PARK SCIENCE

INTEGRATING RESEARCH AND RESOURCE MANAGEMENT
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WATER QUALITY MONITORING IMPROVEMENTS
AT INDIANA DUNES

UNDERSTANDING AVALANCHES
IN GLACIER NATIONAL PARK

DETERMINING THE VOLUME OF THE
1889 JOHNSTOWN FLOOD

CLIMATE VARIABILITY AND ECOSYSTEM RESPONSE
IN WESTERN NATIONAL PARKS

REMOTE SENSING
FOR THE NATIONAL PARKS

EFFECTS OF WHITE-TAILED DEER ON VEGETATION
AT MANASSAS NATIONAL BATTLEFIELD PARK

VOLUME 24 • NUMBER 1 • SUMMER 2006

UNITED STATES DEPARTMENT OF THE INTERIOR NATIONAL PARK SERVICE

From the Editor

Collaboration for the long term

Though not designed to explore a particular topic in depth, this edition of *Park Science* reveals several common themes in how we in national park research and resource management approach our work. Collaboration, for example, is a thread that runs throughout the issue. The articles reflect the variety, complexity, and sheer number of research questions that have a bearing on park management, and they remind us of the broad scientific community with which the National Park Service enjoys fruitful partnerships. They also illustrate a variety of ways in which particular park information needs are matched with the right expertise, including through Cooperative Ecosystem Studies Units and monitoring networks. Herein we see a small sample of results from current collaborative efforts in national park stewardship. The work is helping managers to improve park safety, recognize and anticipate changes in park resources, interpret historical events that affected park resources and the people inhabiting the area at the time, understand ecological interactions, and maintain park ecosystems.

Another theme is how different time scales—from hours to centuries and longer—have significance for park resource management. For example, satellite imagery can help managers understand park changes within hours or days of their occurrence, such as following hurricanes, wildfires, and other fast-acting disturbances. In these circumstances speedy feedback is essential to identifying and protecting high-priority resources at risk. For other management questions, analysis of a time series of images at intervals of years to decades is appropriate and reveals gradual processes, including changes in native and nonnative vegetation and the types and extent of land use adjacent to a park. A particularly dramatic example of resource change illustrated in this issue is the reduction in glacier mass at Glacier National Park, as documented in photographs over the last century. Modeling suggests that the current rate of climate warming could mean the loss of all glaciers in this park by 2030.

These observations at Glacier have been reported as part of a scientific collaboration called the Western Mountain Initiative, a long-term monitoring program in western national parks that has been ongoing since 1991. Other examples of collaborative, long-term monitoring in this issue come from several park areas, including Channel Islands and Shenandoah national parks. For 25 years researchers have been systematically collecting data about kelp forests at Channel Islands and watersheds at Shenandoah. The value of these data becomes clear when they are synthesized to reveal how park resources are changing and why. This information pertains not only to park management but also potentially to regional and national environmental issues. This knowledge of ecological systems is both exciting and a very important outcome of this fundamental park research activity.

Finally, one of the values I see in this publication is sharing the experience of investigators and resource managers so that researchers and managers in other settings might benefit from their findings. The authors of the report on water quality monitoring at Indiana Dunes tell their story with this very point in mind. Other themes and connections await your discovery.

Jeff Selleck

Jeff Selleck

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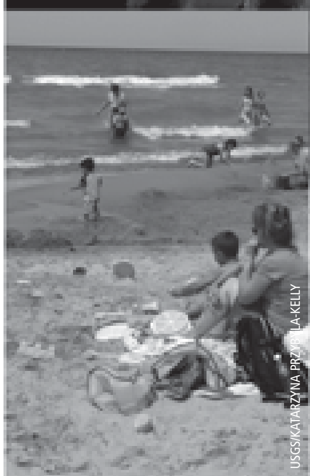
DEPARTMENTS

NPS/DAN RICHARDS



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ON THE COVER

Swimmers enjoy summer sun, sand, and surf at Indiana Dunes National Lakeshore. Thanks to pioneering research by the U.S. Geological Survey and recent modernization in water quality monitoring, park users and managers now enjoy quicker and more reliable reports on water quality at popular swimming beaches where fecal contamination can be a problem. For more of the story, see page 19.

USGS/RICHARD WHITMAN

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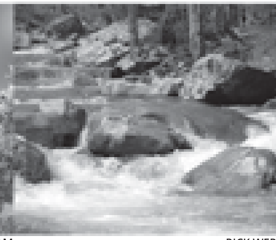

RICK WEBB

NPS/MICHAEL BYNUM

COVER ARTICLE

FEATURES

news & views

Corrections

Hatches Harbor restoration

John Portnoy, ecologist with the National Park Service, points out an error in figure 4 of his article "Estuarine habitat restoration at Cape Cod National Seashore: The Hatches Harbor prototype," published in *Park Science* 22(1):53. The bar graph shows increasing mean tidal range in the salt-marsh restoration site since the installation and gradual opening of culverts in 1999. The mean tidal range for the unrestricted or natural marsh was 1.02 m, not 0.66 m as indicated in the graph.

Parking lot sealants

We received e-mail about our Information Crossfile article, "Are ugly parking lots healthier?," published in volume 23(2):19. Our intent was to call attention to parking lot sealants as a previously unrecognized significant source of concentrated carcinogenic aquatic contaminants called PAHs (polycyclic aromatic hydrocarbons). However, we were too broad in our presentation, implying that any application of sealants would be environmentally detrimental. As Dave Kruse, coordinator of the Pacific West Region Federal Lands Highway Program, points out, "The article fails to [explain] that there are more types of sealants than the coal tar–based sealants that do indeed contain PAHs." Asphalt emulsion sealants, he relates, do not contain coal tar or PAHs and "the vast majority of asphalt sealants are emulsions and not coal tar based." According to Kruse, the National Park Service commonly uses rapid-set asphalt emulsion sealers, including fog seal, slurry seal, and chip seal to maintain pavement.

Our title was also a poor choice as it suggests that allowing park infrastructure to deteriorate benefits the ecological health of parks. Infrastructure, including roads and parking lots, in the national parks must be maintained properly or, as Kruse reminds us, "we will see pavement cracking and breaking up prematurely, which will lead to increased costs and consumption of new oil-based asphalt," another source of PAHs.

We also heard from Roy Irwin, contaminants specialist with the NPS Water Resources Division, who found the article incomplete. He encourages readers to refer to the NPS *Environmental Contaminants Encyclopedia* at http://www.nature.nps.gov/hazardssafety/toxic for questions about road and trail treatments of all types, not just asphalt and its sealants. The encyclopedia is more comprehensive than the EPA source we cited and profiles 118 contaminants, listing benchmarks for toxic concentrations of metals, industrial organic chemicals, and hydrocarbons in water, sediment, soil, and tissues. Asphalt is reviewed at http://www.nature.nps.gov/hazardssafety/toxic/asphalt.pdf and PAHs at http://www.nature.nps.gov/hazardssafety/toxic/pahs.pdf.

Irwin has concerns that asphalt emulsion sealers could plausibly contain PAHs, though he has not seen test results to this effect. "We know that asphalt contains PAHs," he says, "so … I would not … assume any product based on asphalt would not contain PAHs." Irwin explains that compounds listed as inert for a particular product purpose are not necessarily nonhazardous under certain conditions. Complicating the matter is the difficulty of obtaining product scans for a full suite of suspect compounds. Irwin feels that test results of asphalt emulsion sealers that showed method detection limits (MDL) of less than 10 ppb of PAHs and alkyl PAHs "would be reassuring." Still, he acknowledges that the PAHs in asphalt "are relatively immobile until the asphalt breaks down," and says that oil from cars is probably a bigger source of these contaminants.

We regret the misinformation and hope the extended comments help clarify the issue.

—Editor

HIGHLIGHTS

A cultural icon surrounded by a natural treasure: Old-growth forest at Mount Rushmore

The Black Hills of western South Dakota and southeastern Wyoming are an island in the prairie, a metaphor fitting not only for their geological and topographical differences from the surrounding plains, but also for their differences in flora and fauna. Most notably, the Black Hills, or Paha Sapa ("hills that are black") as the Lakota called them, are named for the dark appearance they have when viewed from a distance—a darkness caused by the ponderosa pine (*Pinus ponderosa*) forest that blankets the hills (fig. 1). Although ponderosa pine, as a species and as a forest type, occurs across a large part of western North America, the combination of species and natural processes in ponderosa pine forests of the Black Hills makes it a unique ecosystem.

Mount Rushmore National Memorial is a small portion—1,278 acres (517 ha)—of the 3.8 million acres (1.5 million ha) that comprise the Black Hills. However, because it has been protected from logging since the late 1930s, a popular "legend" perpetuated by park staff is that the memorial houses one of the largest areas of old-growth forest remaining in the Black Hills. By contrast, the majority of the Black Hills forest has been heavily logged. To determine the validity of this legend and to understand the role of the memorial's forest in the Black Hills ecosystem as a whole, we determined the extent and location of unlogged and old-growth forest stands in the memorial using historical documents and field investigations.

Our results suggest that approximately 29% of the memorial has had no tree harvesting activity, and 18% has had only selective cutting of larger trees. When defined according to the only published description of old-growth Black Hills ponderosa pine forest, 901 acres

Figure 1. Old-growth ponderosa pine forest is a natural treasure at Mount Rushmore. NPS

(365 ha) of old-growth ponderosa pine forest occur in the memorial; this is 71% of the memorial's area (fig. 2). Based on current estimates of similar forest in the rest of the Black Hills, Mount Rushmore National Memorial contains the second-largest area of old-growth Black Hills ponderosa pine forest. This work not only substantiates a park legend, but also highlights the significant contribution of the memorial's forest to the Black Hills ecosystem: it provides important habitat for cavity-nesting birds (fig. 3) and other species that depend upon mature forest—a rare occurrence elsewhere in the Black Hills.

Even in areas that have not had logging, the memorial's forest is not pristine, however. More than a century of fire suppression has increased the density of live and dead trees beyond that of presettlement times. These increased densities put the forest in danger of fires that are likely to be more intense than those that drove ecosystem evolution. Ongoing research will provide a clearer picture of management and restoration targets to reduce this danger.

The results of this study add a new dimension to a "Shrine of Democracy"—a cultural treasure that commemorates the growth of the United States. To put things into perspective, the oldest trees within the memorial sprouted just 27 years after Christopher Columbus reached the American continent. These trees have seen immense change in the peoples and uses of the forest. The forest itself is a memorial to a unique ecosystem and these changes.

The oldest trees within the memorial sprouted just 27 years after Christopher Columbus reached the American continent.

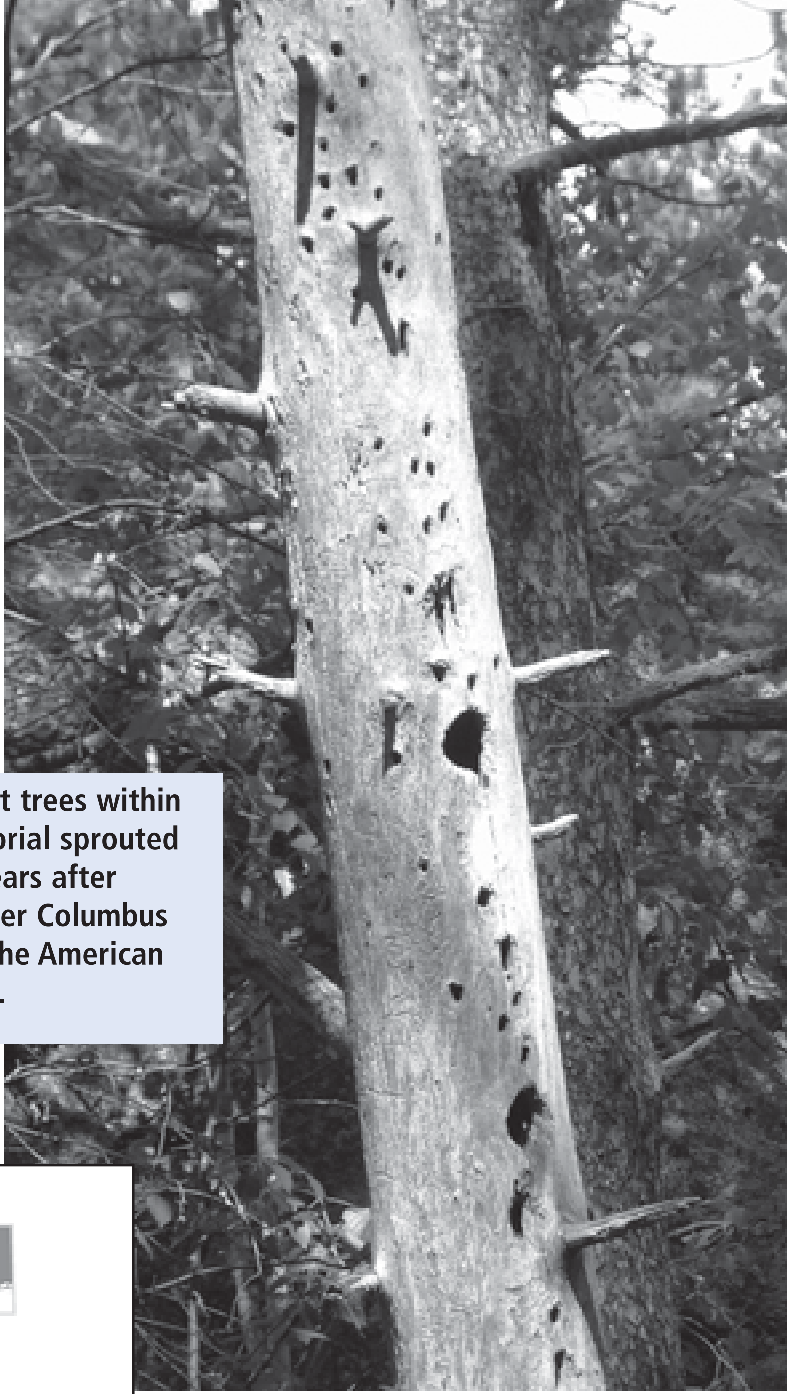

Figure 3. Large holes in this snag provide habitat for cavity-nesting birds like the red-breasted nuthatch. The small holes are evidence of birds searching for insects in the wood. NPS/MICHAEL BYNUM

Figure 2. Shaded areas in the map of Mount Rushmore National Memorial are stands of trees that meet the description of old-growth forest. Black circles identify points with no old stumps, that is, areas presumably without logging. NPS/JOEL BRUMM

—***Amy Symstad***, *Research Ecologist, U.S. Geological Survey, Northern Prairie Wildlife Research Center, 605-341-2807, asymstad@usgs.gov;* ***Michael Bynum***, *Biological Technician, NPS Northern Great Plains Inventory and Monitoring Network, michael_bynum@nps.gov.*

Application of GIS to estimate the volume of the Great Johnstown Flood

Johnstown Flood National Memorial was created in 1964 to commemorate the Great Johnstown Flood of 1889 and preserve the remnants of the South Fork Dam. The earthen dam formed a reservoir known as Conemaugh Lake on the South Fork of the Little Conemaugh River. Originally a reservoir for the Pennsylvania Mainline Canal, in the 1800s the South Fork Fishing and Hunting Club used the lake as a resort for wealthy industrialists. Following heavy rains, the dam broke on 31 May 1889, killing 2,209 people in the flood.

Historical documents presented conflicting information regarding the estimated size of the lake and the amount of water released in the flood. An 1891 engineering report in *Transactions*, the journal of the American Society of Civil Engineers, estimated the reconstructed volume of Conemaugh Lake to be 450,000,000 cubic feet (12,744,265 cu m). However, an 1889 article in *Engineering News and American Railway Journal* estimated the lake to contain 640,000,000 cubic feet (18,125,177 cu m) of water when the dam burst. Unsure which estimate was more accurate, the park staff requested technical assistance from the Northeast Regional Office and the Water Resources Division to calculate the estimated volume of the historical Conemaugh Lake. Kathy Penrod, natural resource specialist at the park; Alan Ellsworth, Northeast Region hydrologist; and James Farrell, Northeast Region GIS specialist, conducted a study to assess the historical estimates of the volume of water held by the dam when it burst.

The team used GIS technology and previously collected data … to determine the high-water line of the lake.

The team used GIS technology and previously collected data from the State of Pennsylvania and the National Park Service to determine the high-water line of the lake. A high-resolution, geo-rectified aerial photograph (all points on the photo correspond to real-world coordinates) served as a background base image of the South Fork Dam region (fig. 1). A digital elevation model (indicating vertical dimensions over the area) yielded 1-foot (0.3-m) contours. This information and the known elevation of the top of the dam gave us a boundary of Conemaugh Lake before the dam breach. Placing this high-water line over the aerial photo revealed an immediate and accurate depiction of the basin. The high-water level lined up with houses and other structures known to have been situated just above the flood area. The high-water level and elevation values within the space that had been the lake enabled the team, using ArcGIS 3D Analyst software, to determine the volume of water in the lake when the dam was breached.

The GIS study produced a lake volume of 449,093,200 cubic feet (12,716,900 cu m), which supports the estimate from the American Society of Civil Engineers' report as the more accurate of the two historical estimates. This volume is approximately equal to 780 American football fields under 10 feet (3 m) of water. The park can now use the confirmed volume in its interpretive exhibits with confidence. The GIS study may also lead to a new exhibit at the park; the park now has a GIS model of the former lake and images of the estimated lake boundary overlaid on modern aerial photography and topographic maps showing present-day towns and villages.

Figure 1. This high-resolution aerial photograph of the Johnstown, Pennsylvania, area is overlaid with the high-water line of former Conemaugh Lake at the time of the catastrophic flood in 1889. Using GIS technology coupled with topographic data, the National Park Service was able to determine the lake's perimeter, calculate the volume of the tremendous flood, and compare the results to historical volume estimates. NPS NORTHEAST REGION

—***Kathy Penrod***, *Natural Resource Specialist, Johnstown Flood National Memorial, kathy_penrod@nps.gov;* ***Alan Ellsworth***, *Northeast Region Hydrologist, alan_ellsworth@nps.gov; and* ***James Farrell***, *Northeast Region GIS Specialist, james_farrell@nps.gov.*

Northward range expansions in the Upper Columbia Basin Network:

The northern mockingbird and the ringtail

For the second time in four years, a nesting pair of northern mockingbirds (*Mimus polyglottos*, fig. 1) was found in the Clarno Unit of the John Day Fossil Beds National Monument in 2005. The brilliant nocturnal singing and wing-flashing of the territorial male was conspicuous and foreign sounding in the dry canyon northwest of the monument headquarters in Kimberly, Oregon. The 2002 nesting event, documented during the monument's biological inventory, was the northernmost Oregon record for that species. But the mockingbird has continued its northward march and several breeding pairs have been found as far north as eastern Washington in recent years. An examination of breeding bird survey and atlas results for the region provides clear evidence that the species is expanding its range northward into the Pacific Northwest.

Another less certain but potential range expansion example in the region is the case of the ringtail (*Bassariscus astutus*), a secretive and nocturnal raccoon-like mammal. In March 2003, a dead ringtail was found in the Castle Rocks Interagency Recreation Area near City of Rocks National Reserve in southern Idaho. This remains the first and only record for the species in the state. However, tracks tentatively identified to the species were found in snow in February 2005 and a well-described ringtail sighting was also reported by a park visitor in May 2006. Through the support of an Idaho State Wildlife Grant, City of Rocks resource managers are using remote cameras to try to document other ringtails. Confirmation of a resident population in the reserve would add a significant northern extension to the species' known range. Though this could be the result of inadequate survey effort—a scenario in which the species has simply been overlooked—it could also indicate a real change in its distribution.

Conservation programs typically focus on declining species undergoing range contraction, but detecting and tracking range expansion of plants and animals are also important. Though this is most obvious for noxious "weedy" species, an equally significant but often more subtle phenomenon can occur among "native" species. Range expansion can signal changes in habitat resulting from human-caused factors. A well-documented example of this is the movement of the brown-headed cowbird (*Molothrus ater*) out of the Great Plains with forest clearing and the spread of domestic livestock during the 19th and early 20th centuries as people settled former forestland. Northward range expansions may also signal a response to climate change. Warming temperatures have been implicated in several recent studies of latitudinal movements by butterflies and other invertebrates, and preliminary results from the Joseph Grinnell resurvey project in Yosemite National Park (California) suggests that mammals may also be responding to regional warming trends by moving up in elevation. Fossil records also provide clear evidence of climate-induced range expansion. The mockingbird is part of a group of several northward advancing bird species in the West including the white-tailed kite (*Elanus leucurus*) and the bronzed cowbird (*Molothrus aenus*). Though the connection between warming temperatures and species range expansion has been difficult to prove scientifically, it is certainly a plausible hypothesis and one worth monitoring over time.

National parks and other units of the National Park System make excellent reference sites to document changes in species distribution, and through the efforts of the NPS Inventory and Monitoring Program, the National Park Service is now positioned to make a significant contribution toward documenting and understanding contemporary range expansions.

Range expansion can signal changes in habitat resulting from human-caused factors.

Figure 1. Northern mockingbird in the Clarno Unit of John Day Fossil Beds National Monument, Oregon. Documentation of nesting by mockingbirds in 2002 and 2005 at the park confirms northern expansion of this species' range, which has since extended into eastern Washington.

—***Tom Rodhouse***, *Ecologist, NPS Upper Columbia Basin Network; phone 541-312-8101; email tom_rodhouse@nps.gov.* ***Jodi Vincent***, *Natural Resources Ranger, City of Rocks National Reserve; phone 208-824-5757; email jodi_vincent@partner.nps.gov.*

The Shenandoah Watershed Study:
A convergence of science and public policy

The benefits of scientific activity in the national parks often extend well beyond park boundaries. A good example of this is provided by the Shenandoah Watershed Study (SWAS), which initiated research and monitoring more than 25 years ago in Shenandoah National Park, Virginia. Over the years, SWAS data and findings have proven relevant to the development, evaluation, and implementation of national air pollution control policies. The SWAS program continues today as a key component of Shenandoah's water and air resource programs and as part of an ongoing multiregional evaluation of surface water response to air pollution reductions achieved through Clean Air Act requirements.

The benefits of scientific activity in the national parks often extend well beyond park boundaries.

