop a single list of numeric ages that users could apply consistently, thereby facilitating comprehension of the geologic history and features of the Grand Canyon.

Dating rocks

Two major categories of geologic dating techniques exist: relative dating and absolute age determinations. Relative dating determines the order in which a sequence of geologic events (e.g., volcanic eruptions, mountain building, sea-level rise, and deposition of sedimentary strata) occurred, but not how long ago the events happened. Absolute age determinations, such as radiometric age determinations, identify when, in years, specific events occurred. Depending on the availability of datable material (e.g., diagnostic minerals suitable for radiometric dating) and the presence of index fossils, investigators have used both techniques to discern the ages of rocks exposed in the Grand Canyon. Sedimentary rocks, which usually do not yield absolute ages, rely on relative dating, correlation, and the use of index fossils. Decaying radioactive isotopes in igneous and metamorphic rocks yield absolute ages.

One of our concerns with the large range ages published in scientific and popular texts is the potential to propagate outdated information and errors. The different ages are a result of improving knowledge, both in the accuracy and precision of geologic dating techniques, and in refinements to the geologic time scale. If interpreters and authors of general interest publications do not research primary scientific sources for their information, a superseded date from a widely distributed, popular publication may be erroneously cited again and again.

The age of Grand Canyon rocks

Beginning with John Wesley Powell in the 1870s, geologists have recognized three main packages, or "sets," of rocks exposed in the Grand Canyon: (1) the crystalline rocks of the Inner Gorge, (2) the tilted rocks of the Grand Canyon Supergroup, and (3) the layered sedimentary rocks in the upper two-thirds of the canyon (fig. 1). As knowledge of Grand Canyon geology progressed, geologists began to identify individual layers of rocks; ultimately more than 100 formal stratigraphic names were applied to rock units in the Grand Canyon. Therefore, our project first required identifying the rock units for which numeric ages are important. We limited our project to the three overall sets of rocks and those rock formations or groups that interpreters and resource managers routinely discuss.

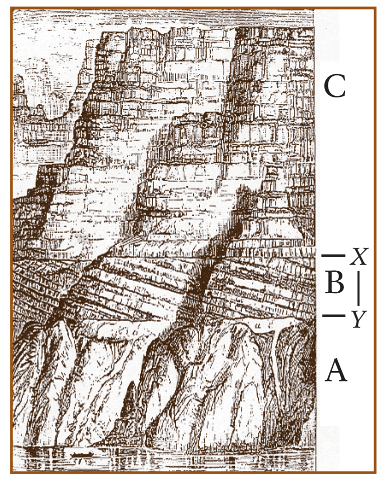


Figure 1. Figure 79 in *Exploration of the Colorado River of the West and its Tributaries* (1875) by John Wesley Powell clearly shows that early geologists recognized the three main packages of rocks exposed in the Grand Canyon.

In an effort to not confuse our users, we selected the term "set" to refer to Powell's three main packages of rocks, because this term is not part of the formal stratigraphic hierarchy such as "group," "series," or "complex." The three sets of rocks are categorized based on stratigraphic position, age, physical characteristics, and overall geologic history (table 1, page 82). The "Vishnu Basement Rocks" (of undetermined thickness) consist of the ancient igneous and metamorphic rocks exposed in the Inner Gorge. The "Grand Canyon Supergroup Rocks" (12,000 feet [3,600 m] thick) are late Precambrian sedimentary and volcanic rocks predominantly deposited in rifted basins. The "Layered Paleozoic Rocks" (3,000–4,000 feet [900–1,200 m] thick) include the flat-lying sedimentary rocks in the "stair-step" canyon walls (figs. 2 and 3, pages 80–81).

Within these sets, we assigned numeric ages for 17 units at the group or formation level, using radiometric dates where available (table 1). Our goal was to be as accurate as possible in assigning numeric ages. Only where the science allowed did we round numbers for easier interpretive use and better retention by the public. These numeric ages are an important translation for park managers and the public; they also promote consistency and utility in interpretive and resource-management communications.

THESE NUMERIC AGES ARE AN IMPORTANT TRANSLATION FOR PARK MANAGERS AND THE PUBLIC.

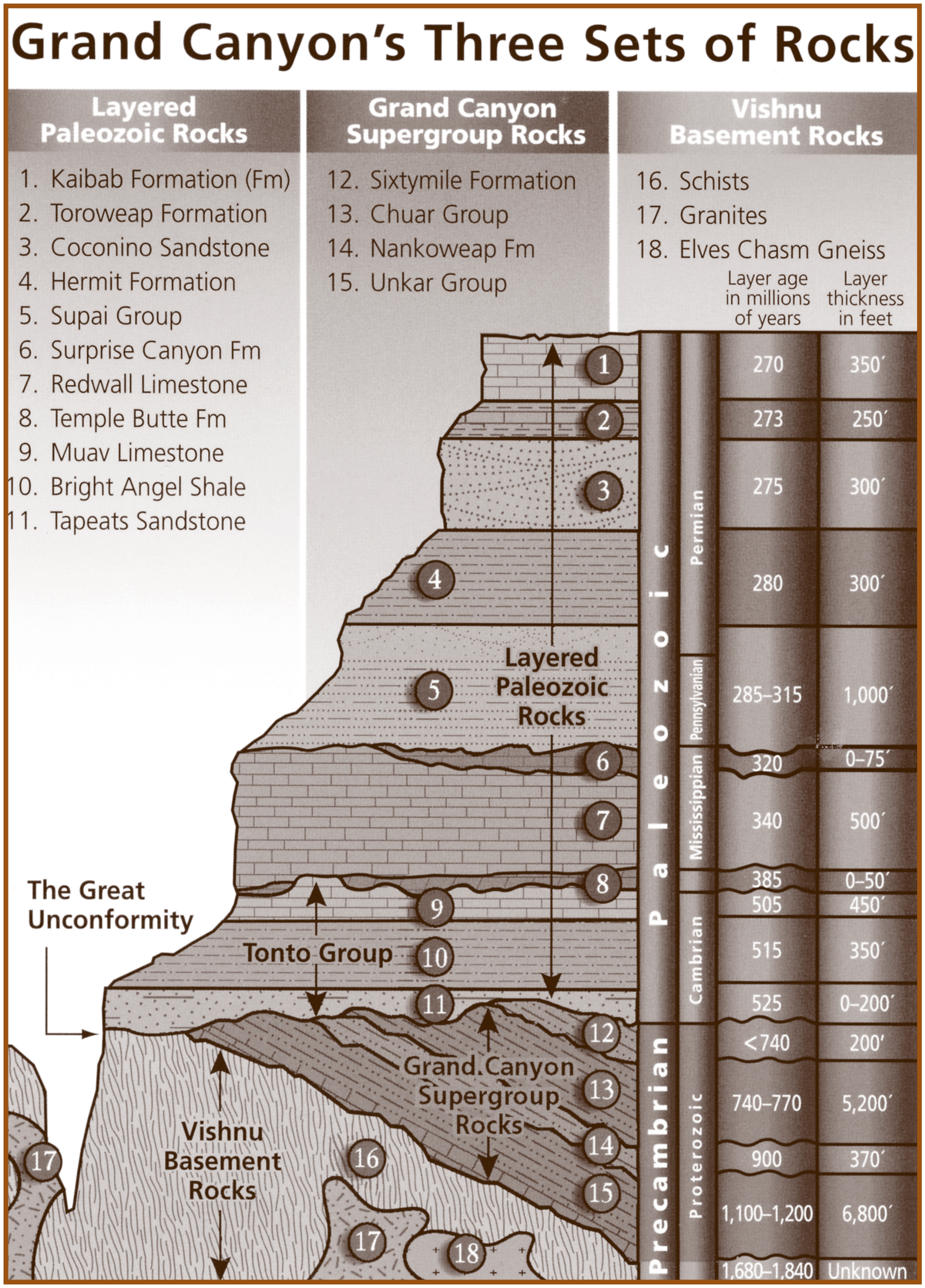
Vishnu Basement Rocks

We established the informal name Vishnu Basement Rocks for all of the ancient crystalline rocks at the bottom of the Grand Canyon because no formal nomenclature encompasses all the metamorphic units and individual igneous plutons exposed there. We chose "Vishnu" because the public is familiar with the Vishnu Schist and "basement" to indicate the type of rock assemblage and its position.

