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PARK Science

Integrating Research and Resource Management in the National Parks

National Park Service
U.S. Department of the Interior

Natural Resource Program Center
Office of Education and Outreach

- Plague management at Wind Cave
- Survival of the prairie fringed orchid at Pipestone
- Water quality monitoring in southeastern coastal national parks
- Management of ponderosa pine at Mount Rushmore

WHITE-NOSE SYNDROME IN BATS

Biologists strive to understand and contain the invasive fungal infection affecting hibernating bats in the Northeast

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From the Editor

A remarkable transformation

Progress through science is not necessarily linear and orderly, or ensured at all. It takes people of imagination, persistence, and insight to design beneficial applications and make breakthroughs. It also takes an open mind and willingness to accept and act on the truths that come from science, which may at times be unpopular or seem unbelievable. We need time to consolidate information, to ask shrewd questions for the future.

In 1990, *Park Science* reported that the National Park Service had arranged for the National Academy of Sciences to investigate how we could improve our science programs, which were perceived as having developed in a "haphazard" fashion. We excerpt that article in this issue (20 Years Ago in *Park Science*) to stimulate reflection on our progress as a scientific organization, and I believe time affords a beneficial perspective.

I have several observations. (You can add your own to this list.) We have come a long way since the days when park rangers carried out resource management duties in parks as one of many important collateral duties. We now have a cadre of scientifically trained specialists to conduct these activities, and most natural resource parks have a dedicated natural resource specialist or group of specialists to address management issues. Though our focus is park-based, it now considers park management concerns from the landscape perspective. The Natural Resource Challenge (FY 1999–FY 2007) provides for systematic inventories of park natural resources and monitoring to determine their condition. We have developed a new model for natural resource monitoring that shares expertise among similarly situated parks in 32 networks, involving more than 270 parks across the country. Early science and technology programs, such as Air and Water Quality, and Mining and Minerals, were consolidated in the mid-1990s in the Natural Resource Program Center, improving coordination of the scientific, policy, and regulatory expertise they offer parks. New programs have been added to address issues related to biologic resources, environmental quality, geology, social science, and soundscapes. Partnerships for better collaboration with scientists and public education about park science have increased through the Internet-based Research Permit and Reporting System, park-based Research Learning Centers, and interagency Cooperative Ecosystem Studies Units. These initiatives have given parks access to researchers in virtually all academic disciplines and researchers better access to national parks. Finally, study results are routinely communicated to the public. This transformation is remarkable and important as we strive to keep up with the challenges of climate change, invasive wildlife diseases, habitat fragmentation, caring for threatened species, ecological restoration, and other resource concerns discussed in this issue.

Please join me in reading this issue of *Park Science* not only for the information and insights it provides but also in appreciation of the many gains made in improving applications of science in the parks and nurturing the National Park Service as a scientific institution.

—Jeff Selleck

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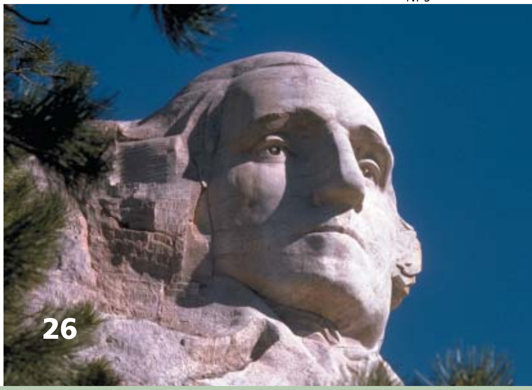

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DEPARTMENTS

ON THE COVER

What's wrong with this picture? The white patches on the nose and wing membranes of this eastern small-footed bat (*Myotis leibii*) are an invasive fungal growth affecting bats in the northeastern United States and Canada. Discovered just three years ago, white-nose syndrome is spreading rapidly from its discovery site in New York, through 11 additional states and two Canadian provinces. In April of this year bats affected by the fungus were discovered at Great Smoky Mountains National Park. The article on page 20 will introduce you to what is known about this troubling disease and how to help prevent its spread.

RYAN VON LINDEN, NEW YORK DEPARTMENT OF ENVIRONMENTAL CONSERVATION

NOTES FROM ABROAD

STATE OF SCIENCE

SCIENCE FEATURE

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UPCOMING ISSUES

Fall 2010
Seasonal issue. October release. Contact the editor with late submission ideas.