The initial focus of SWAS was the harmful effects of acidic deposition associated with atmospheric pollution on the park's sensitive streams (figs. 1 and 2). Over time the SWAS program evolved to address additional issues that challenge Shenandoah's watershed ecosystems (fig. 3, page 10). Also, through coordination with the Virginia Trout Stream Sensitivity Study (VTSSS), the geographic focus of research and monitoring has expanded to include watershed systems on public lands throughout the mountains of western Virginia (fig. 4, page 10). The coordinated SWAS-VTSSS programs now involve routine water quality monitoring in 65 forested mountain watersheds and associated streams.

Scientific understanding

Early in the history of the SWAS program, data obtained for Shenandoah's White Oak Run watershed served as the basis for initial calibration of MAGIC, a watershed acidification model used for estimating water quality benefits of prospective controls on acidic emissions. MAGIC was one of the primary models used by the National Acid Precipitation Assessment Program (NAPAP), which led to passage of the 1990 amendments to the Clean Air Act. More recently, MAGIC has been used in critical loads analysis to identify acidic deposition reductions needed to

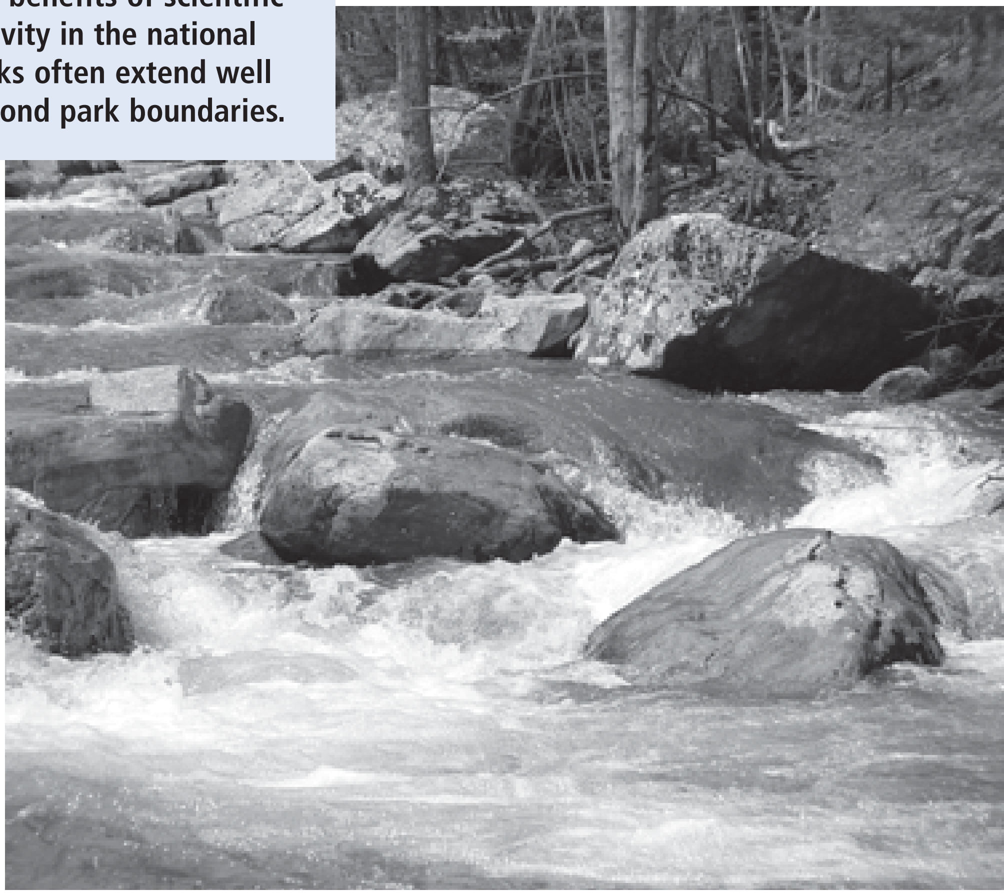

Figure 1. The SWAS program focuses on changes in the acid-base chemistry of stream water as an integrator of watershed response to acidic deposition. Changes in pH and other chemical properties of streams have been shown to affect the diversity and productivity of fish and other aquatic life. RICK WEBB

Figure 2. Most of the larger streams in Shenandoah National Park support populations of native brook trout (*Salvelinus fontinalis*). RICK WEBB

avoid stream acidification or obtain recovery from stream acidification in various national parks.

During the NAPAP studies, data obtained through the SWAS-VTSSS programs served to fill what otherwise would have been a significant regional information gap, and contributed to analysis that identified the mid-Appalachian area as one of the regions most affected by acidic deposition and the one region most likely to experience a continuing increase in surface water concentrations of sulfate, a principal component of acidic deposition. This prediction has been borne out in a recent analysis of trends in surface water composition reported to the Congress by the U.S. Environmental Protection Agency. Whereas sulfate concentrations in surface water declined during the 1990–2000 period for four northeastern regions with sensitive surface waters, the region for which the SWAS-VTSSS programs provide data experienced increasing stream-water sulfate concentrations and continuing acidification. Subsequent trend analysis based on SWAS-VTSSS data indicates that some streams in the region may be recovering from acidification. However, the degree of recovery is small in relation both to the magnitude of historical acidification and to recovery observed in other areas.

Data obtained through the SWAS-VTSSS programs served to fill what otherwise would have been a significant regional information gap.

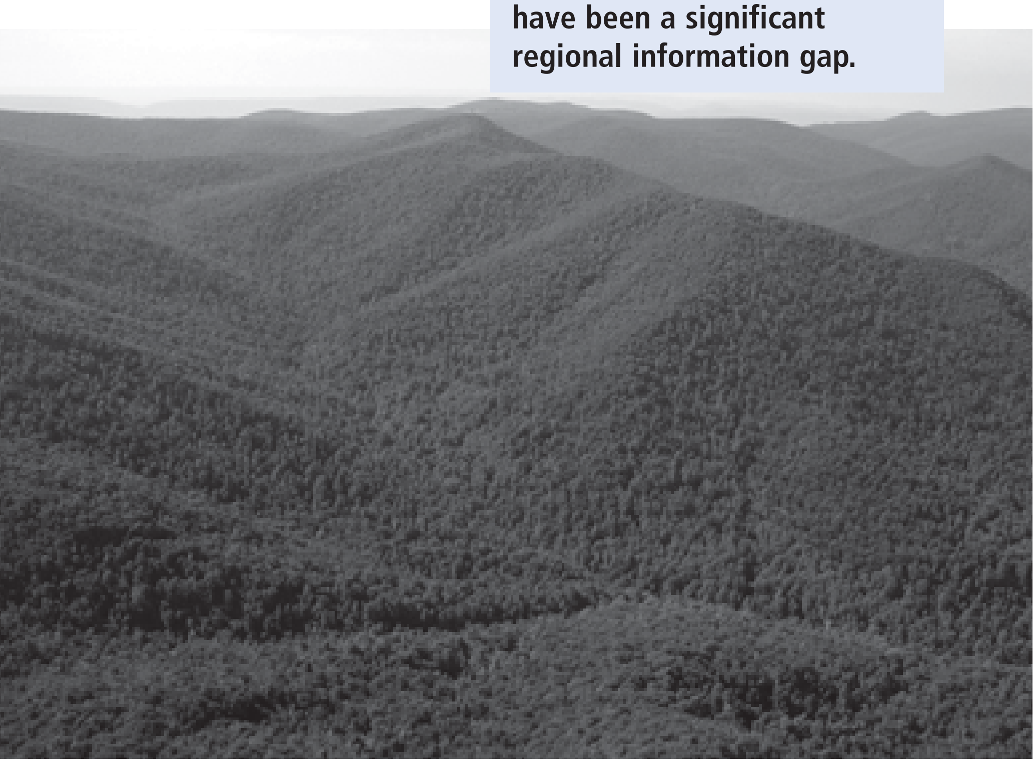

Figure 3. The Staunton River watershed is one of the intensively studied watersheds in Shenandoah. Data collection under SWAS includes continuous discharge gauging and weekly determination of stream-water chemical composition. Data collection is coordinated with monitoring of stream biota conducted by the park's Natural Resources Branch. RICK WEBB

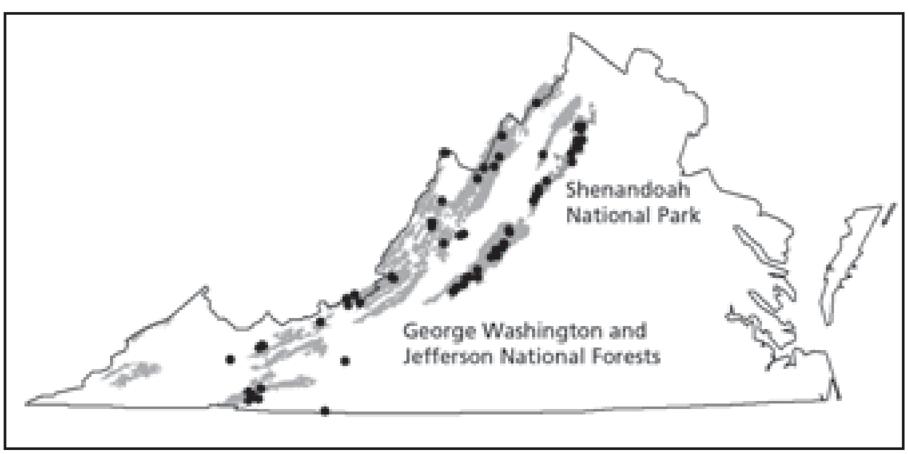

Figure 4. The map shows the distribution of study sites under SWAS in Shenandoah National Park and VTSSS in the surrounding national forest areas. The two programs are coordinated to develop information on ecosystem response to air pollution in western Virginia's forested mountain watersheds. RICK WEBB

Policy implementation

During the past few years the SWAS-VTSSS programs have had a role in policy implementation. The introduction of SWAS-VTSSS data and findings contributed to settlements in two major Clean Air Act cases brought by the U.S. Department of Justice and the U.S. Environmental Protection Agency against two midwestern power companies. The settlement agreements, reached in 2005, require the installation of pollution control equipment and other measures that will decrease emissions of sulfur dioxide and nitrous oxides by more than 260,000 tons (235,868 metric tons) per year. These are the largest such settlements to date.

The SWAS-VTSSS programs are maintained as a cooperative effort of the National Park Service, the U.S. Environmental Protection Agency, the USDA Forest Service, and the Department of Environmental Sciences at the University of Virginia, with assistance from Trout Unlimited, as well as other resource management agencies. More information is available at http://swas.evsc.virginia.edu.

—***Rick Webb***, *Projects Coordinator of the SWAS-VTSSS programs, Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia; rwebb@virginia.edu.*

Exotic plant control successes tempered by long-term challenges

At Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial in western Pennsylvania, successes in dealing with the exotic plants Japanese barberry (*Berberis thunbergii*) and giant and Japanese knotweed (*Polygonum sachalinense* and *P. cuspidatum*, respectively) are tempered by an ongoing, long-term challenge in removing garlic mustard (*Alliaria petiolata*). Results of projects to remove exotic bush honeysuckle (*Lonicera* spp.) have been mixed. Outcomes of these exotic plant removal projects tend to vary by plant and by site location.

At Allegheny Portage Railroad National Historic Site, volunteers removed barberry from a wooded area and a field in 2002 (fig. 1). In 2003, park staff treated the re-sprouting populations at the wooded area and thousands of seedlings at the field area with herbicide. Also in 2003, park staff and a Student Conservation Association (SCA) crew seeded the field area with native grasses by top-layering it with a mixture of top-soil and seed, and hand-tamping the plots. At the wooded area, no further treatment was required and in 2006 the area remains free of re-invading plants. At the field area, some follow-up treatment to remove new seedlings was again required in 2004. But by 2005 and continuing this year, monitoring of the site found no new plants, and the native grasses planted in 2003 had become well established.

Figure 1. Volunteers from Girl Scouts of the USA and Environmental Alliance for Senior Involvement removed barberry plants from a field at Allegheny Portage Railroad National Historic Site in 2002. The site has now been restored with native grasses. CHERYL NOLAN/ENVIRONMENTAL ALLIANCE FOR SENIOR INVOLVEMENT

Both parks have also experienced success with controlling giant and Japanese knotweed (fig. 2). A contractor at Johnstown Flood National Memorial first treated knotweed populations in 2001, with follow-up treatments annually by park staff in 2002 through 2004. In 2005, monitoring of the site showed knotweed levels had fallen below the threshold level and no treatments were required. The monocultures of knotweed have now been replaced by a more diverse native plant community through natural revegetation at this site. At Allegheny Portage Railroad National Historic Site's Staple Bend Tunnel Unit, knotweed control has taken a little longer, but native revegetation has also replaced vast monocultures of this plant pest. Except for some seeding at a field area, the revegetation has also been accomplished naturally, thanks to a good, native seed-bank at the site.

Figure 2. Areas formerly covered by giant and Japanese knotweed have naturally revegetated with native grasses and forbs such as these Joe-pye weeds at Johnstown Flood National Memorial. A single stalk of knotweed can be seen (lower right), but knotweed occurrence was below the threshold level for treatment in 2005. NPS/KATHY PENROD

At Johnstown Flood National Memorial, exotic bush honeysuckle has been treated in the historical former lakebed and in wooded areas near the park's picnic area. Park staff, interns, and an SCA crew removed plants from the lakebed from 2001 through 2004. Volunteers from the local community college removed plants from a wooded area in 2004. Outcomes have been mixed, with good success at the wooded area where native revegetation is occurring, but some problem areas persist in the lakebed area where new honeysuckle plants continue to invade the meadows.

These successes in dealing with large and imposing exotic plants have been tempered by another challenge posed by a small but ubiquitous plant, garlic mustard (fig. 3). At the Summit area of Allegheny Portage Railroad National Historic Site, park staff, volunteers, and interns have treated garlic mustard for up to six years by hand-pulling all flowering plants each year. Despite declines in population size approaching 90%, the park's data show that a few populations continue to increase even after six years of treatment. Originally, park staff expected to be treating the garlic mustard populations for five years, based on the available scientific literature for long-term seed viability. However, most garlic mustard populations are still re-emerging. Apparently, eradication will be a longer-term effort than originally anticipated.

Figure 3. Garlic mustard is a small plant that is proving to be a larger control challenge than barberry or knotweed at Allegheny Portage Railroad National Historic Site.

With increasing years of treatment, chances of success of garlic mustard control are improving. The success in eradicating populations appears to increase with increasing number of years of plant removal, although the data are highly variable (table 1). The average decline in plant numbers tends to increase with increasing number of years of treatment; however, populations may continue to increase even after six years of treatment (table 1).

Because all flowering garlic mustard plants in treated populations were removed, the recurring plants are likely to be coming from seeds present in a dormant soil seed bank. Though dispersal from off-site is another possibility, it is probably not a major factor in the persistence of the treated populations. With each passing year, park staff assumes that the dormant soil seed bank is being depleted, but apparently it takes longer than six years for the depletion to be complete.

It is difficult to predict which plants or sites will achieve favorable results. The parks' success in dealing with barberry and knotweed are encouraging in the battle against exotic plants. However, garlic mustard and sites where a good, native seed bank is lacking are presenting longer-term challenges.

Table 1. Garlic mustard population trends at Allegheny Portage Railroad National Historic Site, Pennsylvania, 2001–2005

Years treated (running)	Populations in sample	Populations eradicated	Populations decreasing[1]	Average population decrease	Populations increasing	Average population increase
2	5	0%	4	60%	1	26%
3	2[2]	50%[2]	2	91%[2]	0	No data
4	8	0%	6	60%	2	46%
5	9	11%	6	86%	3	167%
6	8	38%	7	88%	1	168%

Note: The control treatment was hand-pulling of flowering plants.
[1]Includes populations eradicated.
[2]May not be representative because of small sample size.

—***Kathy Penrod***, *Natural Resource Specialist, Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial, Pennsylvania; kathy_penrod@nps.gov.*

Information Crossfile

Predicting the spread of sudden oak death in California

Sudden oak death has reached epidemic levels in some coastal forests of central California. Identified in 2001, the pathogen *Phytophthora ramorum* causes the disease, which has spread rapidly along the Pacific Coast. The deadly fungus is not confined to oaks; investigators have confirmed bigleaf maple (*Acer macrophyllum*), wild rose (*Rosa gymnocarpa*), Douglas fir (*Pseudotsuga menziesii* var. *menziesii*), coast redwood (*Sequoia sempervirens*), and dozens of other species, including rhododendron (*Rhododendron* spp.) and other popular horticultural plants, as hosts. (Further details about host plants are available at http://www.suddenoakdeath.org. The Web site also provides information about research, nursery updates, management recommendations, training, and regulations.)

Sudden oak death manifests itself as either lethal branch or stem infections, or nonlethal foliar and twig infections. The lethal form of the disease kills several ecologically important trees, including tanoak (*Lithocarpus densiflora*), coast live oak (*Quercus agrifolia*), California black oak (*Quercus kellogii*), canyon live oak (*Quercus chrysolepis*), and Shreve's oak (*Quercus parvula* var. *shrevei*) (Rizzo et al. 2002). Except for tanoak, these oak species appear to be epidemiological dead-ends or "terminal hosts" because the pathogen does not form spores and spread from the trees.

Many governmental agencies are involved in finding solutions to this problem. For instance, the California Oak Mortality Task Force is composed of agencies such as the USDA Forest Service, National Park Service, and California Department of Forestry along with the University of California and many other local agencies and private organizations. The task force has established an extensive monitoring program for the disease. The program focuses on the early detection of pathogen activity at isolated locations, where applying chemical treatments or attempting eradication may be possible. The considerable cost of monitoring necessitates careful targeting and prioritization and presents a significant challenge given California's extensive size, the diversity of host species, and the environmental variability in the state. Therefore, understanding where and when the risk of establishment of *P. ramorum* is elevated is essential in order to effectively monitor the disease and manage threatened forests.

The Integrated Pest Management Program of the NPS Pacific West Region has designed a variety of devices for disinfecting park visitors and staff of the organism causing sudden oak death, which can be transported unwittingly to and from parks in soil clinging to anything from shoes to bicycle tires. This device is being tested for effectiveness and acceptance by bicyclists at a park administered by the Mid-Peninsula Open Space District in the San Francisco Bay area.
NPS/BRUCE BADZIK

Meentemeyer et al. (2004) presents a model for predicting the spread and establishment of sudden oak death in plant communities in California. The California Oak Mortality Task Force is already using this model to target early detection monitoring and predict oak and tanoak mortality. Based on the combined effects of spatial variability in climate (i.e., 30-year monthly averages [1961–1990]) and host vegetation (i.e., USDA CALVEG dataset) for each month of the pathogen's general reproductive season (December–May), the model predicts the risk of continued spread and establishment. The five predictor variables are a host species index and four temperature and moisture variables (i.e., precipitation, relative humidity, and minimum and maximum temperature). Investigators evaluated the model's performance by comparing its predictions to field observations of disease presence and absence.

The model mapped sites as very high risk where dense concentrations of host species (i.e., very high host index values) coincide with highly suitable climate conditions (e.g., mild temperatures [64°F–68°F {18°C–20°C}] and water existing on plant surfaces for at least 6–12 consecutive hours). Very high risk habitats occur in the coastal environments within 30 miles (50 km) of the Pacific Ocean. In addition, high risk areas form a nearly contiguous band through the coastal counties from the Oregon border to northwestern San Luis Obispo County. High risk habitats occur where moderately high host index values correspond with moderately to highly suitable climatic conditions.

To date, plants at Golden Gate National Recreation Area, Muir Woods National Monument, and Point Reyes National Seashore have been infected with the disease. Additional monitoring this year will be investigating whether or not the disease occurs at Santa Mountains National Recreation Area and Redwood National Park. The pathogen affects both urban and wildland forests and may spread via nursery plants and soil movement. Hikers and mountain bikers also commonly transport the pathogen (see photo, page 13). Although much remains to be learned about the ecology and epidemiology of sudden oak death, the model that Meentemeyer and others present serves as a seemingly simple yet effective management tool for targeting forests for early detection monitoring and protection. Based on the model's results, an alarming number of uninfected forest ecosystems in California face considerable risk of infection by *P. ramorum*. The risk maps of Meentemeyer et al. (2004) are available at http://kellylab.berkeley.edu/SODmonitoring/SODmapsState.htm.

More information about *P. ramorum* is also available at http://www.aphis.usda.gov/ppq/ispm/pramorum (U.S. Department of Agriculture) and http://www.na.fs.fed.us/sod (USDA Forest Service).

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Collecting 25 years of data from the kelp forests of Channel Islands

Some of the world's largest kelp forests encircle the islands of Channel Islands National Park, which was established in 1980 to preserve self-sustaining examples of coastal ecosystems in southern California. These extensive kelp forests can stretch up to 200 feet (60 m) from their anchors on the seafloor to the surface, providing a vertical infrastructure that is home to more than 1,000 species of plants and animals (see photo).

In 1981 the National Park Service instituted a "vital signs" monitoring program to inform, guide, and evaluate stewardship of the park. In order to measure change over time, managers established fixed monitoring sites, which are physically marked and geo-referenced to ensure that sampling occurs in precisely the same places every year. Nine of the original kelp-forest monitoring sites have giant kelp (*Macrocystis pyrifera*) forests, one site is in a state of transition possibly to a kelp forest, and echinoderms dominate the remaining six sites. Of these six sites, purple sea urchins (*Strongylocentrotus purpuratus*) dominate two of them; purple and red sea urchins (*S. franciscanus*) dominate two; spiny brittle stars (*Ophiothrix spiculata*) dominate one; and spiny brittle stars and red sea urchins dominate one.

Managers selected the monitoring sites on the basis of physical setting and biogeographical zone. With respect to physical setting, kelp forests north of the islands are exposed to winter storm waves from the Gulf of Alaska, while those on the southern shores are protected from winter storms. Southern coast kelp forests are exposed to large summer swells generated from winter storms in the Southern Hemisphere and nourished by seasonal upwelling from adjacent oceanic basins (Davis 2005). These different physical settings create three large biogeographical zones, which are defined by warmer and cooler water masses that bathe the islands. Managers established a total of 16 monitoring sites that punctuate these zones, including sites for comparing fished with unfished kelp forests. The California Department of Fish and Game owns and manages the marine resources out to 3 miles (5 km) from the park's boundary. In 2003 the State of California created a network of marine protected areas around the Channel Islands, closing off about 20% of park waters to fishing.