The many reliable radiometric age determinations of the igneous and metamorphic Vishnu Basement Rocks (e.g., Ilg et al. 1996; Hawkins et al. 1996; Karlstrom et al. 2003) facilitated our determination of numeric ages for this set. The challenge was to interpret the geologic significance of the dates in a meaningful context for interpreters and resource managers. We differentiated Grand Canyon's oldest rock unit, the Elves Chasm Pluton (1,840 million years ago), from the rest of the Vishnu Basement Rocks. The Elves Chasm is significantly older, at least 90 million years, than any other basement rock. It formed before the main tectonic collisions that produced most of the other rocks comprising the Vishnu Basement Rocks (1,680–1,750 million years ago). We also chose to exclude a few younger plutons, which formed about 1,400 million years ago, from the overall age of the Vishnu Basement Rocks. These rocks postdate the main tectonic events that formed this set and, though interesting, are a detail better left to the advanced study of Grand Canyon geology.

Grand Canyon Supergroup Rocks

Grand Canyon Supergroup Rocks are primarily sedimentary. However, radiometric age determinations of the Cardenas Basalt, ash beds, and other datable material within the sedimentary rocks provide age constraints for this set. We included some dates from paleomagnetic stud-



ies, which use the natural remnant magnetization in Earth materials, to further define the time span. The Supergroup rocks predate the Cambrian Period, when hard-shelled organisms first appeared in the fossil record, so they have few identifiable index fossils. Our dates are bracketed by the ages of the basal Unkar Group at 1,100–1,200 million years ago (Arizona Geological Survey, M. Timmons, personal communications, 2003–2005) and the Chuar Group at 740–770 million years ago (Dehler et al. 2005). No datable material has been found in the uppermost Sixtymile Formation (see table 1). The Supergroup is the focus of active geologic investigation, so these ages may change as new information becomes available.

Layered Paleozoic Rocks

Assigning numeric ages for units of the Layered Paleozoic Rocks was the most difficult. Because no single stratigraphic name exists for this set, Layered Paleozoic Rocks is also an informal term; nevertheless, their rock type, age, and overall geologic setting naturally package them together. No reliable radiometric dates exist for these sedimentary rocks, so their ages are constrained by index fossils. Units with richer fossil records have more precise age constraints. After analyzing a unit's fossil assemblages, researchers identify the geologic age (Beus and Morales 2003) by correlation to chronostratigraphic charts. All geologists use the same basic divisions of geologic time (e.g., eras and periods). The *International Stratigraphic Chart* (Grandstein and Ogg 2004; International Commission on Stratigraphy 2005) is the most accurate and up-to-date time scale available for worldwide correlation of rock units. We used it as our basis for determining the numeric ages for rocks in Grand Canyon National Park. However, investigators have used many local or regional scales, such as the *North American Chronostratigraphic Scale*, for finer subdivisions. These other scales work well for describing regional geology but can be difficult to correlate worldwide. The relationship between the *North American Chronostratigraphic Scale* and the *International Stratigraphic Chart* is not straightforward. Hence, we consulted Dr. Ronald Blakey, a stratigrapher at Northern Arizona University, to ensure that we had developed a set of reasonable dates for the Layered Paleozoic Rocks.

The other challenge of determining the age of the Layered Paleozoic Rocks was identifying the best single number to represent the age of each unit. Sedimentary rocks are usually deposited over long periods of time, and some units exposed in Grand Canyon contain significant gaps in the rock record, called unconformities. Furthermore, many formations, in particular the Tonto Group, record marine transgressions as sea level rose, making the unit older in the west than in the east. Because most developed areas of Grand Canyon National Park are in the eastern canyon, we targeted our compilation on the age of rocks there.

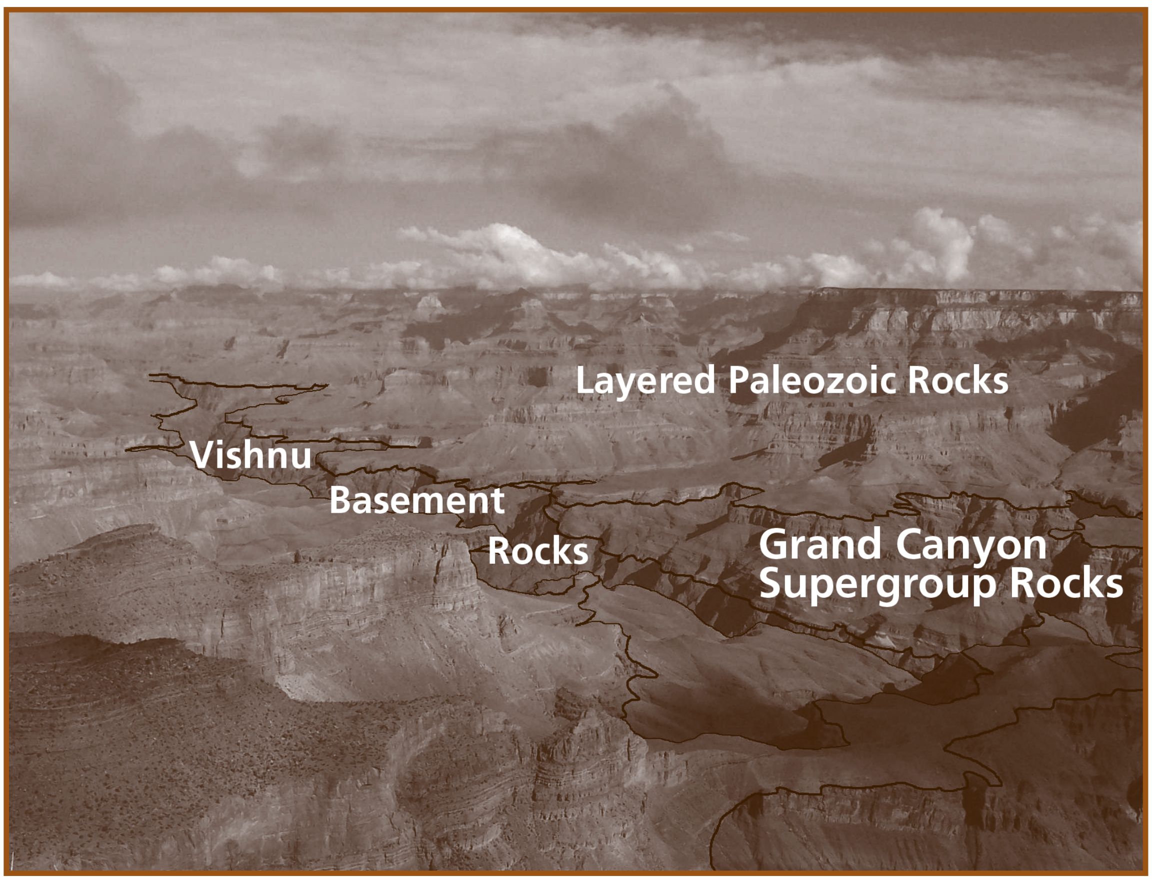


Figure 2 (facing page). This stratigraphic column, developed for *Grand Canyon Yardstick of Geologic Time* (Mathis 2006), shows the three sets of rocks. Descriptions of the canyon's geologic history often focus on individual rock layers, particularly the easily recognized, horizontal sedimentary rock layers, and less on the overall stories of the three sets of rocks exposed in the canyon. Truer understanding of the canyon's history comes when individual rock units are placed in the context of the three sets. COPYRIGHT GRAND CANYON ASSOCIATION

