PARK SCIENCE

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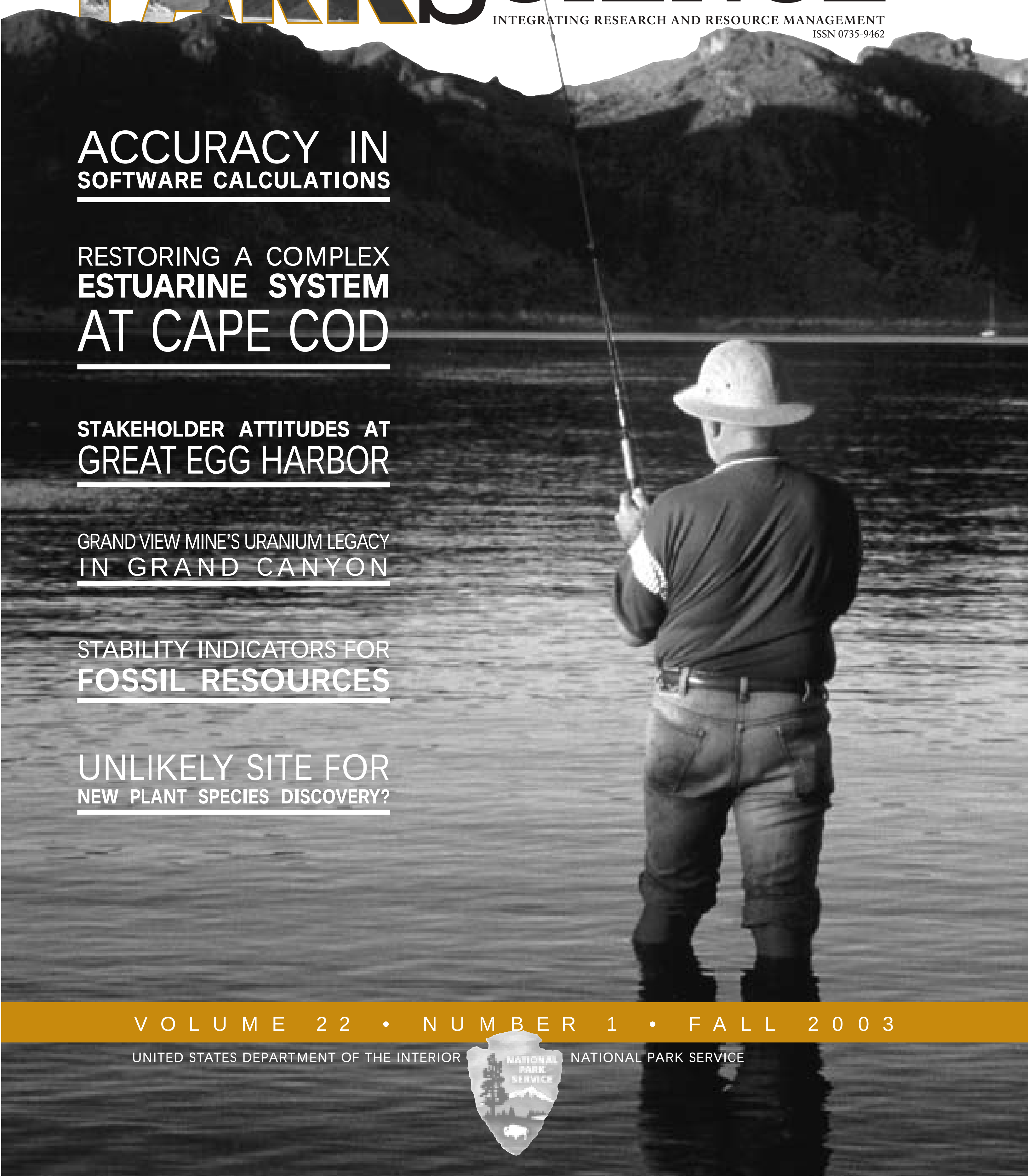

ACCURACY IN SOFTWARE CALCULATIONS

RESTORING A COMPLEX ESTUARINE SYSTEM AT CAPE COD

STAKEHOLDER ATTITUDES AT GREAT EGG HARBOR

GRAND VIEW MINE'S URANIUM LEGACY IN GRAND CANYON

STABILITY INDICATORS FOR FOSSIL RESOURCES

UNLIKELY SITE FOR NEW PLANT SPECIES DISCOVERY?

VOLUME 22 • NUMBER 1 • FALL 2003

UNITED STATES DEPARTMENT OF THE INTERIOR NATIONAL PARK SERVICE

From the Editor

THE HUMAN ELEMENT

We start this issue with an exercise in thinking that is sure to challenge every reader. In our cover article Roy Irwin examines the question of accuracy in spreadsheet software calculations. He raises a concern that resource managers and researchers should be aware of: calculations by statistical spreadsheets, including Microsoft Excel—the standard spreadsheet for the National Park Service—can be inaccurate under certain conditions. As the article points out, scientists need to be prepared to evaluate the degree of accuracy required from calculations for particular park applications and the potentially problematic effects of very large numbers and sample sizes and other combinations of data and analyses that can cause problems. The article is a reminder that vigilance and judgment—human attributes—are needed to use software correctly and to draw valid conclusions from what the numbers tell us.

The powers of observation, collaboration, critical thinking, and persistence are other important human capabilities highlighted in this issue. Chris Lea and Rob Naczi describe their experience in making a new plant species discovery at Thomas Stone National Historic Site that helped to reconcile a confusing, nearly 160-year-old error in plant taxonomy. Keen observation, help from colleagues, and knowing where to turn next to unravel the mystery aided their efforts, resulting in important information becoming available for park management and clarifying the botanical record, a benefit extending well beyond park boundaries.

A good illustration of the marriage between the technical aspects of science and their expert and creative application is the article on salt marsh restoration at Cape Cod. Decades of research has documented the loss of tidal marsh wetlands and other environmental changes caused by diking, drainage, and filling of the estuary. Involving many individuals and organizations, science has been marshaled to understand the dysfunction of the system and to monitor its restoration through the reestablishment of natural tidal fluctuations. The long-term project at Hatches Harbor, rooted in science, requires political coordination, technical engineering, flexibility to apply new study results as they become available, and time to build confidence among the stakeholders that the restoration is meeting ecological and flood-protection goals.

These are just three examples in this issue that demonstrate the importance of people to the effective use of science in preserving park natural resources. Despite the numerous technical tools available to help us make the most accurate measurements and conduct the most extensive analyses, science is impossible without the scientist. Scientists see connections between things not thought to be connected, they understand the limits of the tools of their trade and apply them correctly, they combine disparate parts into a cohesive whole, and they rally resources and the help of colleagues. Ingenuity, creativity, persistence, judgment, critical thinking, and vigilance, while not quantifiable attributes, are essential to good science. Clearly science needs the human element as much as we need science.

Jeff Selleck
Editor

PARKSCIENCE

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DEPARTMENTS

ON THE COVER

Mercury concentrations in fish at Lake Mead National Recreation Area (Nevada and Arizona) are below the national average. Nevertheless, the National Park Service wanted to assess potential differences in human exposure to the toxic metal based on the edible portion of different sizes of fish from various lake locations. The author of our cover article on the accuracy of software calculations, Roy Irwin, conducted the analysis in 1998. Neither sample sizes nor numbers were very large—circumstances that if true might cause concern—and Microsoft Excel was satisfactory in calculating simple summary statistics such as the mean, median, and confidence levels. On page 32 Irwin describes a variety of potentially problematic conditions that can affect the accuracy of software calculations.

NPS PHOTO BY LESLIE PAIGE

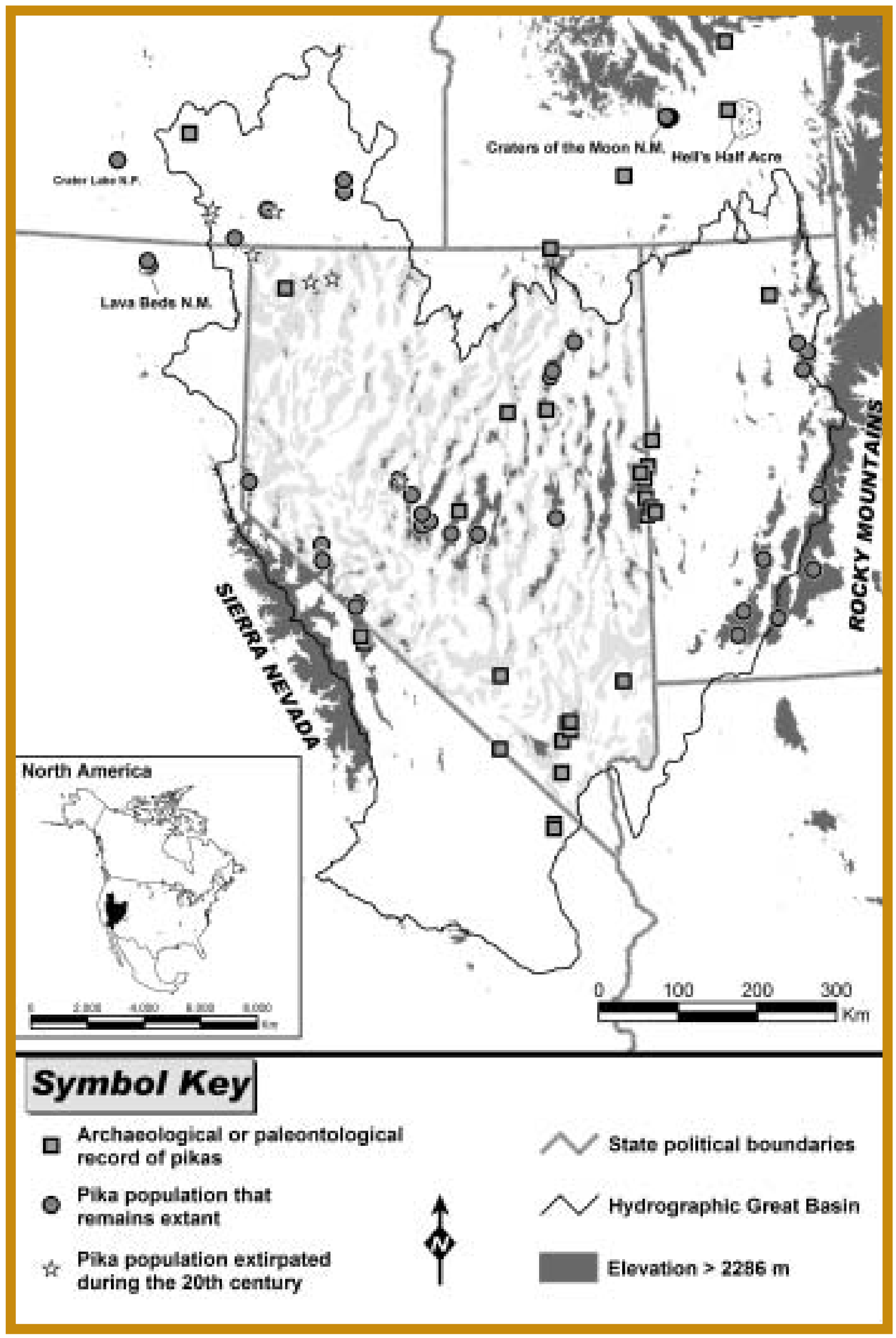
COVER ARTICLE

FEATURES

news&views

CORRECTION

In the article by Erik Beever regarding persistence and apparent extirpation of pika populations in and around the Great Basin that appeared in the spring 2002 printed edition, *Park Science* 21(2):23–29, the original figure 2 contained 24 data points that were assigned the wrong symbols and thus misclassified. This revised figure presents a more accurate picture of persistence and extirpation of pika populations in the region over time.



JOHN CHARLES WOODS

Hose named director of National Cave and Karst Research Institute

Louise D. Hose became the first permanent director of the National Cave and Karst Research Institute in December 2002. Hose now leads staff and partners in the effort to further develop and refine the long-term vision of the institute from her office in Carlsbad, New Mexico. She provides expertise built over 30 years in research, education, exploration, and conservation efforts related to caves and karst. She has explored and studied caves in New Guinea, England, Greece, South Africa, Oman, and Yugoslavia, but her most extensive work has been in the western United States and Mexico. *National Geographic* has twice featured her research: <http://magma.nationalgeographic.com/ngm/0304/feature2/index.html> and <http://www.nationalgeographic.com/ngm/0105/feature4/index.html>. She currently leads the institute through a "gearing up" phase, which is likely to last through 2003, and will consist of staff recruitment, design of the headquarters building, and initial operational setup.

With the selection of Hose, Zelda Chapman Bailey—who served as the institute's interim director for two years and moved the institute from merely a concept to a fledgling but thriving organization—left the institute in May 2003. She now serves as director of the National Institute of Standards and Technology (NIST), Boulder Laboratories, in Boulder, Colorado. Bailey's primary goal as interim director was to establish the institute on a solid foundation of strong partnerships that would allow the institute to grow into a world-renowned center for cave and karst issues.

The National Cave and Karst Research Institute Act of 1998 (Public Law 105-325) enabled the National Park Service to establish the institute. The mission of the institute is to facilitate speleological research, enhance public education, and promote environmentally sound cave and karst management. In January 2003, the National Park Service, the City of Carlsbad, and the New Mexico Institute of Mining and Technology, who constitute the three primary partners involved in establishing the institute, signed a memorandum of understanding to facilitate its development and management. The latest news regarding the institute is available at <http://www2.nature.nps.gov/nckri/index.htm>.

USGS scientist is recipient of wilderness science award

Jan van Wagtendonk, an internationally known research forester stationed at Yosemite National Park, was the recipient of the USDA Forest Service's 2002 Excellence in Wilderness Stewardship Research Award. This award recognizes van Wagtendonk's career of more than 30 years in wilderness science. From 1972 through 1993, van Wagtendonk was employed as a research scientist with the National Park Service. Since 1994, he has been a research scientist with the U.S. Geological Survey.

His research at Yosemite National Park has assisted in the development of wilderness fire management and visitor use management programs that have contributed substantially to interagency wilderness stewardship programs in the Sierra Nevada. He has made major contributions to wilderness fire programs both in the Sierra Nevada and across the country with his work on fuel dynamics, fire prescriptions, remote sensing, and the application of geographic information systems to fire management.

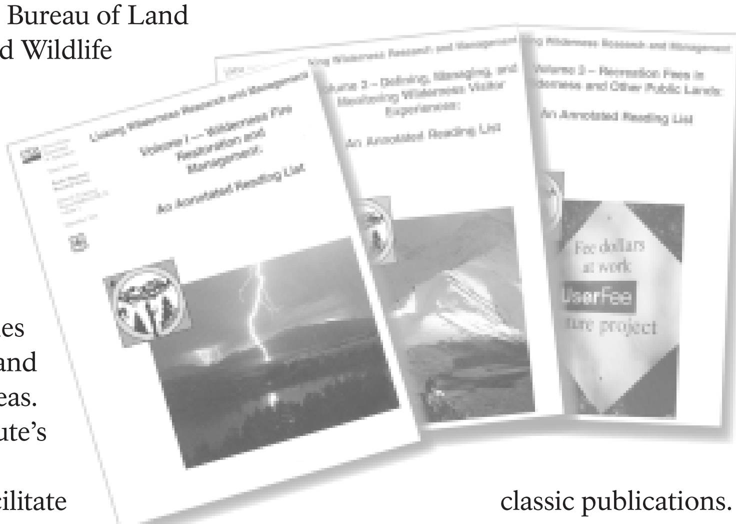
Van Wagtendonk developed a concept and methodology for determining trailhead quotas and recreational carrying capacities—that is, how many people engaged in recreational activities a wilderness area can "support" without adverse environmental effects. Managers have found this information to be critical for making decisions relating to development, visitor use, and staffing plans. Although other researchers were developing similar work concurrently, van Wagtendonk's work was the first to take a numerical approach and to be applied to an actual management situation. Managers in several national parks and wildernesses in national forests in Oregon, North Carolina, and California have used the techniques developed by van Wagtendonk.

Jan Van Wagtendonk (left) is presented the Forest Service's 2002 Excellence in Wilderness Stewardship Research Award by Forest Service Chief Dale Bosworth.

Information Crossfile

NEW TOOLS TO ACCESS WILDERNESS RESEARCH INFORMATION

While many scientists conduct research relevant to wilderness, the Aldo Leopold Wilderness Research Institute (Leopold Institute) is entirely focused on wilderness. This federal interagency (National Park Service, USDA Forest Service, Bureau of Land Management, Fish and Wildlife Service, and U.S. Geological Survey) institute is dedicated to developing and communicating knowledge needed to sustain the many ecological and social values of wilderness, parks, and similarly protected areas.



The Leopold Institute's Research Application Program strives to facilitate wilderness management decisions that are based on sound knowledge of current and relevant science by ensuring that research information is readily available to managers, policymakers, and others interested in wilderness management. Many land managers have limited time to search for and access the primary research literature; however, they can base their decisions on the best available scientific knowledge only if they are aware of current and relevant science and how it fits into their management goals. This article highlights three efforts recently undertaken to facilitate access to research information.

Expanded Website

The Leopold Institute's revised website, <http://leopold.wilderness.net>, includes information that addresses the challenges of maintaining and restoring fire to wilderness, managing for naturalness vs. wildness, the effects of fish stocking, understanding and managing day use and high-density recreation use, recreation user fees, understanding visitor experiences, and managing recreation site impacts. The site features a database of institute publications that is searchable by author, year, keyword, and subject. It also provides information about the institute's research and research application programs, staff activities, current and completed projects, and links to other relevant websites. Most information on the site is categorized by subject to facilitate finding relevant information quickly. This site was designed to provide information to a wide audience as soon as it becomes available.

Annotated Reading Lists

The *Linking Wilderness Research and Management* series of annotated reading lists was developed to help land managers and others wade through the plethora of potentially relevant research on specific wilderness issues. Each volume begins with background references necessary to understand the overall issue. Then, useful references for identifying management goals, understanding influences on those goals, and selecting and implementing management approaches are provided. Within each section, articles are annotated to clarify their relevance to that section and to highlight their importance for wilderness management.

Rather than produce comprehensive bibliographies, which may be unwieldy for those with limited time, the authors included overviews, the most current examples of literature addressing pertinent concepts, and frequently cited classic publications. These lists can provide a starting point for readers interested in more detail on specific subjects to conduct their own literature reviews.

To date the first four volumes in the series have been completed: Volume 1: *Wilderness Fire Restoration and Management*, Volume 2: *Defining, Managing, and Monitoring Wilderness Visitor Experiences*, Volume 3: *Recreation Fees in Wilderness and other Public Lands*, and Volume 4: *Understanding and Managing Invasive Plants in Wilderness and Other Natural Areas*. A fifth volume will address *Backcountry Recreation Impacts to Wildlife*. All volumes are available at <http://leopold.wilderness.net/resapp.htm>.

Research in a Nutshell

This effort summarizes research findings into an easy-to-read and accessible format so that readers can decide whether the more detailed publications are relevant to their objectives. The *Research in a Nutshell* series includes brief overviews of selected Leopold Institute research projects that highlight research results and management implications and list associated publications or products. These web-based summaries are also available at <http://leopold.wilderness.net/resapp.htm>.

__Vita Wright__, Research Application Program Director, Aldo Leopold Wilderness Research Institute, vwright@fs.fed.us.

USGS Western Ecological Research Center publication briefs

Resource managers may be interested in publication briefs from the USGS Western Ecological Research Center (WERC). Briefs are posted at <www.werc.usgs.gov/pubbriefs/index.html>, in some cases along with a copy of the scientific publication. The briefs provide nontechnical summaries of research findings published in recent scientific articles by WERC scientists. The briefs emphasize management implications of the research, provide the researcher's contact information, and supply the publication citation.

Currently posted briefs cover plant diversity and fire effects, assessing alien plant threats and setting priorities for managing problem species, potential effects of atmospheric nitrogen deposition on alien annual plants, alien plants and fire in desert tortoise habitat, introduced species and their missing parasites, Native American impacts on fire regimes, and human disturbance of shorebirds. Resource managers who have a potential interest in the implications of the research may request publication briefs to be mailed to them with a copy of the publication.

Western Ecological Research Center is one of 18 centers of the Biological Resources Division of the U.S. Geological Survey. Scientists and staff are based in offices located throughout the Pacific Southwest. Scientists focus on cross-regional issues, so research is neither geographically nor client-restricted. Researchers use broad syntheses, systems analysis, and applications of nontraditional approaches to serve clients' needs, including ecological research, monitoring and technology development, and basic biology and modeling. Scientists at the center have expertise in various taxonomic and ecological disciplines, such as herpetology, conservation biology, wetlands ecology, and ecological restoration. They also have specialized abilities and experience in techniques and methodologies such as geographic information systems (GIS), radio and satellite telemetry, and amphibian monitoring.

A new website about science in the Northeast Region

A new website is available where users can access information about ongoing research in national parks in the Northeast Region and read or download the final technical reports. The URL is currently <www.nps.gov/phso/ science>, but will change to <www.nps.gov/nero/science> (with an interim period where users of the first address will be directed to the new address). This user-friendly site describes new projects as they are funded and summarizes the progress of on-going projects. Ultimately, the final report goes on-line in PDF format. The final reports will become a large on-line library where users can easily access the wealth of information being generated by research in the parks in the Northeast Region. Take a look!

__Betsie Blumberg__, Writer-Editor, Penn State University, bmb4@psu.edu.

Website works toward effective communication for firefighters and fire managers

The organizations comprising the wildland firefighting and fire management community are fragmented, and as such do not always work effectively together to achieve common goals (First Annual National Wildland Fire Policy Summit, final report, 2002; available at <http://www.iawfonline.org/pdf/Final_Report_from_2002_Policy_S.pdf>). Intentionally or not, the International Association of Wildland Fire (IAWF) has launched a website that responds to this problem. The website <http://www.iawfonline.org/> takes strides toward more effective communication and potentially more effective working relationships within the wildland fire community.

The IAWF website links to the National Park Service's fire and aviation "FireNet" site <http://www.nps.gov/fire/index.htm> and many sites of other agencies, associations, fire consortia, and fire crews, as well as sites for kids and sites with photos. It also provides links to publications about fire; documents and reports; trainings, workshops, and conferences; employment; and research sites. Moreover, fire simulation models and reports, detection and remote sensing sites, structural fire and emergency medical system sites, weather forecasts, air quality, and fire danger information are listed and linked.

The International Association of Wildland Fire is a nonprofit, professional association representing members of the global wildland fire community. The purpose of the association is to facilitate communication and provide leadership for the wildland fire community. Working to fulfill their purpose, the IAWF website also provides information about upcoming national and international events of interest to firefighters and fire managers. The association also distributes two publications: *Wildfire* (general interest articles on topics and issues in wildland fire) and *International Journal of Wildland Fire* (a scientific publication).

New publication about woodlots at Gettysburg

The results of inventories of the woods at Gettysburg National Military Park have recently been published by Penn State University's College of Agricultural Sciences in a booklet called "Woodlots and Landscape Features at Gettysburg National Military Park: A Pictorial Record and Management Perspective from the 1990s." This booklet records, with an abundance of photos, the vegetation in six woodlots at the park for the purpose of providing a baseline from which managers can develop goals for restoring the woodlands to their late 19th century state and maintain the forests' ecological integrity.

The park commemorates the famous Civil War battle and the landscape in which it was fought. In southeastern Pennsylvania, the park encompasses about 5,733 acres (2,320 hectares). Approximately two-thirds of the park is open agricultural fields and pastures, and one-third is woods and a small area in orchard and developed spaces. Civil War era photos of forests at the park show oaks, hickories, ash, and red cedar, with white oak being the most abundant of the oaks. These species are still well represented.

Important to re-creating the landscape of the battle is the restoration of an uneven-aged forest dominated by oaks. Natural and human disturbances in the 20th century have resulted in a low regeneration of oaks, indicating that their dominance in the overstory may be replaced by ash, cherry, and maple. The current ratio of large ash, cherry, and maple saplings to that of oak saplings was found to be much greater than the current ratio of mature ash, cherry, and maples to mature oaks.

The historical species composition of the woods is threatened by exotic invasives; foraging small mammals such as squirrels, mice and voles; and especially deer that prefer to feed on native oaks rather than exotics such as Japanese barberry. Faster-growing ash and cherry have a better chance of reaching the sapling stage of growth, beyond the reach of deer, than do the slower-growing oak seedlings. A deer management program at the park is expected to control the size of the deer herd and thus encourage the development of the oak seedlings.

This publication is available from the Resource Management Office of Gettysburg National Military Park, 97 Taneytown Road, Gettysburg, PA 17325.

***Betsie Blumberg**, Writer-Editor, Penn State University, bmb4@psu.edu.*

Natural History Guide to American Samoa is NPS model

Natural History Guide to American Samoa is a collection of 39 short (1–3 pages) articles that provide a glimpse into the marine and wildlife resources in American Samoa's tropical, oceanic environment. Eight biologists from the American Samoa Department of Marine and Wildlife Resources, National Park of American Samoa, and Land Grant Program at the American Samoa Community College wrote the articles. They highlight general topics, such as local natural and cultural facts, biodiversity in the rainforests and coral reefs, seasons, and geology of the islands. Articles about the marine and terrestrial environments and their species comprise a majority of the guide. However, an index of some Samoan plant names, a bird checklist, and 12 articles about birds are also included.