Generally speaking to monitor the 16 sites, divers perform 750 dives with 625 hours of bottom time during a typical field season (June through October) (David Kushner, Channel Islands National Park, written communication, October 2005). In addition to NPS and volunteer divers, the California Department of Fish and Game and Channel Islands National Marine Sanctuary provide

Pacific jack mackerel in kelp forest at Channel Islands National Park, California.

trained divers to aid in data collection. In 2005 the park's kelp-forest monitoring program added an additional 16 monitoring sites, effectively doubling the monitoring program. In order to evaluate the effectiveness of the marine protected areas, managers strategically placed these new sites inside and adjacent to four of the marine protected areas.

The kelp forest monitoring program has now accumulated 25 years (1982–2006) of data, which includes population dynamics of 69 taxa of algae, fish, and invertebrates. Mangers used information collected in conjunction with the kelp-forest monitoring program to support the implementation of new marine reserves at Channel Islands National Park and the closure of the abalone fishery in southern California. The monitoring program has provided some of the only fishery-independent data on species such as abalones, sea urchins, and sea cucumbers (Channel Islands National Park, Kelp Forest Monitoring Program Summary, 2005). According to Davis (2005), data from Channel Islands has helped to change fishery management strategies, develop and evaluate population and ecosystem restoration methodologies, and recognize and demonstrate unsustainable uses.

In addition, researchers find the data set useful because it is relatively long term and covers a wide range of conditions with several major El Niño events, consists of a diverse number of sites (i.e., 16 fished and un-fished sites on five islands), and is biologically comprehensive (i.e., includes data on fish, invertebrates, and algae) (Dan Reed, University of California–Santa Barbara, written communication, September 2005). Researchers have used the data set to examine the spatial variability in species assemblages (Reed et al. 2000); document the management of sustainable fisheries (Schroeter et al. 2001); aid in the restoration of white, pink, and green abalone (Rogers-Bennet et al. 2002); evaluate habitat of the endangered white abalone (Lafferty 2003); determine that fishing for lobsters indirectly increases epidemics in sea urchins (Lafferty 2004); and investigate how rocky reefs change over time, transitioning between kelp forests and urchin barrens (Lafferty and Behrens 2005).

According to Davis (2005), the vital signs program at Channel Islands National Park has endured "because it proved to be a cost-effective way to reduce uncertainty [in management decisions] and increase success of conservation efforts." Furthermore, Kate Faulkner, chief of Resource Management at Channel Islands National Park, attests that the dataset supports research that "highlights the importance of both long-term monitoring and unfished marine protected areas in gaining understanding of marine ecosystem dynamics."

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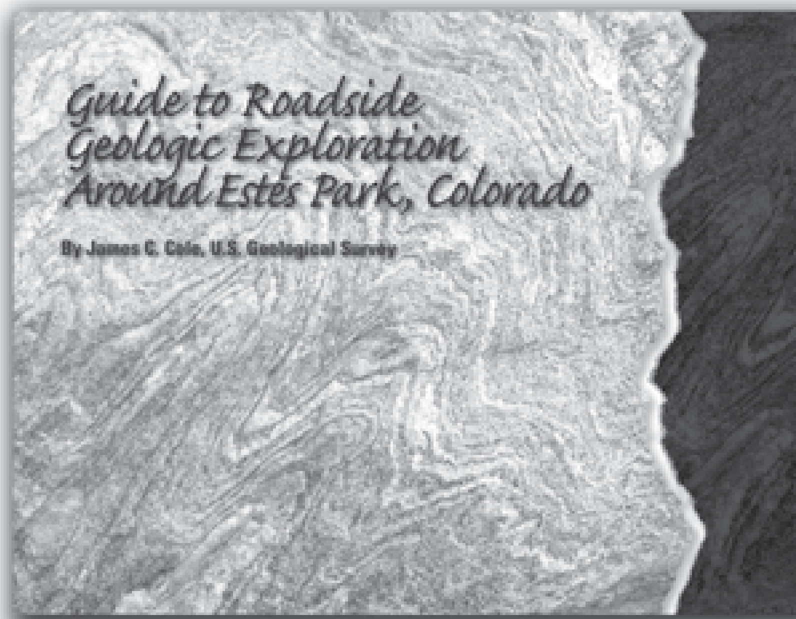
Award-winning publication brings together park and partners

The U.S. Geological Survey (USGS), National Park Service (NPS), Association of Earth Science Editors (AESE), and Rocky Mountain Nature Association (RMNA) celebrated an award-winning partnership in Rocky Mountain National Park, Colorado, on 28 September 2005. The partners had received a First Place National Association of Government Communicators Blue Pencil Award for the colorful publication, *Guide to Roadside Geologic Exploration Around Estes Park, Colorado* (see photos). Jim Cole, USGS research geologist, is the author of the book, which the U.S. Geological Survey produced and the Association of Earth Science Editors published. Vision Graphics, Inc., printed the popular roadside guide.



ASSOCIATION OF EARTH SCIENCE EDITORS

Jim Cole (right), USGS research geologist and author of *Guide to Roadside Geologic Exploration Around Estes Park, Colorado*, received a first place NAGC Blue Pencil Award in the category of softcover book. Dave Shaver (left), chief of the NPS Geologic Resources Division, and Larry Frederick (center), chief of interpretation at Rocky Mountain National Park, help to celebrate the award-winning collaboration among the U.S. Geological Survey, National Park Service, Association of Earth Science Editors, and Rocky Mountain Nature Association. NPS/KATIE KELLERLYNN

In addition to providing an illustrated guide for a one-day general geology field trip during the AESE annual meeting, the publication serves as a general-interest publication that enhances public awareness of local geology. The 22-page book presents a series of six self-guided roadside explorations of earth science topics: mountain uplift, landscape-scale erosion and weathering, folded and metamorphosed basement rocks, flash flooding in mountain valleys, engineering and politics of large water diversion projects, and glaciation and climate change.

The superintendent of Rocky Mountain National Park, Vaughn Baker, and the chief of interpretation, Larry Frederick, participated in the AESE field trip and are enthusiastic about the book and the geologic lessons it discusses. The NPS Geologic Resources Division, a supporter of the publication, purchased 1,000 copies for internal distribution and resale at park visitor centers and other RMNA sales outlets. The guidebook has spurred discussion about additional possibilities for enhanced geologic education between the author and the Rocky Mountain Nature Association (a nonprofit "friends" group for the park). In addition, the author is working with park staff to increase opportunities for geologic interpretation.

Winning publications of NAGC Blue Pencil Awards exemplify the high standards of individual professionalism and public service in government communicators, like Jim Cole, and promote exchange of ideas with the public. The 20 award categories for publications honor the best writing, editing, and graphic design produced by government communicators or for government agencies. The awards serve the purpose of the National Association of Government Communicators by developing among government leaders, partners, and the public awareness and understanding of the function of professional communicators in fulfilling the public's right and need to be informed about governmental activities at every level. In the case of *Guide to Roadside Geologic Exploration Around Estes Park, Colorado*, the public's enjoyment of natural resources in national parks is also enhanced.

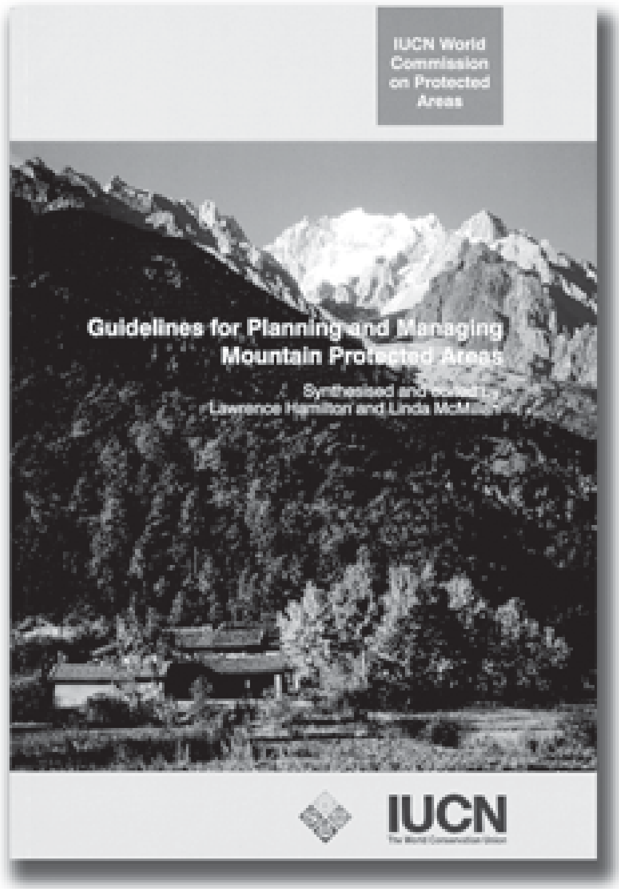
World Conservation Union— an international resource

The World Conservation Union is a source of information and guidance for conservation efforts around the globe. Formerly known as the International Union for Conservation of Nature and Natural Resources (IUCN), the organization is the world's largest conservation network, according to its Web site (http://iucn.org). Its mission is to "influence, encourage, and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable." The IUCN brings together 82 states, 111 government agencies, more than 800 nongovernmental organizations, and 10,000 scientists and experts from 181 countries in a worldwide partnership.

The IUCN's activities are carried out by six commissions:

- Ecosystem Management—Guiding the management of natural and modified ecosystems
- Education and Communication—Promoting sustainability through education and communication
- Environmental, Economic, and Social Policy—Advising on economic and social factors that affect natural resources
- Environmental Law—Advancing environmental laws and their application
- Protected Areas—Advising and promoting terrestrial and marine reserves, parks, and protected areas
- Species Survival—Supporting species conservation and protecting endangered species

Experts in these fields from all over the world share their experience with local problems and their vision for global solutions. Thus, the organization produces publications reflecting an international perspective on the conservation issues that concern natural resource managers worldwide. One relatively recent example is *Guidelines for Planning and Managing Mountain Protected Areas* (see photo), an updated handbook that was the product of a workshop convened just before the World Parks Congress of 2003 held in South Africa. The handbook was synthesized and edited by Lawrence Hamilton, vice-chair for Mountains, World Commission on Protected Areas, IUCN; and Linda McMillan, Access and Conservation Commission of the International Mountaineering and Climbing Federation (known as UIAA, Union Internationale des Associations d'Alpinisme).



WORLD CONSERVATION UNION/IUCN

The book describes the special features of mountain environments and offers guidelines for designing protected areas in these steep and remote places where conditions vary greatly with altitude. Such places are reservoirs of rich biodiversity because of their isolation, variations of physical geography, and unstable terrain. The handbook offers guidelines on the management of biodiversity within these regions, and also treats conditions other than those of natural resources that may affect the protected areas. Mountains are often the boundaries between political entities, presenting a special set of challenges for protected areas along borders. One guideline for a protected area where a watershed is shared, for example, encourages managers to engage in cross-boundary dialogue about effective watershed management.

The guidelines consider the management of mountainous parks or preserves that straddle international borders, called "transboundary protected areas." Managing these areas can be especially complex because the surrounding political units may have differing laws and customs; therefore, management practices need to be acceptable to each adjacent entity and to the traditions of indigenous peoples. (An example of a transboundary protected area familiar to many *Park Science* readers is the Waterton/Glacier International Peace Park on the Canada-United States border.) The handbook also devotes much attention to respecting the "sacred, spiritual, and cultural significance" of mountains, and to the visitor experience where both the mountain and the visitor require protection.

The World Conservation Union Web site features a very large catalog of publications that may be of interest to natural resource managers (http://www.iucn.org/bookstore).

Reasoned action and lethal management of deer in Cuyahoga Valley National Park

Traditionally resource management was a profession focused on administering natural resources. However, over the past 30 years, managing humans has emerged as a significant component of the job. For example, introducing a new policy or management plan necessitates informing and educating the public and seeking public input. Management actions that achieve desired effects by managers but are not relevant to the public are unlikely to garner long-term support (Manfredo 1992). For this reason, identifying public beliefs and attitudes concerning management actions is a critical step in the management process. The more managers know about the factors underlying public support for or opposition to policies or issues, the more likely their ability to develop effective messages or other types of interactions to influence public response.

A case regarding lethal management of deer (*Odocoileus virginianus*) in Cuyahoga Valley National Park, Ohio, epitomizes challenges managers face when planning and managing for abundant deer populations in the context of intense public scrutiny. Fulton et al. (2004) uses the theory of reasoned action to help understand attitudes and beliefs about lethal control of deer. The outcome is significant because lethal control is the most broadly used management tool for reducing deer populations; moreover, even relatively small minority opposition to lethal control can lead to significant social conflict and protracted decision making concerning the use of lethal control. (Fulton et al. 2004).

The theory of reasoned action addresses human behavior that deals with the relationships among beliefs, attitudes, intentions, and behavior. Various investigators have used the theory to predict and explain why people have or have not engaged in a wide variety of behaviors, including smoking, signing up for a treatment program, using contraceptives, wearing seat belts or safely helmets, voting, exercising regularly, and choosing a career. The theory rests on the assumption that humans are reasoning animals who systematically use or process the information available to them. The theory suggests that underlying beliefs ultimately determine one's behavior. Therefore, changing behavior is viewed primarily as a matter of changing the underlying cognitive structure (Manfredo 1992).

In the case of lethal management of deer at Cuyahoga Valley National Park, investigators used a mail-back survey to collect data from Ohio residents in the surrounding nine-county area of the park. The survey addressed attitudes toward two potential management actions: (1) no action and (2) reduction of the deer population through lethal control. Investigators assessed attitudes toward these two alternatives by asking respondents questions that measured the level of acceptability with respect to each action (table 1).

From the returned surveys and follow-up phone calls to nonrespondents, investigators defined two groups of residents: "near" (<10 km or 6.2 mi from the park) and "far" (>10 km from the park). According to the study,

See "Information Crossfile" in right column on page 50

Table 1. Beliefs about "no action" and "lethal control" of deer in Cuyahoga Valley National Park

Taking no action would	A lethal control program would
• lead to too many car collisions with deer	• reduce the risk of deer-vehicle collisions
• lead to too much damage from deer to shrubs, crops, and gardens	• reduce damage by deer to shrubs, crops, and gardens
• increase the risk of disease associated with deer such as Lyme disease	• reduce the risk of diseases associated with deer such as Lyme disease
• increase the damage done by deer to native plant species	• reduce the damage done by deer to native plant species
• decrease the diversity of plants and animals	• help maintain the diversity of plants and animals
• maintain a healthy deer population	• maintain a healthy deer population
• cause unnecessary pain and suffering to deer	• cause unnecessary pain and suffering to deer
• conflict with the purpose of a national park	• conflict with the purpose of a national park
• maintain opportunities to see deer	• decrease opportunities of seeing deer
• upset local residents and visitors	• upset local residents and visitors

ADVANCES IN RECREATIONAL WATER QUALITY MONITORING at Indiana Dunes National Lakeshore

By Wendy Smith, Meredith Nevers, and Richard Whitman

Indiana Dunes National Lakeshore comprises more than 15,000 acres (6,075 ha) at the southern tip of Lake Michigan and serves more than 2 million visitors each year. Like all national parks, Indiana Dunes places a high priority on visitor safety. With miles of sandy beaches attracting hundreds of thousands of swimmers annually, attention to swimmer safety plays a big role in park management (fig. 1). Indiana Dunes has improved its ability to protect the health of swimmers through better science-based management and increased understanding of contaminants. Most research has focused on *Escherichia coli* and its nature, sources, and distribution because it is widely accepted as an indicator of potential pathogens. Though research on *E. coli* and recreational water quality is continually generating new information, public beach managers may gain valuable insight into this management issue from our experience at Indiana Dunes. This article reviews one of the longest maintained indicator bacteria monitoring programs in the National Park System, highlights lessons learned, and summarizes research findings that may be of interest to public beach managers.

Figure 1. More than 2 million people per year visit Indiana Dunes National Lakeshore with hundreds of thousands enjoying the sandy swimming beaches. The timely and accurate measurement of water quality to protect swimmers' health has long been a problem for park managers. USGS/KASIA PRZYBYLA-KELLY

E. coli as an indicator of beach water quality

Indiana Dunes swimming beaches occasionally receive waste from wildlife and domestic animals, boat discharge, septic systems, and combined sewer overflows. Because water containing sewage may include a variety of disease-causing agents (e.g., parasites, bacteria, and viruses), managers need to monitor beach water quality. Accordingly, staff at Indiana Dunes National Lakeshore has been monitoring the water quality at its beaches since 1979.

E. coli is a bacterium present in the gastrointestinal tracts of humans and other warm-blooded animals. It serves as an indicator bacterium because, though it is generally harmless (Geldreich 1978), its presence is associated with fecal contamination and human pathogens (Cabelli et al. 1979).

According to the Beaches Environmental Assessment and Coastal Health Act (BEACH) of 2000, all states must adopt the U.S. Environmental Protection Agency's (EPA) established water quality criteria for monitoring bacteria. For freshwater, the strictest federal criterion—adopted by Indiana—is that no single sample should exceed 235 colony forming units (CFU) of essentially culturable *E. coli* per 100 ml (3.4 fl oz) of water, or a geometric mean of 126 CFU/100 ml over the course of 30 days. According to Indiana standards, if this level is exceeded, beach managers should issue a swimming advisory.

Until 2004, staff at Indiana Dunes regularly monitored for *E. coli* once a week and closed national lakeshore waters to swimming if levels were above the EPA standard. Sampling was generally conducted on Thursdays in an attempt to know *E. coli* levels before weekend beachgoers arrived and therefore protect swimmers.

Ongoing research at Indiana Dunes during that time led to the interesting discovery that *E. coli* may not always be an effective indicator of water quality. Though this bacterium is found in the intestines of warm-blooded animals, scientists discovered that it can also persist and perhaps thrive in many other natural environments (Whitman and Nevers 2003).

E. coli may not always be an effective indicator of water quality.

Research conducted by the U.S. Geological Survey (USGS) has shown that temperate forest soils in the watershed of Dunes Creek (a Lake Michigan tributary within the Indiana Dunes State Park, which is encompassed by the national lakeshore) harbor *E. coli* throughout the entire year. The persistently high *E. coli* counts in the creek itself may be due to sediment-borne bacteria eroding into the water. In these cases, there was no significant human fecal input, yet *E. coli* was present (Byappanahalli et al. 2003).

E. coli have also been found year-round in the shore sand as far from the shoreline as the foredunes, making the sand a non-point and generic source of *E. coli* contamination to the beach water. When waves strike the beach they churn up the sand and carry *E. coli* into the water. Research has shown that *E. coli* counts in nearshore and submerged sand are typically several orders of magnitude higher than in the beach water (Whitman and Nevers 2003). Although visitor contact with contaminated sand may be more common if beach water is closed to swimming, the health effects of *E. coli* presence in sand are unknown.

E. coli are also present on the green alga *Cladophora*, which often amasses along the Lake Michigan beaches and harbors high densities of the bacterium (Whitman et al. 2003). In a recent study, mean concentrations of *E. coli* per gram (0.04 oz) of *Cladophora* were 10,000 CFU. Wave action can wash *E. coli* from *Cladophora,* increasing the likelihood of a beach closure (Whitman et al. 2003).

Researchers and resource managers are now recognizing that *E. coli* are much more common in the natural environment than previously suspected. A recent study even found *E. coli* in the fluid of bog-dwelling pitcher plants (Whitman et al. 2005). Not only can *E. coli* exist in these various environments, but recent studies also indicate that, in some areas, they can actually reproduce. In one research project at Indiana Dunes State Park, hot water was used to treat the forest soil, killing off all but extremely small numbers of *E. coli*. After the heat treatment, not only did the bacteria grow back, but they persisted in the test plot for more than a year afterward (Byappanahalli et al. 2002).

These naturally occurring reservoirs of _E. coli_ exist in the seeming absence of fecal material and lead to questions about _E. coli_'s suitability as an indicator of fecal contamination.

These naturally occurring reservoirs of *E. coli* exist in the seeming absence of fecal material and lead to questions about *E. coli*'s suitability as an indicator of fecal contamination. In many cases, today's beach managers may decide to close a beach when naturally occurring *E. coli*, as opposed to *E. coli* from a contamination event, are present. Because *E. coli* appear to be naturally abundant and generally harmless, unless a combined sewer overflow or another known source of human sewage input has occurred, many beach closures are likely unnecessary for protecting public health. The actual source of the *E. coli* and the concomitant presence of pathogens still need to be determined.

Shortcomings of *E. coli* monitoring methods

Monitoring methods for *E. coli* also are problematic for beach managers. Traditional monitoring practices rely on culturing *E. coli* from water samples collected at the beach, and results are not available until 18–24 hours after sampling. By then the bacteria levels in the beach water may have changed significantly, and the beaches are either closed too late to protect visitor health or the closures are unnecessary. In fact, many studies show little or no correlation between indicator levels from the sampling day to the next day when the results are used by managers to make decisions about beach closures (Whitman et al. 1999) (fig. 2).

In 2004, staff at Indiana Dunes National Lakeshore tested its beaches five to seven days per week to help researchers improve their understanding of the environmental conditions associated with high bacteria levels (for example, caused by heavy rains). That summer, though 33 water samples exceeded the water quality standard, only three of those exceedances occurred on consecutive days. According to Scott Hicks, assistant chief of Resource Management at Indiana Dunes, "It is only when consecutive exceedances occur that issuing a swimming advisory based on the previous day's sample correctly warns the public of high bacteria levels." This means that only 9% of the closures in 2004 accurately reflected *E. coli* levels that truly exceeded the EPA standard. The rest of the time, thousands of people may have been kept out of the water unnecessarily.

On the other hand, every water quality report suggesting a beach closure indicates that on the prior day, if the beaches were open, people were swimming in water that exceeded the standard for safe swimming. This happened 30 times in 2004 when samples exceeded the water quality standard.