Figure 3. The view of the Grand Canyon from Moran Point shows the Vishnu Basement Rocks in the Inner Gorge, the tilted Grand Canyon Supergroup Rocks, and the Layered Paleozoic Rocks. NPS/CARL BOWMAN

Table 1. Sets of rocks at Grand Canyon National Park

Set	Formation name	Numeric age[1] (millions of years ago)	Geologic age	Rock type(s)	Layering	Geologic setting
Layered Paleozoic Rocks	Kaibab Formation	270	Permian	Sedimentary	Horizontal	Coastal plains form alternately above and below sea level
	Toroweap Formation	273				
	Coconino Sandstone	275				
	Hermit Formation	280				
	Supai Group: Esplanade Sandstone	285–315				
	Supai Group: Wescogame Formation		Pennsylvanian			
	Supai Group: Manakacha Formation					
	Supai Group: Watahomigi Formation					
	Surprise Canyon Formation	320	Mississippian			
	Redwall Limestone	340				
	Temple Butte Formation	385	Devonian			
	Tonto Group: Muav Limestone	505	Cambrian			
	Tonto Group: Bright Angel Shale	515				
	Tonto Group: Tapeats Sandstone	525				
Grand Canyon Supergroup Rocks	Sixtymile Formation	740	Precambrian	Sedimentary with some igneous	Tilted	Basins open as seaway develops
	Chuar Group	740–770				
	Nankoweap Formation	900				
	Unkar Group	1,100–1,200				
Vishnu Basement Rocks	Vishnu, Brahma, and Rama schists; most plutonic rocks	1,680–1,750 (~1700)		Metamorphic and igneous	Vertical	Island chains collide with the continent
	Elves Chasm Pluton	1,840				

[1]International Stratigraphic Commission (2005).

Results and distribution

We completed our original compilation of Grand Canyon rocks in 2003. Because of refinements in the geologic time scale and new findings by researchers, we revised it in 2004. Further revisions may be necessary as knowledge of Grand Canyon geology improves, new or improved absolute dating techniques are developed, or the geologic time scale is modified. Given the current knowledge of Grand Canyon geology, table 1 compiles our best numeric ages of its rocks.

Originally, we only distributed our age compilation to staffs at the Grand Canyon Association (GCA) and Grand Canyon National Park. Both now use the numeric ages in their interpretive programs, publications, exhibits, and resource management reports (fig. 4). We later wrote a series of articles published in *Nature Notes* and *Boatman's Quarterly Review*. These articles,

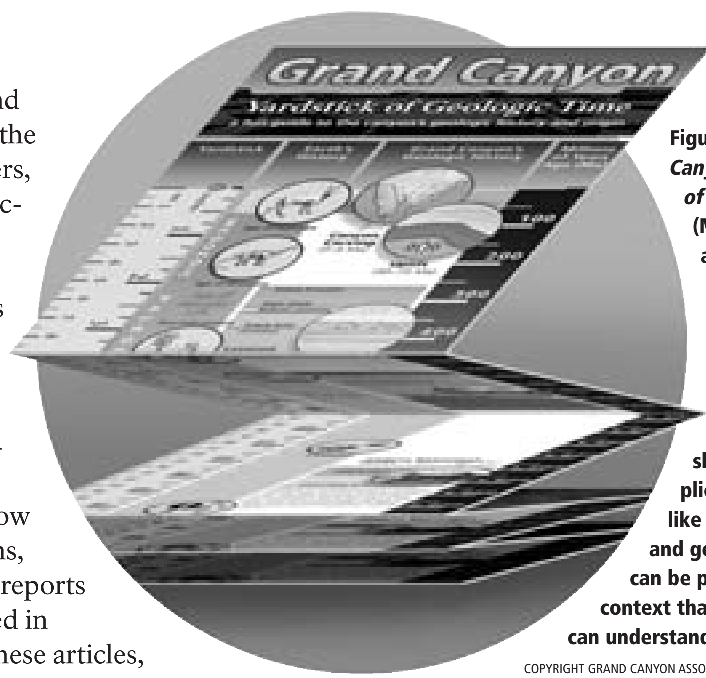


Figure 4. ***Grand Canyon Yardstick of Geologic Time*** **(Mathis 2006) is an interpretive publication about geologic time and the ages of Grand Canyon rocks. It shows how complicated subjects like geochronology and geologic history can be placed into a context that park visitors can understand.**

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which targeted lay audiences and Colorado River guides, explained geologic dating techniques and summarized the ages of Grand Canyon rocks. These publications further encouraged consistency among park cooperators who interpret and otherwise communicate the ages of Grand Canyon rocks.

The interpretive articles and age charts are available to an even wider audience through the Tour of Park Geology Web site maintained by the NPS Geologic Resources Division (http://www2.nature. nps.gov/geology/parks/grca/age/). The U.S. Geological Survey also used our compilation in their Geology of National Parks Web site at http://3dparks.wr.usgs.gov/ (accessed 13 December 2006).

Conclusions

From literature searches, consultations with geologists, and interpretations of scientific data, we compiled the numeric ages of rocks exposed in Grand Canyon National Park. Our age compilation provides information about the age of Grand Canyon rocks in a form meaningful to interpreters, park managers, and visitors. The primary outcome of this project is that the ages given for Grand Canyon rocks are more consistent in interpretive media, park documents, and popular GCA publications. While the compilation is our primary product, the interpretive publications based on this work provide additional information about how geologists tell time and why these dates are important. With this broader perspective, the age of Grand Canyon rocks becomes more meaningful. Furthermore, providing a consistent set of reliable ages adds to the credibility of geologic interpretation.

Providing a consistent set of reliable ages adds to the credibility of geologic interpretation.

This project is a good example of collaboration among scientists, resource managers, and interpreters. Interpreters had a significant need for consistent, reliable ages for Grand Canyon rocks, which this project filled; they also gained a better understanding of geologic dating techniques. With increased knowledge, interpreters may be able to facilitate greater comprehension of the science behind their geologic presentations. Additionally, this compilation and accompanying background information about dating methods can help interpreters address the socio-political controversy regarding deep time and evolution. Resource managers benefit by having an internally consistent and scientifically credible time scale to apply to internal and external geologic and paleontological work. Finally, working directly with researchers has fostered communication and credibility among park interpreters, resource managers, and the academic community.

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Mike Timmons (New Mexico Bureau of Geology and Mineral Resources), Ron Blakey (Northern Arizona University), and Karl Karlstrom (University of New Mexico) provided valuable insight into the rocks exposed in the Grand Canyon and assisted us with our compilation of best numeric ages. Jim F. Wood (NPS Geologic Resources Division) posted the results of our work on the Internet.

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Using prescribed fire to restore evolutionary processes at Ozark National Scenic Riverways

The case of the collared lizard

By Angela R. Smith, summarizing the research of Alan R. Templeton

> "Earth's biodiversity is the product of past evolution, and is not, nor has it ever been, static. Hence, conservation programs should try to preserve processes (such as evolution) that affect living organisms and ecosystems rather than conserving the current status quo of the living world."
>
> —Alan Templeton

At its most basic level, the National Park Service (NPS) mission is to protect and preserve resources. Yet meaningful assessment of our success in this broad mandate can be difficult. In parks set aside to preserve exceptional natural resources, aspects such as water quality, species diversity, and natural processes will inevitably be part of the "protection and preservation" yardstick. But managers must also consider other issues when implementing the NPS mission. For example, on a global scale, human activities are causing massive impacts on biodiversity at the ecosystem, community, species, and genetic levels. Though impacts on species diversity are often more obvious and thus receive more human attention, impacts on *genetic* diversity affect the very foundation of all the other levels.