Winter 2010–2011
January 2011 release. Topical issue: Climate change research and management applications. Contributor's deadline: 8 October.

Spring 2011
Seasonal issue. Month-of-May release. Contributor's deadline: 12 February 2010.

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

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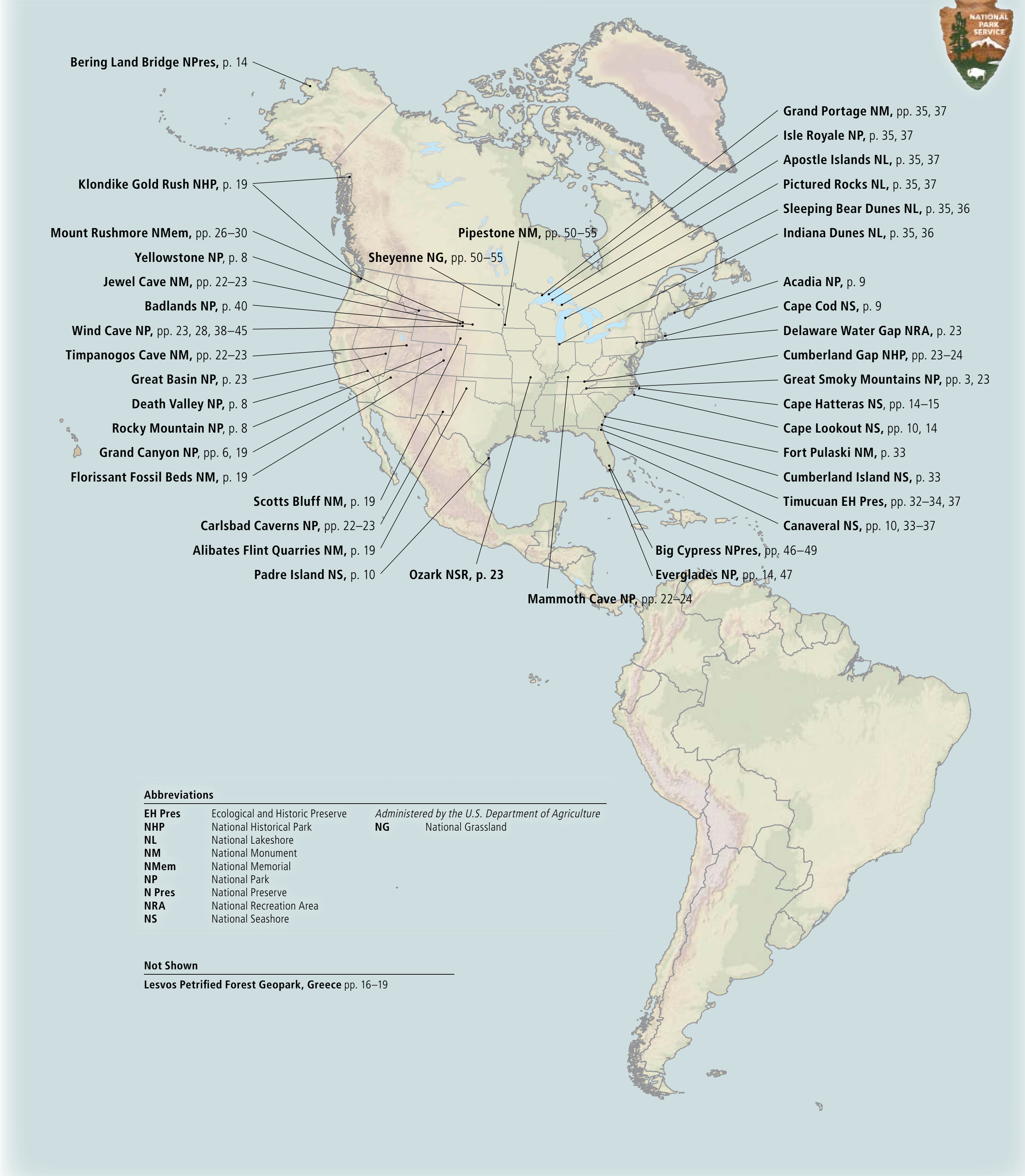

Abbreviations

EH Pres	Ecological and Historic Preserve
NHP	National Historical Park
NL	National Lakeshore
NM	National Monument
NMem	National Memorial
NP	National Park
N Pres	National Preserve
NRA	National Recreation Area
NS	National Seashore

Administered by the U.S. Department of Agriculture

NG	National Grassland

Not Shown

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Comments & Corrections

PARKScience (CONT'D)

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

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

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

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

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Suggested article citation

Castle, K. T., and P. M. Cryan. 2010. White-nose syndrome in bats: A primer for resource managers. Park Science 27(1):20–25.