Test results not only vary from one day to the next, but studies in Lake Michigan and a marine beach in California also show that fecal indicator bacteria levels can vary substantially over very short distances (from centimeters to meters) and over short time periods (from minutes to hours) (Boehm et al. 2002, Whitman and Nevers 2004). Water samples collected in the morning can have high counts although the water may be safe for swimming a few hours later as *E. coli* CFU counts fall below the EPA limit. This pattern has commonly been attributed to disinfection by sunlight, which kills *E. coli* cells or makes them non-culturable (Whitman et al. 2004). Whereas the vast majority of beach managers sample their water in the morning—before the potential for sunlight disinfection—*E. coli* counts are often lower in the afternoon, making the time of sampling an important component of the monitoring program. If they sampled in the afternoon the *E. coli* levels might be below the 235 CFU/100 ml closure level.

E. coli densities also vary significantly with water depth, with higher counts in shallow water rather than in deep water (Whitman and Nevers 2004). In one study on 63rd Street Beach in Chicago, researchers learned that at least six water samples would have to be taken at a single location to achieve 70% precision around the 235 CFU/100 ml level (Whitman and Nevers 2004). Unfortunately, only a single sample is collected at most beaches. In these cases, the samples do not represent the high variation inherent in beach water, and will likely grossly over- or underestimate the actual *E. coli* count.

Improving advisory accuracy

Each day that a beach is closed may prevent swimmers from becoming ill, but it also causes loss of valuable recreational access. On any given day, the net effect of this trade-off depends on the level of contamination and health risk that actually exists, how many people were exposed to the water, and what the management decision was for that day. Rabinovici et al. (2004) describe a method for evaluating the effectiveness of swim-closure policies in terms of the overall costs and benefits to swimmers. Results from that case study involving four summers (1998–2001) of water quality and visitor use data from Indiana Dunes State Park beach showed that nearly two-thirds of swim closures based on *E. coli* levels were unnecessary. According to Bob Daum, chief of Resource Management at Indiana Dunes National Lakeshore, "The public needs more information. They need a method to help them make an informed decision rather than having to rely on a beach being designated as open or closed based on a system shown to be inaccurate."

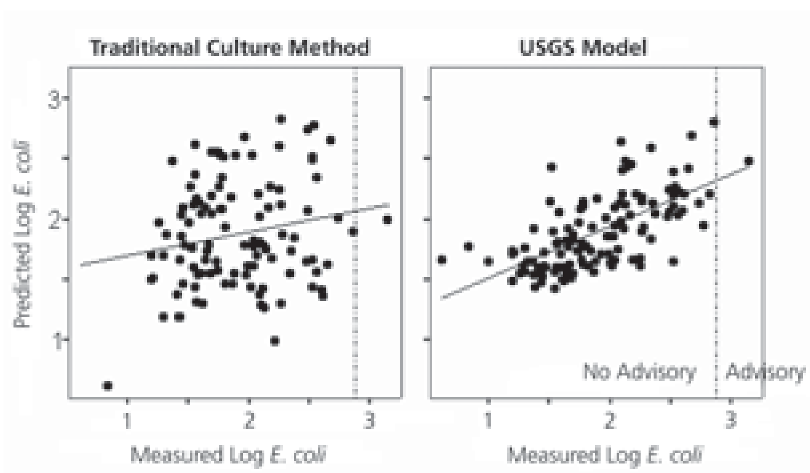


Figure 2. The current model uses yesterday's *E. coli* level to estimate current swimming conditions (left). The USGS model, SAFE (right), uses lake and weather conditions, such as cloud cover, wave height, turbidity, and lake current direction and speed to estimate near real-time water quality. The USGS model explained about 10 times more variance than the current EPA approach.

Future directions

In 2005, the U.S. Geological Survey initiated a pilot project at one of the most popular Indiana Dunes beaches that considered a completely new way of determining *E. coli* concentration in the water. Through Project SAFE (Swimming Advisory Forecast Estimate), *E. coli* concentration was estimated using surrogate parameters such as wind direction, water turbidity, and the quality of water in a nearby river outfall (fig. 3). In 2006, Project SAFE is being used for managing five beaches in Lake and Porter Counties, including one at Indiana Dunes National Lakeshore, that are directly affected by contaminants, particularly during prevailing north winds (fig. 4).

Further, in association with Project SAFE in 2006, the U.S. Geological Survey will test a more rapid means of analyzing microbiological water quality using quantitative PCR (polymerase chain reaction). PCR is a

Water samples collected in the morning can have high counts although the water may be safe for swimming a few hours later.

Figure 3. Kasia Przybyla-Kelly from the USGS Lake Michigan Ecological Research Station takes water quality samples at Indiana Dunes. Samples are analyzed for turbidity and are used for the prediction of *E. coli* levels. USGS/DAWN SHIVELY

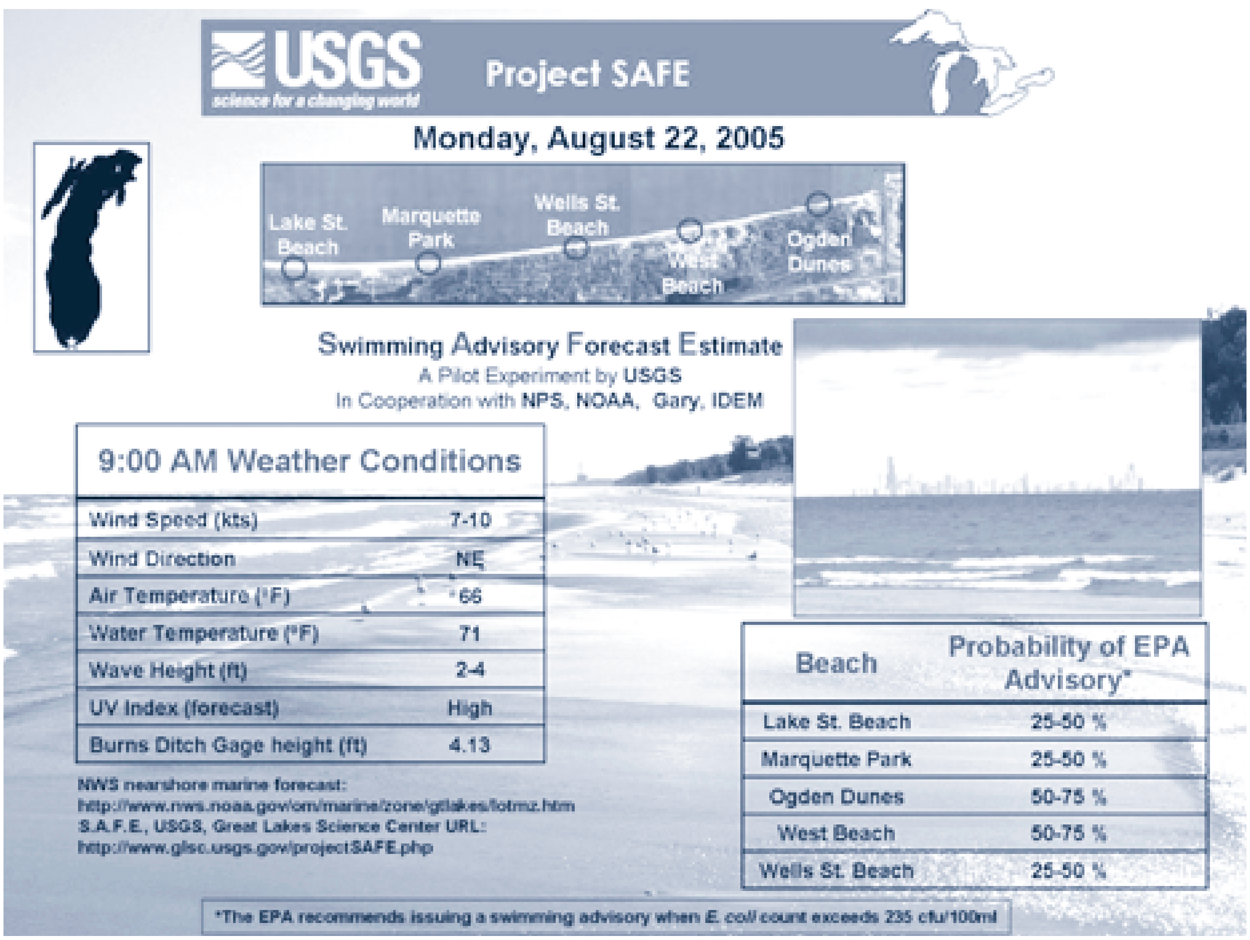


Figure 4. A sample Web output screen from Project SAFE. This model developed by Richard Whitman and Meredith Nevers, U.S. Geological Survey, predicts the *E. coli* every weekday by 10 am. Beach advisory predictions are e-mailed to area managers and can be accessed from the USGS Web site (http://www.glsc.usgs.gov/ProjectSAFE.php) by following Internet links from local newspapers. The insert shows a view of Chicago from Indiana Dunes National Lakeshore on the day of the forecast.

Figure 5. Experiments are under way at the park to determine the concentration of enterococci, a fecal coliform bacteria, using quantitative PCR. This technique can potentially measure fecal indicator bacteria in less than two hours compared to the 24-hour test now in use.
NPS/WENDY SMITH

molecular process used by biologists to replicate DNA in order to identify the genetic characteristics of an organism (fig. 5). In quantitative PCR this reaction is designed for one organism, in this case the bacterium *Enterococcus faecalis*, an indicator of fecal contamination. Scientists take water samples, extract DNA from the bacteria, and measure DNA replication over a short period of time. In just a few hours—instead of the usual 18–24 hours needed for traditional culturing—they are able to count the concentration of the bacteria, relate it to the concentration in the original sample, and determine the public health risk. This technique will enable managers to learn of water quality conditions that morning, in time to issue accurate swimming advisories for the day. This is a trial application of this method, but the hope is that some day a technique can be developed to directly measure the presence of pathogens in swimming water and give managers real-time indications of the recreational water quality of beaches.

The recent success of the Indiana Dunes beach management program has been possible only through the pioneering, park-based research of the U.S. Geological Survey in cooperation with state and local agencies. This collaborative experience has shown how historical data, diligence, and commitment to science-based management and research can improve visitor safety and enhance enjoyment of the park.

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RESPONSE OF WESTERN MOUNTAIN ECOSYSTEMS TO CLIMATIC VARIABILITY AND CHANGE:

THE WESTERN MOUNTAIN INITIATIVE

By Nate Stephenson, Dave Peterson, Dan Fagre, Craig Allen, Don McKenzie, Jill Baron, and Kelly O'Brian

Mountain ecosystems within our national parks and other protected areas provide valuable goods and services such as clean water, biodiversity conservation, and recreational opportunities, but their potential responses to expected climatic changes are inadequately understood. The Western Mountain Initiative (WMI) is a collaboration of scientists whose research focuses on understanding and predicting responses of western mountain ecosystems to climatic variability and change. It is a legacy of the Global Change Research Program initiated by the National Park Service (NPS) in 1991 and continued by the U.S. Geological Survey (USGS) to this day as part of the U.S. Climate Change Science Program (http://www.climatescience.gov/).

FRAMING THE QUESTIONS

The rate and magnitude of ecosystem responses to climatic warming are variable and uncertain, ranging from gradual to abrupt, from moderate to profound. The least understood and least predictable responses are perhaps those of greatest importance to NPS natural resource managers: responses that are both abrupt and profound (NRC 2001; Gunderson and Pritchard 2002). Recent examples of such responses include ongoing drought-induced tree mortality on millions of hectares of forest in New Mexico, Arizona, and southern California (Breshears et al. 2005; U.S. Forest Service 2003), and an increase in area burned by severe wildfires in the western United States during the past two decades (Westerling and Swetnam 2003). In both cases, thresholds of ecosystem resistance to change were quickly exceeded, leading to large and often unexpected changes that will have long-term consequences for protected areas.

Against this backdrop, the Western Mountain Initiative is guided by four major questions that address ecosystem patterns and processes at large spatial scales across the West, with an emphasis on mountainous national parks:

1. How are climatic variability and change likely to affect spatial and temporal patterns of ecological disturbance (particularly fire)?
2. How are changing climate and disturbance likely to affect the composition, structure, and productivity of vegetation (particularly forests)?
3. How will climatic variability and change affect hydrologic processes in the mountainous West?
4. Which mountain resources and ecosystems are likely to be most sensitive to future climatic change, and what are possible management responses?

Western mountain ecosystems are well suited to address these and related questions because they have (1) compressed climatic and biogeographic zones containing many ecosystems within relatively small areas, (2) rich paleoecological resources, which record past environmental changes and consequent ecosystem responses, and (3) common ecological drivers, such as snowpack and fire, which facilitate comparisons across ecosystems.

The WMI network—historical perspective

Data collected in several western national parks since the inception of this research program in 1991 have improved our understanding of the effects of climatic variability on mountainous ecosystems. Most of the major forested and alpine ecosystems in the West are represented within the WMI network (fig. 1). A brief summary of the sites and results to date follows.

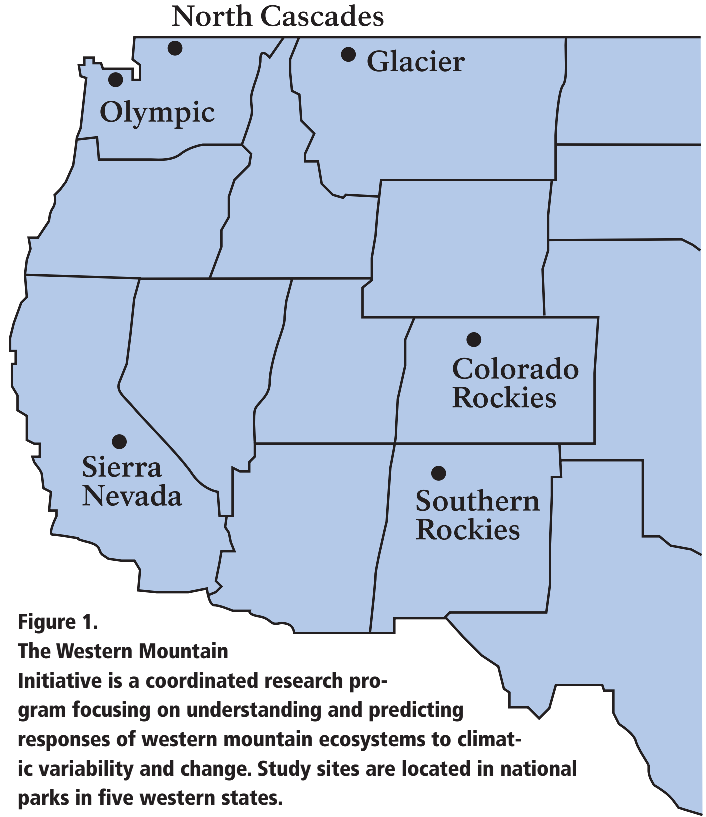


Figure 1.
The Western Mountain Initiative is a coordinated research program focusing on understanding and predicting responses of western mountain ecosystems to climatic variability and change. Study sites are located in national parks in five western states.

Pacific Northwest and northern Rockies

Global change research projects within Olympic, North Cascades, and Glacier national parks (Washington and Montana) joined forces in 1998 to form the CLIMET (Climate-Landscape Interactions on a Mountain Ecosystem Transect) research program. This transect ranges from maritime to continental climates, with striking westside (wet) versus eastside (dry) contrasts at each of the three primary study locations. CLIMET focuses on ecosystem productivity, hydrology, and fire, with empirical studies at a variety of spatial and temporal scales.

Simulation modeling was used to quantify responses of natural resources to climatic variability and change (Fagre et al. 2005), and statistical modeling was used to establish the biophysical "niche" of dominant tree species in the region (McKenzie et al. 2003). Ecosystem models were used to quantify potential major changes in snow distribution, annual watershed discharge, and stream temperature under the warmer, wetter climate for the Pacific Northwest region. For example, if warming continues at the current rate (about 0.16° C or 0.29° F per decade) all glaciers in Glacier National Park are predicted to disappear by 2030 (Hall and Fagre 2003); there were 150 glaciers in 1850, but today only 27 persist (fig. 2, pages 26–27). Modeling also predicts increased productivity in some low-elevation forests, which could generate higher fuel loads that in turn could increase fire severity, particularly in a changing climate (McKenzie et al. 2004).

If warming continues at the current rate ... all glaciers in Glacier National Park are predicted to disappear by 2030.

CLIMET documented growth increases in high-elevation tree species over the past century (McKenzie et al. 2001) and widespread establishment of trees in subalpine meadows (Peterson 1998). This research program also demonstrated strong relationships between regional tree growth patterns and variability of snowpack and drought. Rapid establishment of subalpine fir (*Abies lasiocarpa*) has occurred in meadows in response to reduced snow duration, paralleled by increased krummholz (shrubby tree growth) density at tree line and increased colonization of alpine tundra by upright trees. Major fire years were linked to drought and may be associated with cycles of El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation.

Sierra Nevada

With Sequoia, Kings Canyon, and Yosemite national parks (California) forming the core study areas, the Sierra Nevada project has focused on understanding the effects of changing climate and fire regimes on montane and subalpine forests, combining contemporary ecology (emphasizing natural climatic gradients), paleoecology (emphasizing tree-ring and palynological, or pollen, studies), and modeling. Scientists have found that forests in warmer climates are more dynamic than those in cooler climates, with higher rates of tree birth and death (Stephenson and van Mantgem 2005). Thus, climatic warming might lead to higher forest turnover rates, hence younger forests, with potentially cascading effects on wildlife, biodiversity, and ecosystem services.

Investigations of fire effects on forest pattern and dynamics have led to modifications in prescribed fire programs. Modeling results provided land managers with projections of the consequences of natural fire, prescribed fire, mechanical thinning, and climatic change on Sierra Nevada forests. The project's detailed reconstructions of past fire regimes (Swetnam and Baisan 2003) are now used by land managers to help set targets for restoring fire to mixed-conifer forests.

Central Rockies

Located in Rocky Mountain National Park (Colorado) the central Rockies project has focused on the vulnerability of forest ecosystems, aquatic ecosystems, and hydrology to variability in climate, fire, insect outbreaks, and herbivory by large mammals. Empirical data, modeling, and monitoring have quantified the effects of climatic variability (e.g., ENSO) on fire and insect outbreaks over the past 400 years. Tree line expansion into tundra has not occurred since the mid-1800s, although changes in growth form from krummholz to upright trees have occurred. Old coniferous forests responded to changes in disturbance regimes rather than directly to changing climate. Quaking aspen (*Populus tremuloides*) forests, which have high native plant and insect diversity, are also the vegetation type most heavily invaded by nonnative species (Chong et al. 2001).

Regional climate has responded to changes in land use that add moisture and pollutants to the atmosphere near mountains.

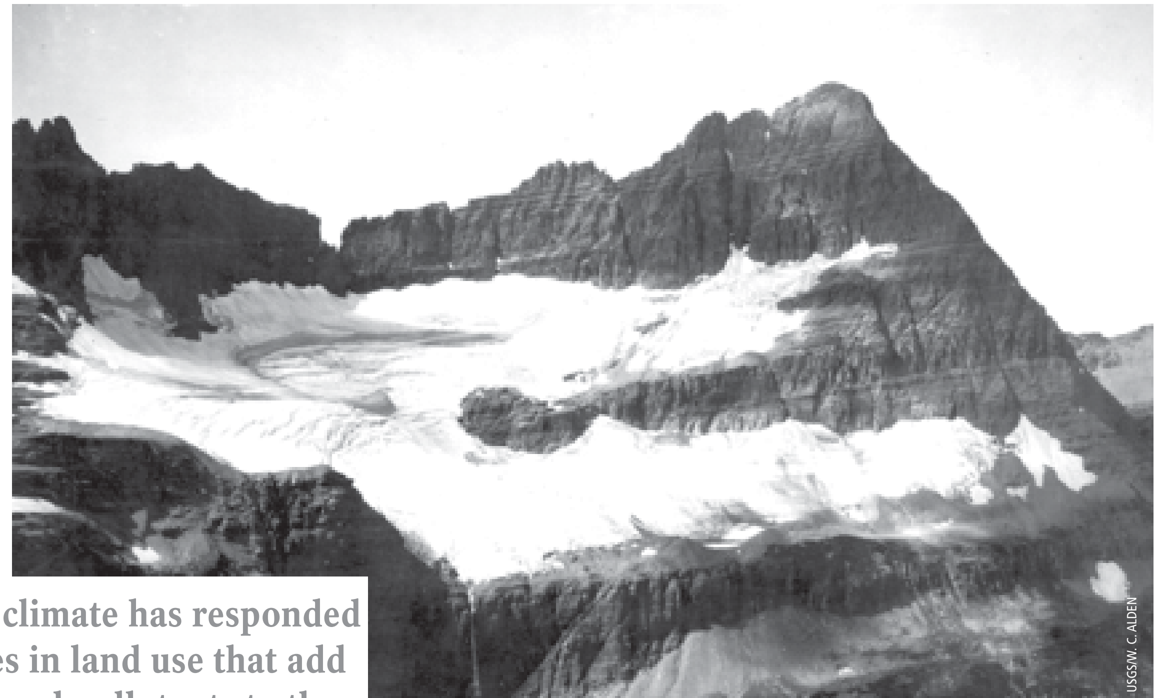


Figure 2. Photographs from 1913 (above) and 2005 (right) vividly illustrate a decline in glacial mass at Shepard Glacier in Glacier National Park, Montana. Modeling conducted as part of the Western Mountain Initiative research project predicts that all park glaciers will disappear by 2030 if the current rate of climate warming continues.

Research has shown that hydrologic systems in the central Rockies are particularly sensitive to variation in temperature and precipitation. Simulations of stream discharge and ecosystem processes show that the timing of snowmelt, though not water volume, is particularly sensitive to climatic warming (Baron et al. 2000a). In addition, regional climate has responded to changes in land use that add moisture and pollutants to the atmosphere near mountains (Baron et al. 2000b). Finally, elevated deposition of atmospheric pollutants, especially nitrogen, has affected the vegetation and soils of some alpine and subalpine ecosystems in the central Rockies.