Gene flow–a natural process

The importance of genetic diversity cannot be overstated. Without it, a population cannot evolve and adapt to environmental change. Given the rate at which environmental change is occurring worldwide, the ability to adapt to new conditions has been and will become critical for many species. *Genetic drift* is the random loss of a population's genetic variation. Genetic drift is greatly accentuated when local populations are isolated from one another and are small in size: genetic variation decreases within each local population as individuals become more genetically similar to each other. In this instance, genetic *differentiation* increases between isolated populations; that is, Colony A will become genetically different from Colony B if the colonies do not have access to each other. Genetic drift and isolation can prevent the spread of adaptive characteristics outside of the population of origin, which disrupts the evolutionary and speciation process (Templeton et al. 2001).

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Conversely, *gene flow* occurs when Colonies A, B, and C all have access to each other. In this case, genetic variation within a single population (Colony A, for example) will increase, but overall, all three colonies will become more genetically similar. Gene flow also allows new mutations (the source of genetic variation) to spread from their population of origin to other populations. By increasing local variation and allowing that variation to spread, gene flow helps populations to evolve and adapt to changing conditions.

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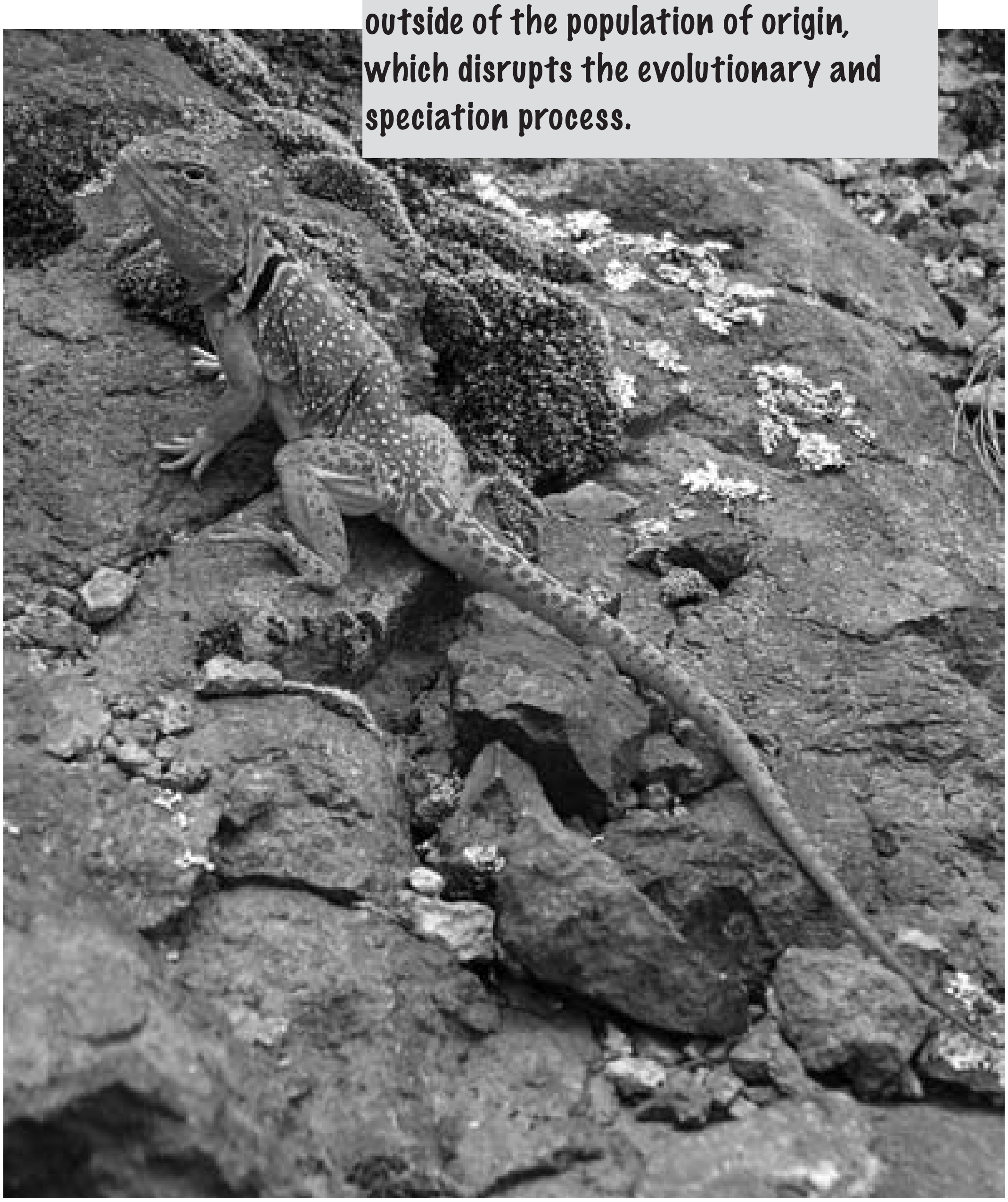

Figure 1. Collared lizards are recovering in the Ozark National Scenic Riverways area thanks to a prescribed burning program that reduces thick underbrush in the forest, allowing the reptiles to disperse and colonize new glades. Colonies are no longer as isolated from one another and gene flow among them is on the rise. ALAN R. TEMPLETON

Decline of the collared lizard

One illustration of genetic isolation and possible management responses can be found in and around Missouri's Ozark National Scenic Riverways. Ongoing research is revealing a fascinating example of successful species protection and preservation through managed restoration of a natural process: fire. The story begins with habitat loss and the collared lizard.

The male collared lizard is spectacular to behold (fig. 1). At 8–14 inches (20–35 cm) in length, it is relatively large and brightly colored, and its turquoise or green legs and orange throat overshadow the female's brown and usually smaller body. Two brown or black lines across the necks of both female and male collared lizards (see fig. 1) gave rise to their popular and scientific names (*Crotaphytus collaris collaris*).

Missouri is at the eastern edge of collared lizard range. These animals prefer desertlike habitat and are more commonly found in the Southwest and Great Basin. In Missouri, collared lizards occupy glades, which are open areas with thin, rocky soil, usually on south- or southwest-facing slopes (fig. 2). The hot and dry microclimates within glades provide habitat for an important diversity of desert-adapted plants and animals (Nelson and Ladd 1981).

Figure 2. Ozark glades are typified by thin, rocky soil and are usually located on south- or southwest-facing slopes, resulting in hot, dry microclimates that suit collared lizards. Fire suppression on adjacent forest tracts had prevented the species from dispersing and colonizing glade habitat. A prescribed fire program has reversed the declining trend in collared lizard numbers. ALAN R. TEMPLETON

Glades were once maintained by fire. Whether natural in origin or set by Native Americans, fire often swept through the Missouri Ozarks, keeping the woodlands open and grassy (Anderson and Bowles 1999). Tree-ring studies at Ozark National Scenic Riverways indicate that between 1640 and 1800 fire occurred approximately every five years (Guyette and McGinnes 1987). When European settlers arrived, they commonly harvested the woodlands and eventually implemented fire suppression measures. Deprived of fire, the once-abundant glades began to diminish in area and number and were replaced by forest that was much denser (fig. 3). Where collared lizards had formerly moved freely from one glade to another, they began to be limited to their original colonies because they could not locate new habitat through the dense underbrush.