The purpose in writing the guide was to make the results of natural resource studies available to local teachers, students, visitors, and others who might be curious about Samoa's environment. An outcome of the guide may be that it could serve as a model for resource managers throughout the National Park Service. The guide promotes involvement of the local scientific community, provides scientifically sound information, and engages the public as partners in resource preservation through education—all strategic objectives of the Natural Resource Challenge.

Park managers have taken seriously the dissemination of the information. The National Park Service, in cooperation with local agencies, has distributed more than 4,000 printed copies of the guide to schools on the four populated islands in the territory. Also, they will distribute 2,000 copies of a recent Samoan translation. The guide is available at <http://www.nps.gov/npsa/book/index.htm> to be downloaded as PDF or viewed online. The editor, Peter Craig (marine ecologist with National Park of American Samoa), encourages the use of these articles for educational purposes and to modify them to reflect local conditions at other islands.

NPS PHOTOS

Sooty terns (top) and Matafao Peak, National Park of American Samoa.

HIGHLIGHTS

Restoration of ecological balance in Constitution Gardens Lake:

an example of integrated resource management in an urban park

In 2002, resource managers at National Capital Parks—Central initiated a multifaceted three-year project to restore Constitution Gardens Lake, a 6.75-acre (2.6-ha) artificial water body located in downtown Washington, D.C. The lake provides a setting for some of the nation's most recognizable monuments and is the site of the 56 Signers of the Declaration of Independence Memorial. The lake also provides visitors with an escape from urban stress and is important for urban biodiversity.

Since its completion in 1976, the lake has suffered chronic ecological problems stemming primarily from its design: it is a closed, shallow system with an impermeable bottom that is entirely exposed to direct sunlight and fed by a municipal water source. From the beginning, the system's artificiality promoted an unbalanced ecology characterized by significant algal blooms and rapid sedimentation rates. These problems have been extremely difficult to manage, and costly, short-term fixes have done little to address underlying causes.

> **"Costly, short-term fixes have done little to address underlying causes."**

A significant fish kill during summer 2001 prompted park managers to consider long-term solutions and develop a restoration plan that specifically addressed the root of these problems. Natural resource staff believed that restoration should incorporate integrated pest management strategies. Specifically, they determined that success hinged on (1) stabilizing the lake's physical and biogeochemical properties, (2) reestablishing the lake's biotic communities, and (3) developing an action-oriented monitoring program.

To date several major actions have been completed to stabilize the system's ecological dynamics. Specifically, to facilitate more efficient nutrient cycling within the lake, park staff dredged tremendous volumes of nutrient-laden sediments from the lake's bottom. Additionally, they removed nonnative fish species that produce large amounts of waste; this aided in reestablishment of native fish populations in spring 2002. Resource managers have also developed methods to detoxify chloramine from municipal water sources used to fill the lake.

In spring 2003, managers used several physical and biological controls in an attempt to stabilize the lake's oxygen regime and increase nutrient cycling within the system. For example, park staff installed a new circulation and aeration system to reduce stagnation and increase oxygen transfer throughout the water column. Also, staff used microbial additives to stabilize and increase microbial populations. Healthy colonies of bacteria absorb and cycle nutrients, simultaneously reducing nutrient concentrations in the water available for algal growth during the growing season and moderating sediment deposition rates. Finally, park staff constructed large underwater planters and planted native vegetation such as cattails and bull rush. A healthy plant population will help cycle nutrients and produce oxygen during warm weather while also providing cover for young fish. Sustained success hinges on a comprehensive monitoring plan based on preestablished tolerance levels for specified parameters such as nutrient concentrations, pH, and dissolved oxygen that are linked to corresponding corrective actions.

Restoration of the lake will significantly enhance Constitution Gardens as a whole and will be a model for other cities with similar urban water bodies. However, resolution of the problem is complex. Not only do many of the factors involved act synergistically, but management actions tend to receive intense public scrutiny because of the lake's prominent location. Despite these challenges, long-term, cost-effective management of the lake is well within the capabilities of park resource managers.

***Gopaul Noojibail**, Natural Resource Specialist, National Capital Parks–Central, Washington, D.C.; gopaul_noojibail@nps.gov.*

Reptiles and amphibians surviving in isolated natural area

Rock Creek Park, approximately 1,754 acres (702 ha), lies within the boundaries of Washington, D.C. Urban growth and development have encroached upon the park since its establishment in 1890 as a natural area. Development and manipulation of the environment have reduced critical reptilian and amphibian habitats to small, isolated areas, and some habitats have disappeared altogether.

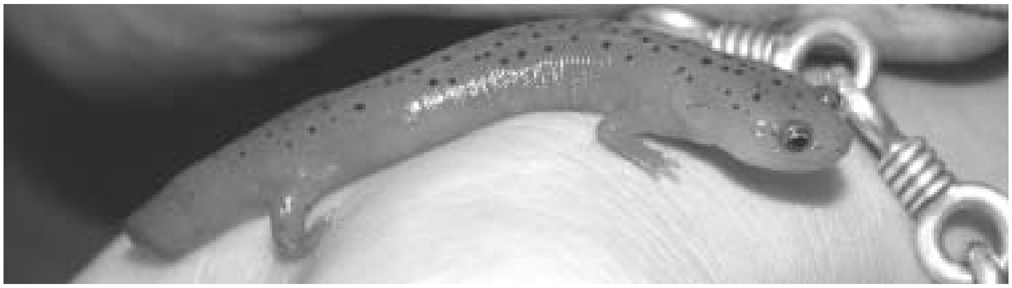
Rock Creek Park in partnership with Robin E. Jung of the U.S. Geological Survey (USGS), Patuxent Wildlife Research Center, is conducting an inventory and monitoring study of the reptiles and amphibians in the park as part of the Northeast Amphibian Research and Monitoring Initiative (NE ARMI). The unique location of the park as an island of nature surrounded by residential development has led to its selection as one of the "index sites" for the NE ARMI. Beginning in 2001, NPS and USGS employees intensely surveyed many of the ephemeral pools, streams, springs, and seeps located in the park (figs. 1 and 2). Methods include egg mass counts in the ephemeral pools to document species use and population trends, larval surveys using dip nets at the pools to determine tadpole species and numbers, cover-board surveys using pieces of plywood cut into different sizes to determine species utilization of park areas, and streamside salamander surveys using transects and quadrats to estimate streamside salamander populations. Investigators will analyze this information in relation to a group of environmental and landscape variables and compare the data to other parks and refuges as part of NE ARMI.

While several species historically found in the park have disappeared, investigators have documented 15 salamander and reptile species and rediscovered one salamander species, northern red salamander *(Pseudotriton ruber)* which had not been recorded in the park for 15 years (fig. 3). Through the combined efforts of park staff and Jung, the presence and abundance of the reptiles and amphibians found in Rock Creek Park will be documented. They will also make recommendations to protect and restore habitats for reptiles and amphibians. Because of the baseline inventory data being collected, park staff will be able to develop a monitoring protocol that can be implemented to help protect critical habitats and ensure the survival of these species into the future.

***Ken Ferebee**, Natural Resource Management Specialist, Rock Creek Park, Washington, D.C.; ken_ferebee@nps.gov.*

NPS PHOTOS BY KEN FEREBEE

Figures 1 and 2 (above). Ephemeral ponds located in the northern end of the park are critical habitat for egg laying and larval development of salamanders, frogs, and toads.



USGS PHOTO BY PRIYA NANJAPPA

Figure 3. A northern red salamander *(Pseudotriton ruber)*, found in a groundwater seep adjacent to a tributary of Rock Creek, is the first recorded in the park in 15 years.

Vegetation Inventory and Monitoring Program revisited at

Shenandoah National Park

The National Park Service is committed to inventorying and monitoring the natural resources under its stewardship. Effectively meeting this commitment is a complex challenge. The Long-Term Ecological Monitoring System at Shenandoah National Park, Virginia, has been in operation for more than a decade. However, in 1999 the natural resources staff decided it was time to reassess both the objectives and the design of their vegetation inventorying and monitoring programs. Staff needed to address fundamental questions about how to determine which data are statistically relevant. How much change in the canopy composition, for example, is important to detect? How much change is significant? The original program objectives were very broad. Staff wanted to clearly define what level of change sampling should detect and then design a protocol that would provide that information.

"Staff needed to address fundamental questions about how to determine which data are statistically relevant"

Technicians sample herbaceous vegetation within a newly installed (upgraded) forest long-term monitoring plot in Shenandoah National Park.

In March 2000 staff at Shenandoah National Park hosted a one-day workshop for the purpose of developing statistically precise objectives for the Vegetation Mapping Program. There were 17 participants including park staff, and scientists from Virginia Tech, Virginia Department of Forestry, Virginia Natural Heritage Program, Penn State, the Nature Conservancy, the U.S. Geological Survey, and the USDA Forest Service. Participants broke up into three working groups, each focusing on an area of interest previously identified by resource managers at the park.

The group focusing on general forest trends recognized the need to follow changes in vegetation composition and distribution. From this need the group developed three management objectives. One of these, for example, was to detect a 50% change in density of any one species of tree (dominant or codominant) within any one forest cover type over a five-year period. The related sampling objective required 90% assurance of such detection, accepting a two-in-ten chance that a change may be inferred when it really did not occur.

Another group focused on forest health. This working group addressed threats to the forest, such as air pollution, invasive exotics, white-tailed deer, and visitor trampling. The group recommended the management objective: to see a 20% decrease in the acreage of a specific exotic plant species parkwide from 2002 to 2005. The sampling objective required 80% assurance of detecting a 20% change in coverage of an exotic species over those years with a two-in-ten chance that a change may be inferred that did not occur.

The third group, focusing on special and unique ecosystems and species, identified several community types and species that are extremely rare at the park. For each of these, the group developed management and sampling objectives similar to those from the other working groups.

Having defined objectives at the workshop, the next step was to evaluate the current sampling process at Shenandoah and determine whether it could meet the objectives. Duane Diefenbach, USGS Biological Resources Division Cooperative Research Unit at Penn State, performed this statistical analysis. His results indicated that few of the newly defined program objectives could be met with existing data under the current sampling design. He recommended modifying factors such as the timing of sampling, the choice of strata for randomizing, and sample size. Diefenbach worked with natural resources staff at the park during the summer of 2002 to develop a sampling design that can meet or reevaluate the objectives, as needed.

This project is a work in progress. In summer 2003 staff began sampling according to the new design, and several more years will pass before managers at Shenandoah National Park can evaluate its success.

Information about the Vegetation Mapping Program at Shenandoah is available from Wendy Cass at 540-999-3432 or wendy_cass@nps.gov. The technical report of the workshop and statistical evaluation is available at <www.nps.gov/phso/science/FINAL/SHEN_sampling_design.htm>.

***Betsie Blumberg**, Writer-Editor, Penn State University, bmb4@psu.edu.*

Present landscape reflects historic appearance in Washita Battlefield National Historic Site

Washita Battlefield National Historic Site in Oklahoma may be in an enviable position. Park staff and volunteers have nearly eliminated tamarisk from the site. The Natural Resource Challenge through an Exotic Plant Management Team (EPMT) enabled this accomplishment. There are some caveats, however: tamarisk remains along an ephemeral tributary of the Washita River, and a major effort will have to be maintained to combat new sprouts and diminish upstream seed sources. Nevertheless, all standing tamarisk along the 1.25 miles of the Washita River that flows through the park has been cut down. The Chihuahuan Desert–Shortgrass Prairie EPMT (based in Carlsbad Caverns National Park) is anticipated to return to Washita Battlefield at least two more times over the winter-spring of 2003–2004. These trips will focus on cutting and treating the remaining tamarisk lining the tributary, and revisiting previously treated areas where tamarisk saplings have resprouted.

Park managers understand that Washita Battlefield National Historic Site does not represent ecosystem-level processes. Furthermore, eliminating tamarisk (or any other exotic) from within its boundaries has little effect on the untold acres of nonnative plants present on the agricultural lands of the surrounding Great Plains. Yet Washita Battlefield is a cultural (and natural) landscape, sacred to the Cheyenne, Arapaho, and other tribes affiliated with the site. The enabling legislation of the historic site requires the National Park Service to return the battlefield as closely as possible to its appearance in 1868, the year of the battle. For all the visitors who come to the site trying to imagine the altercation between the U.S. Cavalry and the Plains Indians 135 years ago, it is important that the landscape reflect its historic appearance. By removing a visually intrusive, nonnative tree from along the length of the Washita River, the National Park Service has honored its enabling legislation and improved the experience of visitors.

__Kurt Foote__ is currently the Natural Resource Program Manager at Vicksburg National Military Park, Mississippi. He can be reached at kurt_foote@nps.gov.

Water quality analysis of Fort Pulaski National Monument

Fort Pulaski National Monument is located in coastal Georgia along the Savannah River, approximately one mile from its junction with the Atlantic Ocean. Two islands, which before human intervention were primarily salt marshes, comprise the 5,200-acre (2,100-ha) site. The monument protects some of the most pristine resources in the area, such as Class 1 waters that are used for recreational harvest of shellfish. However, these waters are potentially threatened. Contamination from industrial sources upstream in the vicinity of metropolitan Savannah includes wastewater treatment pollutants, chemical producers, a natural gas processing facility, and a paper mill. In addition a nuclear weapons production facility is farther upstream. The Savannah River Site is notorious for contamination of the Savannah River and its tributaries, for example, during a tritium spill in 1991.

Industrial development in the Savannah area has, in turn, fueled development of port facilities. Commercial ship traffic requires substantial dredging in the main channel of the Savannah River to sustain the ever increasing depth requirements. During the dredging process contaminants sequestered in the sediments are suspended in the water column, threatening the monument and surrounding areas with reintroduction of contaminants. A proposal by the U.S. Army Corps of Engineers and the Georgia Ports Authority to increase the dredged depth of the shipping channel in the Savannah River to 50 feet mean low water (MLW) from the current depth of 42 feet MLW threatens to exacerbate the problem.

In 2001 and 2002 the park received Natural Resource Preservation Program funding for small parks and contracted with Savannah State University to conduct a water quality analysis of the 4,800-acre (1,940-ha) salt marsh estuary within the monument. The goal of this research was to acquire baseline chemical data necessary to evaluate the ecological health of water resources at the monument. Investigators designed the project to evaluate the levels of chemical pollutants, including heavy metals and organic compounds, in marsh-estuarine sediments and oyster tissues. The study used sediment, oyster, and water samples acquired from nine locations within the monument's boundary. Investigators focused data analysis and interpretation on problems that would be of immediate concern to park management.

The results of the study indicated that chemical contamination has caused no significant impact of waters within the monument. Of utmost significance, however, is that park managers now have substantial baseline data regarding the health and condition of the salt marsh estuarine environment. Scientific information now exists to adequately evaluate changes over time in the ecological health and water resources of Fort Pulaski National Monument.

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Volunteers help restore disturbed lands in Grand Canyon National Park

Visitors may see cliffrose, Indian paintbrush, stemless townsendia, early flowering wood-betony, and varieties of cacti and penstemon in the ponderosa pine or piñon-juniper woodlands on the South Rim of the Grand Canyon. They may also notice Dalmatian toadflax, cheatgrass, spotted knapweed, Mediterranean sage, and rush skeletonweed. While these latter plants may contribute to the colors of the landscape, they are some of the 160 plant species not native to Grand Canyon National Park.

NPS PHOTO BY MIKE BOOTH

Dedicated volunteers in the park have helped to restore disturbed lands by donating more than 16,500 hours to the vegetation management program in 2002. They rehabilitated more than 24 acres (10 ha) of disturbed lands while they gained hands-on experience removing exotic species, planting native species, collecting seed, and spreading mulch. Even a few hours of manually digging Mediterranean sage with hand picks contributes to the overall preservation of park resources. Many groups and organizations such as Elderhostel and Sierra Club return annually to satisfy their vested interest in the restoration projects in which they participate. Volunteers take pride in their work and many remember the specific plants they have planted.

Partnerships' and volunteers' long-term commitment to restoration efforts greatly benefit Grand Canyon National Park. Volunteers help the National Park Service achieve its mission and goals. Some volunteers return to their homes and seek out local natural areas in which they can volunteer. They may even carry a sense of stewardship into their own backyards.

***Lori J. Makarick**, Restoration Biologist, Grand Canyon National Park, Arizona; lori_makarick@nps.gov.*

TRIASSIC PARK:

first year results of the ongoing paleontological inventory of

PETRIFIED FOREST NATIONAL PARK

By William G. Parker

Petrified Forest National Park was established to protect natural and cultural resources in northeastern Arizona, including fossil trees and other plants and animals of the Late Triassic Period (about 210 to 235 million years ago). This year marks the 150th anniversary of the beginning of paleontological research, though the majority has been done in the last 80 years, resulting in a large amount of published scientific data (e.g., Camp 1930, Daugherty 1941, Ash 1972, Long and Murry 1985). As of 2003, investigators have documented more than 400 fossil sites within the park, including more than 250 vertebrate sites (fig. 1). In 2001, resource managers initiated a project funded with monies from the Recreational Fee Demonstration Program to locate and document all known paleontological localities beginning with vertebrate sites.

First, resource managers clearly defined what constitutes a "site" in order to locate these localities. A site is a geographic location where fossil resources are noted or collected, documented by curators, and deposited into a museum collection. Many of these sites are listed in scientific literature or in unpublished reports (Evanoff 1994, Long and Murry 1995, Parker 2002). Investigators from the Museum of Northern Arizona conducted the last general inventory of park fossil resources in 1979 (Cifelli et al. 1979). Unfortunately, during this study they only roughly mapped and described the localities and took very few photos of the sites. During the new inventory, investigators document these historical sites in three ways: (1) plotting with geographic information systems (GPS), (2) documenting the physical description, and (3) photographing the site. Investigators are not placing any physical markings now, in order to avoid confusion with numerous marked cultural sites in the park.

Preliminary work in the summer of 2001 resulted in the documentation of 35 preexisting and 10 new vertebrate sites, which far surpassed initial goals and expectations for the project. Work was even more productive in 2002 with investigators documenting 34 preexisting and 22 new sites. To date, investigators have located and documented more than 40% of all known vertebrate fossil sites in the park using the new criteria. In addition, investigators recovered numerous vertebrate fossils, which are now protected from loss by erosion (fig. 2). All of these specimens are scientifically important; however, the skeleton of a large, extinct, crocodile-like aetosaur *(Stagonolepis wellesi)*, the second most complete aetosaur skeleton recovered from the Triassic of Arizona, is most notable. This inventory is ongoing and future phases will include documentation of localities with plant, invertebrate, and trace fossils.

NPS PHOTO BY WILLIAM PARKER

Figure 1. The inventory crew investigates a fossilized tree in the Devil's Playground area of the park.

NPS PHOTO BY RANDALL IRMIS

Figure 2. In 2002 the inventory teams discovered an armor plate of a Triassic reptile in the Rainbow Forest. This plate belongs to a new species of animal previously unknown in Arizona.

Continued in right column on page 40

PLANT INVENTORY AT SMALL MARYLAND PARK

CONTRIBUTES TO DESCRIPTION OF A NEW SEDGE SPECIES

By Chris Lea with Rob Naczi

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Figure 1. This specimen of *Carex kraliana* was collected at Thomas Stone National Historic Site. The plant had been misclassified in several herbariums across the country. This find contributed to the description of a species new to science. (Label modified for plant conservation purposes.)

The discovery of a vascular plant species that is unknown to science would be a significant and surprising event for any of our national parks. Thomas Stone National Historic Site, just 30 miles from Washington, D.C., would probably not top anyone's list as a likely venue for such an event.

In May 2001, as Assateague Island National Seashore Ecologist, I made a two-day visit to the 325-acre park that commemorates the Charles County, Maryland, home of Thomas Stone, a member of the first Continental Congress and a signer of the Declaration of Independence. My official task was to plan vegetation data collection sites for a National Park Service team that would work on a vegetation classification and mapping effort later in the summer, a project of the NPS-USGS Vegetation Mapping Program. In an unofficial capacity, I was also a cooperator with Botanist Chris Frye of the Maryland Natural Heritage Program on a multiyear project to inventory and map the taxonomically difficult plant genus *Carex* (sedges) across the state (Frye and Lea 2001).

Carex is one of the largest genera of flowering plants in the world. Many species are dominants in many temperate habitats and are ecologically important for wildlife food, stabilization of slopes, and their role in plant succession. I arranged with park Resource Manager Rijk Morawe to inventory species of *Carex* as I encountered them during the vegetation classification reconnaissance to support the statewide *Carex* research and to provide the first inventory of this diverse genus at the national historic site.

Near the end of my second day in the park, I had documented 26 species of *Carex*, none of which was remarkable for the area. However, I noticed a certain sedge growing in several large clumps along the floodplain of a creek that was subtly different from several common Maryland species. Suspecting something unusual, I collected a specimen for further study (fig.1).

> "I noticed a certain *Carex* ... that was subtly different from several common Maryland species. Suspecting something unusual, I collected a specimen for further study."

A new species discerned

Later that summer, I examined a folder of specimens at the North American vascular plant collection at the Smithsonian Institution and found that a number of specimens labeled as *Carex crebriflora* matched the unusual Thomas Stone plant exactly. Others labeled *C. crebriflora* did not compare as well, but I attributed this to my inexperience with the species, which had never been recorded for Maryland. Because of the significance of a new state record, I sent the specimen for confirmation to Dr. Tony Reznicek (University of Michigan Herbarium), an authority on North American *Carex* whom we had frequently consulted for the Maryland *Carex* project.

Reznicek agreed that the specimen represented a new find for Maryland, but determined that it was not *C. crebriflora*. He recognized the Thomas Stone *Carex* as one that two of his colleagues were studying; Dr. Rob Naczi (Delaware State University and second author of this story) and Dr. Charles Bryson (U.S. Department of Agriculture) were conducting research to describe a new species: *Carex kraliana* (Naczi et al. 2002). *Carex kraliana* (named in honor of botanist Robert Kral) is actually widespread in the southeastern United States. It had been collected by field botanists as early as 1844 yet had remained undetected as a distinct species by previous taxonomic investigators. In many herbarium collections (including the Smithsonian's) it was usually labeled *Carex crebriflora* or one of several other similar species.

Remembering the confusing variability I had seen in the Smithsonian specimens, and with the benefit of Reznicek's advice on key characteristics of the new species, I reexamined them along with specimens at the George Mason University herbarium and found a number of *Carex kraliana* specimens that had been labeled as other species that were quite similar. Ironically, I had collected one of the specimens as a graduate student six years earlier at Prince William Forest Park in northern Virginia. Naczi confirmed the revised identifications, and along with Bryson cited these and the Thomas Stone specimen as paratypes (collected examples of a newly described species that exhibit its range of variation) in the description of *C. kraliana* (Naczi et al. 2002). These findings also extended the range of *Carex kraliana* on the Atlantic coastal plain from southeastern Virginia some 150 miles north to the vicinity of Washington, D.C., and were timely enough to be included in the treatment of the new species in *Flora of North America* (Bryson and Naczi 2002). In a second interesting discovery, Naczi also determined that a Thomas Stone specimen of *Carex digitalis*, a common Maryland species, could be assigned to the variety *C. digitalis var. floridana*, giving Thomas Stone another first Maryland record and another northern range extension for a vascular plant taxon.

The tornado that devastated the town of La Plata, Maryland, in April 2002 also affected Thomas Stone National Historic Site, flattening forest that included the stand in which *Carex kraliana* was found. The fate of the paratype population is not known, but Frye and I found *C. kraliana* in a second Charles County location in 2002. Although the species is presently considered rare in Maryland, additional occurrences are expected.

The value of inventories

Several lessons are evident. First, natural resource inventories conducted at national parks may uncover information that contributes not only to understanding park natural history but also adds to regional floristic knowledge and taxonomic research. Second, the collection of voucher specimens (examples of floral or faunal species kept in a repository to be used as references for scientists) has been a source of controversy within the National Park Service and among its cooperators. As this story shows, voucher specimens are not only useful, but in some cases absolutely necessary for determining the significance of park resources. In this case a single collection at a park was critical to determining significant natural and scientific resources at the park and also led to the discovery of many more significant specimens from other areas. Third, when possible, successful merging of park inventories with larger-scale investigations is cost-effective and also brings regional and national expertise to assist the conservation and natural history interests of the park. Finally, natural resource inventories have the benefit of adjusting our collective conventional wisdom by showing that small parks, including many established primarily for historical themes, may prove to be surprising reservoirs of biodiversity and important for investigation into the natural sciences.