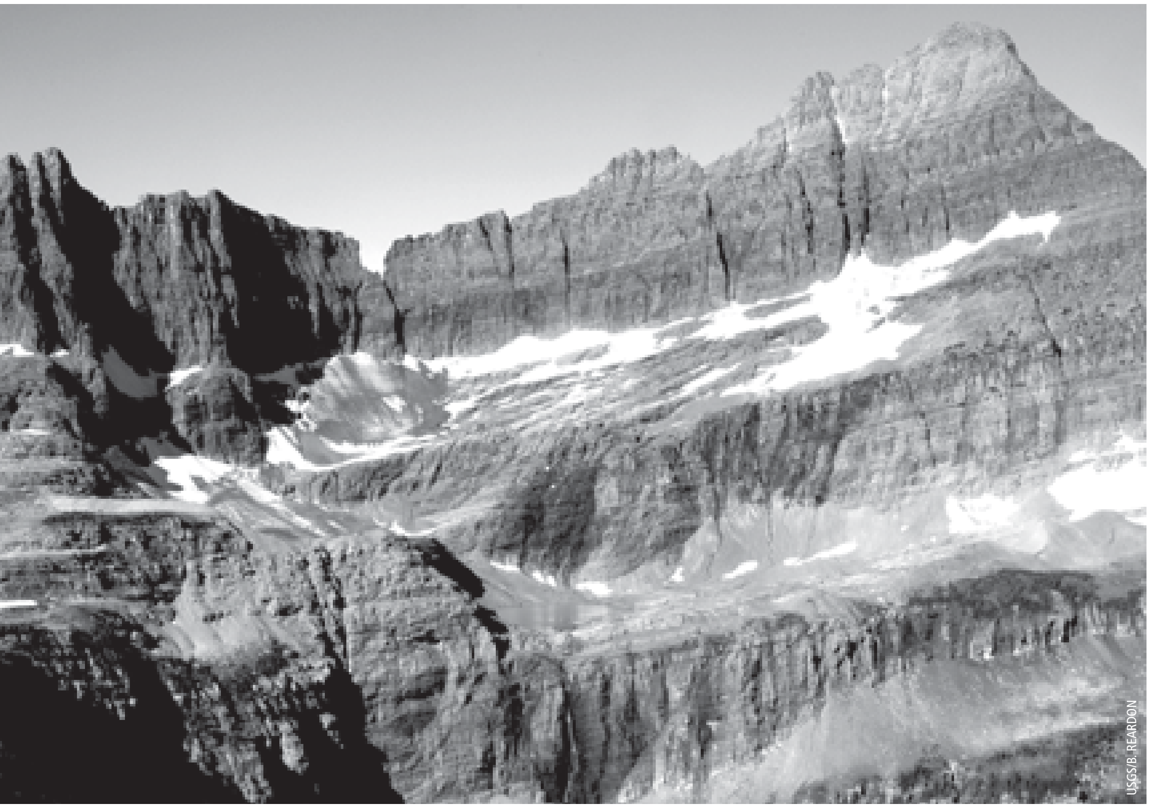
Southern Rockies

Focused on locations in New Mexico and Colorado, the southern Rockies project assesses the sensitivity of semiarid forests and woodlands to climatic change. The project analyzed recent forest dieback caused by past droughts (Allen and Breshears 1998) and extensive dieback of woody plants caused by the extended current drought, which began in 1996 (Breshears et al. 2005) (fig. 3). The dominant vegetation across extensive portions of this region has shifted in just a few years from pinyon pine (*Pinus edulis*) forest to juniper (*Juniperus* species) forest as a result of pinyon pine dieback, with associated changes in understory vegetation and wildlife habitat.

Also in the southern Rockies, tree-ring reconstruction of crown-fire dates revealed strong associations between past droughts and regional-scale surface-fire years. Charcoal deposits from sediment cores recorded abundant evidence of past fires during the Holocene and suggest that the post-1900 cessation of widespread fire is a phenomenon that has not occurred during the past 9,000 years (Allen 2002). Monitoring of responses of vegetation cover and composition, tree growth, water runoff, and surface erosion to interannual climatic variation started in 1991 during the wettest 15-year period of the last millennium. This monitoring has continued through the ongoing severe drought that began in 1996, documenting ecosystem responses to different climatic conditions.

Scientific approach

Building on the strengths of these regionally focused projects, the Western Mountain Initiative emphasizes synthesis across sites and regions. WMI is conducting modeling and cross-site syntheses of long-term data, and sponsors workshops that bring together regional and



USGS/B. REARDON

subject-matter experts. We seek to further improve our mechanistic understanding of how climatic variability and change affect western mountain ecosystems directly (e.g., by affecting plant populations and vegetative productivity) and indirectly (as mediated through altered patterns of ecological disturbance and hydrology). To this end, we organize our work around (1) natural experiments in time, (2) natural experiments in space, and (3) ecosystem modeling in order to best examine responses of western mountain ecosystems to climatic variability and change.

For example, previous WMI studies and other sources have developed proxy reconstructions (natural experiments in time) of past changes in climate, fire regimes, and ecosystem responses that provide an important context for evaluating future trends in climate and natural resources. At millennial time scales, pollen and charcoal in sediments reveal ecosystem responses to widespread and long-term climatic shifts (Whitlock and Anderson 2003). At decadal to millennial time scales, tree rings reveal annual to seasonal changes in climate and fire (Swetnam and Baisan 2003) and consequent trends in populations of forest trees (Swetnam and Betancourt 1998). At time scales of a few years to a century, instrumental records, written records, photographs, and plot data offer fine resolution for mechanistic understanding. Also, quasi-periodic climatic phenomena such as the Pacific Decadal Oscillation (Mantua et al. 1997) and El Niño-Southern Oscillation (Diaz and Markgraf 2000) offer a context for climatic change, particularly when they drive climatic extremes.

The Western Mountain Initiative is a collaboration of scientists whose research focuses on understanding and predicting responses of western mountain ecosystems to climatic variability and change.

Regarding natural experiments in space, our network of research and monitoring sites allows us to generalize across temperature regimes (continental vs. maritime [longitudinal comparisons], warm vs. cool [latitudinal comparisons]), and precipitation regimes (e.g., Mediterranean vs. monsoonal [Sierra Nevada vs. southern Rockies], wet vs. dry [Pacific Northwest to southern Rockies]).

Figure 3. In the southern Rocky Mountains, dieback of around 2.5 million acres (1 million ha) of pinyon pine in 2002–2003 was the result of an extended drought that began in 1996. Researchers with the Western Mountain Initiative have documented a shift in portions of this extensive regional vegetation type toward juniper dominance, with significant implications for wildlife habitat. USGS/CRAIG ALLEN

The network also offers researchers steep elevational gradients that are associated with steep temperature and moisture gradients.

Finally, the RHESSys (Regional Hydro-EcoSystem Simulation) model (Tague and Band 2001, 2004; Band et al. 1993, 1996) provides a framework for organizing our understanding of ecosystem change. This modeling approach relies on empirical data collected in western mountain ecosystems to (1) frame hypotheses based on past modeling results, (2) scale up empirical results, and (3) identify sensitivities of specific mountain landscapes to climatic change (Urban 2000).

Western mountains in the greenhouse: A sense of urgency

The past century has been a period of dynamic change for many western mountain ecosystems. By documenting the past response of natural resources to climatic variability at annual, decadal, and centennial scales we have established an important context for inferring the effects of a warmer climate.

Forest dieback in the southern Rockies and parts of the Sierra Nevada is a particular concern because it signals that long-term drought caused an ecological threshold to be exceeded. Dieback at large scales not only changes the structure of current forests, but may be a precursor to future changes in forest composition and structure. Dieback also alters fire behavior, likely predisposing forests to more widespread or severe wildfires. Insect outbreaks appear to be increasing throughout much of the Rockies and eastern Cascades, causing even more concern about dieback and fire (Logan and Powell 2001).

The effects of a warming climate must be assessed in the context of contemporary land use and other human-caused changes. For example, elevated nitrogen deposition in some western mountains is affecting high-elevation lakes and streams and the aquatic organisms that inhabit them (Fenn et al. 2003). Similarly, oxidant air pollutants transported from the San Francisco Bay area and San Joaquin Valley of California are reducing photosynthesis and productivity in ponderosa pine (*Pinus ponderosa*) and Jeffrey pine (*Pinus jeffreyi*) in the mixed conifer forests in the Sierra Nevada (Bytnerowicz et al. 2003). These findings suggest that natural resources in locations with multiple stresses may be more susceptible to climatic change in the future than those resources in locations that experience few to no such stresses.

Based on empirical data and modeling, we expect several significant changes in western mountain ecosystems during this century. The extent and severity of wildfire will likely increase as a result of increased temperature and drying of fuels (McKenzie et al. 2004), compounded in areas where fuels have accumulated for several decades in the absence of fire. Warmer winters will mean less snowpack, earlier melting, and less water storage as snow during summer, lowering summer streamflows in creeks and rivers and reducing water supply for downstream uses such as irrigation, recreation, and municipal consumption (Stewart et al. 2004). At the current rate of warming, most glaciers will disappear from the northern Rockies and will continue to decrease in the Cascades (Hall and Fagre 2003). Finally, continued warming may alter species composition at upper and lower treelines, as species that are better adapted to the new conditions begin to dominate (McKenzie et al. 2003).

The Western Mountain Initiative has demonstrated the value of long-term research and monitoring in U.S. national parks to detect significant changes over time and their causes—including climate and other factors. It has linked with international efforts to monitor mountain ecosystems, and national parks in the western United States are now contributing to a global network seeking early warnings of the effects of climatic variability and change on natural resources. The activities of the Western Mountain Initiative permit resource managers to be better prepared for a climate altered by greenhouse gases wherever they have high-quality scientific data available to detect changes in the condition of natural resources.

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REMOTE SENSING FOR THE NATIONAL PARKS

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and

Forrest Melton

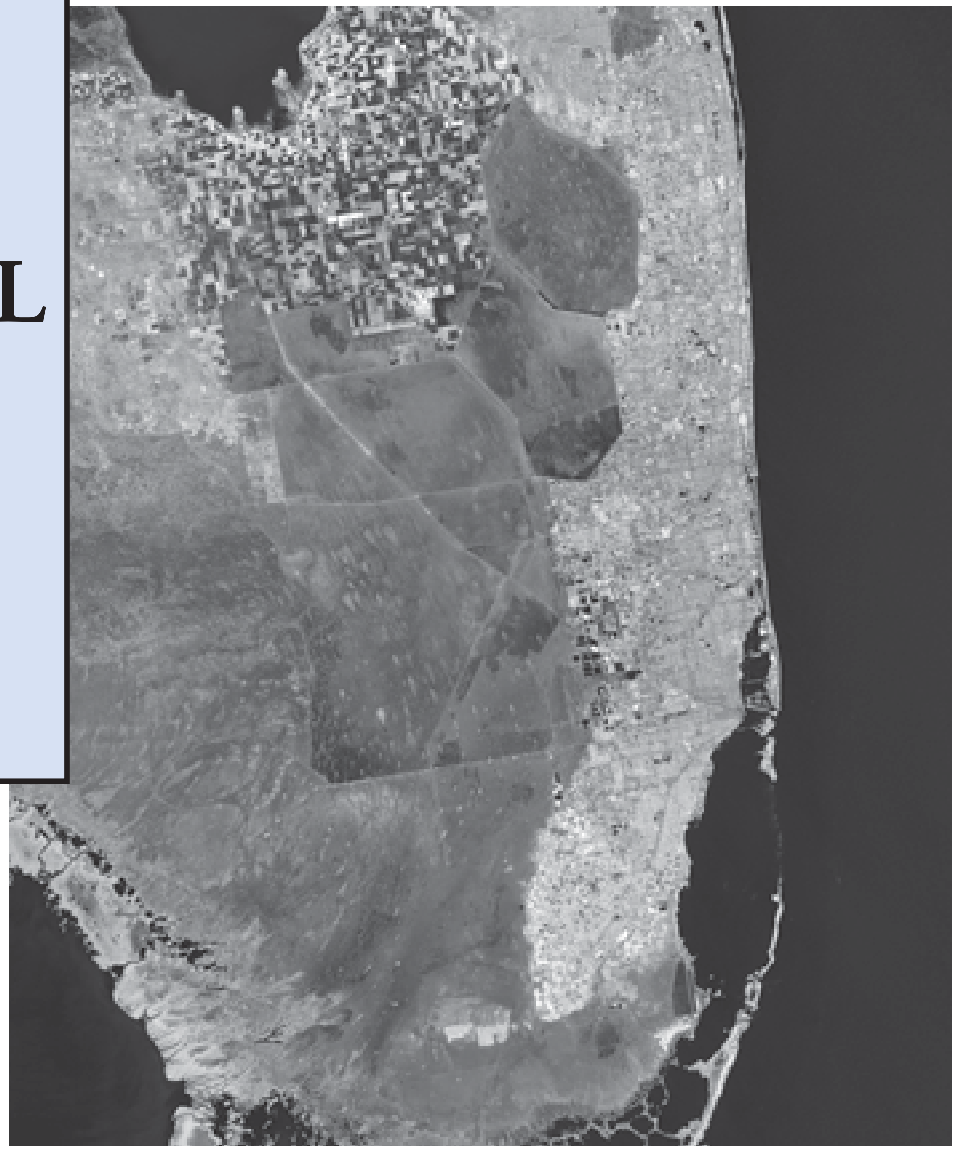

Figure 1. This January 2002 Landsat 7 image of South Florida reveals a variety of land uses and infrastructure in and around Everglades and Biscayne national parks and Big Cypress National Preserve, including farming, water conservation and control, residential development, roads, levees and canals, and the coastal metropolis of Miami-Dade counties. Analysis of a time series of images from sensors on board this and other satellites can assist park managers in detecting changes in land use and ecosystem conditions. LANDSAT 7, OBTAINED FROM THE NATIONAL PARK SERVICE REMOTE SENSING IMAGE ARCHIVE

Remotely sensed data are well established as valuable sources of information for natural resource managers. Now, the accumulation of multi-decadal historical records, implementation of new sensors, and developments in analytical techniques are driving a rapid expansion in the application of remotely sensed data. Time series of images are used to analyze landscape-scale changes in natural resources, while data from high-resolution sensors can be used to detect and quantify small changes in topography, map plant species or even individual plants, or measure flows of nutrients and energy that alter plant growth and affect fire risk (fig. 1). Several recent reviews document the broad range of applications of remotely sensed data to support conservation of biodiversity and ecosystem management, and to evaluate broader issues of land use change (Kerr and Ostrovsky 2003; Turner et al. 2003; Hansen et al. 2004). Some of these applications can directly support monitoring and management needs in units of the National Park System, including high-priority areas of monitoring landscape dynamics, invasive species, and other disturbances.

Remotely sensed data.... can directly support monitoring and management needs in units of the National Park System.

Evaluating landscape dynamics

Habitat loss and fragmentation are continuing threats to biodiversity in parks (GAO 1994). For more than 30 years, Landsat satellites have recorded images of Earth's surface from space, and these images provide a unique decades-long, moderate resolution (at scales of 100–260 ft; 30–80 m) record of land cover change in and around national parks. Hansen et al. (2002) and Parmenter et al. (2003) used LandSat data from 1975 to 1995 to document changes in land cover types in the area of Yellowstone National Park (Wyoming, Montana, Idaho). This multi-decadal record permitted the evaluation of land cover changes caused by natural and human-related processes, including increases in exurban development adjacent to the park and widespread changes to forest structure resulting from the 1988 Yellowstone fires. Development occurred in and near high-quality, low-elevation wildlife habitats that are used by species that also inhabit Yellowstone. Associated field research showed that this development resulted in greater densities of avian brood parasites and predators, leading to diminished reproduction in these "source" habitats (Hansen and Rotella 2002). Similarly, Narumalani et al. (2004) used a combination of aerial photography and satellite imagery to map land cover in and near Effigy Mounds National Monument (Iowa) from the 1940s into the 1990s. This time series revealed periodic changes in the structure and composition of habitats outside the national monument, such as conversion of forest to pasture, while habitats inside it remained relatively unchanged.

With existing data sources, similar analyses could be conducted for most parks. The National Park Service is a member of the Multi-Resolution Land Characteristics Consortium (MRLC) and contributed to the purchase and processing of Landsat imagery of the conterminous United States from about 1992 and of the United States (including Alaska and Hawaii) and Puerto Rico for 2001 (http://www.mrlc.gov/index.asp). MRLC processed the imagery and applied algorithms to classify each pixel and thereby create maps of derived products. These products—including maps of vegetation type, impervious surface, and forest cover—are available for all national parks via the Natural Resource GIS Program (http://science.nature.nps.gov/nrgis/). A separate collaboration by NASA and the U.S. Geological Survey (USGS) purchased global sets of Landsat imagery (the GeoCover dataset) from multiyear periods around 1975, 1990, and 2000. More than 15,000 of these images have been geographically corrected (orthorectified) to allow users to overlay images from different dates and thus simplify the detection of land cover change. These images are available from http://edc.usgs.gov/products/satellite.html. Though they have not been converted into maps or other derived products (as in the case of the MRLC), they nonetheless represent a unique global data set spanning three decades of change. Landsat images provide managers with a tool to place current park land cover in historical context, one that can sometimes be further extended by incorporating historical aerial photography and ground-based photos in the analysis.

Landsat images provide managers with a tool to place current park land cover in historical context.

High-resolution commercial satellite images, with pixel sizes of 2 to 13 ft (60 cm to 4 m), provide a similar resolution, less-expensive alternative to aerial photography for some uses. Goetz and collaborators (2003) used Space Imaging Corporation's IKONOS satellite imagery to determine the percentage cover of impervious surfaces, trees, and riparian buffer zones for a large area (507 sq mi; 1,313 sq km) near Washington, DC. Using a combination of manual and automated ("unsupervised") classification techniques, they achieved mapping accuracies that exceeded 80%, equal to maps produced by more costly manual classification of aerial photographs. Because the mapped landscape characteristics were functionally and statistically correlated with water quality in small watersheds (Snyder et al. 2005), these maps also are suitable for evaluating landscape characteristics that directly influence the quality and quantity of water that enters units of the National Park System in the Washington, DC, area.

A future use of high-resolution satellite imagery may be to survey animal populations. Initial studies have demonstrated the feasibility of this approach (Laliberte and Ripple 2003), and in 2006 NASA is supporting a field evaluation of the use of QuickBird imagery from Digital Globe, Inc., imagery to count elk and bison adjacent to Grand Teton National Park (Wyoming).

A future use of high-resolution satellite imagery may be to survey animal populations.

The NPS Inventory and Monitoring networks identified landscape-scale disturbances as a high priority for monitoring, but resources often limit the ability of the networks to deploy a ground crew to measure even the most basic attributes, such as area, of a major disturbance. Remotely sensed images are routinely used by news media to report on national and international disasters like the 2004 tsunami in Indonesia or the 2005 flooding of New Orleans. Parks are regularly affected by small and large disturbances and, in these situations, "emergency" requests for data acquisition can be submitted to obtain no-cost ASTER (45-ft or 15-m resolution) imagery. The procedure for emergency acquisition of imagery varies among commercial vendors. QuickBird satellite images, for example, can be requested at any time, and if the satellite is not allocated to a conflicting task, the images will be archived and made available for purchase in the future. High-resolution IKONOS images also can be acquired by making a more detailed request to Space Imaging Corporation.

Parks are regularly affected by small and large disturbances and … "emergency" requests for data acquisition can be submitted to obtain no-cost ASTER … imagery.

Because fires are a common source of disturbance and are an important driver of vegetation state and condition, an interagency project is drawing from the archive of Landsat images to create a fire atlas for all major fires (greater than 500 acres [202 ha] in the East, and 1,000 acres [404 ha] in the West) that have occurred in the

United States since 1982. The project collaborators will use these Landsat images to develop maps of fire severity and to more accurately map fire perimeters in national parks. This information is necessary to report burned area by severity class and to evaluate current land condition, and as a step toward achieving land health goals of the U.S. Department of the Interior. On a much finer time scale, the USDA Forest Service uses data from the MODIS instrument to map active U.S. fires each day. Current maps can be viewed on the Internet at http://activefiremaps.fs.fed.us/activefiremaps.php.

A huge potential exists for remote sensing data to contribute to monitoring and managing invasive plants.

Finding and mapping invasive plants

A huge potential exists for remote sensing data to contribute to monitoring and managing invasive plants, and the National Park Service and its collaborators are slowly accumulating successes such as identifying and mapping the widespread invasive plant cheatgrass (*Bromus tectorum*). Cheatgrass has invaded and threatens many national parks in the West, creating major ecosystem-level impacts through competition with native species and by changing fuel loads and fire patterns. The timing of green-up and senescence (the period of maturity to death) for cheatgrass differs from that of native vegetation, and cheatgrass is therefore easily detected using remotely sensed data (Peterson 2005).

Individual plant species have been most successfully identified from data collected by hyperspectral sensors—sensors that measure a high number of contiguous spectral bands. Usually mounted in aircraft, these sensors have both a high spectral and spatial resolution (variable, but typically 1–100 ft; <1–30 m)—and a high cost for data acquisition and analysis. An exception is the Hyperion hyperspectral sensor, which is satellite-borne and generates data with a moderate (100 ft; 30 m) resolution. Hyperion data were used to successfully detect small infestations, and even individual trees, of the invasive species Chinese tallow (*Triadica sebifera*, fig. 2), a pest in many parks in the Southeast (Ramsay et al. 2005). Use of this technique for other species would greatly enhance the ability of the National Park Service to economically use moderate resolution hyperspectral data to detect new plant infestations.

Most invasive species work focuses on locating, mapping, and managing invasive species. However, researchers and resource managers also need to understand how invasive plants impact and alter the functioning of natural ecosystems. Gregory Asner of Stanford University, working with data collected by the NASA AVIRIS (Airborne Visible/Infrared Imaging Spectrometer) hyperspectral sensor in Hawaii Volcanoes National Park, estimated leaf area and levels of plant water and nitrogen in a 3,360 acre (1,360 ha) area near the summit of Kilauea Volcano in Hawaii Volcanoes National Park. These plant attributes allowed for the remote detection of stands of the invasive Canary Island tree *Myrica faya* and of patches of the invasive herb Kahili ginger (*Hedychium gardnerianum*) that exists in the understory (Asner and Vitousek 2005). Understory vegetation is normally invisible to conventional remote sensing techniques; however, detection of both invasive plant species was possible due to their effects on water and nitrogen levels in the forest canopy, which were observed by remote sensing. Thus, the remotely sensed data and associated model identified the locations of both the invasive canopy and understory species. This method also enabled the assessment of the impacts of these exotic species on forest water and nitrogen cycles.