Printed on recycled paper.

Dear Park Science Editors:

It was with great interest that I read your winter edition of Park Science, *which focused on the topic of soundscapes research and management.*

I am the Artist-in-Residence (AiR) Program coordinator at the South Rim of Grand Canyon National Park, which hosts a new year-round program, joining the well-established North Rim seasonal program. This season, the South Rim program is hosting three artists whose artwork is related to the issue of ambient sounds. Soundscapes is not only a scientific focus, but also a new discipline that has clearly caught the imagination of contemporary artists.

Our park's artist program is unique in a few ways. We are the only NPS AiR program that operates year-round and the only program that has expanded its criteria to encourage participation from cutting-edge, conceptual, contemporary artists who are directly engaged in issues that concern the parks. These issues include, but are not limited to, conservation, effects of global warming, indigenous people's rights, land and water use rights, and issues associated with noise and light pollution.

I see a real opportunity for collaboration between scientists and artists who are studying and looking for solutions to the same issues that affect our parks and our world. If any of your contributing scientists or readers are interested in making some of these connections, I would be most happy to facilitate that.

For more information on the artists who are addressing these urgent issues, please visit our "selected artists" page: http://www.nps.gov/grca/supportyourpark/selected-artists.htm.

Of particular interest to soundscape scientists will be the following artists:

- "Cowboy" Randy Erwin, "vocalist & yodeler," whose original music includes collected ambient sounds, both natural and man-made (AiR November 2009; cowboyrandy.com)
- Andrew Demirjian, "media artist," who intends to "take field recordings at consistent times around the South Rim, at varying elevations and contrasting degrees of scale capturing intimate and vast sonic textures." (AiR July 2010; andrewdemirjian.com)
- Aaron Ximm, "sound artist," whose work intends to "help keep the quiet parts of the world to speak for themselves." (AiR September 2010; www.quietamerican.org)

Thank you for this timely and interesting edition of *Park Science* and for the opportunity to let our NPS scientists know what is going on in the parallel world of the arts.

Sincerely,

Rene Westbrook
Coordinator, South Rim Artist-in-Residence Program
Grand Canyon National Park
Rene_Westbrook@nps.gov