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BIRDS SURVEYED
IN SIX NATIONAL PARKS
IN PENNSYLVANIA

By Betsie Blumberg

In cooperation with the National Park Service, investigators from Pennsylvania State University conducted a comprehensive inventory for birds at six national parks in Pennsylvania: Allegheny Portage Railroad National Historic Site, Eisenhower National Historic Site, Gettysburg National Military Park, Hopewell Furnace National Historic Site, Johnstown Flood National Memorial, and Valley Forge National Historical Park. The objectives of the bird inventory project were to (1) obtain a comprehensive inventory of birds and (2) make recommendations for long-term sampling to monitor birds at each of these parks.

To meet the first objective, investigators surveyed bird populations during the spring migratory, breeding, fall migratory, and winter seasons, May 1999–May 2001. They used point-count and vehicular-road techniques for all birds. They used additional diurnal surveys for raptors and vultures, nocturnal surveys for owls, separate loggerhead shrike *(Lanius ludovicianus)* inventories at Eisenhower National Historic Site, and riparian-bird surveys at Johnstown Flood National Memorial and Valley Forge National Historical Park. Between 1999 and 2001 the number of bird species at the six parks ranged from 94 species at Johnstown Flood National Memorial to 163 species at Valley Forge National Historical Park. Investigators counted a total of 186 species for all parks combined. The number of species of special concern from federal, state, and national lists (table 1) at the parks varied from 10 at Johnstown Flood National Memorial to 23 at Gettysburg National Military Park, and investigators found a total of 31 species of special concern in all parks combined. Most notably, investigators located 21 of these species within at least one of the parks during their respective breeding seasons.

"Investigators located 21 of these species within at least one of the parks during their respective breeding seasons."

Monitoring bird populations

Based on field-testing of survey protocols and results of inventories for two years, researchers made recommendations for monitoring bird populations at the six national parks. First, point-count, vehicular-road, and diurnal raptor and vulture surveys should be conducted twice a season during all seasons for two consecutive years out of every five-year period at each of the six parks. Second, owl surveys should be conducted three times each winter season for two consecutive winters out of every five years at all of the parks. Third, to supplement this work at Valley Forge National Historical Park, riparian birds should be surveyed eight to ten times between October and April for two consecutive years out of every five-year

Dr. David Klute surveys birds by point-count method at Valley Forge National Historical Park.

period. Fourth, at Eisenhower National Historic Site, loggerhead shrikes should be surveyed four times every year between May and early July.

Resource management specialists implementing these recommendations will create an extensive long-term database of information on the presence, relative abundance, and distribution of species. Based on data derived from this project and future inventories, they will be able to better protect and manage species of special concern within these six national parks.

The final report of this project is available at <http://www.nps.gov/phso/science/FINAL/Birds6parks.htm>.

About the author

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Table 1.

Status of Bird Species of Special Concern Detected from May 1999 to May 2001 at Six National Park Sites in Pennsylvania

SPECIES	STATUS	PARKS
Pied-billed grebe *(Podilymbus podiceps)*	SV	VAFO
Yellow-crowned night-heron (*Nyctanassa violacea)*	SE	GETT
American black duck *(Anas rubripes)*	AW	VAFO
Osprey (*Pandion haliaetus)*	ST	GETT, VAFO
Northern harrier *(Circus cyaneus)*	FMC, SV	EISE, GETT, VAFO
Bald eagle *(Haliaeetus leucocephalus)*	FT, SE	HOFU
Red-shouldered hawk *(Buteo lineatus)*	FMC	ALPO, EISE, GETT, HOFU, JOFL, VAFO
Upland sandpiper *(Bartramia longicauda)*	SCI, SI, AW	GETT
Common snipe *(Gallinago gallinago)*	SV	EISE, GETT
Barn owl *(Tyto alba)*	SV	GETT
Short-eared owl *(Asio flammeus)*	FMC, SE	EISE, GETT
Long-eared owl *(Asio otus)*	SI	HOFU, VAFO
Northern saw-whet owl *(Aegolius acadicus)*	SV	ALPO, GETT, HOFU, VAFO
Red-headed woodpecker *(Melanerpes erythrocephalus)*	FMC	EISE, GETT, HOFU, VAFO
Northern flicker *(Colaptes auratus)*	FMC	ALPO, EISE, GETT, HOFU, JOFL, VAFO
Loggerhead shrike *(Lanius ludovicianus)*	FMC, SE	EISE
Marsh wren *(Cistothorus palustris)*	SI, SV	VAFO
Wood thrush *(Hylocichla mustelina)*	FMC, AW	ALPO, EISE, GETT, HOFU, JOFL, VAFO
Veery *(Catharus fuscescens)*	FMC	ALPO, EISE, GETT, HOFU, VAFO
Blue-winged warbler *(Vermivora pinus)*	FMC	HOFU, JOFL, VAFO
Brewster's warbler (blue-winged warbler and golden-winged warbler hybrid)	FMC	HOFU
Chestnut-sided warbler *(Dendroica pensylvanica)*	FMC	ALPO, EISE, GETT, HOFU, JOFL, VAFO
Black-throated blue warbler *(Dendroica caerulescens)*	AW	ALPO, GETT, HOFU, JOFL, VAFO
Cerulean warbler *(Dendroica cerulea)*	FMC, AW	ALPO, GETT, HOFU, VAFO
Canada warbler *(Wilsonia canadensis)*	AW	ALPO, GETT, HOFU, VAFO
Worm-eating warbler *(Helmitheros vermivorus)*	FMC, AW	ALPO, EISE, GETT, HOFU, VAFO
Louisiana waterthrush *(Seiurus motacilla)*	FMC, AW	ALPO, EISE, GETT, HOFU, VAFO
Field sparrow *(Spizella pusilla)*	FMC	ALPO, EISE, GETT, HOFU, JOFL, VAFO
Grasshopper sparrow *(Ammodramus savannarum)*	FMC	EISE, GETT, JOFL, VAFO
Henslow's sparrow *(Ammodramus henslowii)*	FMC, AW	GETT, JOFL
Eastern meadowlark *(Sturnella magna)*	FMC	ALPO, EISE, GETT, JOFL, VAF

Notes: Resource managers selected birds of special concern from federal, state, and national lists: federally endangered (FE), threatened (FT), or management concern (FMC); state endangered (SE), threatened (ST), critically imperiled (SCI), imperiled (SI), or vulnerable (SV); Audubon Watchlist (AW) for the northern Ridge and Valley and Allegheny Plateau physiographic provinces in Pennsylvania.

The six national park sites are Allegheny Portage Railroad National Historic Site (ALPO), Eisenhower National Historic Site (EISE), Gettysburg National Military Park (GETT), Hopewell Furnace National Historic Site (HOFU), Johnstown Flood National Memorial (JOFL), and Valley Forge National Historical Park (VAFO).

Crater Lake clarity: it doesn't get any better than this

By Scott F. Girdner

The remarkable color and clarity of Crater Lake has dazzled visitors for generations. When the park commemorated its 100th anniversary in summer 2002, a new generation of visitors from around the world celebrated the wonders of Crater Lake for the first time. Their first view was one of surprise and amazement at the lake's beauty and majesty. Previous generations had the same reaction when initially seeing the lake. Geologist Clarence Dutton wrote in 1886, "As the visitor reaches the brink of the cliff, he suddenly sees below him an expanse of ultramarine blue, of a richness and intensity which he has never seen before, and will not be likely to see again." Likewise, Author Zane Grey wrote in 1919, "I expected something remarkable, but was not prepared for a scene of such wonder and beauty.... Nowhere else had I ever seen such a shade of blue.... How exquisite, rare, unreal!"

Reports of early explorations of Crater Lake indicated the remarkable color and clarity resulted from a deficiency of suspended particles in the water, and unlike most lakes, few phytoplankton (microscopic plants) in the top 50 feet (15 m). Recent studies at Crater Lake by Emmanuel Boss (Oregon State University) and Bruce Hargreaves (Lehigh University), along with information collected through the park's lake monitoring program (fig. 1), have shown just how amazing Crater Lake's

Figure 1. Scientists aboard the park research vessel *Neuston* recover a sediment trap from Crater Lake. Studies such as this have revealed extremely low concentrations of dissolved organic compounds, contributing to lake clarity.

clarity is. The waters of Crater Lake are actually resetting the standards for the optical properties of “pure water” and may have the highest clarity of any lake in the world. At the same time, this information underscores the delicate balance in the Crater Lake ecosystem and the potential for future pollution to degrade the world-renowned clarity of the lake.

Joseph Diller attempted the first measurement of the lake’s clarity in 1896 by lowering a white 10-inch-diameter dinner plate until it disappeared. Diller and other early explorers must have been amazed that the dinner plate was still visible at nearly 100 feet (30 m) deep! Since that time, investigators have taken hundreds of readings using a standard black and white Secchi disk to measure water clarity; the deepest reading, taken in June 1997, was a staggering 139 feet (42 m).

Why is Crater Lake so clear?

To appreciate the lake’s remarkable color and clarity, one must understand the relationship between ultraviolet (UV) light and the presence of dissolved organic matter in water. In most lake and ocean systems, dissolved organic matter, resulting from plants and animals within the watershed, limits the penetration of UV light. Only a very small amount of organic matter dissolved in water is needed to absorb the UV rays. Because the UV light is absorbed near the lake surface, aquatic organisms within the lake are mostly protected from the harmful UV rays. In Crater Lake, however, the natural concentration of organic matter is minimal, low enough to allow significant UV light penetration into the lake.

“To appreciate the lake’s remarkable color and clarity, one must understand the relationship between ultraviolet (UV) light and the presence of dissolved organic matter in water.”

NPS PHOTOS

Crater Lake has very little dissolved organic material near the surface compared to even the clearest ocean environments: less than half the absorption of the clear waters of the Gulf of Aqaba, the Red Sea, and the Tongue of the Ocean in the Bahamas. The level of organic material in Crater Lake is so low that UV light penetrates as deep as 320 feet (100 m). A recent analysis of published UV measurements (Hargreaves 2003) indicates that in some months the surface waters of Crater Lake have greater UV transparency than any other known lake or ocean in the world! (Lake Vanda, in Antarctica, was a close second.) The results of these studies along with data collected during the park’s monitoring program indicate the top 50 feet (15 m) of Crater Lake has greater UV transparency than the values published for pure water.

Research

The effects of UV penetration on the world’s lakes and oceans are significant because of recent changes in Earth’s ozone layer, the impact of climate change on dissolved organic matter, and the corresponding fluctuations in underwater UV levels. Therefore, this research at Crater Lake is important. The work of Hargreaves and Boss will contribute to establishing new UV absorption limits for pure water and will also help in determining the ecological factors that control the underwater penetration of UV light in lake and ocean ecosystems.

We do not fully understand the direct effects of UV light penetration on the ecology of Crater Lake. Investigators speculate that a combination of limited nutrients and the deep penetration of harmful UV light influence the virtual absence of phytoplankton during most of the year in the upper 50 feet (15 m) of Crater Lake. Because of the limited phytoplankton in near-surface waters, very few particles exist to interfere with the penetration of visible light, and consequently the clarity of Crater Lake is still as clear as it was 100 years ago. The near absence of phytoplankton in surface waters also helps to explain the lake’s beautiful color, which comes from rays of sunlight that are not absorbed by particles but rather are scattered upwards into the eyes of generations of visitors. Further studies on the effects of UV light penetration and the Limnological Monitoring Program at Crater Lake will continue to assess the long-term trends to ensure preservation of this irreplaceable gem.

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Paleontological Resource Monitoring Strategies for the National Park Service

By
Vincent L. Santucci
and
Alison L. Koch

Figure 1. A great variety of fossils are preserved in more than 160 units of the National Park System, including (clockwise from top) Late Paleozoic reptilian or amphibian tracks at Grand Canyon National Park, Arizona; tracks of a camel *(Pecoripeda)* and cat *(Besiopeda)* at Death Valley National Park, California; a petrified tree (a conifer called *Cupressinoxylon*) at Big Bend National Park, Texas; and burrows from a worm-like animal at Arches National Park, Utah. Fossil conservation in the national parks hinges on knowledge of their presence and distribution and is enhanced through inventory and monitoring.

The ability to manage and protect fossils is contingent upon an understanding of their occurrence and distribution, both geologic and geographic, and the factors threatening their stability. Paleontological resources at or near the surface will ultimately deteriorate over time.

Within the National Park Service, a paleontological resource inventory strategy has been established to compile baseline paleontological resource data. These data support both scientific and management objectives and are crucial prerequisites for the development and implementation of fossil monitoring in national parks.

This work represents a first effort to establish the critical elements for monitoring in situ paleontological resources in the National Park System. The monitoring design identifies natural and human variables that threaten or impact in situ fossils. Rates of weathering and erosion, climate, topography, and a wide variety of human-related activities are considered as part of this assessment.

Why monitor paleontological resources?

Legislation and ethics support the establishment of natural resource monitoring within the National Park Service. The National Park Service Organic Act (1916) and the National Parks Omnibus Management Act (1998) authorize the preservation and stewardship of all park natural resources and identify the need for park managers to use sound science in making decisions about resources.

The conscience of the National Park Service management regarding natural resource preservation was elevated through the writings of Richard Sellars in his book *Preserving Nature in the National Parks: A History* (1997). Sellars' work inspired a movement that resulted in the Natural Resource Challenge, which established funding and guidance for milestone programs, including a focused effort to inventory and monitor natural resources.

More than 160 units of the National Park System have been identified with paleontological resources. Collectively these fossils span all ages of geologic time from the Precambrian to recent, and preserve a variety of paleoecosystems, providing key information about the history of life (fig. 1). Millions of visitors are attracted to national parks by the spectacular fossils they preserve, ranging from charismatic dinosaurs, mammals, and trees to remarkable assemblages of the life of ancient oceans, lakes, forests, and prairies, including their small animals, insects, and plants.

Paleontological resource inventory and monitoring are necessary to preserve park fossil resources as required by the NPS Organic Act and longstanding NPS policy. Inventory is the comprehensive compilation of baseline resource data. Monitoring is the establishment of measurable indicators ("vital signs") to assess the condition and stability of resources.

A variety of natural and human variables threatens the condition and stability of paleontological resources. These threats may result in the deterioration or loss of fossils, a scenario contrary to the established resource preservation mission of the National Park Service.

What are the threats?

A threat includes any natural or human factor that may adversely impact a paleontological resource. These threats have the potential to cause the deterioration or loss of paleontological resources at or below the surface (table 1, page 24). Typically, multiple threats work concurrently to affect the stability of in situ paleontological resources.

Physical, chemical, and biological factors, although natural processes, may adversely affect the stability of paleontological resources. For example, high rates of erosion within fossiliferous rock units in Badlands National Park and Hagerman Fossil Beds National Monument result in the exposure and loss of paleontological resources at the surface (fig. 2). Loss of resources may occur very quickly, as in Channel Islands National Park, where mammoth fossils can be exposed in sea cliffs, then fall into the sea during a single winter storm season.

Human activities can be assessed in consideration of how they may benefit or adversely impact natural resources and processes. In 1999 the National Park Service compiled data on 721 incidents of fossil theft or vandalism, demonstrating a significant human threat to paleontological resources (Santucci 1999). High levels of souvenir collecting of petrified wood have resulted in Petrified Forest National Park being listed as one of the National Parks Conservation Association's 10 most endangered parks. The potential human-related threats to paleontological resources are best illustrated through the story

Figure 2. A primary factor in fossil stabilization, erosion is monitored closely by park staff at Fossil Butte National Monument, Wyoming. Changes in measurements between the substrate and the top of a reference stake (not visible) are recorded along with local temperatures, precipitation, wind speed, and other factors that affect erosion. Together, the data help the park anticipate management action necessary to preserve park fossils.

Table 1.
Factors that Affect the Stability of In Situ Paleontological Resources

SURFACE

Physical	Chemical	Biological	Human
Tectonics • seismicity • folding/faulting • extrusive events (lava flows) *Weathering/Erosion* • solar radiation • freeze/thaw • wind • water • fire • gravity • mass wasting • abrasion during transport	• surface water • soil/lithologic pH • mineral replacement • oxidation (rust, pyritization)	*Displacement* • pack rats • harvester ants *Destruction/Damage* • burrowing organisms • trampling ungulates • vegetation (root & lichen growth)	• construction (buildings, roads, dams) • mining • military activities (construction, vehicles, ballistics) • theft/vandalism • poor science and recovery technique • livestock • agriculture • recreational activities (off-road vehicle travel)

SUBSURFACE

Physical	Chemical	Biological	Human
Tectonics • seismicity • folding/faulting • intrusive events • metamorphism *Weathering/Erosion* • freeze/thaw (permafrost) • water movement (piping, cavern formation) • gravity • mass wasting • compaction • rock falls	• groundwater • soil/lithologic pH • mineral replacement • metamorphism (partial melt, recrystallization)	*Displacement* • root growth • bioturbation *Destruction/Damage* • burrowing organisms • root growth	• construction (buildings, roads, dams) • mining • military activities (construction, ballistics) • theft/vandalism • poor science and excavation technique (dynamite)

of Fossil Cycad National Monument. This unit of the National Park System was established in 1922 and abolished in 1957 following years of poor management practices that resulted in the extreme degradation and eventual loss of the fossil resource (Santucci and Hughes 1998).

From a management perspective, inadequate baseline paleontological resource data is an additional threat. Although the National Park Service has made significant advances in paleontological resource management through comprehensive inventories, targeted research, and better documentation of resource degradation, many park managers still lack sufficient paleontological data to assess threats and resource conditions.

“Inadequate baseline paleontological resource data is an additional threat.”

How do we measure and monitor loss?

In order to quantify loss, the National Park Service has established a system using vital signs as measurable indicators of change to resource conditions. Paleontological localities vary widely in terms of rock types, fossil preservation, geomorphic characteristics, and human accessibility. Therefore, any specific indicator may not be useful or appropriate at all fossil sites. Surface condition may be an approximate indicator of subsurface stability. Only a few studies have attempted to assess or measure impacts to in situ paleontological resources. Colbert (1966) established methods for monitoring rates of erosion. Fremd (1995) presented strategies for periodic surveys, called cyclic prospecting, that assess surficial occurrences of fossil vertebrates at a locality. Hockett and Roggenbuck (2002) conducted a social science study assessing human attitudes and behaviors relative to fossils. This study represents the

Standing petrified trees are among the 147 species of fossil plants that have been discovered on Specimen Ridge in Yellowstone National Park, Wyoming. Wood and leaf fossils made the identifications possible, including 81 species new to science.

first effort to establish specific vitals signs for fossil resources, which we refer to as paleontological resource stability indicators (PRSI), as in the following list.

Climatological Data Assessment PRSI: This indicator assesses data on annual precipitation, rainfall intensity, relative humidity, wind speed, and freeze-thaw index (number of 24-hour periods per year when temperature fluctuates above and below 32°F [0°C]).

Rates of Erosion Assessment PRSI: This indicator assesses data on both inherent and dynamic factors such as specific rock (lithologic) characteristics, slope, soil loss, vegetation cover, and rates of denudation for fossiliferous rock units.

Human Activity/Behavior Assessment PRSI: This indicator assesses data on visitor use, visitor access routes and their proximity to fossil localities, documented cases of theft or vandalism, and commercial market values of fossils.

Periodic Site Assessment PRSI: This indicator assesses data on the relative turnover rate of specimens at each fossil locality by monitoring the numbers of specimens destroyed (lost) or exposed (gained) at the surface. This information can be obtained through cyclic prospecting, photographic monitoring, and other spatially predictive models.

Conclusion

Establishing strategies and guidance for paleontological resource monitoring has clearly emerged as the critical next step for the management of fossils in the national parks. Managers in more than 160 parks with fossils often lack a staff specialist and need reasonable and consistent standards and methods for monitoring paleontological resource conditions. The use of paleontological resource stability indicators provides a multidimensional approach to assessing the conditions of in situ fossils. Paleontologists, geologists, archeologists, and climatologists are being consulted in order to develop resource-specific protocols. In addition, a conceptual model for paleontological resource monitoring that identifies cause-and-effect relationships is currently being developed. Adoption of Servicewide protocols for monitoring these resources will further enable assessment of the threats and conditions affecting fossils throughout the National Park System.

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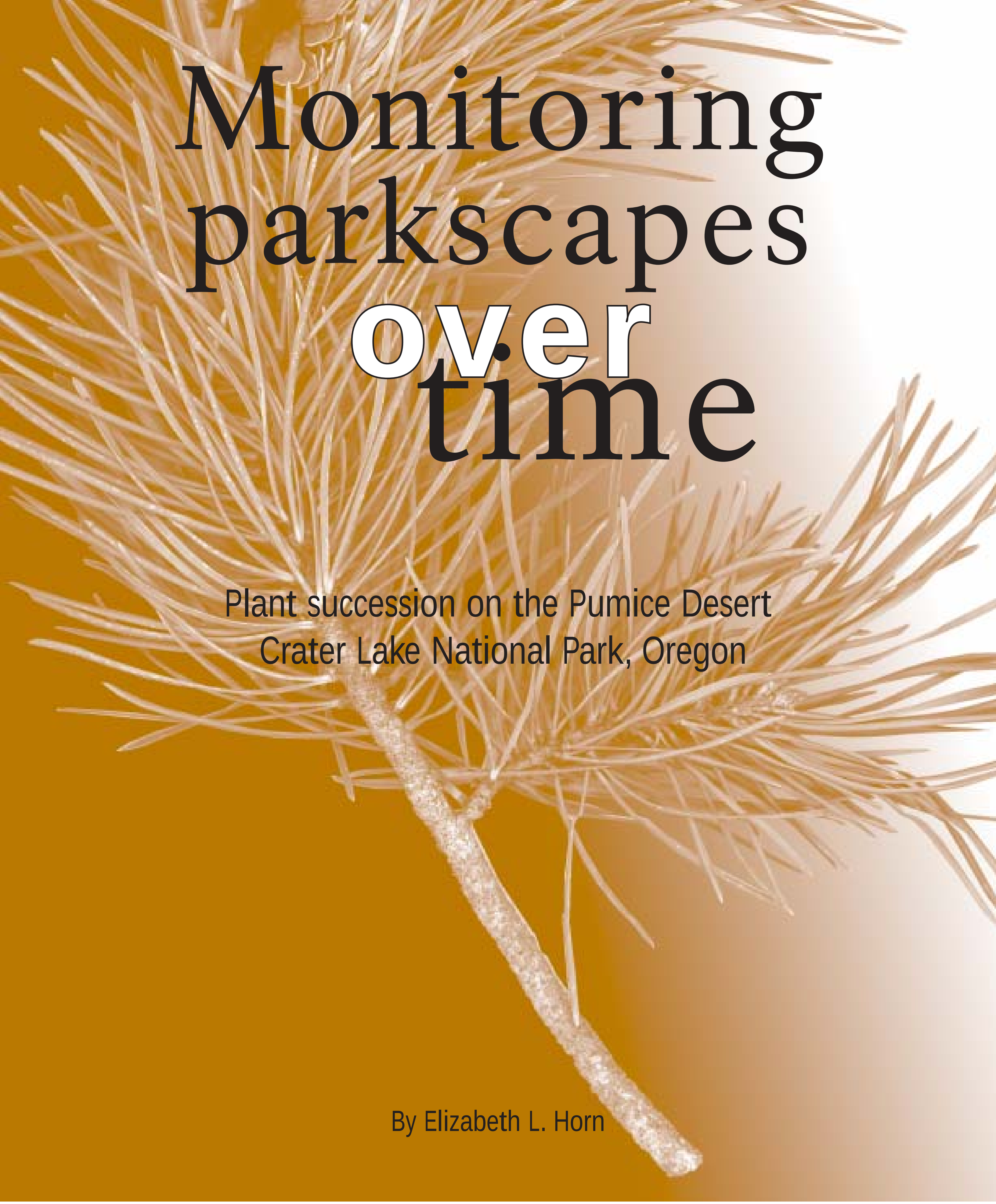

Monitoring parkscapes over time

Plant succession on the Pumice Desert Crater Lake National Park, Oregon

By Elizabeth L. Horn

The Pumice Desert is a conspicuous natural feature in Crater Lake National Park, Oregon. Contrasting sharply with the surrounding lodgepole pine *(Pinus contorta)* forests, the Pumice Desert is a rather barren-appearing, flat area of about 5.5 square miles (14.2 square kilometers). The Pumice Desert is about 4 miles north of the Rim Drive on the north entrance road.

Park staff were unsure of the explanation for this opening along the park's north entrance road. Why was plant succession so slow? What were the factors that kept and maintained this opening? What kept lodgepole pine from colonizing the area in greater numbers? Specific answers are hard to find. Studies showed many factors were interacting to hinder plant succession, including gopher activity, infertile soils, soil temperatures, and seed source. Few pine seedlings were found during field work, suggesting a problem with recruitment.

An interpretive sign along the park roadway explains that the ancient Mount Mazama had massive glaciers along its flanks. One of these glaciers carved a deep valley north from the summit, extending several miles beyond the park boundary. After the glaciers melted, glowing avalanches of gaseous material filled the valleys and depressions around Mt. Mazama. The porous pumice soil was probably more than 100 feet deep in the valley now occupied by the Pumice Desert.