Figure 2. Highly invasive Chinese tallow trees, pests in many national parks in the southeastern United States, can be distinguished from native vegetation using economical, satellite-borne sensors. The strong spectral contrast of tallow trees (appears red in original but is shown by arrow here) permits the use of moderate resolution (98 ft; 30 m) sensors, such as Hyperion, to identify trees or infestations. See Ramsey et al. 2005. COURTESY OF CHERYL MCCORMICK, UNIVERSITY OF GEORGIA

Ecosystem models help with management

A powerful use of remotely sensed data is to generate and test predictions of ecosystem dynamics through models. Examples of such synergism include dynamic predictions of snowpack, streamflows and water temperatures, soil moisture, fuel loads and fire risk, and nutrients in pristine and polluted watersheds (White et al. 1998; Fagre et al. 1997). Models are excellent tools for mitigating environmental risks and evaluating management decisions in an uncertain ecological setting. Models allow resource managers to assess the behavior of ecosystems in response to a variety of factors that are internal (e.g., fire, tree blowdown, erosion) and external (e.g., interannual, decadal, and long-term climate change) to a park. Ecosystem models that rely heavily on remotely sensed data have traditionally been retrospective, intended for use in understanding how various pieces of ecosystems fit together (Tague and Band 2004). With the advent of new technology, many of these models can now be run in both near real-time and forecast modes that use present conditions to initialize simulations that evolve from one week to as much as a century into the future (fig. 3) (Nemani et al. 2003).

Models are excellent tools for mitigating environmental risks and evaluating management decisions in an uncertain ecological setting.

Scientists at the NASA Ames Research Center and their collaborators have created the Terrestrial Observation and Prediction System (TOPS, http://ecocast.arc.nasa.gov). This data and modeling software system brings together technologies in information technology, weather and climate forecasting, ecosystem modeling, and satellite remote sensing to inform management decisions related to floods, droughts, forest fires, human health, and crop, range, and forest production. TOPS automatically integrates and preprocesses remotely sensed data from a variety of sensors so that land-surface models can be run in near real-time to provide ecological forecasts.

TOPS incorporates ecosystem models that predict vegetation growth and standing biomass, snowpack dynamics, nitrogen and phosphorus cycling, fire behavior (e.g., FARSITE model), and soil moisture. This software can access, process, and convert imagery from MODIS, Landsat Thematic Mapper, ASTER, and IKONOS satellite sensors into biophysical variables such as canopy cover, leaf area index, and fraction of absorbed radiation, and use these variables to perform ecosystem simulations

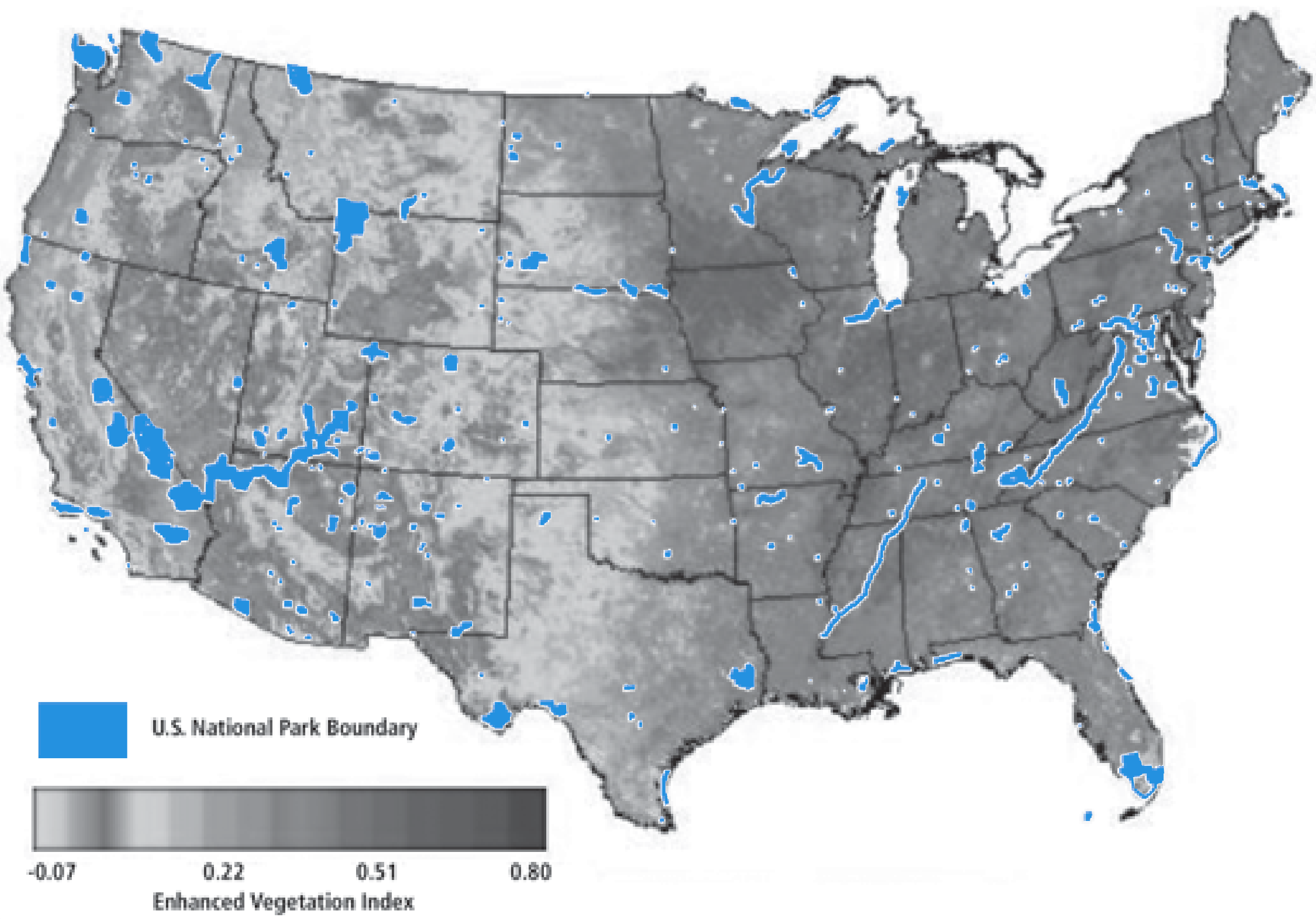

Figure 3. Ecological models allow data from satellite, suborbital, and ground sensors to be integrated to provide continuous monitoring of ecosystem conditions within all U.S. national parks. For example, this 8-km- (5-mi) resolution enhanced vegetation index (EVI) dataset from 22 August 2005 can easily be subset for each of the park boundaries to provide near real-time assessments of vegetation conditions within each park. A full-color version of this figure is available from the *Park Science* Web site. COURTESY OF FORREST MELTON, NASA AMES ECOLOGICAL FORECASTING LAB

at spatial resolutions ranging from 12 ft (4 m) to 3,300 ft (1,000 m) (fig. 4). Similarly, TOPS modeling software also provides ready access to a variety of standard MODIS products (table 1) such as fire occurrence, snow cover, and vegetation productivity.

Through a NASA-NPS collaboration, TOPS is used at Yosemite National Park (California) at 30-m and 1,000-m resolutions to produce real-time measures of conditions and forecasts of ecosystem variables including snowpack, soil moisture, and streamflows (fig. 5). Hydrologic models, such as the Regional Hydro-Ecologic Simulation System (RHESSys), have been used with TOPS for a subset of watersheds in Yosemite. Retrospective analyses conducted to date have accurately modeled peak streamflows in the upper Merced River watershed, and may provide another means of forecasting floods in the park. Thermal anomaly data (MOD-14) from the MODIS instrument are also processed by TOPS to provide a real-time monitoring capability for wildfires that occur within and adjacent to park boundaries. Future plans at Yosemite include using the TOPS framework to explore the impact of invasive species on biogeochemistry, and the impacts of climate change and variability on species distribution and fire risk. The successful implementation and routine use of TOPS products at Yosemite could serve as a model for integrating ecosystem models with satellite data for decision making in national parks throughout the country.

NASA-NPS partnerships

NASA and the National Park Service signed a memorandum of understanding in January 2005 to enable interagency partnerships using NASA's imagery and technological expertise to help the Park Service better address its management goals. Under this agreement the National Park Service and NASA have cosponsored a workshop focused on park resource monitoring needs (http://science.nature.nps.gov/im/monitor/meetings/StPetersburg_05_rs_pa/rs_pa_wrkshp_proc.cfm), begun to implement TOPS in prototype national parks, and completed a NASA-sponsored intern program that used Landsat images to monitor postfire vegetation change in Yosemite. In addition, NASA is funding several large studies specifically focused on NPS needs. These studies will use remote sensing information to identify burned areas at high risk to invasive plants, improve monitoring of land cover change in and around national parks, and improve our understanding of the consequences of land cover change on energy and water cycles. NASA also will assist park education and interpretation specialists by developing dynamic visualizations and means to communicate results of its research.

The trend for the future is clear: park managers will increasingly use remote sensing data. This trend will be driven by improved remote sensing technology and decreased costs, improvements in

The trend is clear: park managers will increasingly use remote sensing data.

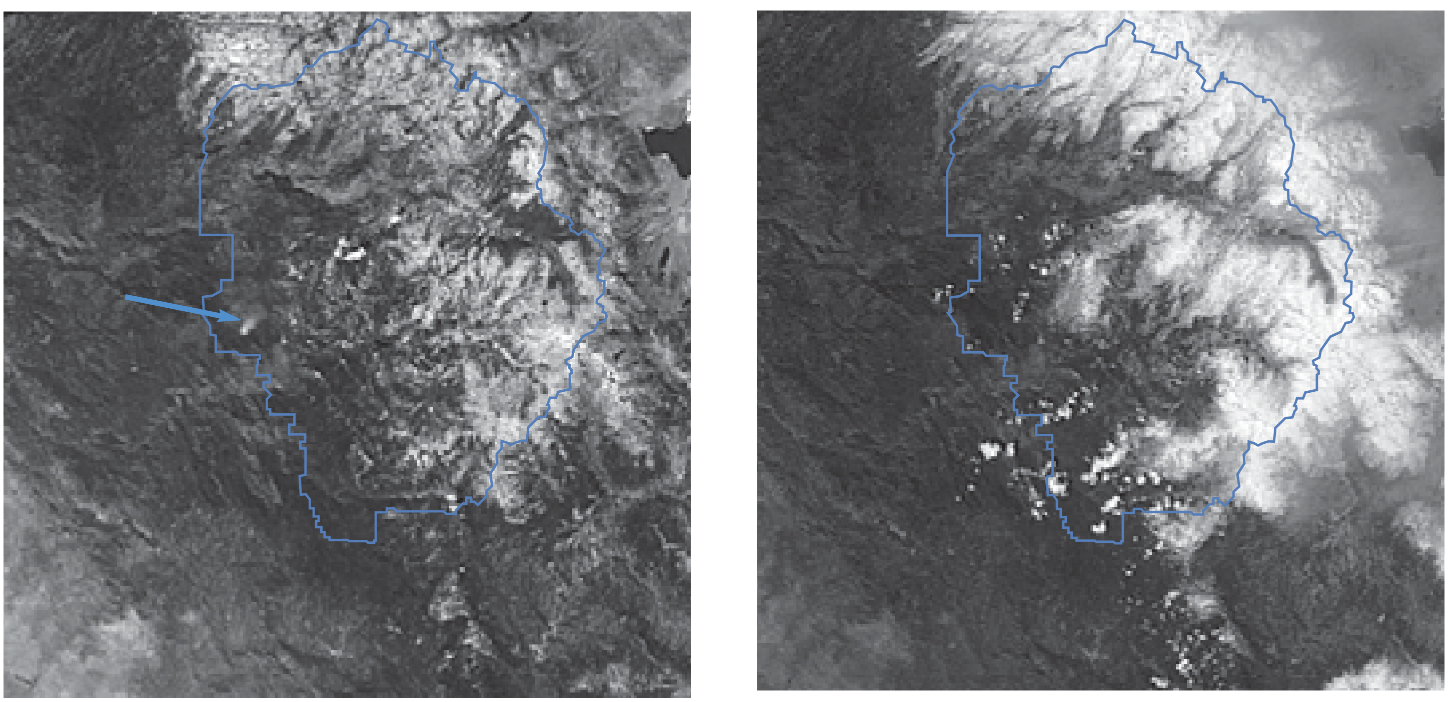

Figure 4. Satellite and suborbital sensors provide information on ecosystem conditions at a range of resolutions and scales. Using systems like TOPS, these 250-m (820-ft) resolution MODIS Direct Broadcast images of Yosemite National Park in California can be delivered to park personnel within hours of data capture onboard the satellite, providing an immediate snapshot of parkwide conditions for use in monitoring events such as the 14 September 2005 fire (left, arrow) and the extent of snow cover on 4 June 2006 (right).

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Table 1. Examples of satellite sensors most commonly used for ecological studies, and typical applications that are useful to protected-area managers

Application	Sensor / Cost[1]	Resolution[2] (m)	Description	Example application
Land cover, vegetation types, water quality	QuickBird $$ IKONOS $$ SPOT $ ASTER * TM/ETM $	<1–3 1–4 2.5–20 15 30	Directly measure surfaces in black and white (panchromatic) or multi-spectral images. Panchromatic images are higher resolution but without color needed to distinguish many features.	Hansen et al. 2002, 2004. Goetz et al. 2003, Homer et al. 2004, Peterson 2005
Individual species or species composition	IKONOS $$ QuickBird $$ Hyperion $ AVIRIS $$$	1–4 <1–3 30 <1	High spatial or high spectral resolution is necessary to distinguish small or unique objects. AVIRIS is airborne and is very expensive. Hyperion and AVIRIS are hyperspectral sensors.	Asner and Vitousek 2005, Ramsey et al. 2005
Phenology, land condition, snow cover, current fires, seasonality	MODIS * AVHRR * SPOT Veg $	250–1,000 1,000 1,000	High revisit frequency is most suitable for near real-time monitoring of phenological changes, fires, and similar events.	Reed et al. 2003, Justice et al. 1998
Water quality—chlorophyll, turbulence, color	MODIS * AVHRR * SeaWiFs *	250–1,000 1,100–4,000 1,100–4,500	Very high revisit rates permit daily or more frequent monitoring of sediment or smoke plumes, red tides, upwellings, dust storms, etc.	Warrick et al. 2004, Justice et al. 1998
Topography	Lidar $$$ QuickBird $$ IKONOS $$ SPOT 3D $$	<1 vertical <1–3 1–4 16	To create high-resolution digital elevation maps. Lidar is an active radar with a vertical resolution of <1 ft (30 cm).	Lefsky et al. 2002

Note: The table illustrates only a few typical applications. See Turner et al. (2003) or Faundeen et al. (2004) for more complete reviews of sensors and their uses.

[1] * = some or all products available at no cost, $ = inexpensive (<$2/sq mi), $$ moderate cost, $$$ very expensive.

[2] Higher resolutions are generally panchromatic (black and white) and lower resolutions are multi-spectral.

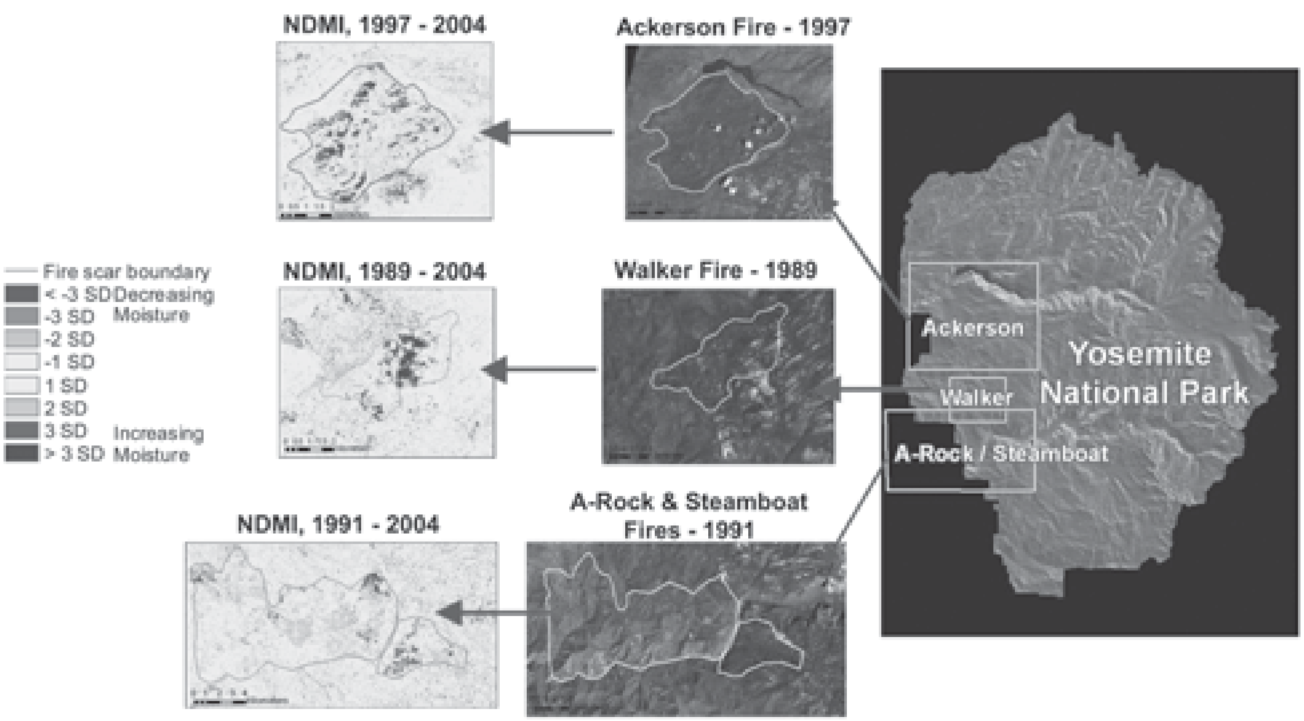

Figure 5. Satellite data can be used to monitor long-term ecosystem response to disturbance. For example, Landsat data have been used to monitor ecosystem conditions following three major fires in Yosemite National Park, revealing a consistent increase in vegetation moisture following fire occurrence. Fire boundaries are determined using Landsat scenes collected after the fire in which the fire scars are clearly visible. The normalized difference moisture index (NDMI) was calculated using a time series of Landsat scenes, and the cumulative change in NDMI from the date of fire occurrence through 2004 is shown for each fire. A full-color version of this figure is available from the *Park Science* Web site.

COURTESY OF M. SYFERT, J. RUDY, L. ANDERSON, J. JENKINS, AND C. CLEAVE / NASA AMES DEVELOP analytical techniques, and ever stronger relationships among the National Park Service, NASA, and the remote sensing community.

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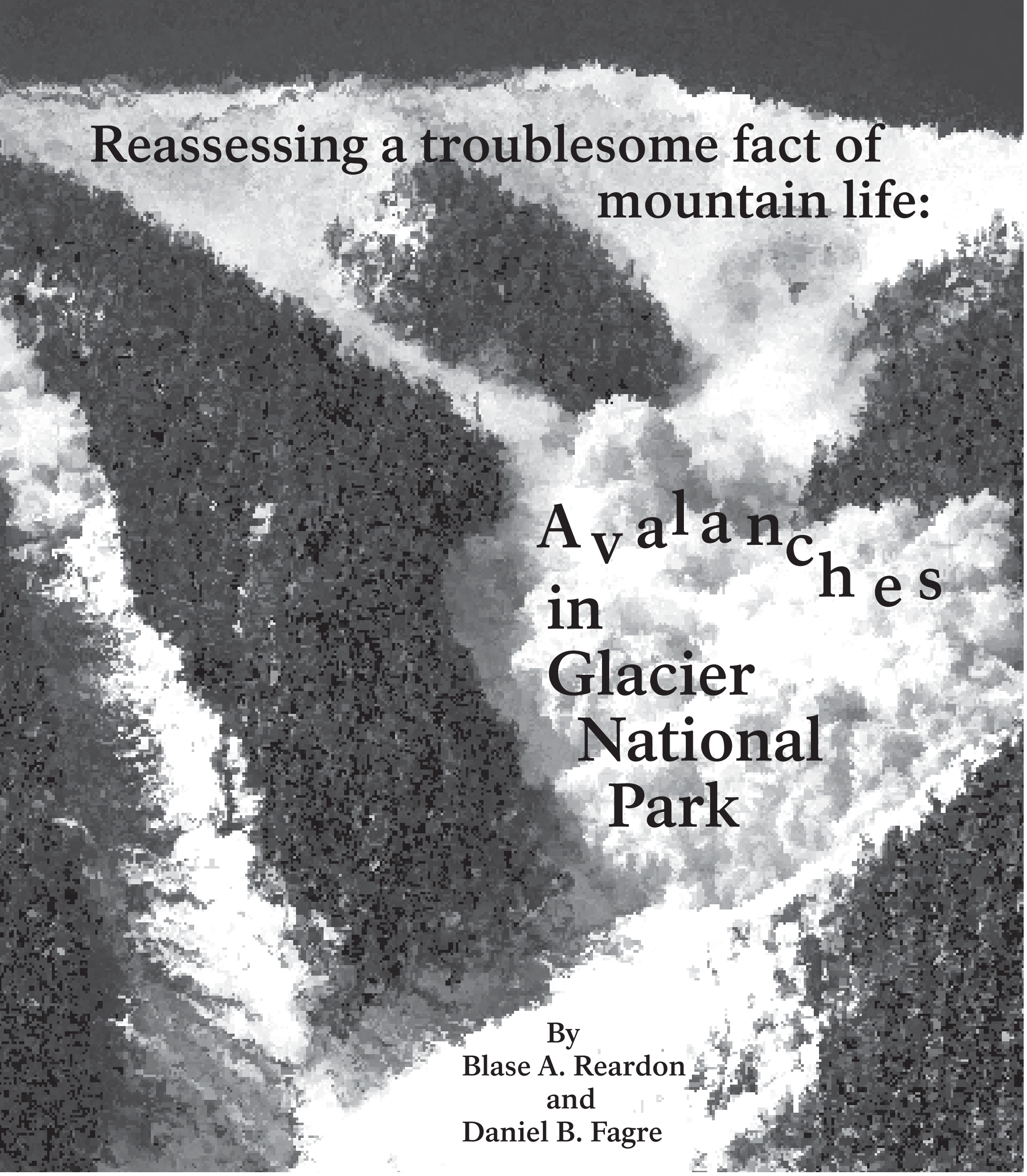

Reassessing a troublesome fact of mountain life:

Avalanches in Glacier National Park

By
Blase A. Reardon
and
Daniel B. Fagre

Figure 1 (above). The avalanche research has focused on two transportation corridors in Glacier National Park: the Going-to-the-Sun Road that bisects the center of the park, and John F. Stevens Canyon, at the park's southwest corner.