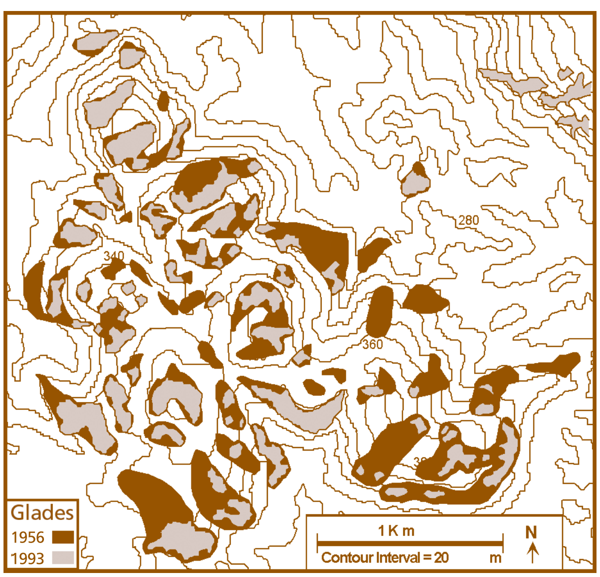

Figure 3. Decline in glade habitat in the Stegall Mountain Natural Area from 1956 to 1993. A prescribed fire program was implemented to manage natural communities and increase glade habitat. ALAN R. TEMPLETON

Eastern red cedar (*Juniperus virginiana*), which had been controlled by fire, began to invade the glades, and in turn allowed successional invasion by other woody species. With reduced habitat and isolated colonies, collared lizard populations declined. Without the ability to interact with other collared lizard groups, genetic diversity was diminished and long-term survival of the collared lizard was threatened.

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A genetics study confirms this connection between habitat change and genetic drift. Using molecular markers called microsatellite loci, researchers compared genetic variation among collared lizards in the vicinity of Ozark National Scenic Riverways and the Southwest. Their analysis revealed a very unusual pattern. In the past, collared lizards in the northeastern Ozarks shared the same genetic variants, a pattern indicating much gene flow, but in a matter of decades the populations became fragmented and gene flow halted (Hutchison and Templeton

1999). Over this relatively short period most genetic variation among collared lizards living in any single glade was lost; genetic variation among all glades, however, was retained (a pattern typical of genetic drift). Hence, genetic variation in the Ozarks as a whole was high, but no single collared lizard population had access to it.

Prescribed fire

By the 1980s, no known populations of collared lizards existed within a 50-mile (80 km) radius of Ozark National Scenic Riverways or Stegall Mountain Natural Area, which is jointly owned and managed by the Missouri Department of Conservation, The Nature Conservancy, and the National Park Service. Between 1984 and 1989 Dr. Alan Templeton of Washington University in St. Louis and the Missouri Department of Conservation implemented a program to increase collared lizard numbers in the area. The initial effort involved translocating three populations of collared lizards that were living in threatened habitat. Twenty-eight adult lizards were translocated to three glades in three releases (one per glade) from 1984 to 1989: 10 on each of two glades and 8 on the third. All of the lizards survived but they did not colonize other available glades in the area, one of which was only approximately 200 feet (60 m) away. Monitoring by Templeton indicated that each of the translocated populations rapidly lost about half of its initial genetic variation—though a different, random subset—which mimicked the pattern discerned in the 1999 collared lizard genetics study. Land management of the Stegall Mountain Natural Area included a fire suppression policy, which remained in effect through 1993. Monitoring over this period revealed no dispersal or colonization of the nearby glades and, thus, no genetic exchange (Templeton et al. 2001).

In 1994, after a Biodiversity Task Force recommended the use of managed fire on a landscape level, the Missouri Department of Conservation and the National Park Service began a prescribed fire program at Stegall Mountain. The first unit planned for treatment was partially burned in 1994 and completely burned in 1996. In 1997, a second unit to the south of the first was also burned, and by 1999 about 5,000 acres (2,025 ha) of the Stegall Mountain area had been treated with prescribed fire.

Results

The effect was dramatic. Vegetation monitoring revealed significant thinning of the understory, despite little change in the canopy trees (fig. 4). Monitoring of vegetation transects revealed a reduction in sapling density from approximately 1,000 per acre (405/ha) prior to the burn to 600 per acre (243/ha) after the burn (Nigh 2004). For the collared lizards, interglade dispersal went from undetectable before 1994 to being common in the areas that were burned. Since burning, 35.6% of the juveniles (both sexes), 40.8% of adult males, and 8.1% of adult females have dispersed to nearby, uninhabited glades (Templeton 2001). Marked impacts on

Figure 4. Comparison of a glade before (1994, top) and after (2004, bottom) prescribed burning. After fire was introduced, understory vegetation became thinner, allowing collared lizards to disperse and begin to colonize nearby glades.

colonization were also evident. For 10 years, no glades had been colonized by lizards in the study area until the prescribed fire of 1994. However, over the next three years 13 glades were colonized. Twelve of the colonized glades were in the burn area and one was unburned. Interestingly, the unburned glade had been part of a mechanical thinning project conducted by the Missouri Department of Conservation in anticipation of extending the burn area to include the glade. During the winter of 1996–1997, workers cut much of the woody vegetation that separated the two fragments of what was formerly a single glade. Although the collared lizard population on the original glade was very dense, the lizards had not colonized the nearby fragment between 1989 and 1996; however, they did so immediately after the mechanical thinning. (The mechanically thinned area was also burned making the effects of one treatment indistinguishable from the other.) Apparently, the ability of collared lizards to disperse among and colonize glades depends strongly on the intervening forest structure, particularly the understory. In the nine years prior to prescribed fire restoration, no glades had been colonized naturally. Yet by 2003, nine years after prescribed fire, 51 new glades had been colonized with collared lizards (fig. 5) (Washington University, A. R. Templeton, professor of biology, personal communication, 13 September 2006).

There are at least two possible explanations for the apparent inability of collared lizards to disperse through thick underbrush. One is that as visual predators, the lizards were reluctant to move into territory that restricted their field of vision. Also, most long-distance dispersal takes place by hatchlings, which have low food reserves (fig. 6). A sampling of the insects on which they normally feed indicates an abundance of the food source in burned forest, while in unburned areas the insects were virtually absent. Hence they may avoid unburned areas because of the lack of significant food sources (Washington University, A. R. Templeton, professor of biology, personal communication, 8 January 2007).

Remarkable increases in population numbers also occurred following the prescribed fire treatments. The original translocation population had consisted of 28 animals in three releases, but by 2003, 276 collared lizards—nearly 10 times the original release—were documented through mark-recapture techniques on Stegall Mountain. Interestingly, lizards in the newer, mostly unoccupied habitats demonstrated a surprising colonizing ability by having two clutches in 2002 rather than the normal single clutch. Thus, each female in the newly colonized and low-population-density glades was able to have 12–16 offspring. Moreover, the growth rates of these offspring were 1.5 to 2 times the rates estimated from saturated habitats. As a result, many of the hatchlings were of adult size by the end of September of 2002, a phenomenon not observed before by the researchers (Templeton 2002).

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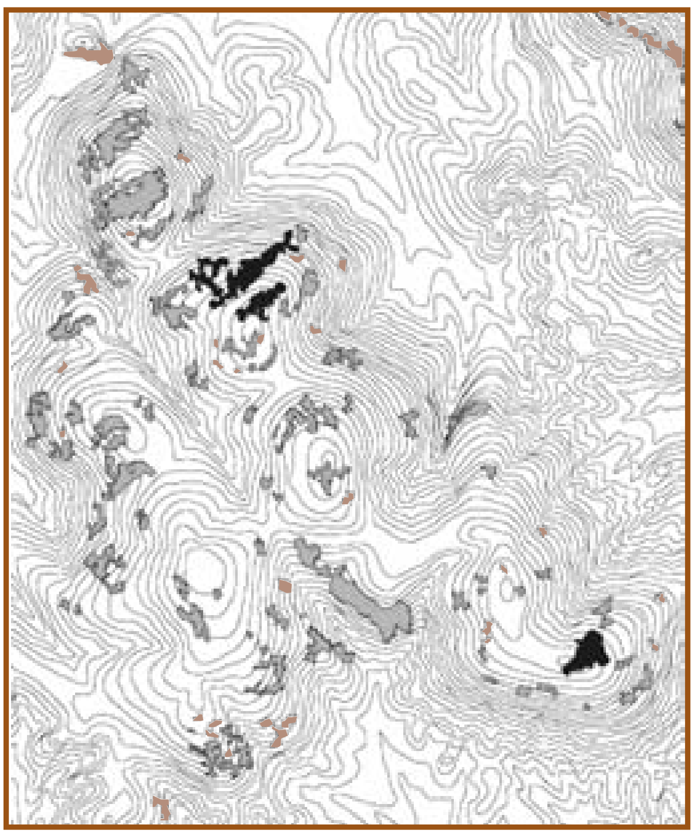