As a graduate student and seasonal ranger-naturalist during the summer of 1964-1965, I studied this desert area as part of my master's thesis. The study was initiated in 1965 to (1) describe the existing vegetation, (2) measure selected environmental factors such as air and soil temperature, evaporation stress, precipitation, soil nutrients and soil moisture; and (3) establish photo points so that any changes in vegetation could be tracked over the years.

Study methods

Vegetation was sampled with 22 line transects, each 200 feet (61 meters) in length and 10.9 feet (3.3 meters) wide for a total transect area of 0.1 acre (0.04 hectare). Coverage data were taken on the basis of line interceptions. Density and frequency data were gathered within the transect, and coverage data were measured on the basis of interceptions along the centerline. Because only three lodgepole pines were found in the 22 line strips, another 100-acre (40.5-hectare) plot was set up to measure only the lodepole pine. The lodgepoles were measured by height and basal diameter; they were not big enough for diameter breast height measurements.

Summer climate data were gathered using a recording hygrothermograph, rainfall was measured with a totalizing gage, and environmental evaporative stress was estimated with Livingston black and white bulb atmometer spheres. Soil samples were taken to a testing laboratory.

Nine of the line transects were randomly selected as permanent plots, although I purposefully included examples of the three microhabitats in the area (north- and south-facing slopes and the flat central wash with fine gravels). Each end was marked with an iron rod. The large tree plot was also marked for future reference. Photos were taken from each end of the strip plots and from each corner of the tree plot.

Findings in 1965

The 1965 research showed only 14 species of plants growing within the plots. The park is home to nearly 600 plant species, so the flora of the Pumice Desert is quite sparse by comparison, with only 0.6 individuals per square foot and plant coverage averaging 4.9%. Most plants demonstrated one or more morphological characteristics typical of alpine or desert plants. The 100-acre (40.5-hectare) tree plot contained 27 trees with an average height of 4.6 feet (1.4 meters). The tallest was 9.8 feet tall (3.0 meters).

Climate data showed air temperatures that were both higher and lower than those recorded at park headquarters. The lack of vegetation probably contributed to these differences. Most significant were the high soil temperatures recorded on sunny days. For instance, when air temperature over a six-hour period did not exceed 83°F (28°C), the surface soil temperature averaged 102°F (39°C).

The pumice soils were generally deficient in nutrients and in organic matter. However, they were not significantly different from other pumice soils in central Oregon where there was more growth than in the Crater Lake Pumice Desert. Reasons for these differences are yet to be studied.

Plot visits in 1977, 1995, and 2000

I revisited and surveyed the vegetation in the permanently marked line strips in 1977 and in 1995. Photos were taken from each end of the plots (see fig.1). The results were fairly consistent each year. Although the 1977 tallies were slightly higher than in 1965 or 1995, the percent cover for each year remained about 4.9% (see table 1). Although individual plant species numbers fluctuated-somewhat from year to year, the totals remained fairly constant.

Table 1.
Research Data Summary

Year	Individuals Per Square Foot	Average Plant Coverage	100-Acre Tree Plot Data
1965	0.6	4.9%	27 trees, averaging 4.6 feet with tallest tree at 9.8 feet
1977	only slightly above 0.6	about 4.9%	not surveyed
1995	only slightly above 0.6	about 5%	not surveyed
2000	not surveyed	not surveyed	47 trees, averaging 8.9 feet, with tallest tree at 49 feet (see fig. 4) Nineteen trees were as tall or taller than the tallest tree in 1965.

In 2000 the trees in the 100-acre tree plot had increased dramatically, from 27 to 47 in number (see figs. 2 and 3). The average height was 8.9 feet (2.7 meters) tall, a substantial increase in size showing good growth over the interim 35 years. The tallest tree was 49 feet (14.9 meters). Nineteen of the trees measured in 2000 were as tall or

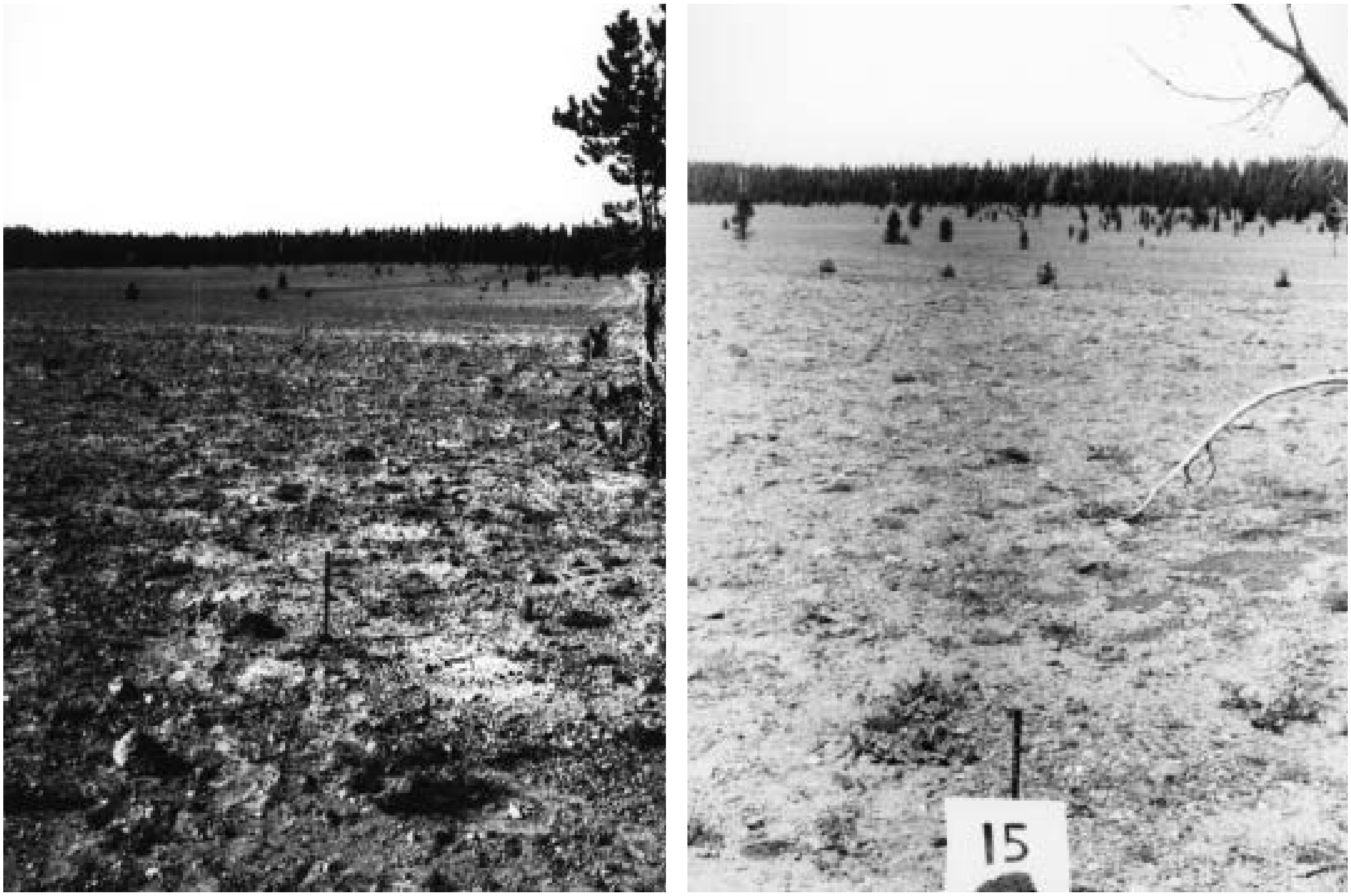

Figure 1. Vegetation plot in 1965 (left photo) with one lodgepole pine along its edge. Right-hand photo taken in 1995 showed the tree was dead; a few limbs protrude into the photo. Background shows increased number of trees invading from the northern forest edge.

taller than the tallest 1965 tree (see fig. 4). Many of the trees showed distinctive mounding at the base, caused either by wind deposition or gopher activity. More than half the trees had multiple stems or trunks, a characteristic not uncommon in harsh environments. What triggered the successional processes after what appeared to be a long time of low productivity is unknown. One possibility is a general warming of the climate, which would favor a longer growing season.

Effect of visitors on vegetation—an interesting side story

A small vehicle turnout with an interpretive sign had been established in1958 along the north entrance road at the south edge of the Pumice Desert. Visitors had walked into the Pumice Desert from the interpretive pullout, and the effect was obvious within an area of about 100 yards (91.4 meters) from the pullout. To quantify this, a sampling strip was laid out in 1965 and the results were compared to the other plots. The total number of individuals counted in this single plot was 1,037 compared with an average of 2,580 individuals in the other 1965 plots. The cover was 1.6% compared with the 4.9% average of the other plots. This reduction in plant cover occurred during a short seven-year period (1958–1965). This data collection was only done in 1965.

Figure 2. Typical multistemmed lodgepole pine photographed in the summer of 2000. This tree has nine trunks and measured 19 feet in height.

Figure 3. Author examines base of multi-stemmed, bushy lodgepole pine. Multiple trunks are not uncommon in harsh environments. There could be several causes. Genetics can create a predisposition for multiple stems, but the surrounding forest did not exhibit multiple stems. Rodent seed caches could result in multiple stems. However, examination of seedlings under 6 inches in height determined that seedlings have single stems, while slightly larger bushy-shaped trees clearly showed apical stem damage. This would release the side stems to grow upright. The damage could be caused by wind-borne pumice abrasion, gophers, or winter drying from low snow levels. In some cases, gopher gnawings were clearly present. Although the researchers have some guesses, the cause of this phenomenon would be an interesting future study.

Park and researcher contributions

The project was very much a joint effort from its 1965 beginning. Crater Lake managers and staff provided time and transportation for doing the research. Purdue University provided the climate and recording equipment. However, the single most important ingredient was the participation of park staff. Park biologist Richard Brown was the enthusiastic instigator. Staff donated their time off to help tabulate plants on the plots and make climate and soil recordings. The park had a darkroom, and several staff developed photos of the plots. The maintenance staff made the iron rods to mark the plots and devised a coding system for their identification. It became everyone's project and provided a focus for the developing camaraderie among the staff.

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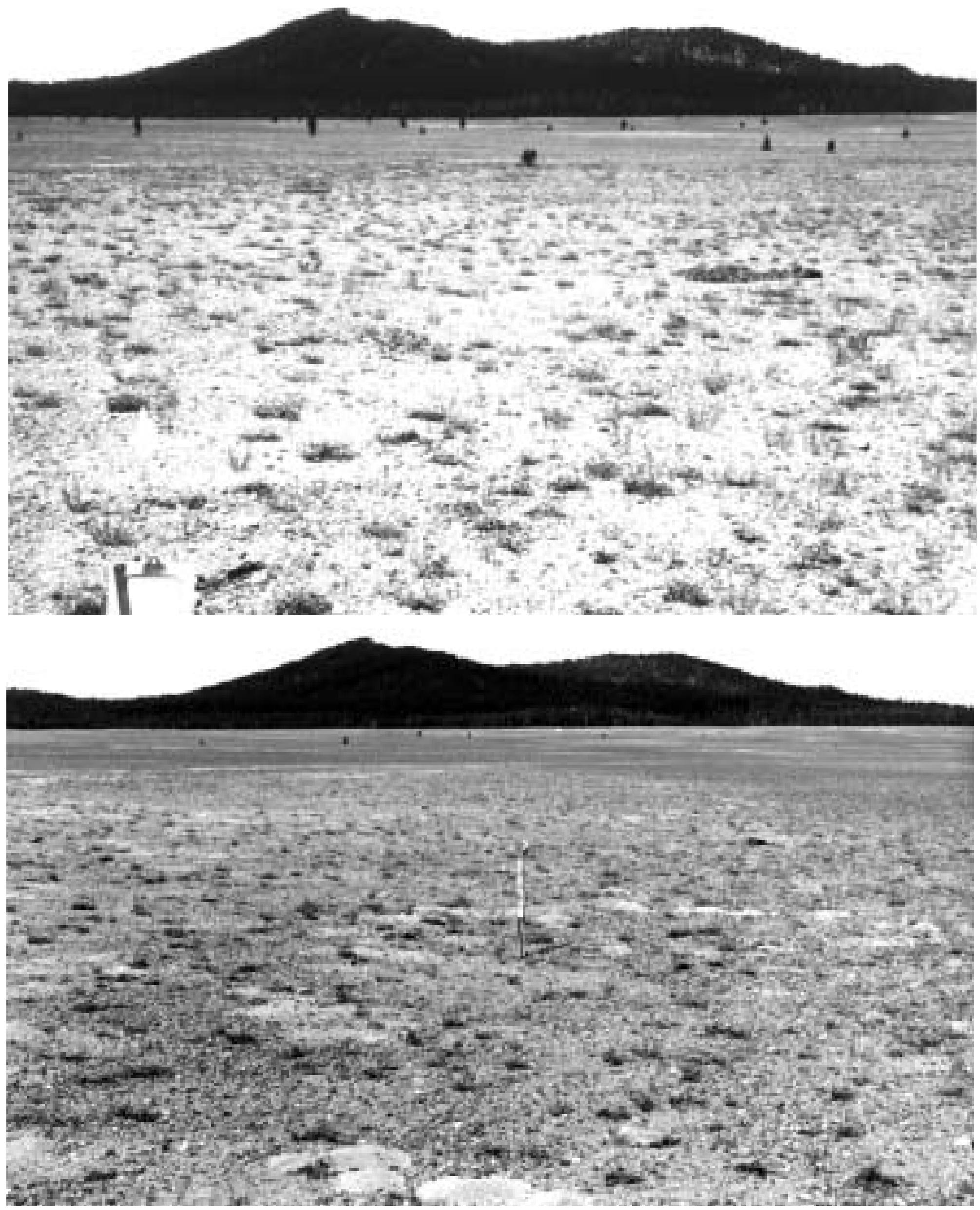

Figure 4. View from northwest corner of the tree plot, lower photo taken in 1965; upper photo taken in 2000. Note the increased number of trees in the middle ground in the 2000 photo. Note the large areas of barren ground. Pocket gopher mounds show in the foreground of the 1965 photo.

The case for long-range vegetation studies

Park settings are ideal places for long-range vegetation studies. The 1965 study provided a snapshot in time. It told what was on the Pumice Desert during that particular summer. But it was a static picture. Long-range monitoring has the following advantages:

Park settings are ideal places for long-range vegetation studies.

1. Once a study is set up, it can be monitored with little additional effort or cost. Each additional visit to the site involved about five days each for me and a few colleagues.

2. Photo points can speak volumes even if vegetation is not tabulated. Photo points, once established, are usually not difficult to find again.

3. Park areas are generally not disturbed by human-made intrusions. The vegetation and the landscape are for the most part protected from unnecessary human-caused impacts. However, in this study, there were two artificial intrusions on the Pumice Desert. The first was the route of the Pacific Crest National Scenic Trail. Records show the trail was probably routed on an old fire road through the Pumice Desert in 1929. The trail was moved to a route east of the Pumice Desert in 1976 to line up with the trail around Mt. Thielson north of the park and to reduce plant damage in the Pumice Desert. However, the track and the vegetation changes can still be seen along the old route. The second intrusion is the trampling that has occurred near the interpretive sign. Although the changes near the interpretive sign were not part of the study, both examples are valuable because they illustrate the impact that can occur on delicate plant communities.

4. The data from the 1965 tree plot showed that few trees had populated the Pumice Desert. The 1977 and 1995 vegetation plot data showed little change in the average plant cover or individuals per square foot. Expectations would be that there was also little change in the tree plot data. However, the 2000 data on the tree plot showed that succession was indeed proceeding. Had we not set up and followed up on an additional plot to only monitor tree numbers, we would have assumed that little had changed on the Pumice Desert. We had two sets of data (tree plot and vegetation plot), and if we had stopped with only one set, we would not have had a complete picture. Why the tree numbers have increased while the vegetative numbers remained fairly constant is another interesting question. The answer may be as simple as normal population dynamics, which would be more apparent in the shorter-lived herbaceous plants. Spring moisture, for example, would have a definite influence on the survival of seedling herbaceous plants with shallow root systems. Patience and thoroughness are necessities for long-range monitoring.

Had we not set up and followed up on an additional plot to only monitor tree numbers, we would have assumed that little had changed on the Pumice Desert.

Patience and thoroughness are necessities for long-range monitoring.

Summary

Research during the past 35 years has shown that many interacting factors undoubtedly combine to slow plant succession on the Pumice Desert, including climate, short growing seasons, sterile soils, hot soil temperature in summer affecting seedling survival, and rodent or gopher activity that aerated and mixed the soils (a positive thing) but also negatively affected the vegetation when they ate the roots. However, the number of trees that have become established on the 100-acre tree plot has increased by 75% between 1965 and 2000. Eventually, as succession proceeds, conditions will become more hospitable for new seedlings. The plots established in 1965 allow continued monitoring of this progress. The surrounding lodgepole pine will eventually infiltrate the area and the Pumice Desert will cease to exist.

I greatly appreciate the assistance of the staff of Crater Lake National Park in the many stages of this research. I also would like to acknowledge the assistance of plant ecologists Fred Hall and William Hopkins in resurveying the vegetation plots and the cheerful assistance of Kirk M. Horn throughout.

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HEADS UP!

Uncertainty in software accuracy

By Roy Irwin

Disclaimer: No government endorsement is implied for software examples mentioned. No representation is made that all worthy software alternatives are mentioned or that all potential kinds of problems are described.

Several recent publications have discussed potential problems with accuracy of statistical calculations in MS Excel, including Cox (2000), Cryer (2001), Knusel (1998), McCullough (1998), McCullough (1999), and McCullough and Wilson (1999). Considering the prevalent use of MS Excel by employees of the National Park Service (NPS), what should NPS scientists know about the findings of these publications and the advice of statistical experts? Are calculations in MS Excel—the "standard spreadsheet" used by NPS employees—accurate enough to be credible? Should the National Park Service heed the strong condemnations of Cryer (2001)—"Friends Don't Let Friends Use Excel for Statistics!"—or the more subdued advice of McBride (see details below) that "MS Excel is fine for basic calculations, except percentiles and odd data sets"?

After reviewing the findings in these papers and discussing the issues with independent experts in statistics, I have decided that the answer depends on the situation; therefore, it is difficult to provide blanket "one size fits all" guidance. Instead, I will attempt to alert the National Park Service to some of the issues and summarize some of the basic information that NPS scientists should know.

What's "accurate enough"?

First, I need to consider briefly how to define "accurate enough" in the context of software calculations. Uncertainty in accuracy of software is just one of many known sources of uncertainty. Another source is measurement uncertainty. For environmental studies, measurement uncertainty (factoring in both precision and systematic error, i.e., bias) is seldom lower than plus or minus 3% and is often much higher for parameters like pesticides or for observations such as "percent embeddedness in cobbles" in stream bottom sediments.

> "Uncertainty in accuracy of software is just one of many known sources of uncertainty."

The National Institute of Standards and Technology (NIST) publishes International Organization for Standardization or ISO-compatible sum-of-squares equations for combining uncertainty from many sources (Taylor and Kuyatt 1994). In these equations, if the (standard deviation) contributor to uncertainty from one source is five times lower than another contributor, it is considered trivial and, therefore, not considered in the overall uncertainty equation.

In some cases where the MS Excel answer is not exactly right, that contribution to uncertainty may be considered trivial compared to others. For example, in one of the publications outlining deficiencies in MS Excel (McCullough and Wilson 1999), a standard deviation calculated by MS Excel was 0.0790105482336451. This was compared to a "correct" standard deviation of 0.0790105478190518 calculated by a benchmark standard.

Now What Was That Rounding Rule?

Is 0.0790105482336451

really different from **0.0790105478190518**

or are they both **0.079**?

Although environmental specialists have to be careful not to round numbers too aggressively before using them in subsequent calculations, typically neither rounding rules nor uncertainty estimates justify using more than two or three significant figures in final environmental measurement results. Rounding rules for final results often amount to a crude (better than nothing) way to account for uncertainty. More modern ways to account for uncertainty include confidence intervals for summary statistics and estimates of measurement uncertainty for individual observations. Such uncertainty estimates for environmental data sets often make it clear that we are seldom certain of more than three significant figures, and sometimes we are not certain of more than one or two. The difference between the two examples of standard deviation values shown in the illustration on this page would typically not approach one-fifth of the total estimated uncertainty from combined sources, and thus would usually be considered trivial and not added to overall uncertainty equations.

Furthermore, neither measurement uncertainty nor uncertainty in summary statistics usually account for the largest contributions to overall uncertainty. Other common contributors to uncertainty include model uncertainty, uncertainty in how representative the sample is of the larger population, and errors arising from not using software correctly. In fact, using software incorrectly may be more common when using dedicated statistical software than when using the more familiar, "user-friendly," and ubiquitous MS Excel. Other common sources of errors and uncertainty include choosing the wrong analysis, not meeting critical assumptions, and cumulative rounding errors. Furthermore, there are inherent uncertainties related to our imperfect knowledge of biology and physical science, wrong or crude theories, and various sampling errors. Such errors typically vary in magnitude in both time and space. Collectively, these "additional" sources of uncertainty are probably of greater magnitude than software calculation errors, particularly for simple summary statistics.

I have as yet to see any examples where MS Excel gave an answer for simple statistics—such as a mean or a sample standard deviation—"different enough" not to be considered trivial in comparison with other sources of uncertainty in environmental variables. Many users conclude that for very simple calculations—like a population standard deviation, a mean, or even a 95% "t distribution" confidence interval—answers in MS Excel may be "accurate enough" for analyzing environmental data sets and for commonly used statistics. Hence, given that NPS offices typically already have MS Excel, investment in dedicated statistical software may be difficult to justify.

Graham McBride (National Institute of Water and Atmospheric Research in New Zealand) uses and deems MS Excel useful for some routine analyses, for less-routine multiple one-sided (TOST) tests for inequivalence, and for some Bayesian statistics that use routine functions. McBride points out that MS Excel is fine for basic calculations such as means, standard deviations, and t values, and that most of the criticisms of MS Excel are valid only for very odd data. Although MS Excel may have problems with percentiles, so does the software S-Plus. Except for SAS, statistics packages typically do not explain that there is no one "right" way to calculate percentiles, let alone tell you which one they use. Users should not assume that a particular computer package is automatically acceptable for their purposes; they should seek expert statistical advice when needed. The level of explanation in manuals and help files is often poor (Graham McBride, personal communication, 2002).

> "Users should not assume that a particular computer package is automatically acceptable for their purposes: they should seek expert statistical advice when needed."

> "Calculating complicated statistics ... may be risky when using MS Excel."

Calculating complicated statistics (e.g., regression statistics) may be risky when using MS Excel. Such calculations performed in MS Excel may not yield acceptable levels of accuracy. Hence, for complicated statistics, the investment in dedicated statistical software would be more easily defended, especially in legally or professionally contentious settings. Users should keep in mind, however, that even dedicated statistics software packages can have difficulty with complicated data sets: those that involve large numbers (usually greater than six digits), have a very large sample size (high n), or have constant leading digits (e.g., 90000001, 90000002, and 90000003).

Odd or difficult data sets are typically rare in environmental work, but this may change as more and more continuous data readout probes are used and the National Park Service accumulates long-term data sets from Vital Signs and other long-term monitoring programs.

What sample sizes are too large?

If the individual numbers are high six digits, and the sample size is anything but small, the data set may be starting to "become difficult" even for the relatively simple standard deviation determinations in MS Excel. However, determining the case-by-case limitations may be challenging for ordinary users. It would be nice if the software makers explained particular conditions for each software-hardware combination: if the sample size is less than "n" and no numbers have more than "z" digits, then large sample or large number-related problems will not arise, but they do not (Bruce McCullough, Federal Communications Commission, personal communication, 2000).

In cases where percentiles or complicated statistics are calculated in MS Excel, I recommend that for the purpose of quality assurance, data analyses should be replicated on at least one "dedicated" statistical software program to help ensure accuracy. This software should be dedicated to statistical tasks, such as the following (not necessarily complete) list of typical or widely used examples: SAS, SPSS, SYSTAT, MATHEMATICA, EquivTest, WQStat, MINITAB, STATGRAPHICS, STATA, MAPLE, or S-PLUS.

Words of caution

When complicated statistics are to be calculated, when very large or otherwise difficult data sets are to be analyzed, or when legal or rigorous professional challenges are expected, a logical first step for "additional" quality assurance in software accuracy would be to compare results of analyses of published standard data sets of certified NIST correct answers for calculations of the same type as will be performed for the work at hand (see NIST 2000).

> "The more complicated the statistic, the more can go wrong."

One thing users should keep in mind: the more complicated the statistic, the more can go wrong. Therefore, we should not be surprised to see more software errors of multivariate or other complicated procedures than in calculations of the sample mean. McCullough's 1999 summary confirms more errors on the relatively complicated statistical procedures (such as multi-factor ANOVAs and nonlinear regressions) than on the relatively simple univariate procedures (McCullough 1999).