LEFT, PHOTO OF LARGE SLAB AVALANCHE NEAR RED MOUNTAIN PASS, COLORADO, BY TIM LANE; SOURCE: COLORADO AVALANCHE INFORMATION CENTER; MODIFIED BY NPS

For the past decade, our U.S. Geological Survey (USGS) research team has rummaged through Glacier National Park's archives looking for records of snow avalanches. Our searches have paid off. We have found photographs that show snow avalanches blocking progress during the annual spring opening of the famed Going-to-the-Sun Road, ranger logs that describe cabins and telephone lines destroyed by avalanches, and superintendents' reports that recount avalanche accidents that killed employees or visitors. Recently, we have combined these historical sources with field studies to investigate whether snow avalanches in the park may be more cyclical than random and as much an ecological process as a natural hazard. Our ongoing research in Montana has yielded relevant information for park managers elsewhere who deal with avalanche threats to park infrastructure and for ecologists seeking a better understanding of how mountain ecosystems function.

Springtime avalanches can bury workers or push equipment off the road and over cliffs.

Our research has focused on two transportation corridors: the Going-to-the-Sun Road that bisects the center of the park, and John F. Stevens Canyon, at the park's southwest corner (fig. 1). The Going-to-the-Sun Road is the park's most visited attraction; deep snow and avalanches force the road's closure each winter, and in spring, park crews dig it out using bulldozers and other heavy equipment (fig. 2, page 38). Springtime avalanches can bury workers or push equipment off the road and over cliffs (figs. 3a and b, page 38), as happened in 1953, when two workers died. Our research started with a study of how interannual variations in snowfall and avalanches affect the road opening. The initial study helped park managers predict and plan for the road opening in spring and respond to the many topical questions from park visitors and locals. More recent studies have focused on determining the conditions that create springtime avalanches, which are a

NPS/MARK DUNDAS

Figure 2 (left). The annual spring opening of Going-to-the-Sun Road in Glacier National Park is complicated by deep snow and avalanches, which affect the speed and safety of road-clearing crews. Research at the park has improved avalanche and road-opening forecasts and led to a greater understanding of the climatological conditions that can set off these powerful ecological disturbances.

poorly understood aspect of the avalanche phenomenon.

Relating climate to avalanche patterns

The research has culminated in a partnership between the National Park Service and U.S. Geological Survey to improve the safety of the snow removal crews while providing data for long-term studies of avalanche-climate relationships. During spring opening operations, Glacier National Park Meteorological Technician Mark Dundas and USGS Physical Science Technician Blase Reardon dig snow pits and analyze data from three ridge-top weather stations to issue a daily avalanche hazard forecast for the park snow removal crews. The two technicians also maintain an extensive database of weather and snow conditions and avalanche occurrence. Combining those data with historical data has allowed us to start examining the climate patterns that create the springtime avalanches. In spring 2006, we provided avalanche and meteorological data for a study by the USDA Forest Service National Avalanche Center that investigated wet-snow avalanches and weather patterns in snow climates ranging from Alaska to Colorado and Norway.

In Stevens Canyon, wintertime avalanches can disrupt traffic on the only year-round transportation routes across the northern Rockies—U.S. Highway 2 and the Burlington Northern-Santa Fe Railroad. The highway and railroad run through or adjacent to the Glacier National Park boundary and, significantly, in the runouts of numerous avalanche paths that lie within the park. Using data from mountaintop weather stations, we have investigated a distinct weather pattern that creates these avalanches—bitter cold temperatures and heavy snowfall followed by rapid

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Figure 3a (center). Debris from a large slab avalanche pounds Going-to-the-Sun Road at Glacier National Park in April 2003. This type of avalanche results when a cohesive plate of snow breaks loose from underlying snow or earth and begins moving downslope. In figure 3b (left), researchers and forecasters investigate the fracture line of the slab avalanche several thousand feet above the spectacular park road.

warming. Descriptions of that pattern appear frequently in the historical records of avalanche incidents in the canyon; the earliest is a 1910 report by the Weather Bureau (now the National Weather Service) that details the temperatures and precipitation leading to several avalanche cycles in Stevens Canyon. It is one of the earliest scientific examinations of the weather precursors to avalanches in the United States. Our investigations build on the historical knowledge by quantifying the factors that combine for a dramatic avalanche cycle in Stevens Canyon: average snowfall amounts, typical snow depths, typical temperatures, and number of avalanches. Still, one ranger's frank but unscientific comment in a 1961 log may sum up the pattern most succinctly: "We had rain last night, and hell this morning."

In the course of our research we compiled a century-long record of natural avalanches caused by that pattern. That record has led to additional studies. It is one of the longest, most complete records of natural avalanches available. Most avalanche data are from sites where avalanches are controlled, either with skier compaction or explosives. The fact of avalanche control means you cannot compare avalanche frequency data from those sites with long-term climate records to see how avalanches and climate relate like you can in Glacier. We noticed that the Stevens Canyon record alternates between decade-long periods when avalanches disrupted transportation in the canyon most winters, often multiple times a winter, and periods when avalanches rarely occurred. Most periods of frequent, large-magnitude avalanches correspond with cool phases of the Pacific Decadal Oscillation, a low-frequency climate oscillation involving sea surface temperatures and atmospheric pressure near the Aleutian Islands and along the Pacific Northwest coast.

Ecological effects of avalanches

As an ecologist, Dan Fagre is ultimately interested in avalanches for their effects on the park's mountainous landscape. Avalanches are a natural disturbance like fire. There are avalanche paths on most slopes across the park, and the forests on those slopes are much more complex than forests on slopes undisturbed by avalanches (fig. 4). Large, infrequent avalanches can uproot and snap old trees, leaving openings in mountain forests. Smaller, more frequent slides maintain those openings by destroying slow-growing trees but leaving fast-growing trees and shrubs such as aspen, birch, and alder. The result is greater vegetation diversity and more ecotones—edges between ecological communities. More ecotones means more diverse habitat for wildlife, especially ungulates and birds. We believe the climate patterns that influence the frequency of natural avalanches in the park have broad, long-lasting ecological effects, so any climate changes that alter the frequency or magnitude of natural avalanches will in turn change the forests in the park.

Recently, with our collaborators, we have turned to tree-ring studies to complement our historical research. Trees injured by avalanches respond with scars, reaction wood, or other growth anomalies that can be dated. The tree rings record nearly twice as many avalanches as appear in the historical documents, enabling us to conduct higher-resolution studies of avalanche-climate relationships. The data confirm the association between avalanche frequency and the Pacific Decadal Oscillation we see in the historical record. Though our work continues, our initial results have helped Glacier's managers address avalanche hazards in the park. The park is completing an environmental impact statement (EIS) analyzing a proposal by the railroad to use explosives to mitigate avalanche hazard in Stevens Canyon. The EIS team has used the avalanche history compiled by our USGS research team to assess the extent and frequency of the hazard in the canyon. Such immediate management application for research results is uncommon and rewarding.

Figure 4. Like fire, avalanches are a powerful natural force that shapes forest communities at Glacier National Park. Able to uproot and break trees, they disturb forest continuity, encourage greater plant diversity, and increase the amount of edges among habitats. USGS/BLASE REARDON

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Effects of White-tailed Deer on Vegetation Structure and Woody Seedling Composition at Manassas National Battlefield Park, Virginia

By Bryan Gorsira, C. Reed Rossell Jr., and Steven Patch

Introduction

Manassas National Battlefield Park is located on the northern tip of the Piedmont Plateau, within the Culpepper Basin, a large Mesozoic trough extending north from the central Piedmont (Fleming and Weber 2003). The park is located approximately 4 km (2.5 mi) northwest of Manassas, Virginia, and 42 km (26 mi) west of Washington, DC. The park comprises 2,111 ha (5,212 acres) of which 839 ha (2,073 acres) are forest, varying from early successional stands of Virginia pine (*Pinus virginiana*) to relatively mature oak-hickory and bottomland hardwood forests (Fleming and Weber 2003). Hay fields, abandoned fields, and a high-use administrative area account for 1,215 ha (3,000 acres) of the park. The mosaic of woodlands and fields is ideal habitat for white-tailed deer (*Odocoileus virginianus*, fig. 1). Lands adjacent to the southern and eastern boundaries of the park consist of

The mosaic of woodlands and fields is ideal habitat for white-tailed deer.

residential areas; for now, lands adjacent to the western and northern boundaries of the park remain relatively undeveloped. Development is proceeding at a rapid pace and the battlefield park is becoming an oasis. White-tailed deer densities in the park are high, at about 1 deer per 4 acres (63.4 ± 7.7 deer/km^2, estimated in fall 2000–2004 using spotlight counts with distance sampling; Bates 2005). All forests within the park have a prominent browse line (fig. 2).

types, white-tailed deer can negatively affect forest stand development by reducing growth and survival rates of tree seedlings and saplings, and preventing adult recruitment into tree populations (see review by Russell et al. 2001). Research also suggests that white-tailed deer may cause irreversible shifts in successional stable-state forest communities by altering the species composition of plant communities (Stromayer and Warren 1997, Augustine et al. 1998).

Figure 2. A prominent browse line is evidence of a dense population of white-tailed deer at Manassas. Browsing by deer may be affecting shrubs and herbs in the forest interior to levels that may be detrimental to wildlife species that depend on thick understory vegetation to thrive. NPS/BRYAN GORSIRA

Background

White-tailed deer are at historically high densities in most of the eastern United States (McCabe and McCabe 1984). In some areas, deer densities are estimated to be two to four times higher than pre-European settlement densities (Redding 1995, Van Deelen et al. 1996). Deer density in the park is approximately 63.4 deer/km^2 (~~24.5~~ deer/mi^2) (Bates 2005), which greatly exceeds the estimated carrying capacity of 15.4 deer/km^2 (~~5.9~~ deer/mi^2) for the Virginia Piedmont (Whittington 1984).

The primary factor determining the magnitude of white-tailed deer effects on vegetation is density of deer in an area (Tilghman 1989, Stromayer and Warren 1997, Russell et al. 2001). A substantial amount of research evidence suggests that for some community

The tolerance of a plant community to browsing may vary within community types and among … regions.

Figure 1 (left). Abundant in many parts of the eastern United States, white-tailed deer are a management concern at Manassas National Battlefield Park in Virginia. Recent research at the park measured the effects of white-tailed deer on three forest plant communities, documenting changes in forest structure and succession. NPS/BRYAN GORSIRA

Effects of browsing, however, do not appear to be consistent across the range of white-tailed deer (Russell et al. 2001). For example, some studies detected no effects of white-tailed deer on plant survival and growth, or found only sporadic effects during some years and seasons, for particular sites, or for some deer densities (Russell et al. 2001). The tolerance of a plant community to browsing may vary within community types and among physiographic regions because of differing abiotic and biotic factors of the environment (Mladenoff and Stearns 1993, Augustine and McNaughton 1998, Liang and Seagle 2002). The objectives of our study were to investigate and compare the effects of browsing by white-tailed deer on the vegetation structure and woody seedling composition in three forest types. In particular, we were interested in the effects deer might be having on the succession of the forests in Manassas National Battlefield Park.

Deer exclosures

We compared the effects of deer browsing on three forest types in the park for five years from 2000 to 2004. The forest types studied were oak-hickory, Virginia pine-eastern red cedar (*Juniperus virginiana*) successional, and Piedmont/mountain bottomland, as described by Fleming and Weber (2003).

We collected vegetation data from 10 exclosures (2 x 6 m; 6.6 x 19.7 ft) and 10 control plots in each forest type from June to August each year of the study. Exclosures (fig. 3) were constructed in June 2000 and consisted of welded wire fence, 2 m (6.6 ft) tall, with mesh openings (5 x 10 cm; 2 x 4 in) that facilitated the passage of small mammals. Within the center of each exclosure, we established a vegetation plot (1 x 4 m; 3.3 x 13.1 ft) using metal stakes at each corner. An adjacent control plot (1 x 4 m; 3.3 x 13.1 ft) was paired with each exclosure and located 1 m (3.3 ft) from the side opposite the exclosure entrance. All exclosures were randomly located in and among forest types using a random location generator within ArcView 3.1 (Environmental Systems Research Institution, Redlands, California).

Methods

We estimated ground cover using the point-intercept method (Hays et al. 1981) in three corners of each plot. A

frame (0.5 x 0.5 m; 1.6 x 1.6 ft) with a 10-cm (3.9-in) interval grid (16 points) was placed on the corner. We recorded the type of ground cover below each point (48 points per plot) using the following categories: litter, forb (i.e., all broadleaf plants, including seedlings), grass, fern, moss, and soil. We excluded the corner nearest the exclosure and control entrance because of possible bias from vegetation being trampled.

We estimated vertical plant cover using a vegetation profile board (0.5 x 1.5 m; 1.6 x 4.9 ft; Nudds 1977). The profile board was divided into three 0.5-m (1.6-ft) sections (with 25 squares in each section) and placed at one end of the plot. The number of squares not obstructed by vegetation for each section was then recorded by an observer at the opposite end of the plot. The procedure was repeated with the profile board and observer shifted to obtain counts for the other half of the plot.

We determined survival rates of woody plant seedlings by tagging at least one representative seedling of each species in each plot at the beginning of the study. Because of difficulties identifying species, ash (*Fraxinus* spp.), blueberry (*Vaccinium* spp.), hickory (*Carya* spp.), and oak (*Quercus* spp.) were identified only to genus. Oaks were further divided into either red or white categories based on the presence of bristles on the leaves (Petrides 1972). The height and status (alive or dead) of each tagged seedling was recorded each year of the study. We tagged more than 450 seedlings.

Annual seedling survival rates were consistently significantly lower in the controls than in the exclosures, with few exceptions.

Results

We analyzed only forb cover because of too few numbers in the other ground-cover categories. At the start of the study (2000) the amount of forb cover among treatments (controls vs. exclosures) was not different for any of the forest types ($P = 0.136$). In the bottomland hardwood forest, which flooded in fall 2002 and spring 2003 with declines in forb cover in 2003, overall (control and exclosure combined) forb cover tended to decrease over time (fig. 4b); in the oak-hickory and Virginia pine-red cedar forests overall forb cover tended to increase with time (figs. 4a and 4c, respectively). Forb cover in the controls remained relatively stable compared to the exclosures where forb cover clearly increased (with the exception of noted flood impacts on the bottomland forest) (fig. 4).

Figure 3 (left). A deer exclosure in pine habitat at Manassas. Exclosures like this are used to measure the vegetation response from excluding deer. NPS/BRYAN GORSIRA

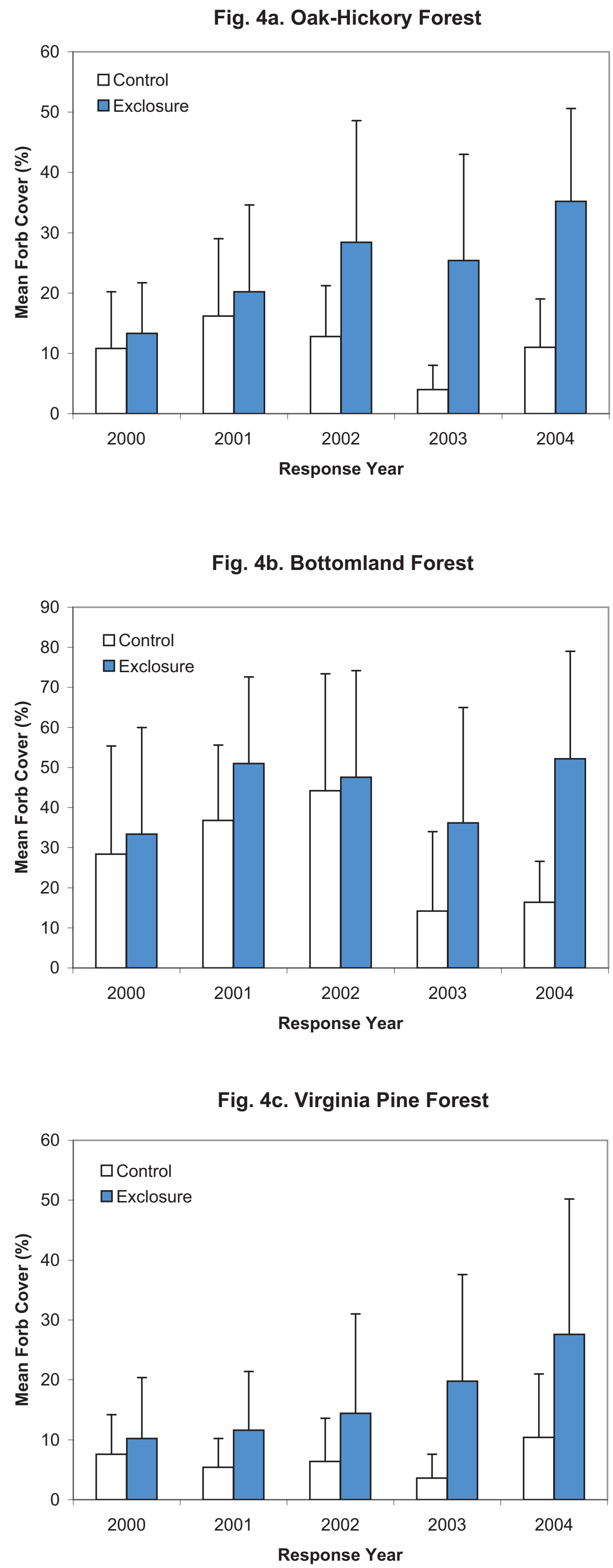

Figure 4. Mean percentage by year of forb cover inside and outside deer exclosures in three forest types—oak-hickory, bottomland, and Virginia pine—at Manassas National Battlefield Park.

We analyzed vertical plant cover in the three forest types at three height intervals: bottom (0–0.5 m, 0–1.6 ft), middle (0.6–1.0 m, 2.0–3.3 ft), and top (1.1–1.5 m, 3.6–4.9 ft) (table 1). At the start of the study we found a significant effect of forest type on the bottom interval for overall vertical plant cover ($P < 0.001$). Similar to results for forb cover, we also noted a greater amount of overall vertical cover of the bottom interval of the bottomland hardwood forest at the start of the study than in the other two forest types (table 1).

Trends in overall vertical plant cover from year 1 to year 5 of the study differed among forest types for the bottom interval ($P = 0.021$), though we found no differences in trends among forest types for the other intervals ($P = 0.941$ and $P = 0.348$). Flooding decreased vertical plant cover of the bottom interval of the bottomland hardwood forest in 2003 (table 1).

A significant treatment-by-forest-type interaction occurred at each interval of vertical cover (all $P < 0.026$). At the beginning of the study, vertical cover at each height interval was greater in the controls than in the exclosures in the Virginia pine-eastern red cedar forest, while the opposite was true for the bottomland hardwood forest; vertical cover in the oak-hickory forest was greater in the controls in the top and bottom intervals, but lesser in the middle interval (table 1). There is a significant treatment-by-year interaction at each height interval (all $P < 0.042$); trends in vertical cover at all heights were consistently less in controls than in exclosures (table 1).

With few exceptions, annual seedling survival rates were consistently significantly lower in the controls than in the exclosures (table 2). Canopy species displaying the greatest mortality from year 1 to year 5 of the study (control treatments) included ashes, hickories, red maple (*Acer rubrum*), and red and white oaks (*Quercus rubra* and *Q. alba*, respectively; table 2). Of the shrub and subcanopy species, boxelder (*Acer negundo*), black hawthorn (*Crataegus* spp.), and spicebush (*Lindera benzoin*) had the greatest mortality from year 1 to year 5 in the control treatments; mortality was not statistically significant for blueberry and redbud (*Cercis canadensis*; table 2). Seedling heights were not analyzed because of high seedling mortality.

Discussion

Herbivory by deer severely impacted forb cover in all three forest types. At the beginning of our study, forb cover was similar between treatments in each of the forest types. By the fifth year forb cover in the exclosures was at least 30% greater than in the controls (see fig. 4). Forbs constitute a large proportion of the white-tailed deer's diet and are heavily consumed in late spring and early summer (McCullough 1985). On the Piedmont Plateau, forbs account for 55.9% of a deer's diet during spring and summer (Whittington 1984).

Herbaceous cover is an important habitat requisite to many species of wildlife, including small mammals (Rossell and Rossell 1999) and ground-nesting birds such as the golden-winged warbler (*Vermivora chrysoptera*; Rossell et al. 2003). Only a few studies, however, have investigated the impacts of deer on herbaceous cover. In a 20-year photographic study, Hough (1965) reported that deer herbivory progressively decreased herbaceous cover in a virgin hemlock hardwood forest in northwestern Pennsylvania. Tilghman (1989) in contrast, found no significant impacts on herbaceous cover at five different deer densities (0–30 deer/km^2 or ~~0–11.6~~ deer/mi^2) in uncut stands of Allegheny hardwood forests on the Allegheny Plateau in northwestern and north-central Pennsylvania.