Figure 5. The map shows changes in the occupancy of glades by collared lizards in the Stegall Mountain Natural Area from 1984 to 2003. All glades were unoccupied before the 1984–1989 translocations of collared lizards (black). These three populations remained stable, though their numbers did not increase, and no new glades were colonized by the end of 1993. In the nine years following a series of landscape-scale prescribed burns (1994–2003) collared lizards increased nearly 10-fold, colonizing 51 new glades (gray). Glades still uncolonized in 2003 are shown in light brown. ALAN R. TEMPLETON

Figure 6. Dispersal by collared lizard hatchlings may be limited by food availability. Insect prey is abundant in areas treated by prescribed fire but lacking in unburned areas. ALAN R. TEMPLETON

Using a rapid method to predict recreational water quality at Cuyahoga Valley National Park, Ohio

By Rebecca N. Bushon, Amie M. G. Brady, and Meg B. Plona

Introduction

Conventional methods for determining recreational water quality are based on concentrations of fecal-indicator bacteria, such as *Escherichia coli*. When found in water, *E. coli* indicates contamination from human and animal waste and the possible presence of disease-causing organisms. Determining levels of fecal-indicator bacteria by conventional methods requires at least 18 hours to process and culture samples before results are available. This length of time is too long to assess water quality, take adequate control measures, and warn recreational users of a health hazard. Decay, dilution, dispersion, and transport of fecal-indicator bacteria in water cause concentrations to change greatly over short periods of time. Because results from conventional methods are not available until the following day, the safety of the water for recreational use may not be accurately assessed. The need for a rapid method that provides reliable results of the current day's bacteria concentrations is widely recognized.

When found in water, *E. coli* indicates contamination from human and animal waste and the possible presence of disease-causing organisms.

U.S. Geological Survey (USGS) scientists, in partnership with the National Park Service (NPS), have been testing a rapid method in Cuyahoga Valley National Park, Ohio, that provides estimates of *E. coli* concentrations in approximately one hour. This rapid method was developed by Lee and Deininger (2004). Previous studies at the University of Michigan showed a strong, significant correlation between the rapid and conventional methods for *E. coli* in samples collected from two Great Lakes beaches, two inland beaches, and the Huron River (Lee and Deininger 2004). The purpose of this study is to compare the results of the rapid method to results of the conventional method for determining concentrations of *E. coli*. Water samples were collected during the May-through-September recreational seasons of 2004 and 2005 at three sites on the Cuyahoga River within Cuyahoga Valley National Park.

The Cuyahoga River connects the national park with the largest system of freshwater in the world: the Great Lakes. The fabled river that burned brought international attention to water-quality issues and encouraged cleanup through the passage of environmental legislation, especially the Clean Water Act. Over the past few decades, the water quality of the Cuyahoga River has improved considerably and the river was designated by the Environmental Protection Agency in 1998 as one of 14 American Heritage Rivers; however, the water quality of the Cuyahoga River is still a primary concern of park managers and visitors. The 23-mile reach of the river within the park receives discharges of stormwater, combined-sewer overflows, and incompletely disinfected wastewater from urban areas. Park visitors are discouraged from canoeing, swimming, and wading in the river because these discharges can be a threat to their health (fig. 1).

Figure 1. An attraction to kayakers, canoeists, and swimmers, the Cuyahoga River can be unsafe because of discharges from stormwater, sewer overflows, and urban wastewater. Managers at Cuyahoga Valley National Park have been testing a method to provide same-day information on E. coli levels in the Cuyahoga River that would improve their ability to protect the health of water enthusiasts. STEVE TUCKERMAN, OHIO EPA

Until improvements in the treatment, disinfection, and detention of sewage and storm-water overflows upstream of the park's boundary become a reality, resource managers need an interim approach to protect human health and to provide safe, water-based recreation for park visitors. Without a realistic method to determine daily water-quality conditions, use of the river will be discouraged, even when fecal indicator concentrations are at safe levels.

Methods

In this study we tested a rapid method of measuring fecal-indicator bacteria that is based on immunomagnetic separation (IMS) and detection of adenosine triphosphate (ATP) (Lee and Deininger 2004). In the IMS/ATP method, the target bacteria attach to bacteria-specific antibodies that are bound to magnetic beads, which are approximately 1 micrometer (3.9×10^{-5} in) in diameter. The target bacteria are separated from the rest of the sample by placing a strong magnet next to the sample tube. The magnet pulls the magnetic beads out of solution. Following several wash steps, the bacterial cells are ruptured by an enzymatic process, releasing ATP, which is the energy molecule found in living cells. The magnetic beads are pulled out of solution and discarded so that the sample to be analyzed only contains ATP. An enzyme/substrate solution (luciferin/luciferase) is added to the concentrated ATP and light emission is measured with a microluminometer. Results are recorded as relative light units per 100 milliliters (RLU/100 mL). Samples were also analyzed by the conventional membrane filtration method ("conventional method") (U.S. Environmental Protection Agency 2002).

We began our testing of the IMS/ATP method for estimating *E. coli* levels in the Cuyahoga River in the summer of 2004. We selected three sites for collecting water samples within the national park: Old Portage (near the upstream boundary of the park), Bath Road (just downstream of a major water-pollution control station), and Jaite (near the center of the park) (fig. 2). These three sites were chosen because of the availability of historical bacteria data. We collected