Cox (2000) likewise suggested that areas in which MS Excel may be unreliable include some relatively complex tasks and unusual data sets:

- Standard deviations and statistics (e.g., t-tests) relying on standard deviation calculations that have large numbers with low variation
- Multiple regressions with very high collinearity
- Nonlinear regression problems
- Distribution tail areas beyond about 10-6
- Procedures (e.g., bootstrap) that rely on a good random number generator

Cryer (2001) offers one of the more strongly worded cautions against using MS Excel for statistics, citing not only problems with regression analyses but also with graphing functions and even with the algorithms used to calculate simple summary statistics such as a standard deviation. Cryer points out that MS Excel has problems with how it treats missing data and same values; it also, among other things, may display many more digits than are warranted.

The problem of displaying too many digits is not limited to MS Excel, however. Some programs allow users to specify the number of digits reported, and in any case, it is typically up to users to apply logical rounding rules, such as those summarized by Irwin (2003). In trials for calculating a sample standard deviation with MS Excel and other dedicated statistical software (i.e., SYSTAT), both programs usually tended to return the same standard deviation when rounded to a reasonable number of digits, so I remain unconvinced that there is a major problem with the way MS Excel calculates sample standard deviations for typical environmental data sets.

Reliability of other software programs

What about reliability of other software programs? Although potential problems with MS Excel have been well publicized, it is less well known that other software and software-hardware combinations can have problems and limitations too. Even dedicated statistical software programs can have difficulty with very difficult or contrived data sets. Using relatively difficult tests in 1999, flaws were discovered in the then-current versions of widely used statistical packages such as SAS, SPSS, and S-Plus (McCullough 1999). In a separate comparison involving relatively simple tests, problems were noted with some of the dedicated statistical packages. In general, however, more serious problems were reported with MS Excel (Landwehr and Tasker 1999).

The picture gets further muddied when considering various multivariate, ordination, and phylogenetic classification programs. For example, taxonomists use such programs to help classify the phylogenetic relationships between species. Many schemes are used, and some programs are developed by individuals and have very little documentation. Users should be aware that the answers may be suspect and are not always consistent between different programs. For example, in one trial, taxonomists tried several popular multivariate software programs on identical data sets and came up with very different answers. When they entered data in a different order, they got yet other answers (Terry Frest, consultant and malacologist, personal communication, 2000).

Controlling a measurement process is difficult without controlling for systematic error (bias). Bias is difficult to estimate if one cannot identify what the right, or at least the "expected," answer is. This makes quantifying uncertainty in the answers from many multivariate, ordinations, and classification programs very difficult. Typically only expert opinion, nonstatistical, or qualitative estimates of uncertainty are possible.

For additional details on estimating measurement and simple types of model uncertainty, see Irwin (2003).

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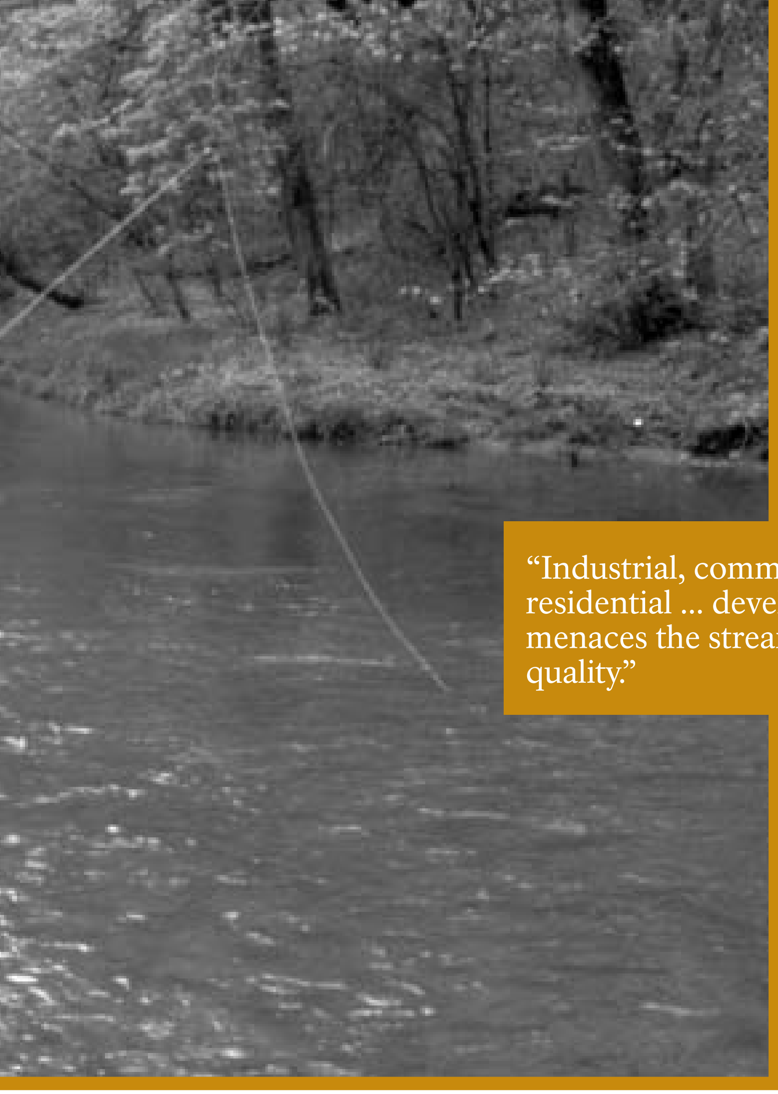
PARTNERING to save VALLEY CREEK

By Betsie Blumberg and Brian Lambert

Valley Creek is an outstanding trout stream in Pennsylvania (fig. 1). Twelve miles long, the creek runs through five townships just north of Philadelphia and flows through Valley Forge National Historical Park where it empties into the Schuylkill River. This limestone stream, remarkable for its beauty, is an important recreational resource for the five-county area around Philadelphia.



> "Industrial, commercial, and residential ... development menaces the stream's water quality."

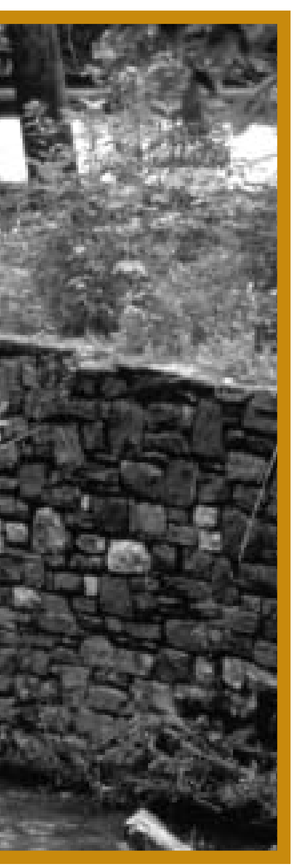


Figure 1. Located north of Philadelphia and flowing through Valley Forge National Historical Park, Valley Creek is an important recreational resource for area residents. In 1993 the creek was officially designated as having "exceptional value," an important management tool for protecting the creek's water quality.

Figure 2. Development in the area of Valley Creek has led to increased erosion of the stream bank, which threatens the collapse of Pennsylvania Route 252. In addition to traditional engineering, the partnership to restore Valley Creek is using soil, rocks, and plants in bioengineering solutions to stabilize stream banks.

The importance of the creek to the local communities is evidenced by the fact that most of its corridor is still wooded, providing food and shelter for a variety of terrestrial animals. Its waters support a thriving aquatic biological community. The Pennsylvania Fish and Boat Commission has designated it a Class A Wild Trout Fishery. Several parks and preserves have been established along its banks to protect the creek and allow public access.

Not surprisingly, Valley Creek is threatened by the booming urban environment from which it provides a respite. In the last few decades, the creek's 23-square-mile (60-square-kilometer) watershed has seen tremendous industrial, commercial, and residential expansion. This development menaces the stream's water quality. Furthermore, as the stream rushes along carrying sediment-laden runoff, it endangers roads, buildings, and bridges as it undercuts its banks, threatening the collapse of Route 252 along its east bank (fig. 2) and endangering archeological sites and the Valley Creek hiking trail at the national historical park along the west bank.

To protect such resources takes political action and in-depth understanding of the stream's ecology. Fortunately, the natural resources staff at the park are not alone in their efforts to protect Valley Creek. Several local conservation groups have devoted their energies to influencing state and municipal agencies to accord Valley Creek maximum regulatory protection, and the Pennsylvania Department of Transportation (PennDOT) has been working with the park to save the stream banks. Four projects illustrate the success of the national historical park's cooperation with other governmental and private groups.

An "exceptional value" creek

Pennsylvania classifies its waterways to designate the acceptable level of water quality degradation that may result from activities in the watershed. This classification guides local municipalities in awarding permits to developers. The most restrictive classification is "exceptional value." Streams with this classification cannot be degraded at all.

In 1987 the Valley Creek Coalition began petitioning the Pennsylvania Department of Environmental Protection to upgrade Valley Creek to exceptional value. The coalition included the Valley Forge chapter of Trout Unlimited; the Open Land Conservancy; the Green Valley Association; the West Chester Fish, Game, and Wildlife Association; and Valley Forge National Historical Park. Many other groups, businesses, and individuals jumped on the bandwagon, as well.

This initiative required the support of five townships and several industries because they all had to develop alternatives for the discharge of their wastewater. The coalition worked with politicians at every level, from local communities to the state capitol. Trout Unlimited sponsored a letter-writing campaign that sent 3,000 letters to the Water Quality Management Department of the Pennsylvania Department of Environmental Protection and the Pennsylvania Fish and Boat Commission.

In 1993, after six years of hard work, the Pennsylvania Environmental Quality Board, which reviews recommendations of the Department of Environmental Protection, approved the designation of exceptional value for Valley Creek, providing an important management tool for protecting the creek's water quality.

Controlling storm water

The Valley Creek Coalition did not disappear after that victory. The problem of storm water flow into Valley Creek remained, and the coalition felt that the Department of Environmental Protection and the townships were not regulating new construction in conformity with the exceptional value classification. In March 2000 the coalition appealed the storm water permit for a company that was expanding its corporate campus in the watershed.

Storm water runoff becomes a problem when development makes large surface areas impervious. When storm water floods into Valley Creek, it raises the water temperature and introduces sediment that turns the water the color of mud. These factors destroy fish habitat, smother aquatic insects and fish fry, cover up fish eggs, and increase erosion. Sensitive species such as brook trout begin to disappear when as little as 2% of the watershed is covered by impervious surface (such as roads), according to the Maryland Biological Stream Survey, a multiyear study of stream health. Furthermore, the stream channel widens and deepens in response to the increased flow, destabilizing the stream banks.

> "Storm water runoff becomes a problem when development makes large surface areas impervious."

In response to the coalition's appeal, in September 2000 the Department of Environmental Protection added a postconstruction storm water control component to its permitting requirements for the Valley Creek watershed. The new component requires that storm water be infiltrated into the ground so that runoff is no greater than it was before development. Because undeveloped land in the watershed is officially considered meadow, postconstruction runoff must equal what would flow from a meadow. Permit applicants must also show that their grading and outlet structures will prevent storm water from causing erosion, carrying pollution, or raising stream water temperature.

> "The new component requires that storm water be infiltrated into the ground so that runoff is no greater than it was before development."

Because Valley Forge National Historical Park is at the bottom of the Valley Creek watershed, everything that flows into the creek eventually impacts the park, so it is especially beneficial to the park to work with the coalition to protect Valley Creek.

Stabilizing the stream banks

The national historical park and PennDOT have a common problem. Valley Creek is eroding its banks so severely that Route 252, which runs along its east bank, is in danger of collapsing. In fact, a 200-foot (67-meter) portion of it did collapse in 1990. Beneath the road is a sewer main that carries 8 million gallons of sewage per day. A break in the sewer would be disastrous, severely polluting the creek, killing stream life, and further damaging habitat. On the west bank, the Valley Creek hiking trail has been damaged in the past and is constantly in similar danger.

In 2000 Valley Forge National Historical Park and PennDOT signed a memorandum of agreement stating that they would split the $600,000 cost of repairing and stabilizing 2,100 feet (644 meters) of stream bank. The park's share came from regional storm damage funding related to Hurricane Floyd. The environmental assessment for the project is being written by the park's natural resource manager, Brian Lambert, and the park staff participated in designing the construction.

The restoration project combines conventional hard engineering with bioengineering, a "soft"approach that uses rock, soil, and plants. Different treatments will be used, appropriate to the characteristics of the three stream sections to be repaired. Bioengineering techniques will stabilize one section where coconut fiber rolls will be installed at the toe, and trees and shrubs will be planted on the upper parts of the stream bank. The second section of the stream bank is an outside bend, where erosive forces are greatest and will be protected by large riprap rock.

Along the third and longest stretch, the stream banks are 8 feet high, almost vertical, and composed of unconsolidated silt. In this section large rocks will strengthen the toe, and shrubs and trees will stabilize the top of the bank. In the middle, a 5-foot-high wall will be constructed using soil, shrubs, and branch-packing in a matrix of plastic geocells. (This technique was chosen where the bank cannot be excavated because of the sewer main behind it, and encroaching into the stream was to be avoided.) A geocell structure, or geoweb, is composed of layers of multiple plastic cells, each about 5 inches in diameter and 6 inches in height, that can be filled with soil, plants, rock, or cement and stacked to form a vertical wall. Branch-packing puts many long, live branches between layers of geocells (or any other kind of layering). The cut end of a branch goes into the soil in the stream bank while the other end sticks out beyond the structure. The branches continue to grow, adding another live dimension to the restoration.

This project will enhance the riparian habitat while stabilizing the stream bank. After an archeological assessment of the site is finished, construction will begin and should be completed within a year.

Restoring a riparian buffer

In Colonial times, streamside woodlands were cleared and farmed along 1 mile of Valley Creek that is within the national historical park. Later, this land was converted to lawn. It was maintained that way until 2000 when PennDOT and the park joined forces to create a wooded riparian buffer along 3,000 linear feet (915 meters) of the stream between the Pennsylvania Turnpike and the Knox covered bridge. PennDOT funded two-thirds of the project.

Woody vegetation is an excellent stabilizer of stream banks. It slows storm water, allowing it to infiltrate into the ground, filters runoff, and shades the creek, keeping its water cool. It also adds detritus to the water, which is food for fish, insects, and crustaceans. And the forest provides habitat for small animals and birds. The USDA Forest Service recommends a minimum 100-foot-wide (30.5-meter-wide) buffer on each bank.

The wooded riparian buffers at the national historical park are only 50 feet (15 meters) wide to avoid impacting the park's cultural landscape. Fibrous-rooted shrubs (3 feet tall; 0.9 meters) are planted in 20-foot-diameter (6.1-meter-diameter) clusters, and 8- to 12-foot-tall (2.4- to 3.7-meter-tall) trees are planted in 40-foot-diameter (12.2-meter-diameter) clusters, creating a mosaic of plantings and small openings (table 1). To protect the plants from being eaten by deer, plastic mesh guards are placed around newly planted tree trunks and a 7-foot-high (2.1-meter-high) vinyl mesh fence surrounds the shrub clusters (figs. 3 and 4). (Where two shrub clusters were experimentally left unfenced, the plants were completely consumed by deer.) This fencing design allows people and animals access to the stream because it does not form a continuous barrier along the stream bank. Park staff maintains the fences and controls exotic invasive plants. The new streamside woodland is coming along well.

Table 1. Trees and Shrubs Planted in Each Cluster

Trees	Shrubs
red maple *(Acer rubrum)*	southern arrowwood *(Viburnum dentatum)*
silver maple *(Acer saccharinum)*	redtwig dogwood *(Cornus stolonifera)*
smooth alder *(Alnus serrulata)*	silky dogwood *(Cornus amomum)*
ironwood *(Carpinus caroliniana)*	ninebark *(Physocarpus opulifolius)*
sycamore *(Platanus occidentalis)*	sweet pepperbush *(Clethra alnifolia)*
black willow *(Salix nigra)*	pussy willow *(Salix discolor)*
pin oak *(Quercus palustris)*	

Who benefits?

Valley Forge National Historical Park partners with many groups on many projects. The park benefits from the energy of committed organizations and agencies and from the fiscal resources they contribute.

> "The park benefits from the energy of committed organizations and agencies and from the fiscal resources they contribute."

Figures 3 (left) and 4. Project staff construct exclosures to protect woody vegetation planted in 20- and 40-foot-diameter clusters so that they will not be eaten by deer. Riparian vegetation stabilizes the soil and increases infiltration of storm water runoff. It also provides food and habitat for aquatic and terrestrial animals.

The park's partners benefit from the facilities and expertise that the park offers. Ultimately, of course, the resources being protected and enhanced are the primary beneficiaries of these partnerships. And because the park's natural resources are the public's to appreciate and enjoy, their stewardship benefits everyone.

Results and spin-offs

As a result of these partnerships, the survival and enhancement of Valley Creek as an outstanding natural, cultural, and recreational resource in the middle of an urban landscape has greatly improved. Exceptional value status adds an important management tool that can be used by both the National Park Service and Pennsylvania Department of Environmental Protection to protect the stream's water quality. A restored streamside woodland nurtures a growing fishery. Improved storm water control limits the creek's erosional power and enables landowners, such as the national historical park, to stabilize stream banks. These projects are rather high profile in that they are very visible, occur on a stream that is prized and protected by a large number of interest groups, and involve well-known partners, such as PennDOT.

An interesting and very beneficial cascading effect has occurred. Exceptional value status caused PennDOT to review its approach to protecting its assets (i.e., roads and bridges) along Valley Creek; this led to its partnership with the national historical park to stabilize stream banks along Route 252. In turn PennDOT chose the park for a riparian buffer project just upstream of Route 252, which was an important reason for the NPS Water Resources Division to fund the park's request to extend the upstream riparian restoration work on Valley Creek several hundred feet.

Of course, with all this interest in protecting the creek, it was politically untenable for the two townships, which encompass 90 percent of the watershed, not to improve their storm water ordinances. Both did, and now their ordinances require control not only of runoff rate, but also volume—a change sought by the park and environmental groups for more than a decade.

> "Now . . . storm water ordinances require control not only of runoff rate, but also volume—a change sought by the park and environmental groups for more than a decade."

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"Triassic park" continued from page 15

This project has demonstrated the importance of conducting fieldwork-based inventories. In many cases, existing data, including field maps, are inaccurate; in extreme cases, actual localities may be positioned as much as three-quarters of a mile from where they were physically mapped. Thus, locality maps not based on fieldwork (e.g., Evanoff 1994) can be unreliable for use in management decisions. In addition, photographs of the older localities do not exist, making their exact relocation almost impossible. Current and future projects that provide accurate GPS data, detailed notes, and site photographs will improve protection and management of fossil resources at Petrified Forest National Park.

> ***"Locality maps not based on fieldwork can be unreliable for use in management decisions."***

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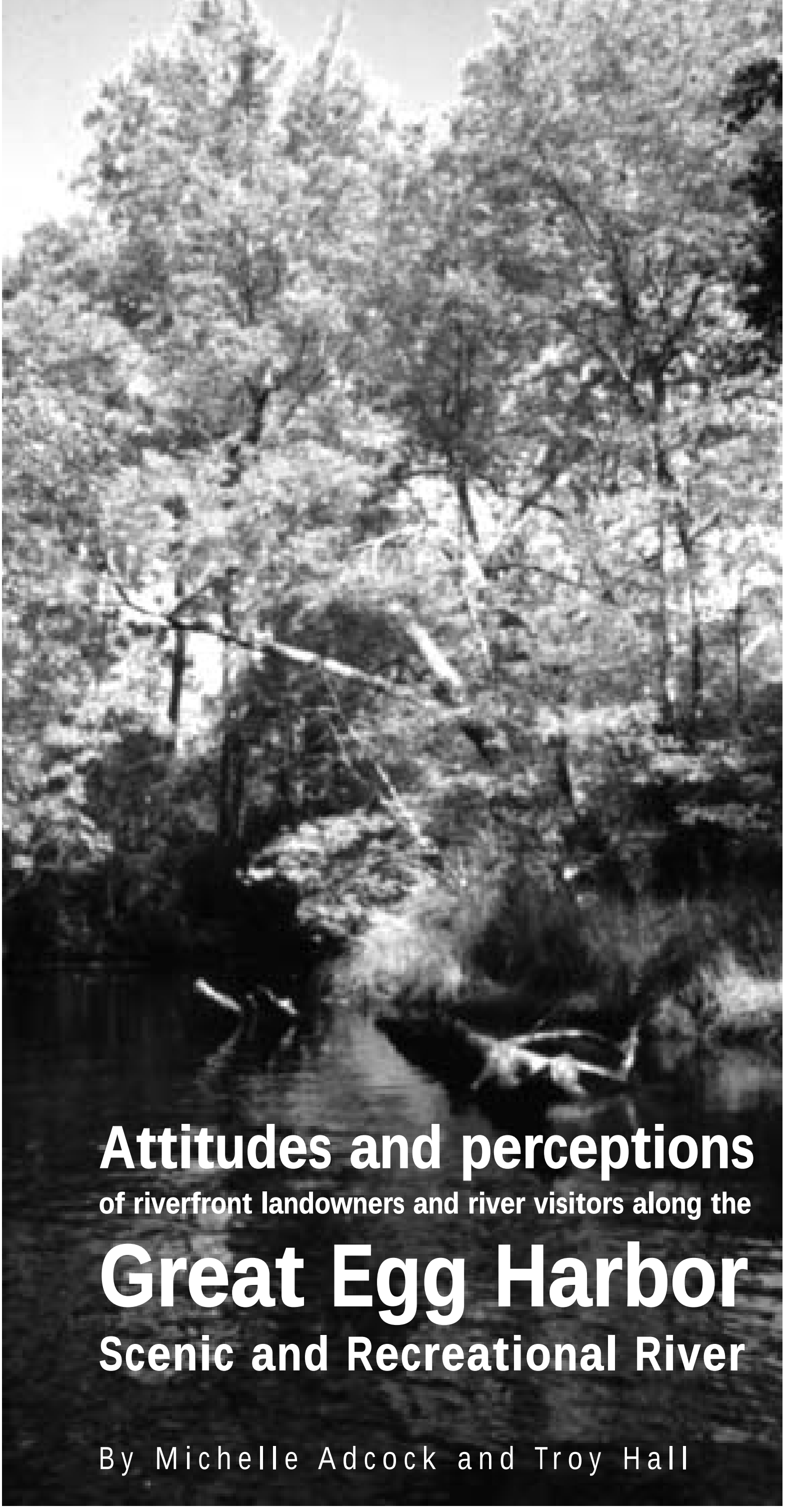

Figures 1 and 2 (left and above). Authorized in 1992, the Great Egg Harbor Scenic and Recreational River runs through the Pinelands of New Jersey and is near the urban centers of Philadelphia, Trenton, Camden, and Wilmington. It attracts recreationists and preserves scenic, natural, and cultural resources, including the Weymouth Furnace historic area.

Attitudes and perceptions
of riverfront landowners and river visitors along the
Great Egg Harbor
Scenic and Recreational River

By Michelle Adcock and Troy Hall

Beginning approximately 20 miles southeast of Philadelphia, Pennsylvania, the Great Egg Harbor River (figs. 1 and 2) meanders through New Jersey's Pinelands on its way to Ocean City, New Jersey, where it empties into the Atlantic Ocean. This waterway boasts natural, scenic, cultural, and recreational resources. Increased residential development and recreational use have generated concerns about crowding, potential conflicts among users, safety, and degraded recreational and scenic quality in recent years. Public officials from municipalities along the river corridor have worked with landowners and environmental organizations to protect the "outstandingly remarkable" resources along the river corridor. In 1992, as a result of these efforts, congress designated the river and some of its tributaries as "recreational and scenic" under the Wild and Scenic Rivers Act of 1968 and made the river a unit of the National Park System. Thereby the National Park Service (NPS) acquired a role in planning and management for the river; however, the National Park Service owns no land within the designation. Instead, the river and its banks are owned by 12 local municipalities, other governmental agencies, private landowners, and businesses that provide recreational services and facilities. The National Park Service reviews local management plans to ensure consistency with the scenic and recreational river designation but have limited legal jurisdiction and no enforcement ability.

As the population of the area has grown and recreation has become more popular, vocal members of the public have expressed concerns over continuing developments (especially subdivision of land and construction of docks), environmental protection, and increased recreational use. In order to develop a Comprehensive Management Plan for the river, the National Park Service needed some clear guidance about public attitudes toward various policies. In an effort to assess public perceptions of current river conditions and to gauge the level of public support for potential management actions in the river corridor, the National Park Service engaged researchers from Virginia Tech to study these issues.

"Increased residential development and recreational use have generated concerns about crowding, potential conflicts among users, safety, and degraded recreational and scenic quality..."

Management actions for the river primarily affect two stakeholder groups: riverfront landowners and river visitors who operate a variety of watercraft on the Great Egg Harbor River. The study focused on these two groups. Results have been used in the development of a Comprehensive Management Plan for the Great Egg Harbor Scenic and Recreational River (see sidebar, page 45).