Deer browsing suppressed vertical plant cover in each forest type in a manner similar to forb cover. The impacts on vertical cover were particularly pronounced during the last two years of our study as substantial differences accrued among treatments (table 1). Vertical plant cover is an important habitat attribute to understory bird species. It has been positively correlated with the abundance and species richness of breeding birds (McShea and Rappole 1992) and the abundance and species diversity of wintering birds (Zebehazy and Rossell 1996). It also has been negatively correlated with predation rates of artificial ground nests (Greenberg et al. 2002). To our knowledge only McShea and Rappole (1992) included vertical plant cover as part of an investigation of deer impacts on vegetation. In their study they concluded that browsing by white-tailed deer (90 deer/km^2; ~~35~~ deer/mi^2) reduced vertical plant cover to the point that it adversely affected the understory bird community in an oak forest of northern Virginia. Other studies throughout the eastern United States, although not directly measuring vertical plant cover, also have reported that deer browsing negatively affects the understory structure of a forest by reducing woody stem densities and heights (e.g., Hough 1965, Alverson et al. 1988, Tilghman 1989, Healy 1997).

Conclusive results that deer reduce survival rates of woody plant seedlings are rare because few studies have monitored individual plants (Russell et al. 2001). In our study we tracked survival of tagged seedlings representing each woody species in each plot over a five-year period. Results clearly indicate that deer browsing adversely affected seedling survival rates of all species except for hackberry (*Celtis occidentalis*), blueberry, and redbud (table 2). In the only

We tracked survival of tagged seedlings representing each woody species in each plot over a five-year period.

other study that quantified seedling survival rates, Liang and Seagle (2002) found that deer (20–30 deer/km^2; ~~7.7–11.6~~ deer/mi^2) significantly reduced survival of green ash (*Fraxinus pennsylvanica*) and American hornbeam (*Carpinus caroliniana*), and generally reduced survival of red maple, sweetgum (*Liquidambar styraciflua*), American beech (*Fagus grandifolia*), and tulip poplar (*Liriodendron tulipifera*).

Table 1. Vertical plant cover in three forest types at Manassas National Battlefield Park, Virginia

Height interval	Forest type	Treatment	Mean % vertical plant cover (SD)					% Change
			Year 1: 2000	Year 2: 2001	Year 3: 2002	Year 4: 2003	Year 5: 2004	
Bottom (0–0.5 m)	Oak-Hickory	Control	44.8 (21.5)	37.6 (20.9)	42.4 (19.9)	35.4 (23.5)	37.8 (13.6)	-7.0
		Exclosure	43.0 (17.5)	53.8 (17.5	54.0 (19.8)	63.8 (19.1)	61.0 (23.4)	18.0
	Bottomland hardwood	Control	79.3 (14.1)	65.4 (28.1)	82.9 (24.7)	43.4 (28.2)	58.0 (21.0)	-21.3
		Exclosure	83.0 (19.4)	82.6 (17.6)	71.6 (26.1)	65.6 (33.5)	82.9 (24.9)	-0.1
	Virginia pine-Eastern red cedar successional	Control	52.8 (24.9)	55.6 (17.6)	52.8 (26.8)	31.8 (21.7)	39.2 (24.2)	-13.6
		Exclosure	24.2 (19.1)	33.2 (23.3)	48.5 (20.7)	37.0 (23.4)	53.8 (18.7)	29.6
Middle (0.6–1.0 m)	Oak-Hickory	Control	12.0 (16.4)	15.0 (16.0)	14.2 (20.6)	7.6 (17.0)	7.6 (15.9)	-4.4
		Exclosure	13.4 (16.5)	17.4 (16.8)	12.7 (16.0)	21.2 (22.3)	17.6 (22.1)	4.2
	Bottomland hardwood	Control	19.3 (23.9)	25.0 (31.4)	24.2 (38.2)	6.0 (8.0)	9.4 (14.9)	-9.9
		Exclosure	25.8 (29.8)	36.8 (38.2)	40.2 (39.9)	36.0 (35.2)	38.6 (29.0)	12.8
	Virginia pine-Eastern red cedar successional	Control	42.2 (31.0)	49.2 (27.2)	50.8 (29.5)	21.2 (26.7)	22.2 (25.0)	-20.0
		Exclosure	11.8 (16.1)	21.6 (23.8)	20.3 (28.1)	14.2 (25.4)	25.4 (23.9)	13.6
Top (1.1–1.5 m)	Oak-hickory	Control	20.6 (25.6)	17.6 (18.6)	12.7 (13.6)	1.6 (3.9)	12.6 (20.0)	-8.0
		Exclosure	15.6 (16.9)	14.6 (20.9)	24.0 (23.7)	15.6 (18.1)	10.2 (12.1)	-5.4
	Bottomland hardwood	Control	10.4 (20.4)	21.2 (23.6)	17.3 (32.3)	8.8 (15.4)	6.0 (9.0)	-4.4
		Exclosure	12.2 (23.7)	16.4 (17.1)	36.4 (34.2)	26.8 (40.1)	27.7 (32.9)	15.5
	Virginia pine-Eastern red cedar successional	Control	46.6 (29.6)	46.6 (35.7)	61.3 (35.3)	22.2 (26.8)	27.2 (31.2)	-19.4
		Exclosure	18.0 (32.9)	26.6 (32.7)	25.5 (34.0)	15.8 (27.6)	23.2 (25.3)	5.2

Note: Percentage of vertical plant cover was estimated in 10 control plots and 10 exclosures for three forest types—oak-hickory, bottomland hardwood, and Virginia pine-eastern red cedar successional—at three height intervals. Control plots and exclosures measured 1 x 4 m each.

Table 2. Survival of tree and shrub seedlings at Manassas National Battlefield Park, Manassas, Virginia

		Year 1 (2000)	Year 2 (2001)		Year 3 (2002)		Year 4 (2003)		Year 5 (2004)		
Species[1]	Treatment	# Seedlings	Survival rate	*P*-value	Survival rate	*P*-value	Survival rate	*P*-value	Survival rate	*P*-value	# Seedlings
Green and white ash	Control	51	0.314	<0.001	0.216	<0.001	0.176	<0.001	0.118	<0.001	5
	Exclosure	54	0.889		0.833		0.630		0.574		32
Black cherry	Control	23	0.696	0.934	0.261	0.026	0.217	0.026	0.130	0.001	3
	Exclosure	15	0.667		0.600		0.467		0.467		7
Boxelder	Control	15	0.467	0.751	0.067	0.006	0.000		0.000		0
	Exclosure	19	0.421		0.211		0.105		0.053		1
Black hawthorn	Control	14	0.643		0.500	0.073	0.286	0.022	0.214	0.015	3
	Exclosure	11	1.000		0.909		0.909		0.818		9
Vaccinium spp.	Control	7	0.429	0.066	0.429	0.117	0.429	0.213	0.429	0.213	4
	Exclosure	12	0.917		0.833		0.750		0.750		9
Hackberry	Control	22	0.545	0.021	0.409	0.601	0.182	0.322	0.091	0.081	2
	Exclosure	19	0.842		0.526		0.316		0.316		6
Hickory	Control	11	0.273	<0.001	0.091	0.020	0.000		0.000		0
	Exclosure	9	0.889		0.778		0.667		0.667		6
Red maple	Control	16	0.125	0.021	0.000		0.000		0.000		0
	Exclosure	13	0.615		0.462		0.462		0.385		5
Rebud	Control	7	0.429	0.087	0.429	0.424	0.429	0.999	0.286	0.555	2
	Exclosure	15	0.800		0.600		0.400		0.400		6
Red oak group	Control	18	0.333	<0.001	0.333	0.018	0.167	0.023	0.111	0.023	2
	Exclosure	17	0.882		0.765		0.588		0.529		9
Spicebush	Control	12	0.583		0.500	0.006	0.083	0.005	0.083	0.086	1
	Exclosure	10	1.000		0.900		0.600		0.300		3
White oak	Control	9	0.556	0.131	0.444	0.246	0.111	0.033	0.111	0.033	1
	Exclosure	11	0.909		0.727		0.727		0.727		8

Note: Seedlings were tagged in 2000, the first year of the study. Seedling survival was monitored 2000–2004 in 10 control plots and 10 exclosures in three forest types: oak-hickory, bottomland hardwood, and Virginia pine-eastern red cedar successional. Control plots and exclosures measured 1 x 4 m each. *P*-values could not be calculated for treatments having survival rates of 0 or 1.

[1]Green ash (*Fraxinus pennsylvanica*) and white ash (*F. Americana*), black cherry (*Prunus serotina*), boxelder (*Acer negundo*), black hawthorn (*Crataegus* spp.), *Vaccinium* spp. (deerberry and lowbush blueberry), hackberry (*Celtis occidentalis*), hickory (*Carya* spp.), red maple (*Acer rubrum*), redbud (*Cercis canadensis*), red oak group (*Quercus rubra* and *Quercus* spp.), spicebush (*Lindera benzoin*), and white oak group (*Quercus alba* and *Quercus* spp.).

In our study seedling survival rates varied among species, suggesting that deer selectively browse across forest types. Selective browsing often alters species composition of a forest stand or ecosystem when preferred species are removed (Augustine and McNaughton 1998, Russell et al. 2001, Liang and Seagle 2002). By the fourth year of our study boxelder, hickory, and red maple seedlings were completely eliminated from control plots, while red and white oak seedlings were severely reduced (see table 2). In addition, ash, black cherry (*Prunus serotina*), and hackberry were the most abundant species at the beginning of our study and continued to be the most abundant at the end (see table 2). These results suggest deer browsing is directing succession of forests toward stands with fewer species and a greater dominance of ash, black cherry, and hackberry, particularly in the oak-hickory and bottomland hardwood forests that are currently dominated by species impacted in our study. Our supposition is supported by Tilghman (1989), who found that browsing at deer densities of 30 deer/km^2 (~~11.6~~ deer/mi^2) caused a dramatic shift in species composition of Allegheny hardwood forests, favoring black cherry. Healy (1997) also found that deer browsing (10–17 deer/km^2 or ~~3.9–6.6~~ deer/mi^2) interrupted oak regeneration in oak forests of Massachusetts, and predicted that future stands would be dominated by white pine (*Pinus strobus*), red maple, and sweet birch (*Betula lenta*).

By the fourth year of our study boxelder, hickory, and red maple seedlings were completely eliminated from control plots, while red and white oak seedlings were severely reduced.

Deer browsing is directing succession of forests toward stands with fewer species and a greater dominance of ash, black cherry, and hackberry.

Conclusions

This study investigated the effects of deer browsing on three forest types common to the northern Piedmont Plateau. Results indicate that white-tailed deer are having a significant impact on the structure and woody seedling composition of forests in Manassas National Battlefield Park and are changing the forest successional process. In each forest type, forb cover and vertical plant cover were suppressed, and species richness and seedling survival rates were reduced. No differences in browsing effects were apparent among the forest types, which may be indicative of the browsing intensity during our study. At 63.4 deer/km^2 (~~24.5~~ deer/mi^2), deer density in the park greatly exceeds the estimated carrying capacity of 15.4 deer/km^2 (~~5.9~~ deer/mi^2) for the Virginia Piedmont (Whittington 1984). Thus, browsing levels in our study were likely too high to discern any potential differences in browsing tolerances among forest types.

The findings in this ecological study justify the need to begin actively managing the deer population in Manassas National Battlefield Park. Browsing by white-tailed deer may be impacting the herb and shrub layers in the forest interior to levels that may be detrimental to wildlife species that are dependent on a thick understory to thrive. In addition, we predict that the future composition of forests in the park, particularly in the oak-hickory and bottomland hardwood types where the greatest number of current dominants is most affected, will shift toward stands with fewer species and a greater dominance of ash, black cherry, and hackberry.

The dilemma for managers at Manassas National Battlefield Park and at the many other parks with high deer numbers is how to deal with this situation. Should high deer numbers be treated as a population fluctuation that will resolve itself naturally, or should we employ heavy-handed management treatments such as population reductions or contraception? Either scenario has the potential for as yet unknown repercussions, including trophic-level responses resulting from population reductions and behavioral changes from heavy use of contraception. In addition, parks have porous borders that, without cooperation from adjacent landowners to control deer populations outside the park, could reduce the effectiveness of treatments within the park. For now, this research information, combined with the results of the distance sampling, has prompted us to develop a request for funding of an environmental impact statement to investigate these and other management options. In the meantime, we continue to collect data from the deer exclosure and control plots with plans to analyze plant species richness and diversity.

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Restoration of threadleaf sedge at Scotts Bluff National Monument

By
Susan J. Tunnell,
James Stubbendieck,
Robert Manasek,
and
Gary Willson

Prairie restoration is a management priority of Scotts Bluff National Monument, Nebraska. More than 365 ha (900 acres) of formerly agricultural land have been added to the park since it was established in 1919. Restoration was necessary to return the vegetation to its condition at the time of migration on the Oregon Trail in the mid-1800s. The park lies in the northern mixed-grass prairie where the original plant community was the *Agropyron-Hesperostipa* association. Dominant species included threadleaf sedge (*Carex filifolia* Nutt.), needleandthread (*Hesperostipa comata* [Trin. & Rupr.] Barkw.), western wheatgrass (*Elymus smithii* [Rybd.] Gould), blue grama (*Bouteloua gracilis* [Willd. ex Kunth] Lag. ex Griffiths), buffalograss (*Buchloe dactyloides* [Nutt.] Engelm.), and many forbs. Much is known about propagation of the grasses, but little is known about threadleaf sedge. Its seed production is extremely low and most efforts to propagate threadleaf sedge have ended in failure. This important native component of the vegetation is valuable for soil stabilization in this windy environment and it provides food for many species of wildlife. Since threadleaf sedge is one of the dominant species in the native plant community, restoration cannot be considered to be complete without this species.

Scotts Bluff National Monument has a long history of grass restoration on previously farmed and other disturbed sites. Sod was transplanted around a newly constructed parking lot in the 1930s, but the first seedings more than 30 years ago included only a few species of grasses. Though these seedings provided perennial grass cover to the land, they were not prairie restorations. Prairie restorations are aimed at recreating the historical vegetation and more fully restoring ecological function to the land. In 1997, the National Park Service and the University of Nebraska used a $124,000 grant from the Nebraska Environmental Trust Fund to begin restoration of the former site of the Scotts Bluff Country Club that was incorporated into the national monument in 1975. The work included removal of building foundations, a swimming pool, irrigation canals, and nonnative trees and was followed by land contouring, native seed purchases, and preliminary research on threadleaf sedge propagation. Park staff planted seed mixtures of native grasses and forbs in two restoration units (12 ha and 5 ha; 29.7 acres and 12.4 acres). Success of those seedings has been rated as excellent by restoration specialists.

Threadleaf sedge, one of the main components of the native park vegetation, was not included in the restoration because seeds were not available. Research conducted in the park by the University of Nebraska has shown that both seed production and germination for this species are extremely low (Griffin 2002; Fassett 2003). In order to fully restore the vegetation community to meet park goals, greenhouse-grown threadleaf sedge plants would need to be transplanted in the old golf course site. Though research at the University of Nebraska is investigating ways to enhance seed production and establish this species from seed, techniques are incomplete and seeds are not commercially available. Additionally, the university's research on vegetative propagation has shown that transplanting plugs of sod was not successful; however, transplanting greenhouse-grown plants into the plant community has been highly successful (Tichota 2000; Stubbendieck et al. 2002). In the late fall and early spring of 2002–2003 and 2003–2004, we investigated the success of a transplant method to incorporate threadleaf sedge, taken from the park and propagated in the greenhouse, back into the restoration units at the national monument.

Methods

University personnel collected threadleaf sedge sod from Scotts Bluff National Monument in early November 2002 and 2003. The sod was transported to the University of Nebraska–Lincoln where it was separated into individual plants (fig. 1) and planted into Ray Leach Cone-tainers™ (3.8 cm in diameter, 20 cm depth; 1.5 x 7.9 in, respectively) in a 2:1 soil mixture of silty clay loam:sand. After separating the plants, we clipped them to a height of 2.5 cm (1 in). The plants were watered every two to four days depending on soil dryness and received a maintenance fertilizer (20-20-20 NPK) every three weeks.

Following six months of growth in the greenhouse, we transplanted 7,000 threadleaf sedge plants into two restoration sites on the former golf course at Scotts Bluff National Monument in May 2003 (fig. 2). The experiment was duplicated in 2004 with an additional 7,000 plants. In order to monitor survival over time, the threadleaf sedge transplants were planted into eight, 6 x 6-m (19.7 x 19.7-ft) plots in each of the restoration sites in both years. We evaluated threadleaf sedge survival on the 16 plots, 2 and 12 months after transplanting. The cost of the project was $28,000.

Figure 1. For the investigation, researchers collected threadleaf sedge samples from Scotts Bluff National Monument, then separated them into individual plants for propagation in the greenhouse. The photo shows a typical threadleaf sedge plant separated from the sod. UNIVERSITY OF NEBRASKA/SUSAN J. TUNNELL

Figure 2. Following greenhouse propagation, resource managers transplanted threadleaf sedge into two restoration units at Scotts Bluff National Monument. UNIVERSITY OF NEBRASKA/SUSAN J. TUNNELL

Results and discussion

The method of collecting threadleaf sedge sod, growing the plants in the greenhouse for six months, and transplanting them in the field was successful in 2003.

However, the increase in annual weedy species and soil disturbance from plains pocket gophers in 2004 reduced the success of the transplants. Whereas the 12-month survival of threadleaf sedge transplants in 2003 was 82%, it was only 29% in 2004. The high density of Russian thistle (*Salsola iberica* Sennen & Pau) and downy brome (*Bromus tectorum* L.), and increased pocket gopher activity in the area where the 16 plots were located in 2004, did not appear to be representative of the entire restored area; therefore, we believe threadleaf sedge survival was greater than the plot measurement (29%) suggests. Densities of Russian thistle and downy brome are highly variable with environmental conditions, and the national monument does not employ special techniques to manage these species.

We determined that this method of transplanting can be viable for restoration, but environmental conditions need to be considered in order to achieve a high level of transplant success. Transplanting threadleaf sedge on appropriate sites will be considered during planning for any future restoration projects at Scotts Bluff National Monument.

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"Information Crossfile" continued from page 18

respondents indicated that lethal control of deer was acceptable (approximately 71% for near, approximately 62% for far) and taking no action to reduce deer populations was unacceptable (approximately 75% for near, approximately 72% for far). That "near" residents were more supportive of lethal control suggests that increased experience with abundant deer populations encourages support of more invasive control techniques such as lethal control.

Data from this study indicate that if certain management reasons are present, more respondents feel lethal control is acceptable. For example, preventing severe consequences for humans (e.g., spread of disease or deer-vehicle collisions) or the natural environment (e.g., maintain a healthy deer herd and ecosystem) make lethal control more acceptable than preventing negative aesthetic impacts (e.g., maintain natural beauty of Cuyahoga Valley National Park) or personal property damage (e.g., damage by deer to shrubs, crops, or gardens on private property). Hence, according to this study, if the scientific information supporting these reasons can be clearly communicated to the public, approximately half of the public generally opposed to lethal control of deer would find it acceptable.

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Cougar Management Guidelines published in Spanish

In our last issue (*Park Science* 23(2):12–13) we reported the publication of *Cougar Management Guidelines*, a thorough work combining historical analysis of cougar management policies, decades of cougar research findings, and recommendations for the management of cougars in the United States, Canada, and Mexico. Written by researchers, managers, and conservationists, the book was lauded as relevant and considered a much-needed information breakthrough. With its recent translation to Spanish (*Puma, Guía de Manejo*) this valuable resource is more relevant than ever for cougar managers in Latin America. Copies of the Spanish translation are available from John Laundre (john@ fauna.edu.mx) and Lucina Hernandez (lucina@ fauna.edu.mx) of the Instituto de Ecología in Durango, Mexico.

Meetings of Interest

2006

Oct. 28–31 As an educational institution, the National Park Service has innumerable opportunities to share with park visitors the results of research and its application to park management. One avenue is through the network of research learning centers that serves national parks across the nation. The annual conference of the Association of Science-Technology Centers in Louisville, Kentucky, may provide insights into this important role. Titled "Appropriate Growth: Sustaining Institutional Advancement," the gathering will explore how educational organizations dedicated to furthering public understanding of science plan for and manage institutional advancement. "A science center that is engaged in appropriate growth has a strong mission and vision, is keenly aware of its strengths and weaknesses, is highly creative, makes good choices, is engaged with its community, and can readily adapt to a rapidly changing local and global environment," according to the conference Web site (http://www.astc.org/conference/index.htm). Conference sessions will explore selecting appropriate learning strategies for science education, developing one's audience, choosing relevant science and research topics to develop into educational messages, the use of technology, and taking science centers to the next level.

Nov. 28–30 Concerned about declining water quality and quantity, expanding population centers, invasions of nonnative species, altered fire regimes, and various human uses of the land, researchers and land managers from multiple agencies and institutions are sponsoring the "Workshop on Collaborative Watershed Management and Research in the Great Basin," in Reno, Nevada. The intent of the gathering is to expand opportunities for researchers and land managers to be more collaborative and efficient in developing solutions to critical ecological and socioeconomic issues affecting the region. They hope to build on the rich legacy of collaborative work already begun, identifying new issues and associated research needs, and developing mechanisms to improve coordination of management and research activities through a collaborative approach. The workshop Web site (http://www.cabnr.unr.edu/GreatBasinWatershed/) shares additional information.

2007

Apr. 16–20 The George Wright Society is gearing up for a thought-provoking week of resource management-related discussions at its biennial conference on parks, protected areas, and cultural sites to be held in St. Paul, Minnesota. Titled "Rethinking Protected Areas in a Changing World," the conference will feature six plenary sessions, more than 100 concurrent sessions, an expanded three-day poster session, field trips, and numerous other special events. Though "change" is a common theme in the lives of park and protected area managers, this conference will highlight the scope and speed of changes in social, political, and economic systems and how they interrelate to transform natural systems. Among the topics to be explored are global climate change, effects of globalization, shifting demographics among park users, incorporating various perspectives into heritage interpretation, erosion of biodiversity, park operations in a time of heightened national security, the decline in historical literacy, and deepening the intellectual engagement of park visitors. For those who cannot attend, proceedings of the conference will be published. Student travel scholarships are offered by the society to encourage greater diversity in the conference and related conservation professions (the application deadline is 10 November 2006). The conference Web site (http://www.georgewright.org/2007.htm) shares more details of the coming event.

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

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