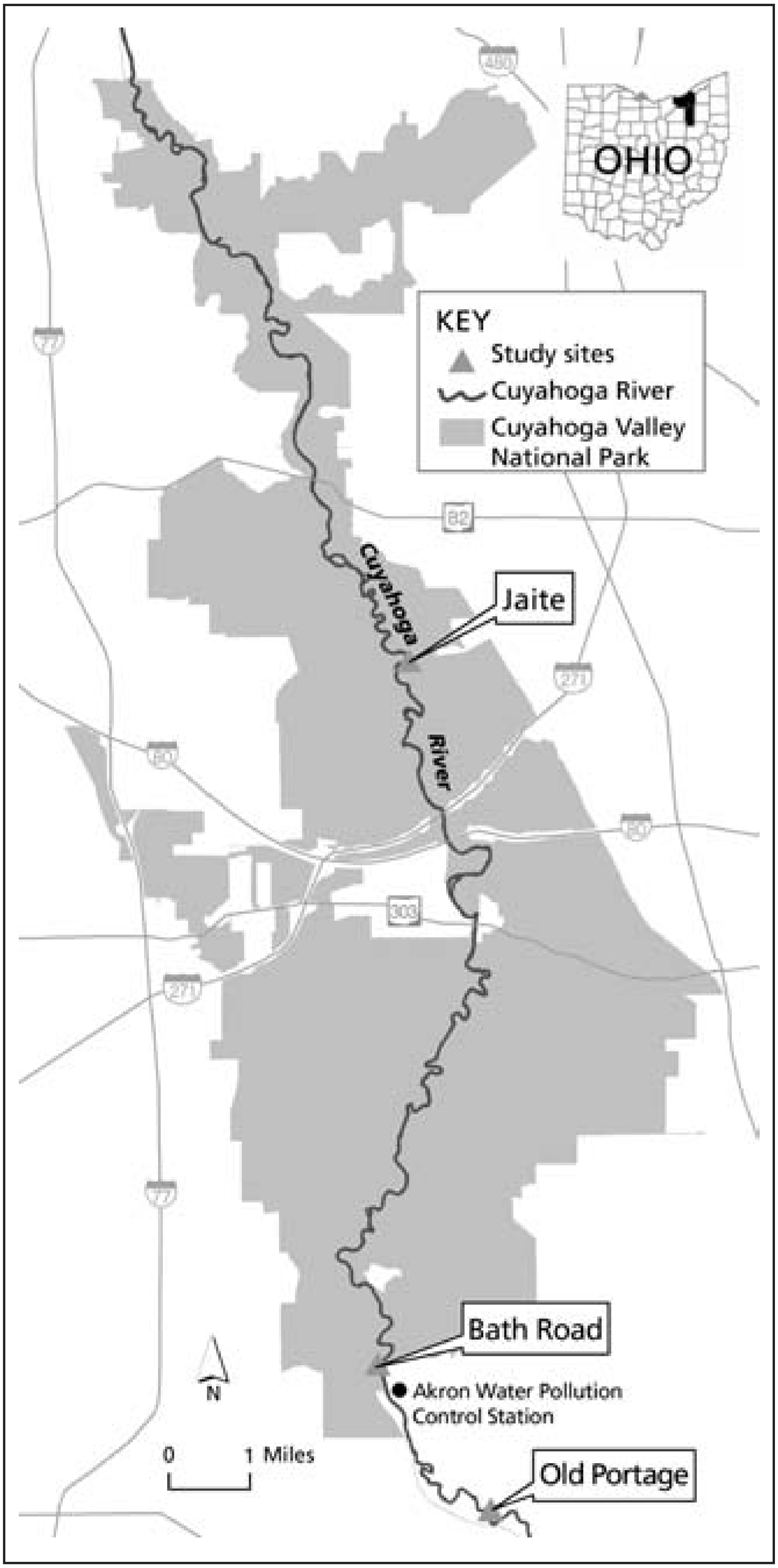

Figure 2. Cuyahoga Valley National Park map showing the location of the three study sites.

CUYAHOGA VALLEY NATIONAL PARK

samples between four and seven days per week at each site during the recreational seasons (May through September) of 2004 and 2005. Samples were collected using a grab-sampling technique, in which a sterile 1-liter polypropylene bottle was plunged below the surface of the water to collect the sample. All samples were analyzed using the IMS/ATP method and conventional method. We collected a total of 206 samples during the study, as follows: 72 from Old Portage, 56 from Bath Road, and 78 from Jaite.

We also measured and tested other water-quality and environmental variables such as turbidity, streamflow, and daily precipitation as possible surrogates for concentrations of *E. coli*. Turbidity is a measure of water clarity and was measured using a Hach portable turbidimeter (Hach Company, Loveland, Colorado). Steamflow data (cubic feet per second) were obtained from USGS streamflow-gaging stations where available or determined from rating curves. Daily precipitation was obtained from the Automated Flood Warning System (http://afws.net/). Quality assurance/quality control procedures were followed to ensure collection of a high-quality data set (Myers 2003).

We examined statistical correlations between the conventional method and other water-quality variables and the IMS/ATP method and chose the variables with the strongest relations to the conventional method for use in predictive models, which we developed for each site.

Results

By use of the conventional method, *E. coli* concentrations in the Cuyahoga River during the study ranged from 70 to 49,000 colony-forming-units per 100 milliliters (CFU/100 mL), with a median value of 380 CFU/100 mL. In Ohio, the recreational water-quality standard for this portion of the river is 298 CFU/100 mL of *E. coli*. Fifty-nine percent of the samples collected exceeded the standard.

Fifty-nine percent of the samples collected exceeded the [health] standard [for *E. coli*].

The relation between the IMS/ATP method in RLU/100 mL and the conventional method in CFU/100 mL at each of the three sites is shown in figure 3. Analysis of the relations between the IMS/ATP method and the conventional method for the Old Portage and Jaite sites indicated Pearson's correlation coefficients (r) of 0.59 and 0.45, respectively, both of which were statistically significant (p <0.0001) (figs. 3a and b). (Pearson's r measures the linear association between two variables; the closer it is to 1 or -1, the stronger the relation. The p-value measures the

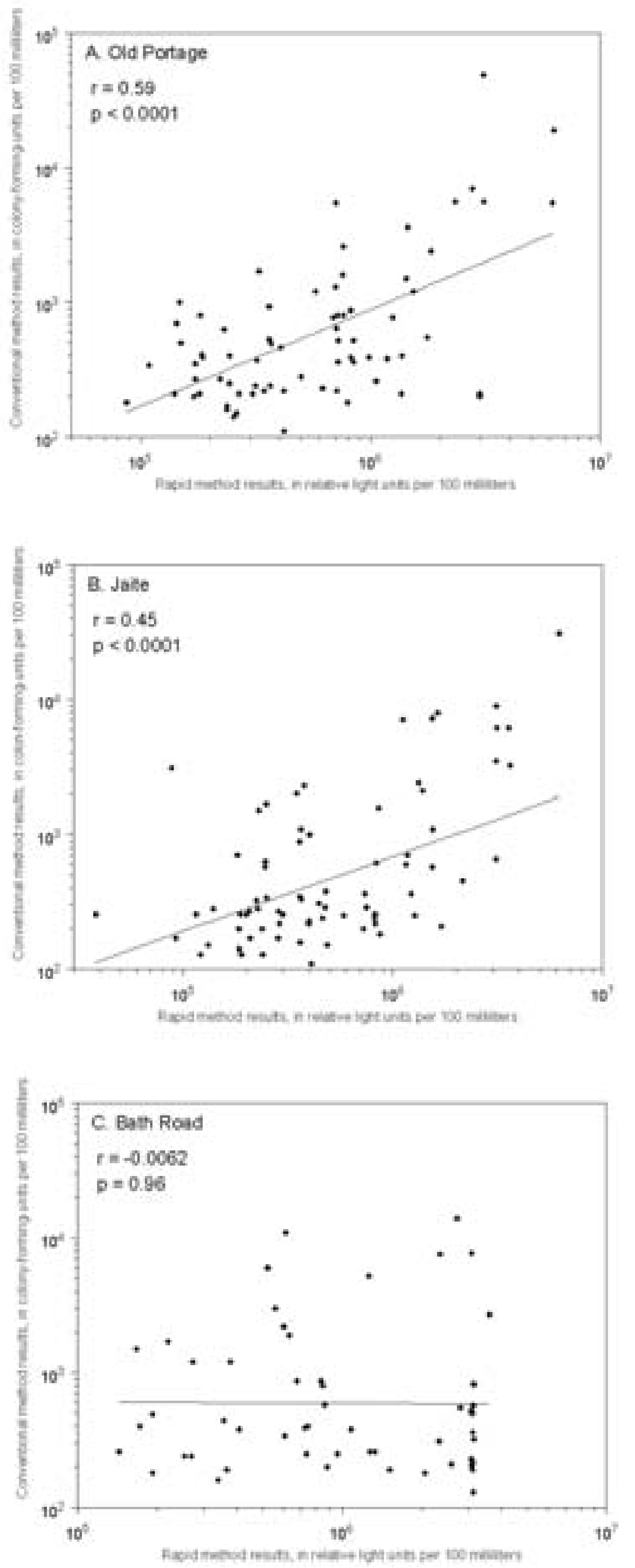

Figure 3. Relations between the immunomagnetic separation/adenosine triphosphate (IMS/ATP) and conventional membrane-filtration methods for estimating *E. coli* concentrations in the Cuyahoga River at (a) Old Portage, (b) Jaite, and (c) Bath Road, Cuyahoga Valley National Park, 2004–2005. (*r* is the Pearson's correlation coefficient, and *p* is the significance of the correlation.)

credibility of the relation; the smaller the p-value, the stronger the evidence that there is a relation between the two variables.) Correlation analysis for the Bath Road site did not show a statistically significant relation (r = -0.0062, p = 0.96) (fig. 3c). Because this site is immediately downstream from a wastewater-treatment center, we feel it is possible that the IMS/ATP method is detecting injured bacteria that may not have had adequate time to recover and grow on culture plates used in the conventional method.