Methods

After getting approval of the public survey from the Office of Management and Budget, we contacted 360 recreational boaters during the summer of 1998 at public marinas, canoe liveries, and public boat launches and asked them to provide their names and addresses for a mail survey. We also acquired names and addresses of riverfront landowners through county tax records. We identified just over 600 individuals for the study. In a survey mailed in the fall of 1998, both groups answered questions about crowding, conflicts among users, safety, environmental and scenic qualities, preferences for quality experiences, and support for current and potential management actions and policies. Two weeks following the initial mailing, we sent postcards indicating the importance of the study and reminding stakeholders to respond. People failing to return the survey within three weeks of the reminders were sent another questionnaire. This final contact resulted in 438 completed surveys and an overall response rate of 44% (44% for landowners and 45% for boaters).

Response bias checks were not performed, and given the relatively low response rate, we should be careful about generalizing from these findings. Other studies have found that nonrespondents tend to be less personally concerned about the particular issues in question (Hall and Shelby 1996, Hockett and Hall 1999). If this is the case with our respondents, then our findings likely represent the views of concerned and involved boaters and landowners. As these are the types of individuals likely to participate in land-use planning, we think our findings are useful.

Results

Perceptions of conflicts

Landowners and boaters were asked if they had noticed various types of conflicts, and if so, whether their experiences were negatively affected (fig. 3). Generally, landowners and boaters indicate similar perceptions of conflict on the Great Egg Harbor River for issues unrelated to private lands. For example, both of these groups are sensitive to reckless boating, speeding boats, and crowding. They also agree that conflicts between users of motorized and nonmotorized boats, and between water skiers and other recreationists, detract from their experiences on the river.

However, there are significant differences between the two groups in their perceptions of noise and issues related to private lands. In each of these cases, landowners are significantly more likely to indicate that impacts related to these issues detract from their experience. Their concerns about trespassing and about conflicts with recreational users are especially pronounced. These findings are consistent with previous research that shows that riverfront landowners often indicate problems associated with littering, vandalism, trespassing, and invasion of personal property (Roggenbuck and Kushman 1980).

Interestingly, the number of docks on the river is much less of a concern than the length of docks (fig. 4). This suggests that riverfront landowners are concerned more about safety and access problems posed by longer docks than by any aesthetic or environmental problems that might be caused by an increased number of docks.

Thus, there are similarities between landowners and recreational boaters, but also some significant differences. In general, landowners are most sensitive to issues, such as trespass and vandalism, which affect them personally as residents. We were therefore interested in learning whether a similar pattern was evident in their support for river management.

FACTORS AFFECTING EXPERIENCE QUALITY

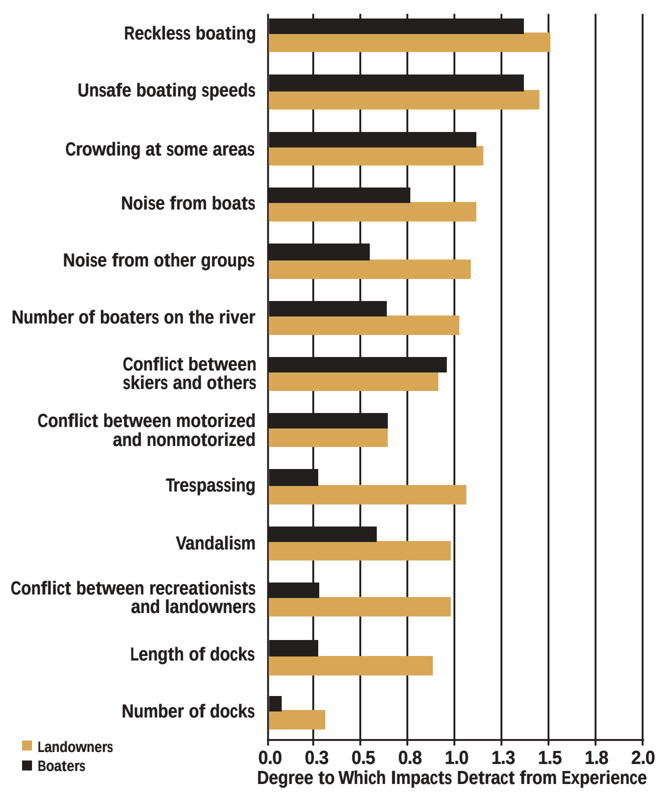

Figure 3. Various factors affect respondents' perceptions of the quality of their experiences. Respondents who did not notice items were classed as indicating "no effect,"represented by zero. The scale was anchored with "3," indicating "detracts a lot."

Figure 4. Dock construction is a controversial issue. The number of docks on the river is much less of a concern than dock length, however.

Attitudes about environmental protection

Respondents indicated on a scale from -2 (strongly disagree) to +2 (strongly agree) their general opinions about environmental issues. The two groups are quite consistent in having generally positive attitudes toward environmental protection (fig. 5). For example, both agreed that the riverbank and vegetation along the river should be protected and that environmental regulations for private lands are necessary to protect the river's resources. Their opinions about specific regulations pertaining to private land are also alike (fig. 6). Both groups support zoning, riparian buffers, restrictions on the developments of new riverfront homes, and other items (see fig. 6). This similarity is surprising—we had expected landowners to be less supportive of actions that could restrict their actions or limit options on their land. Recreational boaters—owning no land by definition—would not be adversely affected, and could conceivably benefit from the aesthetic or environmental effects of such regulations. Evidently, such distinctions are not important for possessing these general environmentally oriented attitudes.

Also important to note is that, despite high levels of general concern for the environment, a sizeable number of both boaters and landowners do not actively support many possible land-use restrictions (fig. 5). For example, only 50% support riparian buffers or restrictions on development (fig. 6). This suggests that, if such actions are contemplated, planners and managers may need to engage in additional dialog with stakeholders who are neutral or opposed to such actions.

One notable exception to the general similarities between boaters and landowners stood out: a majority of boaters, but less than half of the landowners, feel the National Park Service should be more involved in river planning (fig. 5). Landowners were more likely to feel that municipalities, rather than the National Park Service, should take the lead. This suggests that, to gain acceptance from local landowners, the National Park Service may need to educate landowners about its legal role and management obligations. It also suggests that the National Park Service should continue its current strategy of coordination and cooperation, rather than directing the course of policy decisions.

Opinions about dock construction deserve an additional comment. Clearly neither landowners nor boaters support a policy of unrestricted development, but neither do they support a policy of prohibiting construction. Instead, the most favored policy is to allow new docks, but to limit the allowable length. This is consistent with the reactions reported about factors affecting quality experiences (fig. 3).

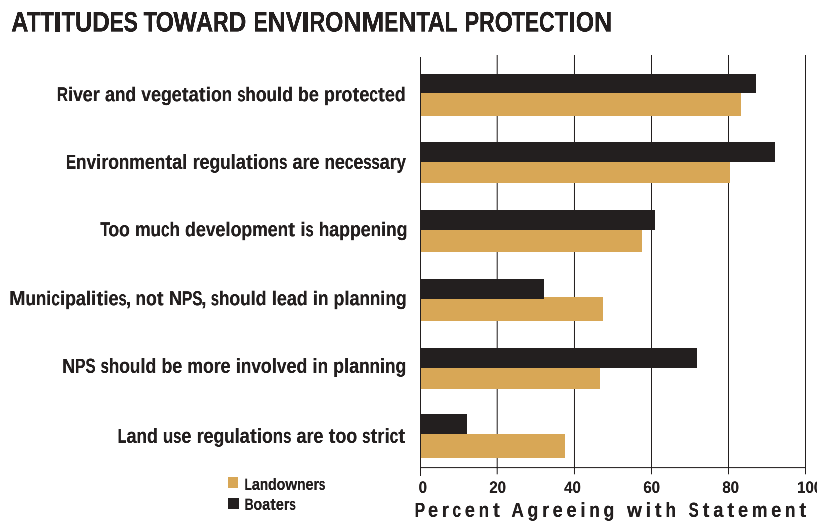

Figure 5. Boaters and landowners are quite consistent in having generally positive attitudes toward environmental protection.

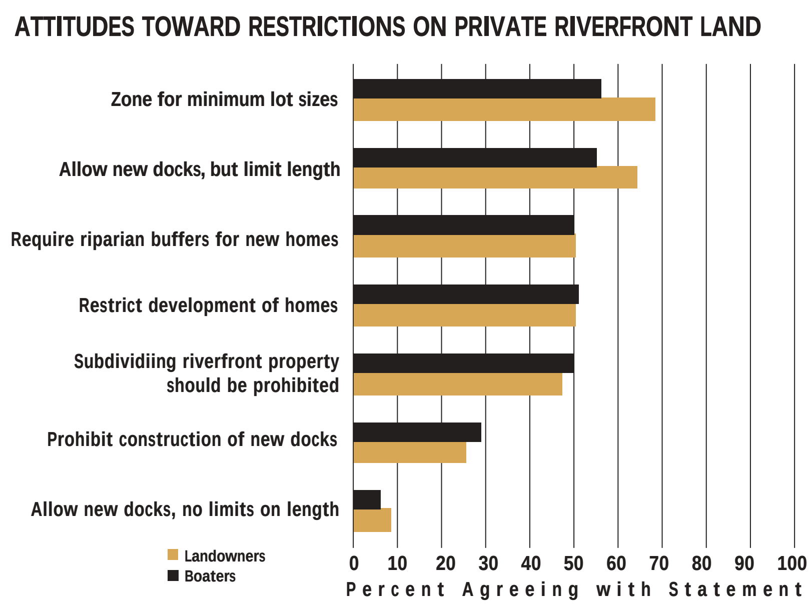

Figure 6. Despite high levels of general concern for the environment, a sizeable number of both boaters and landowners do not actively support many possible land-use restrictions.

Attitudes about recreational developments

Although landowners and boaters have quite similar views on environmental protection, they diverge sharply on their attitudes about new recreational developments (fig. 7). On a scale from -2 (strongly oppose) to +2 (strongly support), respondents indicated their level of support for various recreational developments. Boaters and landowners significantly differ in their evaluations of all seven of these recreational developments. Boaters indicated support for the establishment of additional launching points and public restrooms along the river corridor. Landowners on average opposed or were neutral to these types of developments. Although both boaters and landowners indicated opposition to the construction of new public or private marinas in addition to the construction of new canoe liveries, landowners evaluated these developments more negatively than did boaters. Although both boaters and landowners indicated support for the construction of hiking trails and a nature center on public lands along the river, landowners seem less supportive of these developments. Perhaps landowners do not see themselves as benefiting from such developments, especially boating facilities. Rather, new facilities may raise concerns about new sources of conflict or trespass.

"New facilities may raise concerns about new sources of conflict or trespass."

In general, then, river managers might consider certain types of recreational improvements, particularly those that do not increase use on the water. Most boaters and landowners would support such facilities. However, managers might consider policies that would discourage additional water-based recreational use. Many landowners actively oppose and a majority of boaters do not support such developments. We conclude that both groups are sensitive to conflict and crowding issues.

"Managers might consider policies that would discourage additional water-based recreational use."

Implications

This study identifies points of convergence and divergence that are important to the National Park Service in moving forward with management planning for Great Egg Harbor Scenic and Recreational River. Interestingly, the levels of similarity or difference vary depending on the issue under investigation. In general, both groups of stakeholders we studied support broad environmental goals that are consistent with the wild and scenic river designation. However, there is some question about the level of support that might be encountered for specific types of restrictions that might be considered for private land, and opposition among many landowners toward certain new boating-access developments. Management proposals should, therefore, be clearly defensible in terms of their environmental benefits, in order to maximize public support.

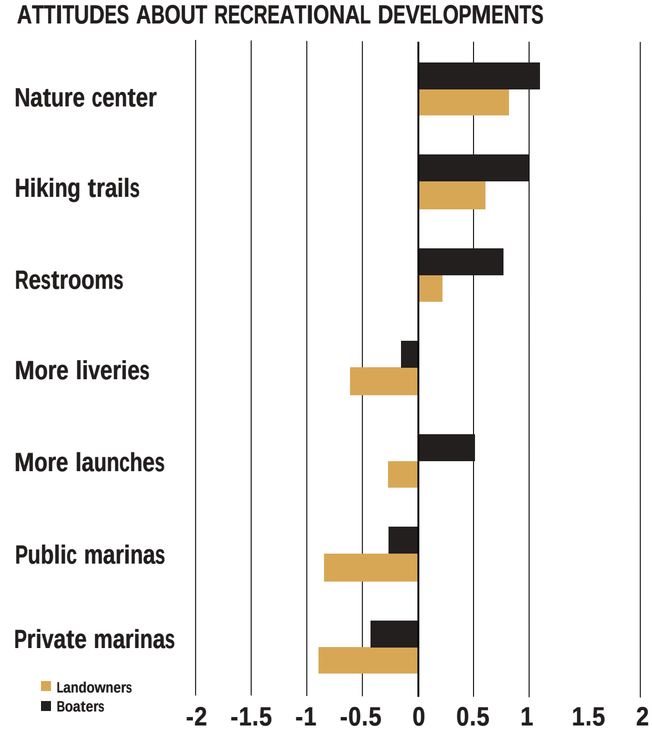

Figure 7. Boaters and landowners significantly differ in their attitudes about seven different types of recreational development.

The data indicate that for the controversial issue of dock construction, the National Park Service might advocate a policy of limiting the length of docks, but be somewhat more lenient about granting permits for the construction of new docks. However, because both boaters and landowners are adversely affected by conflicts and crowding they now experience on the river, any dock or development policy that would increase use should be evaluated carefully.

Results from the survey suggest that conflicts are the most significant problems for both groups. Some of these problems may be amenable to resolution through public education efforts, while others may require more direct regulation or enforcement. For example, issues of noise, trespass, and unsafe speeds might be addressed through boater education about safety and etiquette, while vandalism and reckless boating may require an increased law enforcement presence. The National Park Service and municipalities could work cooperatively with public safety agencies to increase the law enforcement presence along the river and to enforce existing regulations and procedures with stronger penalties for violations.

The study highlights the importance of identifying and characterizing relevant stakeholders for management when planning for recreation and environmental protection. Often in settings such as this, local landowners are vocal and active participants in planning. Our results suggest that this group may share some concerns with other members of the public (for example, about safety or environmental protection), but may be more sensitive to other impacts such as trespass or vandalism. Because of this, they may be reluctant to accept new recreational developments. Studies that approach only the recreating public may fail to capture the views of other stakeholders affected by management decisions and policies.

> "Studies that approach only the recreating public may fail to capture the views of other stakeholders affected by management decisions and policies."

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There is a concern that development pressures may adversely affect this scenic section of the Great Egg Harbor River.

Study findings assist park management planning

By Mary Vavra

The planning committee for Great Egg Harbor National Scenic and Recreational River incorporated information and recommendations resulting from the 1998 Virginia Tech social science study into the May 2000 final Comprehensive Management Plan and Environmental Impact Statement. This fundamental planning tool defines the purposes of resource protection and outlines preferred experiences for living within and visiting the river corridor. The Great Egg Harbor River is managed by the National Park Service in cooperation with the State of New Jersey, four counties, and 12 municipalities.

The social science study compiled information about river users, which gave the National Park Service a profile of park visitors and an understanding that most live within 20 miles of the river corridor. The Great Egg Harbor River is clearly a close-to-home recreational resource. Recognizing that the river was already overcrowded in 1998 and is close to major urban centers, the National Park Service recommended limiting additional public access. Moreover, information gathered from the surveys showed support for increased law enforcement on both the tidal and nontidal sections of the river.

The information gathered through the study also supports limiting the size and design of docks which continues to be a major concern in the tidal section of the river. The National Park Service used the information to work with the New Jersey Department of Environmental Protection to develop state regulations regarding dock designs to ensure that structures do not adversely affect the river's outstandingly remarkable resource values.

About the author

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THE LEGACY OF THE GRAND VIEW MINE

Grand Canyon National Park, Arizona

By Ray Kenny, Ph.D., PG

Small isolated mines in Grand Canyon National Park stand as mute testimony to the early days of mining. Remote mine locations, the daunting task of hauling supplies to mine sites, and removing ore out of the canyon for processing led to the limited and meager success of 19th and early 20th century mining in what is now Grand Canyon National Park. Some miners did manage to extract a significant amount of ore, however. In their wake, the miners left behind conspicuous heaps of waste rock that spread out like aprons in front of mine openings (fig. 1).

Today, many of the mines remain relatively inaccessible. However, improved travel corridors in the park have made some of these mines easy destinations. Moreover, the dramatic boost in backcountry use has increased the probability of visitors encountering these mines. In addition, many abandoned uranium mines that once lay outside the park are now within the recently established Parashant National Monument. These changes have raised important resource management questions about public safety, including waste rock cleanup, public exposure to contaminants and hazardous materials, and control of public access to mine shafts and adits. In an effort to attain the baseline data necessary to tackle these management challenges, researchers from Ft. Lewis College in Durango, Colorado, and New Mexico Highlands University in Las Vegas, New Mexico, measured radioactivity levels in contaminated waste rock piles at the abandoned Grand View Mine. After analyzing the data, we proposed recommendations for pubic safety.

Figure 1 (above). Beginning in 1890, mule teams hauled copper from the Grand View Mine up the Grand View Trail to the South Rim of the Grand Canyon. The National Park Service acquired the mine in 1939.

Background

In general, abandoned mines are found only in isolated pockets and limited areas of the Grand Canyon; the Grand View Mine is one of the more accessible mines, however. It is located about three miles from the South Rim at Grand View Point along the remarkably well-constructed and accessible Grand View Trail (fig. 2). A tenacious prospector named Pete Berry located the rich copper deposits of the Grand View Mine in April 1890. Berry and other miners worked the claim and constructed the steep Grand View Trail (see fig. 2) in the early 1890s (Billingsley et al. 1997, Anderson 1998). In 1895, Berry and others formed the Grand Canyon Copper Company and continued to work the mine—and improve the trail—until 1901. The mine produced high-grade copper ore with one notable specimen ending up on display in the famous 1893 Columbian Exposition in Chicago, Illinois. Berry later sold the mine and the president of a new mining concern, John Page, accelerated

Figure 2. The Grand View Trail leads to the Grand View Mine, one of the more accessible and hazardous mines in Grand Canyon National Park. Construction of the trail began in the late 1890s and the trail crosses a mine waste area that has elevated levels of uranium.

copper ore production. In 1907 the price of copper plummeted and mining activity gradually tapered off and eventually ceased by 1916. The mine was again sold and eventually the National Park Service acquired it in 1939.

The Grand View Mine is associated with a distinctive geologic phenomenon called "solution-collapse breccia pipes" (fig. 3). These features are unusual worldwide but are quite abundant in northern Arizona and southern Utah (Sutphin and Wenrich 1989). Literally thousands of breccia pipes are scattered across the region. Many of the breccia pipes contain relatively low-grade, widely disseminated uranium ore near the surface, but some pipes have small pockets of ore that are more highly concentrated. Natural weathering and erosion processes can concentrate ore (Kenny and Vigil 1999), but past mining activity is primarily responsible for the elevated concentrations of uranium in surface and near-surface soils and waste rock.

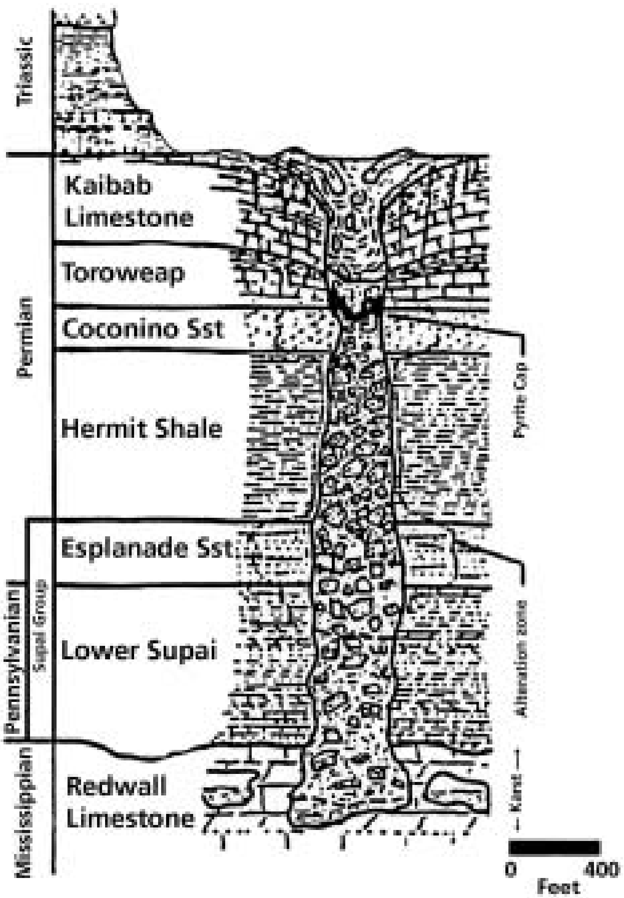

Figure 3. Solution collapse breccia pipes are relatively rare worldwide but are abundant in northern Arizona and southern Utah. Scientists interpret four basic stages of pipe formation (Bowles 1977). Stage 1: The development of an extensive cave system in the Mississippian Redwall Limestone 325 million years ago (McKee and Gutschick 1969, Kenny 1998, Kenny and Knauth 1992). Stage 2: Intermittent collapse of the caves over geologic time (from the weight of overlying rock layers that accumulated on top of the Redwall Limestone) resulting in thousands of feet of vertical pipe elongation. Stage 3: Concentration of metals and dissolved particles from the influx of water directed to the pipes. Most of the metal and uranium was dissolved by surface waters and precipitated in the pipes from groundwater under oxygen-poor, subsurface conditions. Stage 4: Erosion, exposure, and modification of the pipes during uplift of the Colorado Plateau (beginning about 65 million years ago); uranium enrichment was further enhanced by increased precipitation during the great ice ages (from about 2 million to 10,000 years ago).

Study methods

An initial step in the baseline study was to systematically record the radioactive contaminant levels in the soils and waste rock around the various entrances to the mine. Where possible, we established a grid pattern along the surface of the waste rock piles. We used an Exploranium GR-320 gamma-ray spectrometer (fig. 4) to record radioactive potassium, thorium, and uranium. We established local background soil levels by averaging numerous field readings collected on nearby soils not associated with the breccia pipe mine spoils. We also collected surface and outcrop samples for laboratory analyses and independent verification of the field results. We prepared the samples according to established EPA regulations. A private, independent laboratory, Energy Labs, analyzed the samples.

Figure 4. Using a portable gamma-ray spectrometer (arrows), researchers from Ft. Lewis College in Durango, Colorado, and New Mexico Highlands University in Las Vegas, New Mexico, collected data on radioactivity levels in contaminated waste rock piles at the abandoned Grand View Mine. The mine waste rock levels were up to 125 times more than the local mean background uranium levels.

Field and laboratory data

The portable gamma-ray spectrometer (see fig. 4) recorded 144 field readings for uranium, potassium, and thorium that were taken in the vicinity of the Grand View Mine. The mine waste rock adjacent to the Grand View Trail registered the highest uranium levels. A portion of the trail crosses the mine waste rock. Field values for uranium were as high as 233 parts per million (ppm); local background uranium levels were about 1.8 ppm. The mine waste rock levels were as high as 125 times greater than the local mean background uranium levels (Kenny and Diaz 2000).

"The mine waste rock adjacent to the Grand View Trail registered the highest uranium levels."

We performed 18 lab analyses for natural uranium, polonium, and radioactive lead. Like the field readings, lab analyses showed elevated uranium values in samples collected from the mine waste rock area. The laboratory data indicated that the radioactivity associated with the mine waste rock was 100 times greater than the mean total background radiation levels (figs. 5 and 6).

Both field and laboratory results indicate that the radioactivity in the mine waste rock is significantly higher than the natural background levels in the area. Both data sets indicate that pockets or "hot spots" within the mine waste rock are at least 100 times greater than local background values. The difference between the laboratory and field results may be explained by the relatively large number of samples taken in the field compared to the small number of samples analyzed in the lab.

"The radioactivity in the mine waste rock is significantly higher than the natural background levels in the area."