PS

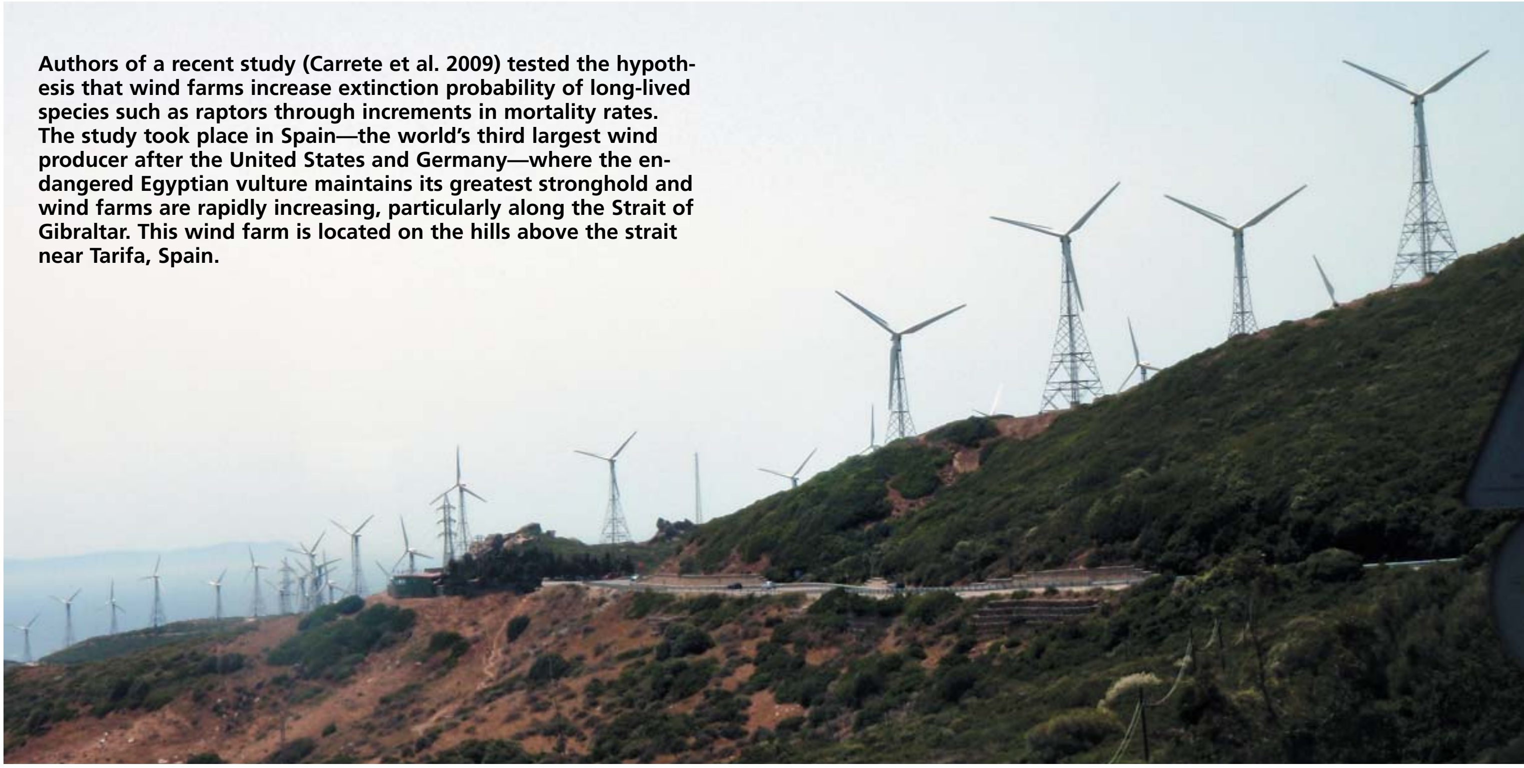
Information Crossfile*

ARTICLES

Avian fatalities and anthropogenic structures: Simple solutions and complex considerations

GEHRING ET AL. (2009) PROVIDE A REFRESHINGLY SIMPLE solution to a growing environmental concern: avian mortality due to collision with anthropogenic structures. The solution: remove nonflashing lights from communication towers. The status quo lighting system of Federal Aviation Administration (FAA) communication towers consists of a combination of red, flashing lights and red, nonflashing lights (Gehring et al. 2009). Results of a study of 24 communication towers in Michigan showed that avian fatalities can be reduced by 50–71% by removing nonflashing/steady-burning red lights. On 20 consecutive days during early-morning hours in May and September (peak songbird migrations) 2005, investigators simultaneously documented avian fatalities at 21 towers that were 380–480 feet (116–146 m) high and four towers that were more than 1,000 feet (305 m) tall. The communication towers had a variety of lighting systems: white strobe lights only; red strobe-like lights only; red, flashing, incandescent lights only; and red, strobe-like lights combined with nonflashing, steady-burning, red lights. Investigators found a mean of 3.7 bird carcasses under towers equipped with only red and white flashing obstruction lights, but a mean of 13 bird carcasses under nonflashing/steady-burning lights in addition to the flashing lights. Hence, "removing nonflashing lights from towers is one of the most effective and economically feasible means of achieving a significant reduction in avian fatalities at existing communication towers" (Gehring et al. 2009, p. 505).

Carrete et al. (2009) take on a more complex scenario involving avian mortality and anthropogenic structures. In this case, wind turbines are the structure, and the subject of avian mortality is an endangered species, Egyptian vulture (*Neophron percnopterus*). Although the study took place in Spain (see photo), and this endangered species' range does not occur in the United States, Carrete and colleagues contend that their findings have worldwide application for long-lived species with slow maturation rates and low productivity (i.e., produce few offspring), such as many raptor species. Model results of Carrete et al. (2009) show that low levels of additional mortality from wind turbines on an already declining population can be biologically significant; that is, reducing the time to extinction. Furthermore, model results show that survival rates varied with age: "Survival increased with age until birds acquired their adult plumage and searched for a breeding territory, at which point it decreased. At older ages (>6 years), survival was higher for both nonbreeding and breeding adults" (Carrete et al. 2009, p. 2956).