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We developed predictive models using multiple linear-regression analysis for the Old Portage and Jaite sites. With this analysis, multiple variables are used to predict *E. coli* concentrations as measured by the conventional method in the river. We selected the variables that showed the strongest relations to the conventional method for use in this analysis. For both sites, IMS/ATP method results and turbidity had the strongest correlation to the conventional method and were used in the models. We found statistically significant relations (p <0.0001) between the predicted *E. coli* concentration from the model and the actual *E. coli* concentration from the conventional method. The R^2 values for the Old Portage and Jaite sites were 0.57 and 0.65, respectively. (The R^2 of the model is the fraction of the variation in the *E. coli* concentration that can be explained by the model's variables. For example, at Old Portage, our model is able to predict 57% of the variation in *E. coli* concentrations. The other 43% of the total variation remains unexplained.)

Compared to the current practice of determining water quality (yesterday's *E. coli* concentrations), the predictive model (based on IMS/ATP and turbidity results) for Jaite correctly predicted water quality as often (72% and 75% for the model and current practice, respectively) and had a lower false-negative rate (8% as compared to 14% for the current practice). False negatives must be minimized because they imply that the risk of recreational use is low when it is not. Although the predictive model for Old Portage did not predict *E. coli* concentrations as well as the conventional method, the model also had a lower false negative rate (4% as compared to 10%). The data used to produce these percentages were from the data set used to generate the predictive model. The models need to be tested at these same sites during a separate year.

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Conclusions

As a result of this study, we find that the IMS/ATP method is a reasonable supplement and could become an alternative to using the conventional method for determining *E. coli* concentrations at some sites. In this study the IMS/ATP method better predicted current *E. coli* concentrations when used in a predictive model with other explanatory variables, rather than as a stand-alone method. Additional work would be needed to optimize the method and increase the predictive capabilities of our models. Accordingly, staff of Cuyahoga Valley National Park has continued to collect and analyze water samples at the Old Portage and Jaite sites to further test and improve the models. In addition, the USGS is working to optimize and increase the sensitivity of the IMS/ATP method, as well as to decrease its cost. Specifically, new *E. coli* antibodies and alternate antibody-bead-coating procedures are being tested.

Compared to other rapid methods that are being tested by other researchers, the cost of equipment for the IMS/ATP method is considerably less expensive. Rapid, molecular methods, such as quantitative polymerase chain reaction (Frahm and Obst 2003) require expensive equipment and detect viable as well as nonviable organisms. The IMS/ATP method only detects viable cells, which may make it more comparable to health risk and the standard plating method. Analyses using the IMS/ATP method now cost approximately $25 per sample; however, new materials are under development and may decrease this cost. The entire process can be carried out by a trained analyst with basic laboratory skills. Although the IMS/ATP method is slightly more expensive than the conventional method (approximately $10 per sample), the value of obtaining same-day results may outweigh the additional cost.

As the method is refined and optimized, IMS/ATP method results could be provided within an hour following sample collection, giving parks with water-based recreation the ability to alert visitors to unsafe bacteria levels. Cuyahoga Valley National Park is in the early stages of preparing a river-use management plan that will address water-quality issues. With the availability of same-day water-quality information, park managers would be able to inform the public of the safety of the river for recreational use. This capability would not only benefit managers and recreational park users, but also would be useful to state and national health organizations that need same-day information on waterborne-bacteria levels. Although the predictive models developed in this study are site-specific, the methodology used for sample collection/analysis and model development may be used in other areas to develop monitoring programs for predicting current conditions.

Acknowledgments

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Conclusion

Researchers believe that with appropriate management, a reversal of genetic isolation and population decline is possible with regard to collared lizards. (Ongoing research indicates plant diversity is increasing, and at least one other animal species—a glade grasshopper—is also increasing in number.) Preliminary conclusions note extensive gene flow among the glades and high levels of genetic diversity (Templeton et al. 2001).

Focusing management on a landscape scale and using natural ecological processes to maintain habitat may be a more successful strategy than pursuing individual species conservation. Fire management is an important part of this approach for this species, and with continued use, the collared lizard and other glade and savanna species can be expected to thrive in the Ozark National Scenic Riverways.

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Meetings of Interest*

5–10 August The Ecological Society of America (ESA) and the Society for Ecological Restoration International (SER) are planning their biennial joint meeting, "Ecology-based Restoration in a Changing World," to be held in San Jose, California. Symposia are the scientific centerpiece of the meeting and will encompass setting goals for ecological restoration and measuring its success. As the ESA Web site (http://www.esa.org/sanjose/) explains, paleoecology, long-term studies, and ecological modeling call attention to the fundamentally dynamic nature of ecological systems, which can make predicting change difficult. Baselines are not easily defined and the effects of climate change and human land use further complicate the matter. Conference organizers stress that "new scientific insights call for more sophisticated consideration of the goals and standards of restoration and, perhaps, of conservation of natural systems generally." They ask, what ecosystem attributes are to be restored, conserved, or preserved? How should ecological research inform these priorities? How can the effectiveness of restoration be assessed? The meeting will delve into these issues of identifying ecosystem attributes to be restored and conserved, the role of research in setting these priorities, and assessing the effectiveness of restoration. Additional information is available at the SER Web site (http://www.ser.org/events.asp).

22–26 September The Wildlife Society is planning its annual conference to be held in Tuscon, Arizona. Sessions, papers, and posters will explore recent research on the conservation of mammals, birds, and reptiles in a wide variety of settings, including along the U.S.-Mexico border. Discussions are planned on the topics of conservation genetics for wildlife biologists and managers and benefits and detriments of sharing wildlife and habitat data online. Symposia will examine numerous topics such as landbird conservation; species, community, and ecoregion responses to rapid climate change; wildlife diseases; wind energy development and wildlife; restoration of wildlife; and many more. The conference Web site (http://www.wildlife.org/conference/index.cfm) has further details.

9–12 October The Natural Areas Association will hold its 2007 annual conference, "Some Assembly Required: Preserving Nature in a Fragmented Landscape," in Cleveland, Ohio. Ecosystem fragmentation has altered biodiversity and intrinsic processes that are critical to natural area function. One of the primary challenges for conservation organizations and agencies involves the selection, acquisition, and subsequent management of fragments containing core ecosystems. The program will examine a variety of topics related to conservation of fragmented ecosystems, ranging from invasive species management to fire ecology and global climate change. The conference Web site (http://www.naturalarea.org/07conference/) shares more details.

28–31 October The Geological Society of America (GSA) will hold its annual meeting, "2007 Earth Sciences for Society," in Denver, Colorado. One of the core missions of GSA is to advance the geosciences in the service of humankind. In that spirit, the program for this meeting will explore themes germane to the proclamation of the year 2008 by the United Nations General Assembly as the "International Year of Planet Earth." Organizers are planning a rich program to explore ways in which geoscience can help realize a safer and more prosperous world, including the search for oil and gas, conservation of water resources, understanding of natural hazards, planetary exploration, the application of information technology, and more. Presentations will describe both pure and applied research. The meeting aims to improve communication among geoscientists, the public, planners, managers, and decision makers. Further information is available at the meeting Web site (http://www.geosociety.org/meetings/2007/).

*Readers with access to the NPS Natural Resources Intranet can review a longer list of upcoming meetings, conferences, and training courses at http://www1.nrintra.nps.gov/NRMeet/.

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