The size of the waste rock piles varies considerably (fig. 7). Uranium hot spots are primarily restricted to the waste rock areas around the north and south adits (see fig. 7); each of these has a surface area comparable to that of a

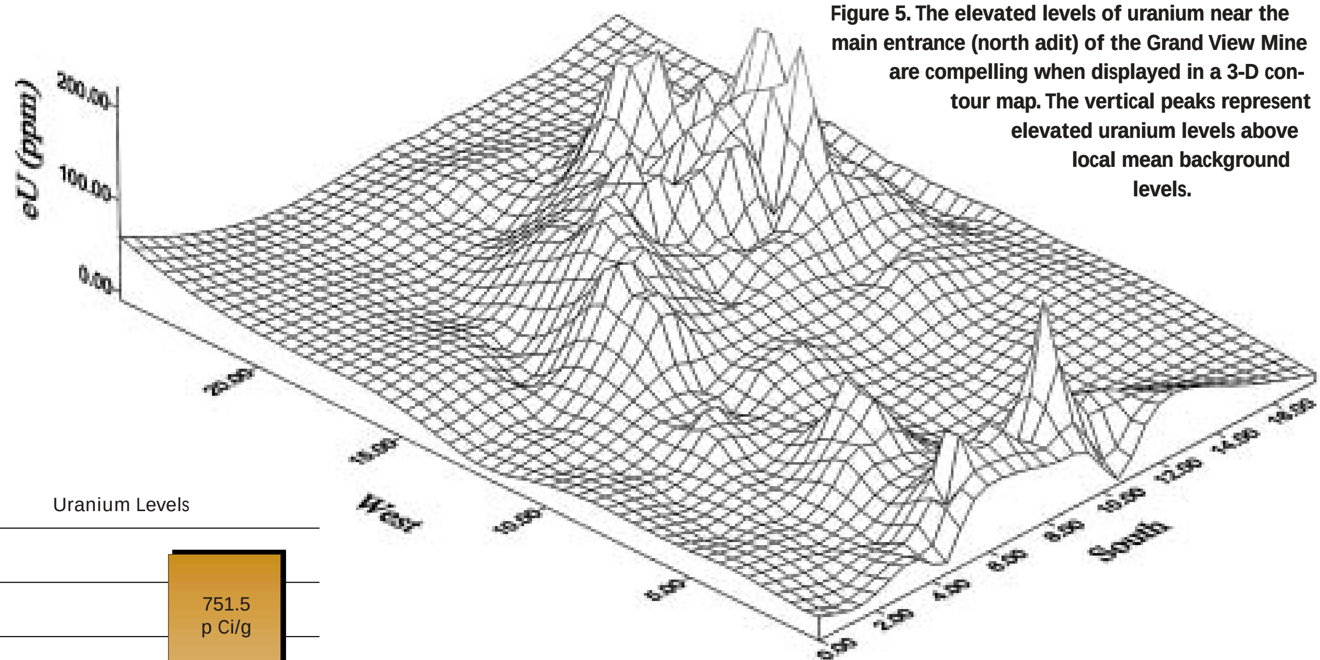

Figure 5. The elevated levels of uranium near the main entrance (north adit) of the Grand View Mine are compelling when displayed in a 3-D contour map. The vertical peaks represent elevated uranium levels above local mean background levels.

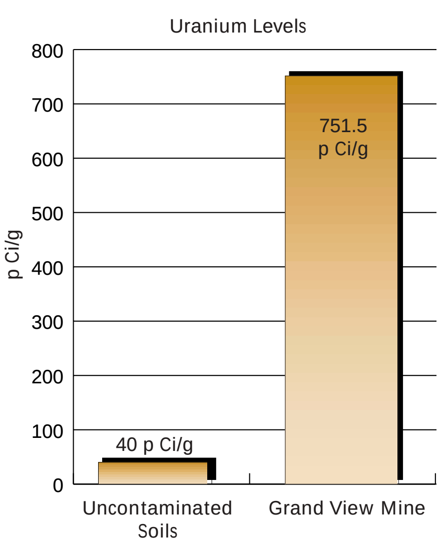

Figure 6. Elevated uranium levels were detected in samples collected from the waste rock of the Grand View Mine. The laboratory data are reported in pico curies per gram (pCi/g) where one curie is that quantity of a radioactive material that undergoes 37 billion transformations per second. The laboratory uranium levels for samples collected from the mine waste rock ranged from 14.9 to 751 pCi/g. The mean total uranium activity of the waste rock pile was 180 pCi/g. The local background uranium values were about 1.8 pCi/g.

football field. The closest park facility to the Grand View Mine is the campground on Horseshoe Mesa. Extensive field data collected at this site indicates that the campground does not have elevated uranium levels.

Field observations

The shafts, entrances, and adits around the Grand View Mine remain open and accessible to the public. Ore hoists, glass, dilapidated buildings, and other abandoned mine equipment scattered about the area are reminders of early mining days. In an effort to reduce the temptation to enter the mines, park staff includes information with every backcountry permit that emphasizes the dangers of entering old mines. However, little information is prominently displayed at the trailhead to discourage hikers from entering the mine, and, unfortunately, the mine openings make an attractive place to find shelter from the searing heat that is common to this area. As such, the mine still poses a public health risk.

"Little information is prominently displayed at the trailhead to discourage hikers from entering the mine."

As part of the study, we compiled information on the behavior of backcountry travelers around the mine. A substantial number of hikers and backpackers entered both the upper and lower mine adits. Only one in 50 did not stop at the main mine entrance ("north adit" in fig. 7) located along the main trail to eat, rest, get out of the sun, or explore for minerals. These observations represent an informal and random sampling. Nevertheless, it appears that the main mine entrance is regularly visited. Significantly, the area around the main mine entrance, including the mine waste rock, has substantially elevated uranium levels. Therefore, these data show and we suggest that this part of the mine should be managed as a restricted area.

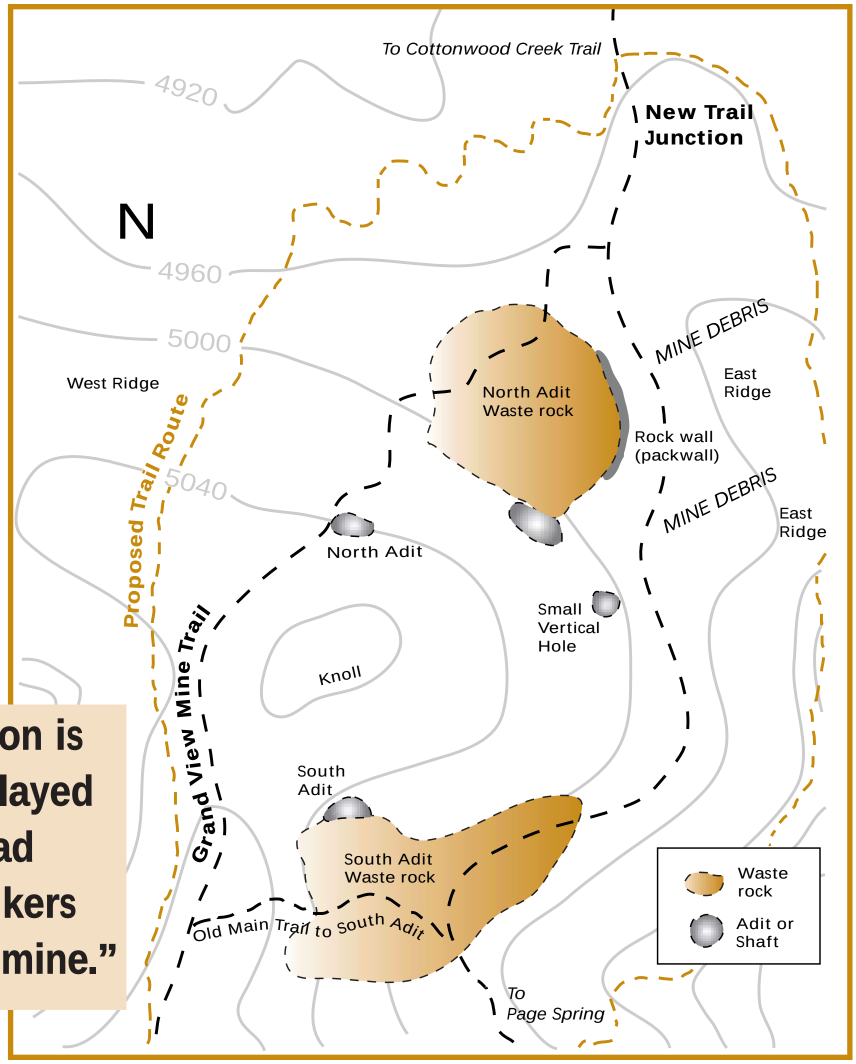

Figure 7. Collection and analyses of data from the study resulted in a recommendation that the trail be routed away from a hazardous waste rock pile where the highest levels of uranium were detected. The proposed trail route is marked on the map. One inch on the map represents about 125 feet on the ground. Adit openings are not to scale.

Health risks

One of the principal concerns associated with uranium is the production of radon gas. Radon is a natural product of uranium decay and is found in relatively low levels in many soils (Dueñas-Parshley and Kenny 2000). Usually uranium concentrations in soils are dependent upon the original uranium concentrations in the rocks from which the soils weathered. Typically, radon concentrations in soils are lower than in rocks because oxidizing surface conditions associated with near-surface weathering usually leach some of the uranium and carry it away. The world crustal average for uranium is about 2.7 ppm (Smith 1993), which is only slightly higher than the local background levels obtained during this study (about 1.8 ppm). Relatively low uranium levels in soils similarly produce relatively low radon levels. However, if the soils were derived from rocks with significantly higher concentrations of uranium, or if natural or human-induced factors concentrated the uranium in a given location, then higher concentrations of radon and related decay (daughter) products may also be found in the soils.

High concentrations of radon gas can accumulate in enclosed environments such as homes and other structures (Spencer 1993) or mine shafts and adits. Prolonged (chronic) exposure can cause lung cancer. The primary health concern related to radon is the inhalation of radioactive daughter products of radon attached to dust particles. These short-lived particles (the daughter products of radon) decay further while still in the lungs. The decay is so rapid that it occurs before exhalation, causing damage to human tissue.

An important health concern, therefore, occurs in areas where elevated uranium activity is found and where daughter products can accumulate. The effect of short-term or acute exposure on hikers and backpackers is difficult to determine with any accuracy. Certainly, health risks will increase with

1. increased temporal contact with the mine waste rock,
2. prolonged contact with dust particles entrained in the air entrapped in mines (stirred up from walking and other disturbance activities),
3. increased activity and physical exertion in and around the mine waste rock, and
4. increased wind activity and subsequent contact with fine particulate matter stirred up by the wind.

"Prolonged contact with dust particles wafted into the air during entry into the mine is potentially the most damaging."

Of all these factors, prolonged contact with dust particles wafted into the air during entry into the mine is potentially the most damaging. This is because the mine is a restricted environment, has elevated radioactive particles, and has a local atmosphere that may become choked with dust particles that can be readily inhaled.

Recommendations

Based on field and laboratory data and field observations, we made several recommendations to improve public safety around the Grand View Mine:

1. Reroute a relatively short segment of the Grand View Trail to avoid crossing the main waste rock pile where the highest uranium concentrations were detected (see fig. 7)
2. Update and distribute information to backpackers and hikers
3. Post warning signs at the trailhead and along the portion of the Grand View Trail that must cross waste rock

Reroute a portion of Grand View Trail

As one approaches the Grand View Mine from the south, the trail crosses the main mine spoils at a constructed rock wall below the north adit (see fig. 7). Significantly elevated uranium levels characterize the waste rock in this area. This portion of the Grand View Trail could be rerouted to the west, beginning just south of the south adit (see fig. 7). The proposed trail would continue west of the mine and switchback into the minor drainage north of the mine before rejoining the old trail south of the campground area. At this new junction, the trail to Page Spring and Hance Canyon would continue east of the present trail, bypass the old mine debris, and join with the old trail south of the south adit (see fig. 7). A portion of the proposed trail would still have to pass the mine adit near the head of Page Spring Canyon. Warning signs could be posted to alert backcountry travelers of the potential danger.

Update and distribute information to backpackers and hikers

Information distributed or posted at the trailhead needs to alert backpackers and hikers about elevated uranium levels at the Grand View Mine. Flyers given to all backcountry travelers should provide information about the health hazards of uranium contamination, warn of the dangers of entering abandoned mines, explain the results of the recent study, identify the areas to be avoided, and provide alternative routes of travel.

Post warning signs

Even after rerouting a portion of the trail, at least two of the mine adits will continue to be easily accessible. This is because the topography of the area dictates, to a large degree, where the trail must be routed in order to accommodate ready access to the springs, the lower canyon trails, and Hance Canyon.

Where the Grand View Trail must cross the waste rock and pass near mine entrances, warning signs should be posted to remind backpackers and hikers that public access to the mine is hazardous. Signs should include a brief description of the hazard, locations to avoid, and where to receive additional information.

Alternatively, the mine entrances could be sealed off with steel bars to allow access for birds and bats but not humans. This option is costly and may not be necessary if the appropriate warning signs are placed and maintained at the trailhead and mine entrance.

Conclusions

The results of this study show that both the waste rock piles and mine tunnels at the Grand View Mine are radioactive and visitor contact with these areas should be discouraged. Proposed management actions should help mitigate the potential risk to visitors. Additional studies may be needed to verify the effectiveness of the proposed mitigation actions.

Continued in right column on page 58

Estuarine habitat restoration at CAPE COD NATIONAL SEASHORE:

the Hatches Harbor prototype

By

John Portnoy,

Charles Roman,

Stephen Smith,

and

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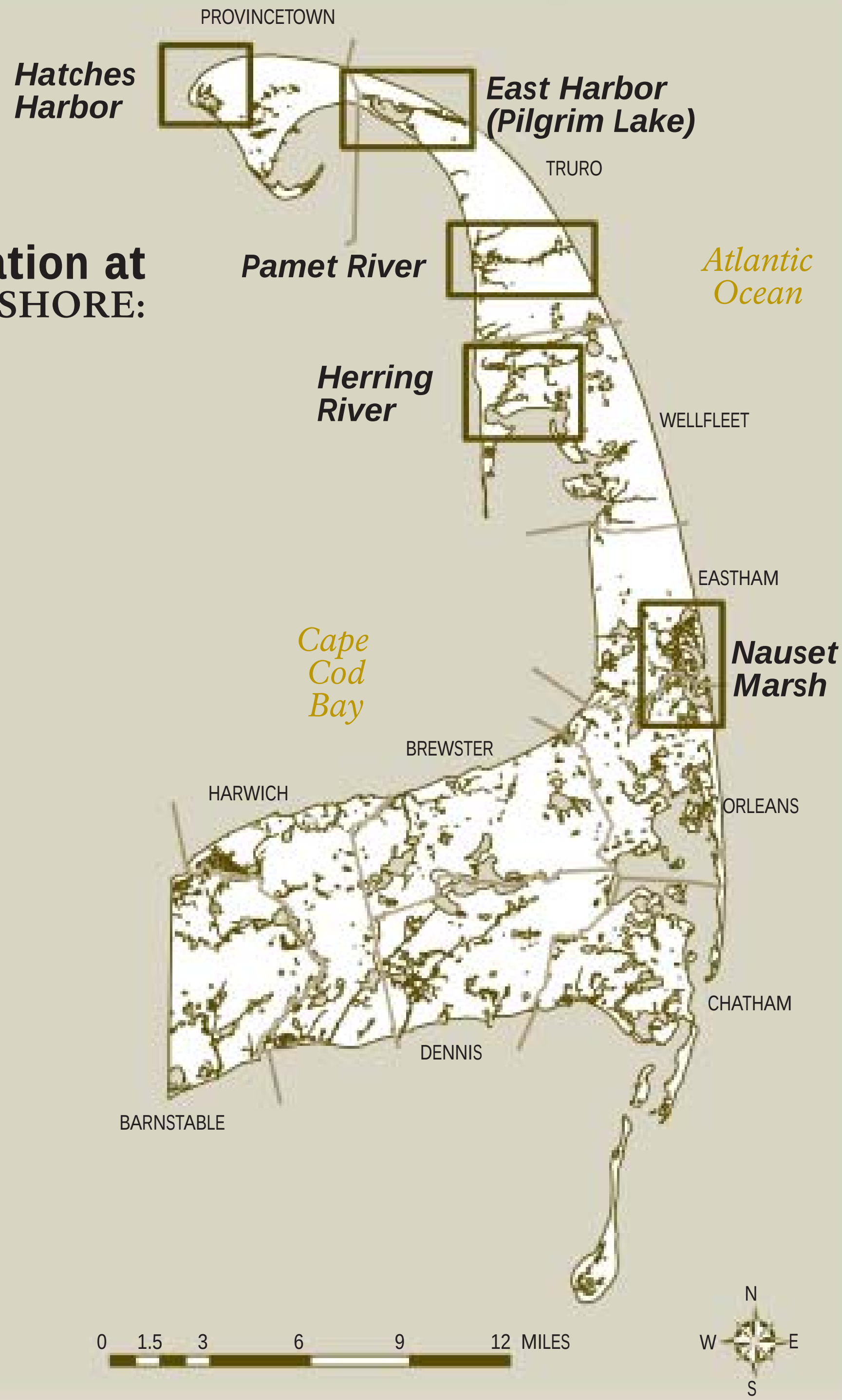


Figure 1. The four largest diked estuaries on Cape Cod occur in three seashore towns on outer Cape Cod: Truro, Wellfleet, and Provincetown. Roads, railways, and dikes restrict large portions of these wetlands. A prototype program for estuarine restoration and monitoring is occurring at Hatches Harbor.

Tidal range (flooding) and salinity are driving forces that define salt marsh ecosystems. Recognizing this, and the degrading effects of human-imposed tidal restrictions, Cape Cod National Seashore and cooperating state and federal agencies have been working for 20 years to restore tidal flow to many diked salt marshes on Cape Cod. Currently scientists from the U.S. Geological Survey-Biological Resources Division, Cape Cod National Seashore, and universities are developing the long-term coastal ecosystem monitoring program for Cape Cod National Seashore, of which estuarine monitoring is an integral component. We report on the status of tide-restricted salt marshes within Cape Cod National Seashore and describe the approach and progress toward habitat restoration at Hatches Harbor (Provincetown, Massachusetts), our prototype for estuarine restoration and monitoring.

The legacy of tidal restrictions

Cape Cod has a 350-year history of coastal wetland loss because of diking, drainage, and filling. An estimated 3,460 acres (1,400 ha) of original salt marsh estuaries remain diked today (Justus 2001). The four largest diked estuaries occur in three seashore towns on outer Cape Cod: Truro, Wellfleet, and Provincetown (fig. 1). With national seashore authorization in 1961, the National Park Service (NPS) received management responsibility for more than 2,100 acres (850 ha) of these diked coastal systems. This acreage represents a loss of 42% of the native salt-marsh habitat present at the time of European settlement (table 1).

Although diking of salt marshes has caused serious estuarine water quality problems on Cape Cod (Soukup and Portnoy 1986, Portnoy 1991, Portnoy and Giblin 1997), the most noticeable effects of diking are changes in vegetation (Roman et al. 1984). Cattails (*Typha* spp.) and, in particular, common reed (*Phragmites australis*) characteristically spread onto tide-restricted marshes, displacing native salt-tolerant grasses. At higher elevations, which are consequently more deeply drained by diking, a large variety of freshwater wetland and upland plants invade diked floodplains once the stresses of salt and waterlogging are removed. Thus, thousands of acres (hundreds of hectares) of original salt-marsh habitat have been converted to freshwater wetlands or upland habitat within four of the five largest tidal marshes in Cape Cod National Seashore (table 1, fig. 1). In response to hydrologic, water quality, and vegetation changes, scientists have documented impacts on fish and decapod crustaceans (Raposa and Roman 2003).

"The most noticeable effects of diking are changes in vegetation."

Although the National Park Service became responsible for stewardship of most of the marshlands, both diked and natural, within the park boundary in 1961, local towns and the Commonwealth of Massachusetts retained ownership and control of the structures (e.g., dikes, culverts, tide gates, and weirs) that restrict tides. Progress in addressing NPS concerns about water management has been slow, but recently successful in Hatches Harbor.

Table 1.
Extent and Duration of Tidal Restrictions in the Major Estuaries of Cape Cod National Seashore

Estuary, township	Total area acres (ha)	Diked area acres (ha)	Year of diking
East Harbor, Truro	719 (291)	719 (291)	1868
Pamet River, Truro	388 (157)	158 (64)	1869
Herring River, Wellfleet	1,100 (445)	1,000 (405)	1909
Hatches Harbor, Provincetown	420 (170)	198 (80)	1930
Nauset Marsh, Eastham	2,334 (945)	<25 (<10)	?
Total	4,961 (2,008)	2,100 (~850)	

Note: The Cape Cod Commission estimates that diked salt marshes total 3,460 acres (1,400 hectares).

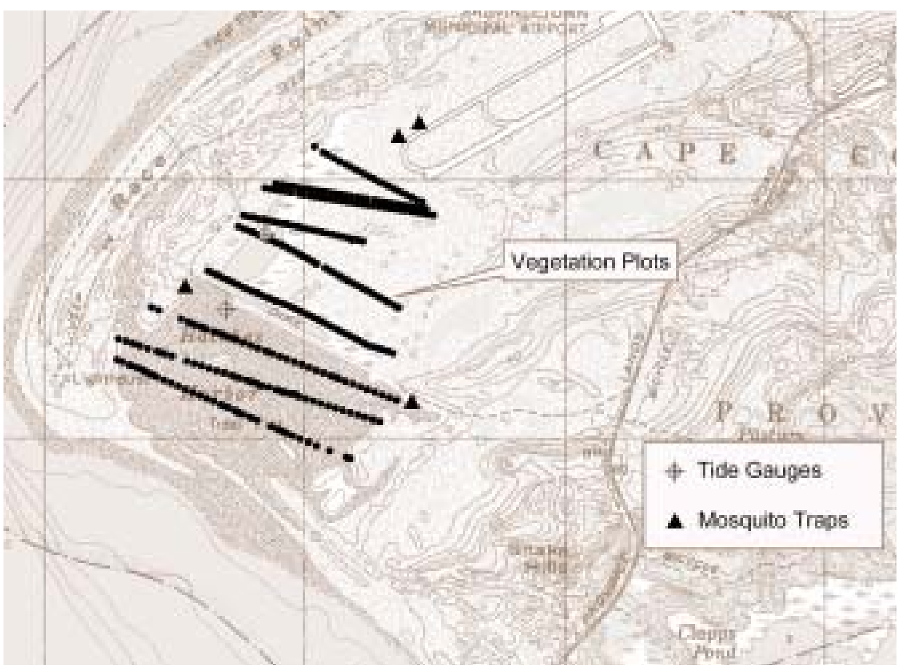


Figure 2. A dike built across the floodplain of Hatches Harbor salt marsh in 1930 isolated about half of the coastal wetland from tidal exchange.

Hatches Harbor, Provincetown

The Hatches Harbor salt marsh developed relatively recently behind the prograding northwestern tip of outer Cape Cod (fig. 1). As such, the peat is sandier and peat depths are shallower than in the older marsh systems to the south. A 1-kilometer-long dike constructed in 1930 for mosquito control essentially bisected the floodplain completely blocking tidal exchange and reducing salinity in the landward half of the wetland (fig. 2). In addition, Provincetown Airport was constructed within the floodplain in the 1940s, about 20 years before park establishment, using the preexisting dike as protection against tidal flooding. As a result by the 1980s, many species of salt-sensitive plants, including 20–25 acres (8–10 ha) of the somewhat salt-tolerant

Phragmites, replaced native salt marsh grasses; relict cover of *Spartina alterniflora* (the dominant species in a natural salt marsh) in the diked marsh amounted to only about 12 acres (5 ha) at lowest elevations nearest the tidal creeks.

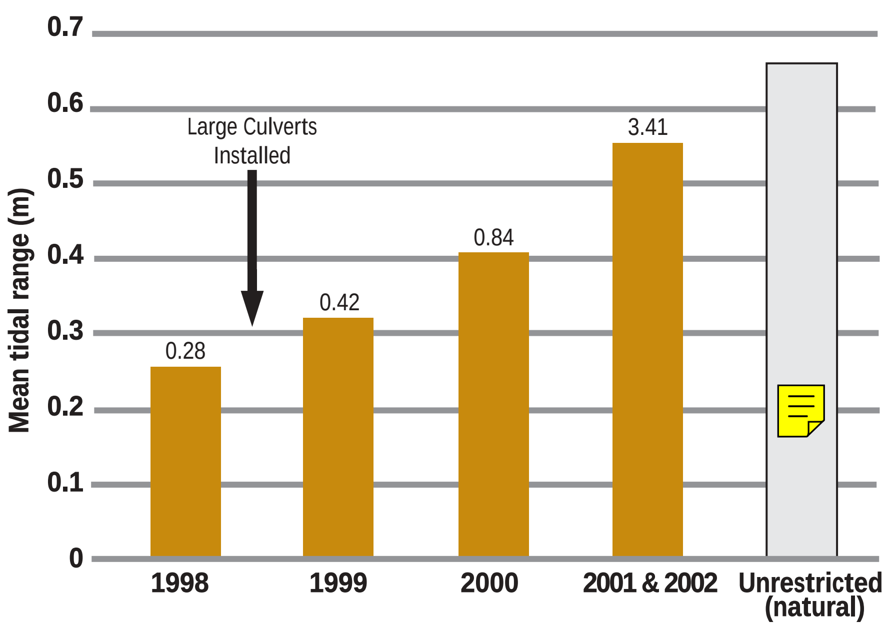
The need for dike repair in 1986 prompted interagency discussions about flood-protection needs of the airport and the possibility of tidal restoration. Engineers from the Federal Aviation Administration determined critical flooding elevations for airport structures, while NPS scientists and cooperators developed a numerical hydrodynamic model of the estuarine system (Roman et al. 1995). The model showed that a wide, low culvert opening (8.5-meters-wide-by-one-meter-high) should provide sufficient seawater flooding to restore between 60 and 90 acres (25–35 ha) of salt marsh and, at the same time, dampen storm tides that may otherwise affect the airport's instrument landing system. In 1997 a planning and regulatory team representing 10 local, state, and federal agencies approved this culvert configuration and a general restoration plan. Pre-restoration monitoring began in summer 1997, with the new culverts installed in winter of 1998–1999 (fig. 3).