Authors of a recent study (Carrete et al. 2009) tested the hypothesis that wind farms increase extinction probability of long-lived species such as raptors through increments in mortality rates. The study took place in Spain—the world's third largest wind producer after the United States and Germany—where the endangered Egyptian vulture maintains its greatest stronghold and wind farms are rapidly increasing, particularly along the Strait of Gibraltar. This wind farm is located on the hills above the strait near Tarifa, Spain.

*Information Crossfile synopsizes selected publications relevant to natural resource management. Unless noted, articles are not reviewed by reference source author(s).

ARTICLES CONT'D

Carrete et al. (2009) make one of the few attempts to assess the demographic consequences of wind-farm mortality; most research to date has focused on quantifying collision rates of birds with turbines. As such, the authors counter the assumption that, all things considered, wind farms have low impact on animal populations, which power companies and some wildlife agencies support. For example, a 2003 report by the American Wind Energy Association puts wind power's effect on birds "into perspective" (Sagrillo 2003). According to this report, the 15,000 wind turbines in existence in the United States in 2001 caused 33,000 avian mortalities. By comparison, buildings and windows caused 100 million–1 billion bird fatalities that year, power lines caused 130–174 million, motor vehicles caused 60–80 million, agricultural pesticides caused 67 million, communication towers caused 40–50 million, cats (feral and house) caused 39 million, and other types of human infrastructure and industrial activities (e.g., jet engines, smokestacks, and bridges) caused 1–4 million. Although the sources of these data seem reputable (e.g., scientific journals such as *Bioscience* and *Earth Island Journal*, as well as findings of the American Bird Conservancy, Wisconsin Department of Natural Resources, and National Wind Coordinating Committee), listed in this way the outcome of avian mortality as a result of wind turbines seems inconsequential. Hence, Carrete et al. (2009) highlight the need for demographic considerations when placing wind farms, particularly for maintaining the precarious balance of a population of territorial raptors faithful to their breeding sites.

[The authors] highlight the need for demographic considerations when placing wind farms.

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—Katie KellerLynn

■ ■ ■

The human footprint in the West

THE HUMAN FOOTPRINT IN THE WEST—A LARGE-SCALE analysis of human impacts—is interesting for at least two reasons. First, the statistics that the investigators, Leu et al. (2008), provide are themselves interesting: The human footprint (i.e., spatial effects of anthropogenic features such as rest areas, campgrounds, oil and gas wells, landfills, interstates, highways, secondary roads, railroads, power lines, irrigation canals, agricultural lands, and urban areas) covers 13% of the western United States. Agricultural lands (9.8%) dominate, followed by populated areas (1.9%) and secondary roads (1.1%); interstate rest stops are the least dominant anthropogenic feature (0.003%). In order to investigate spatial patterns of the human footprint, the authors (2008) developed a classification system with increasing anthropogenic disturbances from 1 to 10; they later "clumped" these classes to highlight patterns. Low-intensity human footprint classes 1–3 cover the majority (48%) of the western United States. Medium-intensity classes 4–7 cover 45%. High-intensity classes 8–10 cover 7%.

Statistics of "intensity areas" can be spatially compared with the National Park Service Inventory and Monitoring networks. The "top 3" areas with the highest-intensity human footprint are (1) Puget Trough–Willamette Valley–Georgia Basin, which corresponds to the North Coast and Cascades Network and the Klamath Network; (2) Great Central Valley, which corresponds to the Sierra Nevada Network; and (3) California South Coast, which corresponds to the Mediterranean Coast Network. The "top 3" areas with the least intense human footprint are (1) Utah–Wyoming Rocky Mountains, which corresponds to the Greater Yellowstone Network; (2) Canadian Rocky Mountains, which corresponds to the Rocky Mountain Network; and (3) Mojave Desert, which corresponds to the Mojave Desert Network (see Leu et al. 2008, fig. 5, p. 1128). In addition, the analysis found that rivers of the western United States were more heavily affected by the human footprint than were lakes. Federal landholdings least affected by anthropogenic features and activities were those of the U.S. Fish and Wildlife Service, Department of Defense, and National Park Service, which together covered 5.3% of the western United States. Those landholdings most affected by the human footprint were Bureau of Reclamation, state, and private lands, which together covered 46.3% of this area.