Despite model predictions, the new culverts were not fully opened after construction. Opening has been done in small increments (figs. 3 and 4) to build confidence among cooperators—especially airport officials—in the reliability of the model and because of concerns for extensive plant death from waterlogging should the marsh fail to drain during each low tide. Experience since 1999 has allayed most concerns.

Monitoring tide restoration at Hatches Harbor

The NPS monitoring team has used a before-after-control-impact (BACI) approach, selecting physical and biological variables that were judged (based on experience elsewhere) to be most sensitive to changes in the principal governing variables: tidal range (flooding) and salinity. The unrestricted portion of the marsh downstream from the Hatches Harbor dike is the control; restoration of tidal flow above the dike is the impact. The BACI design enables a statistical assessment of

1. The degree of difference between control and diked marsh
2. The degree of difference between diked and restoring marsh as tidal restoration proceeds
3. The degree of difference between the control marsh before and after tidal restoration (important because changes in the control would suggest that factors other than the tidal restoration treatment—that is, factors that are functioning on a regional scale—may have



Figures 3 (photo) and 4 (graph). In 1997, a planning and regulatory team with members from local, state, and federal agencies approved a culvert configuration and general restoration plan for Hatches Harbor. The installation of new culverts occurred in January 1999, following two years of pre-restoration monitoring. The photograph shows four new 7-feet-wide-by-3-feet-high culverts at Hatches Harbor with adjustable tide gates that are about half open. The graph documents how tidal range has increased in diked portions of the Hatches Harbor salt marsh with the installation and incremental opening of large culverts. Numbers above bars are cross-sectional areas (m^2) of culvert openings.

affected the trajectory of changes in the biotic community both upstream and downstream of the dike)
4. Convergence in control versus diked-marsh plant communities

As restoration proceeds, we hypothesize that the restoring marsh will become more like the control marsh.

Physical and chemical variables

Tide heights and salinity are monitored periodically—at least semiannually—with month-long (minimum) deployments of sampling probes in the main creek on either side of the dike structure (fig. 2). These data describe the hydrography of the system and its response to incremental openings of the culverts (fig. 4); they further allow a test of model-predicted tide heights. However, most of the biotic community is dependent on the flooding duration and water quality beyond the major creeks, i.e., within the marsh proper. Therefore, marsh water levels' salinity, and sulfide concentrations are monitored within the root zone along permanent transects. We anticipate that increased salinity will suppress *Phragmites* and allow *Spartina* spp. to reoccupy the wetland surface. Initial concerns that the wetland may not drain adequately during low tides—causing sulfide toxicity that can reduce productivity of salt marsh plants, waterlogging, and low redox potentials—have not borne out as low tides have become lower (fig. 5) at the same time as high-tide heights have increased with increased culvert opening (fig. 4). Meanwhile, root-zone salinity has increased about 790 feet (240 m) from creek banks, while sulfide—an indicator of waterlogging and decreased redox potential—has remained extremely low and comparable to the unrestricted control marsh seaward of the dike. Low root-zone sulfide is promoted at Hatches Harbor by the high permeability of the sandy peat, allowing efficient drainage and aeration during low tides.

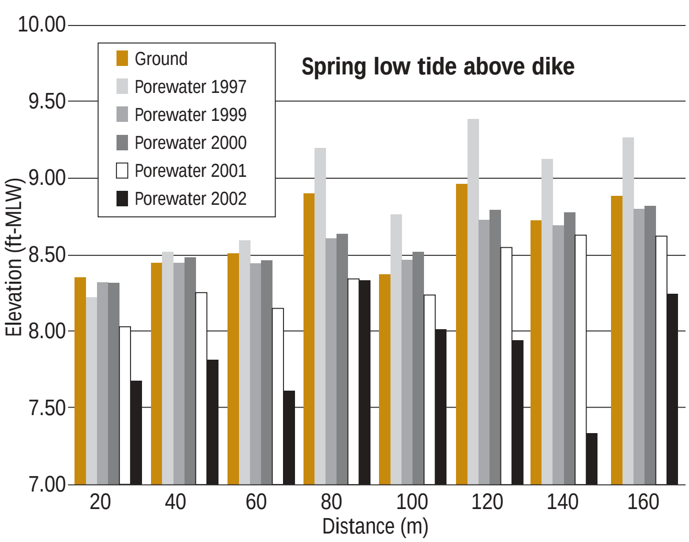


Figure 5. Low-tide porewater levels within the diked marsh at Hatches Harbor before and since incremental culvert openings beginning in 1999. Initial concerns that the wetland might not drain adequately during low tides have not borne out as low tides have become lower at the same time as high tides have increased with increased culvert opening.

Sediment elevation tables (SETs)

The ability of salt marshes to accrete along with sea level rise is a major issue for wetland managers facing the projected effects of global warming. The topic is especially relevant to the management and restoration of tide-restricted salt marshes that have subsided because of drainage, pore-space collapse, increased decomposition, and blockage of tidally transported sediment (Portnoy 1999). When seawater flooding is returned to marshes that have been diked for many years, will sedimentation compensate for past subsidence or will these marshes become waterlogged and unsuitable for recolonization by salt marsh plants, resulting in mudflat and open water habitats rather than emergent salt marsh?

"The ability of salt marshes to accrete along with sea level rise is a major issue for wetland managers facing the projected effects of global warming."

We have established sediment elevation tables (SETs) (Boumans and Day 1993, Cahoon et al. 1999) at Hatches Harbor (and at two other wetlands in Cape Cod National Seashore) to monitor both accretion and subsidence and to see if the current six-inch (15 cm) elevation deficit measured above the dike can be balanced now that tidal flow has been restored. SETs provide a stable base from which to monitor marsh surface elevation repeatedly over time at precisely the same locations in the marsh. In conjunction with SETs measurements, we have also established feldspar marker horizons to determine the amount of sediment deposited on the marsh surface. With the SETs and marker horizons we can precisely determine elevation changes within the marsh and understand what processes are contributing to the elevation change. We gathered information on local rates of sea level rise from NOAA tide gauges to determine whether marsh elevation is keeping pace with rising sea level. Because marsh elevation change is minuscule (just a few millimeters) each year, it is difficult to determine trends based on only a few years of monitoring, but at this point it appears that the elevation of the restoring marsh is increasing at a rate that is greater than the unrestricted marsh.

"We gathered information on local rates of sea level rise ... to determine whether marsh elevation is keeping pace with rising sea level."

Salt marsh vegetation

We used the BACI design to make several comparisons aimed at determining, with statistical certainty, the response of vegetation to tidal restoration. We established permanent one-square-meter vegetation plots in a stratified-random manner throughout the unrestricted marsh and tide-restricted marsh to estimate plant species composition and abundance (cover) between groups of community data (e.g., tide-restricted vs. tide-restored) (Roman et al. 2001). Our initial sampling took place in summer 1997. We performed follow-up monitoring in summer 2000 and summer 2002 as tidal restoration proceeded.

Plant diversity is naturally low within the unrestricted salt marsh; *Spartina alterniflora* dominates, but *Spartina patens*, *Salicornia biglovei* and *europea*, *Limonium nashii*, and *Sueada linearis* are also present. In addition, two species of brown macroalgae (*Ascophyllum nodosum* and *Fucus vesiculosus*) contribute substantially to cover within the unrestricted marsh. By comparison, we found more than 80 species of vascular plants within the tide-restricted—tide-restored marsh, strongly pointing to conversion of this once *Spartina*-dominated marsh to a freshwater—brackish water wetland. Following the BACI study design, we made numerous comparisons.

Changes in vegetation are best demonstrated by comparing the 1997 tide-restricted marsh to the same marsh under tide-restored conditions in 2000 and 2002. In 2000, after just two growing seasons of tidal restoration, there were no changes in the vegetation community, probably because of the small initial openings of the new culverts. By 2002, however, vegetation between the tide-restricted marsh and the same marsh was significantly different. We attribute this difference primarily to a decrease in brackish marsh species, such as purple loosestrife (*Lythrum salicaria*) and soft rush (*Juncus effusus*), as well as some woody vegetation (e.g., blackberry, *Rubus* and bayberry, *Myrica pensylvanica*). Increased soil salinity and flooding duration have caused these species to begin to die back. Invasive, exotic common reed (*Phragmites australis*) (Saltonstall 2002) dominates large portions of the diked Hatches Harbor floodplain. Increased salinity and flooding duration, accompanying tidal restoration, should suppress common reed and favor the reestablishment of the salt marsh grasses that originally dominated the wetland (fig. 6).

From 1998 to 2002, *P. australis* cover decreased in plots close to—within 525 feet (160 m) of—the main tidal creek, but increased or changed very little in plots distant from the creek (fig. 6). Thus, zones of high *P. australis* cover shifted up-gradient, away from the influence of high-salinity tide water, i.e., greater than 20 parts per thousand (ppt). In addition, *Phragmites* biomass and stem height were significantly lower in 2002 than in 1998 (fig. 7), with large reductions between 0 and 330 feet (0–100 m) of creeks where root-zone salinity ranged from 25 to 30 ppt.

Phragmites biomass was positively correlated with the depth of low-tide drainage, and negatively correlated with salinity (fig. 7). Because of the sandy composition and good drainage of Hatches Harbor peat, waterlogging and consequent sulfide toxicity did not occur.

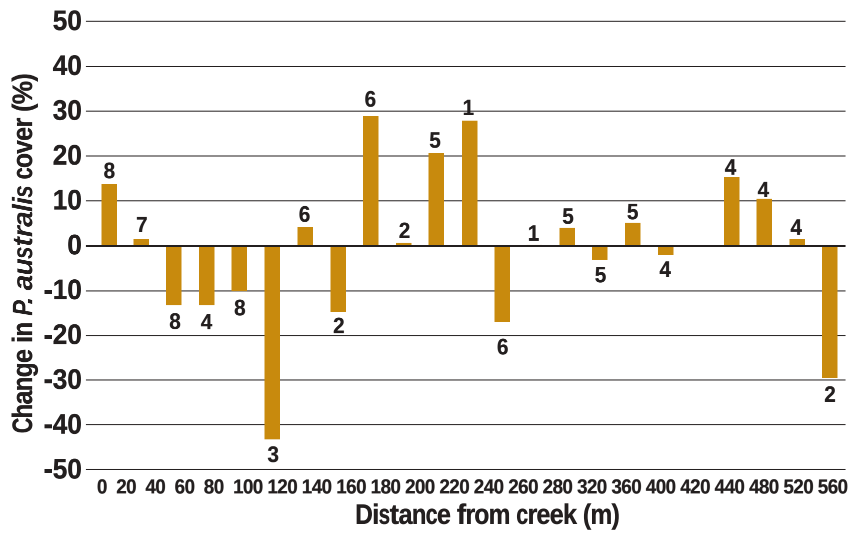


Figure 6. Average percent change from 1998 to 2002 in cover of *P. australis* with distance away from the tidal creek. From 1998 to 2002, *P. australis* cover decreased in plots close to—within 525 feet (160 m) of—the main tidal creek, but increased or changed very little in plots distant from the creek. Thus, zones of high *P. australis* cover shifted up-gradient, away from the influence of high-salinity (> 20 ppt) tidewater. Numbers above and below histograms represent the number of plots in each distance category.

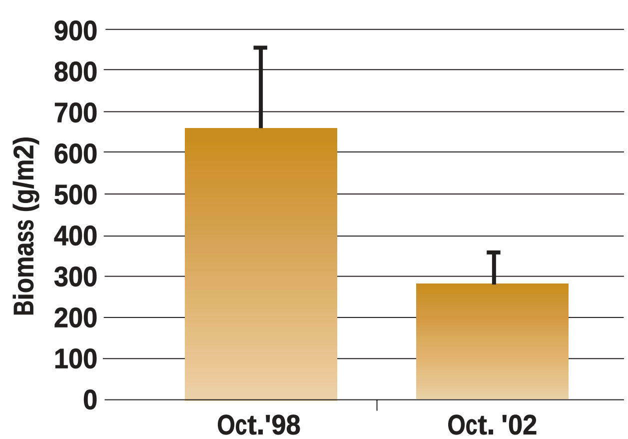


Figure 7. Mean biomass of *P. australis* in 1998 and 2002 (all plots, all transects). *Phragmites* biomass and stem height were significantly lower in 2002 than in 1998, with large reductions between 0 and 330 feet (0–100 m) from creeks where root-zone salinity ranged from 25 to 30 parts per thousand (ppt).

Despite the near absence of sulfides, *Phragmites* in the restoring marsh still has to contend with high salinity (Hartzendorf and Rolletschek 2001), which may explain diminishing aboveground biomass.

Nekton

From 1997 to 1998 and again in 1999, just before and during the initial phases of tidal restoration, we monitored nekton in creek, pool, and marsh-surface habitats on both tide-restricted and natural sides of the Hatches Harbor dike (Raposa and Roman 2001) (fig. 8). We combined and averaged nekton density data with creek and pool data from the period June through September. We collected nine fish species and three decapod crustaceans, with the common mummichog (*Fundulus heteroclitus*) as the dominant species. Before tidal restoration, total nekton density in creeks and pools of the unrestricted control marsh and the tide-restricted marsh was the same. Also, total nekton density did not change, or increase as might be expected, within the tide-restricted marsh after tidal restoration (table 2).

We are also monitoring nekton use of the marsh surface with an enclosure trap method (Raposa and Roman 2001). Nekton, especially the common mummichog, is known to forage and spawn within *Spartina alterniflora* marsh during high tide flooding events. Nekton inhabited only seven acres (3 ha) of *S. alterniflora* marsh in the restricted portion compared to more than 60 acres (25 ha) in the unrestricted marsh; thus, there was much less available habitat in the tide-restricted marsh. With major increases in the openings of culverts and tidal range since April 2001, marsh surface habitat (i.e., flooded during high tide) has greatly increased. We therefore expect to see a commensurate increase in nekton use when this group is resampled in summer 2003.

Mosquitoes

The abundance and species composition of nuisance mosquitoes depend in large part on wetland flooding regimes and salinity. With increased

Figure 8. Investigators monitored nekton (fishes and decapod crustaceans) in salt marsh creeks, pools, and on the marsh surface. The investigator is sweeping the trap with a bar seine. Investigators can attach a skirt of nylon mesh to the top of the trap for sampling deeper habitats.

Table 2.

Nekton Density (per square meter) in the Unrestricted and Restricted Hatches Harbor Salt Marsh in 1997, Before Tidal Restoration, and 1999 with Partially Restored Tides

Species	Restricted 1997 n=90	Restoring 1999 n=90	Unrestricted 1997 n=120	Unrestricted 1999 n=120
Fundulus heteroclitus (mummichog)	22.84	28.38	18.99	14.77
Carcinus maenas (green crab)	0.46	1.47 ***	1.38	1.69
Crangon septemspinosa (sand shrimp)	0.18	0.14	2.16	0.69
Fundulus majalis (striped killifish)	0.10	0.36	0.28	0.58
Menidia menidia (Atlantic silverside)	0.12	0.20	0.65	0.18
Anguilla rostrata (American eel)	0.36	0.12	0.00	0.00
Apeltes quadracus (4-spine stickleback)	0.20	0.09	0.00	0.00
Gasterosteus aculeatus (3-spine stickleback)	0.10	0.10	0.00	0.00
Mugil curema (white mullet)	0.02	0.00	0.04	0.00
Syngnathus fuscus (pipefish)	0.03	0.01	0.00	0.00
Neopanopeus sayii (mud crab)	0.00	0.00	0.00	0.01
Pseudopleuronectes americanus (winter flounder)	0.00	0.00	0.01	0.00
Total Nekton	24.41	30.86	23.50	17.93

Note: Researchers performed two-way analysis of variance to evaluate differences in species density between restricted (1997) and restoring (1999) salt marsh, and then between the unrestricted portion in 1997 and 1999. Nekton density data were log (x+1) transformed. Only one significant difference was noted (***, *Carcinus maenas,* $p<0.01$).

tidal heights and salinity within the floodplain above the Hatches Harbor dike, mosquito breeding habitat in floodwaters may increase or species composition may change, thereby increasing the mosquito nuisance at Provincetown Airport. We trapped adult mosquitoes during two summers (1997 and 1998) before tidal restoration and have continued for four more years (1999–2002) as tidal flow has incrementally increased through the new, enlarged dike culverts. The objective of the monitoring is to represent seasonal abundance and species composition of nuisance mosquitoes over the entire floodplain using repeatable methods as tidal restoration proceeds. Species composition should indicate primary breeding habitats, especially for habitat variables that are most sensitive to changes in tidal flow through the Hatches Harbor dike. We hypothesize that tidal restoration will increase the extent and depth of flooding of the diked wetland surface during high tides; however, improved drainage of freshwater runoff and tidal water through the enlarged culverts during the ebb will limit floodwater mosquito breeding habitat. We further hypothesize that improved access for fish (especially *Fundulus* spp.) to the wetland surface will reduce successful mosquito reproduction. Increased salinity may alter the species composition of nuisance mosquitoes landward of the dike, perhaps favoring salt marsh species (*Ochlerotatus sollicitans* and *Ochlerotatus cantator*).

From 1997 through 2000, mosquito production for all species related directly to summer precipitation. However, we observed large increases in the production of brackish and saline species (*O. cantator* and *O. sollicitans*) in 2001 and 2002 respectively, indicating that habitat for these species is increasing (fig. 9). Continuation of this trend will depend on the persistence of some pools on the wetland surface that are presently poorly flushed or inaccessible to predatory fish. Meanwhile, planning is under way to improve low-tide drainage of the marsh surface by restoring tidal creeks that have filled with vegetation and sediment as a result of diking and its reduction of tidal currents. Over much of the marsh, low-tide drainage may improve without intervention, as radically increased tidal currents are apparently creating a new drainage network across the marsh surface.

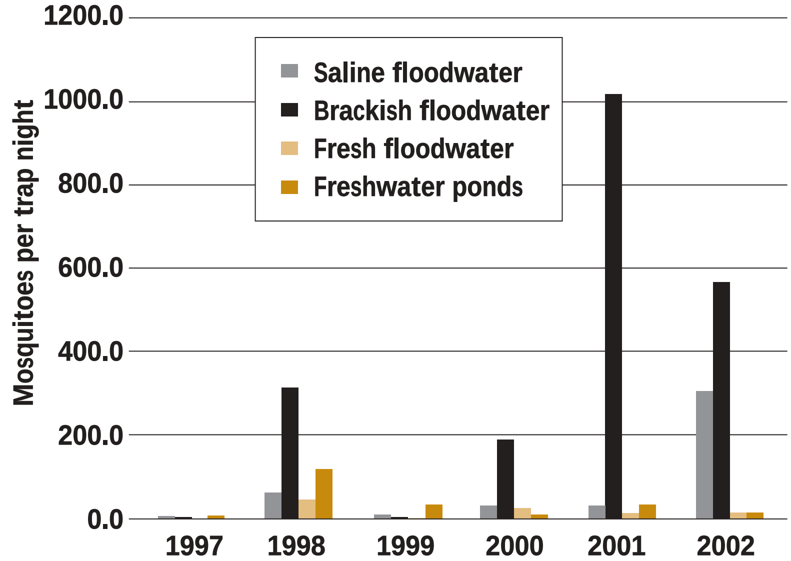


Figure 9. Average numbers of adult mosquitoes captured in combination light-CO_2 traps set biweekly from July–August since 1997 in the Hatches Harbor floodplain.

Conclusions

Salt marsh estuaries are naturally complex systems further complicated by historical alterations to tidal range and salinity; therefore, predicting the ecological effects of restored tidal flow is difficult. Given this uncertainty, the success of salt marsh restoration efforts and informed adaptive management at Cape Cod National Seashore will depend upon our ability to sustain the multidisciplinary monitoring effort. Initial responses of the Hatches Harbor salt marsh to renewed tidal flow show that restoration may continue for several decades. It is therefore important to document changes in physical, chemical, and ecological processes over the long term so that we can better understand the restoration process and improve our predictive capabilities. In parks like Cape Cod with intense public use, adjacent development, and overlapping jurisdictions by agencies with differing management goals, scientifically credible monitoring protocols and results provide a critical basis for improved wetland management.

"The success of salt marsh restoration efforts ... will depend upon our ability to sustain the multidisciplinary monitoring effort."

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"The legacy of the Grand View Mine" continued from page 50

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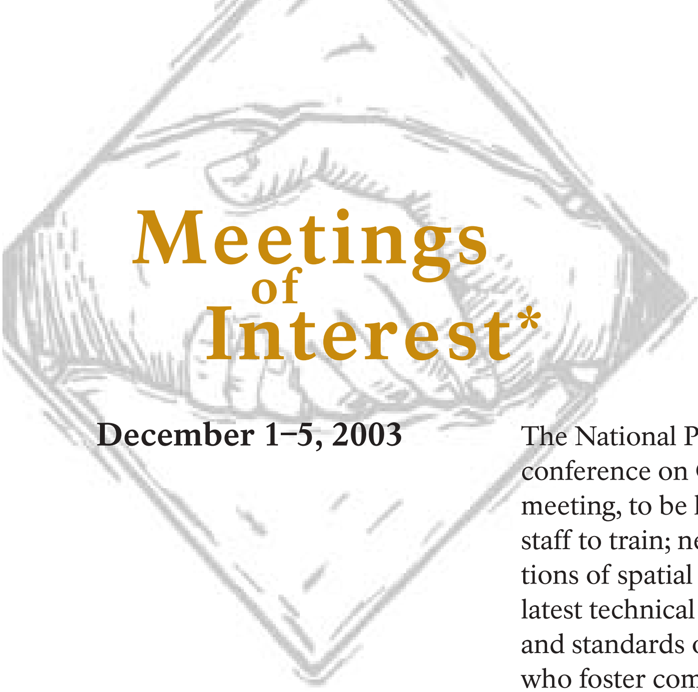

Meetings of Interest*

December 1–5, 2003

The National Park Service presents Spatial Odyssey 2003 "Grounded in Technology," a conference on Geographic Information Systems (GIS) and related technology. The meeting, to be held in Orlando, Florida, provides opportunities for NPS partners and staff to train; network and exchange technical information; learn about special applications of spatial programming (e.g., fire management and law enforcement); preview the latest technical tools, data, imagery, and equipment; and review initiatives, contracts, and standards of E-Gov (an organization of marketing and education professionals who foster communication and business between buyers and sellers of technology and services and government agencies), and other GIS resources available to NPS staff. Conference organizers have planned field trips to the Kennedy Space Center and The Nature Conservancy's Disney Wilderness Preserve. More information is available at <http://www.nps.gov/gis/odyssey/>.

March 17–21, 2004

Spokane, Washington, is the site for the 69th North American Wildlife and Natural Resources Conference. The theme is "Resource Stewardship in the 21st Century: A Voyage of Rediscovery." The Wildlife Management Institute—a private, nonprofit, scientific and educational organization committed to the conservation, enhancement, and professional management of North America's wildlife and other natural resources—is hosting the conference. Sessions focus on resolving conflicts in wildlife management, such as off-road vehicle operation, water recreation and use, energy production, human–large-predator conflicts, and fire management. A special session on the Starkey Project (long-term research on mule deer, elk, and cattle) is also scheduled. More information is available at <http://www.wildlifemanagementinstitute.org/pages/toc2003.html>.

March 22–25, 2004

New Mexico Rare Plant Technical Council is hosting a conference of contributed works on the study and conservation of rare and endangered plants in the Southwest at New Mexico State University, Las Cruces. Papers and poster sessions presented at the "Fourth Southwestern Rare and Endangered Plant Conference" cover research performed in the geographic area that includes the Sonoran and Mojave Deserts to the west, the Colorado Plateau and Southern Rocky Mountains to the north, the Chihuahuan Desert and High Plains Grasslands to the east, the Chihuahuan and Sonoran Deserts to the south, and mountain ranges within this region. Rare, threatened, or endangered plants are the central focus of the research presented; however, presentations also may highlight related topics of population biology, genetics, ecology, reproductive biology, and systematics. Conference planners anticipate posters and papers to focus on the United States of America but also expect presentations on rare Mexican plants. More information is available at <http://nmrareplants.unm.edu/conference/announce.htm>.

* Readers with access to the NPS Natural Resources Intranet can view a comprehensive listing of upcoming meetings, conferences, and training courses at <http://www1.nrintra.nps.gov/NRMeet/>.

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