Second, the human footprint is interesting to resource managers because many of the "reference locations" in the classification system are national parks. Yellowstone and Death Valley national parks are class 1 reference locations, Mount Rainier National Park is class 2, and Rocky Mountain National Park is class 3. For comparison, agricultural areas in the Snake River Plain (Idaho) and Napa Valley (California) are class 8. Los Angeles, California;

Boise, Idaho; and agricultural areas south of Fresno, California, are class 10.

The human footprint in the West is also useful; notably, investigators have made their data set available for download at http://sagemap.wr.usgs.gov. This SAGEMAP Web site is maintained by the U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Snake River Field Station, in Boise, Idaho. Moreover, applications of the human footprint to the National Park System are plentiful. Take, for example, the data set of synanthropic predators (species that benefit from human activities), like corvids, house cats (*Felis silvestris catus*), and domestic dogs (*Canis lupus familiaris*). According to Leu et al. (2003), investigators are modeling human activities that benefit synanthropic predators in order to understand the top-down interaction between predators and prey, in particular shrubland species of concern such as greater sage grouse (*Centrocercus urophasianus*). According to the investigators, "power lines are used by common ravens (*Corvus corax*) and raptors for nesting and for hunting perches. Human impacts in rural areas, including agriculture, landfills, and recreational sites, often provide abundant and new food sources which potentially increase the numbers of common ravens, American crows (*Corvus brachyrhynchos*), black-billed magpies (*Pica hudsonia*), brown-headed cowbirds (*Molothrus ater*), and red foxes (*Vulpes vulpes*)" (Leu et al. 2003, p. 1). Furthermore, linear features such as railroads, primary and secondary roads, and irrigation canals enhance the movements of synanthropic predators into previously unused regions; they also facilitate the spread of invasive plant species. Therefore, these features are useful for mapping potential invasions. In addition, the human footprint provides a graphic representation of habitat fragmentation, on the one hand, and connectivity, on the other. These data would allow managers to map anthropogenic features that act as barriers to species movement or dispersal. Finally, using the human footprint, resource managers could investigate how species of concern have responded (in distribution and abundance) to particular features or the cumulative impact of human presence on the landscape.

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—Katie KellerLynn

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The effects of whale watching on the reproductive fitness of humpback whales

TWENTY-FIVE YEARS (1980–2005) OF OBSERVATIONS OF humpback whales (*Megaptera novaeangliae*) in the southern Gulf of Maine—primarily around Stellwagen Bank (east of Boston and north of Cape Cod) and Jeffreys Ledge (off the coast of Gloucester, Massachusetts, and north to New Hampshire and Maine)—show no negative effects of whale-watching exposure on the long-term calving rate of female whales, the likelihood that a female will have a calf in a given year, or the likelihood that the calf will survive until at least 2 years of age (Weinrich and Corbelli 2009). Gulf of Maine waters serve as feeding grounds for humpback whales from April to December and as popular whale-watching sites. National Park System units adjacent to the Gulf of Maine are Cape Cod National Seashore (Massachusetts) and Acadia National Park (Maine). Although other species of whales and dolphins are "watched" in New England, humpback whales are the primary focus of wildlife tourism in this area. Investigators wanted to determine whether whale watching, which began in New England in 1975, was affecting the health of these animals, and selected reproductive fitness as an indicator of health. With a life expectancy of 50 years, some of these animals were alive when whale watching started.

Notably, this study did not cover adult males, other whale species or other populations of humpback whales, or behavioral indicators of disturbance. Furthermore, the study focused on calf production and calf survival, but did not include other forms of reproductive activity such as communication and mating displays. For comparison, results published in the spring 2009 issue of *Park Science* indicate that boat noise affects the spatial-acoustic behavior of vocally active male humpback whales in Abrolhos Marine National Park, Brazil (Sousa-Lima and Clark 2009). These males produce "songs"—long, patterned sequences of sounds—presumably as a reproductive display on breeding grounds. In the Brazilian study, 77.8% of "singing" male humpback whales moved away from the oncoming boat, with 66.7% of these initiating movement at 2.5 miles (4.0 km) distance; 44.5% stopped singing for at least 20 minutes.

In the Gulf of Maine study, observers went onboard whale-watching vessels of two to four operators, some of which had multiple boats, out of Gloucester, Salem, Boston, and Provincetown, Massachusetts. Observers made "control" sightings in the Great South Channel, a relatively remote, offshore habitat used by the same population of whales but which receives little, if any, whale-watching traffic; however, the vessels from which these observations were made were not fundamentally different from the whale-watching vessels. During each sighting event, observ-

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ers photographed the whales' dorsal fins and fluke pigmentation patterns for individual identification. Investigators identified the whales using a catalog maintained by the Whale Center of New England in Gloucester, Massachusetts, which contains records for 346 female humpback whales. Observers recorded females at least 8 years old (the age of maturity) or seen with at least one calf. The catalog contains 283 sexually mature, female humpback whales. Calves born after 2003 were excluded from the survival analysis. Observers also recorded the total number of exposure minutes and the total number of interactions per sighting. One approach and one departure equaled one "interaction." If more than one boat was "watching" at the same time, then each boat counted as an interaction, but the total number of exposure minutes was not multiplied by the total number of boats. The greatest number of sightings occurred in 1999 with 13,891 sightings during 873 trips, covering 191 days. Mean cumulative exposure time was 1,746.8 minutes (range 1–13,746 minutes), and the mean number of interactions was 89.8 (range 1–614). In reality, these numbers represent only a fraction of the total number of whale-watching exposure that each animal received. Given the high exposure level of the study population, the lack of deleterious effects from whale watching on the reproductive health of these animals is indeed notable. The authors suggest that "management efforts may, at times, be best concentrated on issues in which progress may be more difficult but ultimately may have greater conservation benefits" (Weinrich and Corbelli 2009, p. 2938). These issues include not only acoustic disturbance, as documented by Sousa-Lima and Clark (2009), but also entanglements, collisions with commercial shipping traffic, pollution, and the loss of important habitats.

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—Katie KellerLynn

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SUMMARIES

Polarized light pollution: Alternative hypotheses and resource management concerns

HORVÁTH ET AL. (2009) INTRODUCE THE TERM "POLARIZED light pollution" and suggest caution in the placement and use of artificial polarizers. Polarized light pollution refers predominantly to highly and horizontally polarized light reflected from artificial surfaces, which alters the naturally occurring patterns of polarized light experienced by organisms in ecosystems. Common artificial polarizers are asphalt surfaces (e.g., roads and parking lots), black plastic sheeting, dark-colored paint work (e.g., on cars), black (polished, horizontal) gravestones, and black or gray windows. Oil spills and open-air oil reservoirs are locally significant artificial polarizers. Similar to a polarizing filter on a camera, an artificial polarizing surface reduces reflection from nonmetallic surfaces, increases contrast and color saturation, and darkens shadows. In the 1960s, research began to show that many animals are capable of perceiving the polarization of light and using it as a rich source of information (see Horváth et al. 2009, p. 317).

Generally, light pollution is a nighttime phenomenon, affecting nocturnal and crepuscular species; however, polarized light pollution can occur day or night wherever both a light source and a polarizing surface are present. Furthermore, the magnitude and prevalence of polarized light pollution have greatly increased with human activity. Horváth et al. (2009) highlight the potential effects of polarized light pollution on habitat selection, laying eggs, foraging, navigation and orientation, predation, and population dynamics. The following examples show some of the direct and indirect effects on the behavior and fitness of polarization-sensitive animals.

Perhaps most obviously, water-seeking insects use horizontally polarized light to locate water bodies. Among available visual cues, polarization is the most reliable under variable lighting conditions. Yet, foraging on artificial polarizers (e.g., a red car roof) wastes time and energy for these species. Moreover, for some species, landing on artificial reflectors can be lethal; obligate waterbirds (i.e., birds that require open water for survival) such as ruddy duck (*Oxyura jamaicensis*), common loon (*Gavia immer*), dovekie (*Alle alle*), and brown pelican (*Pelecanus occidentalis*) are occasionally found dead or injured and stranded (unable to take off) in large asphalt parking lots.

Predators use polarization sensitivity (e.g., detection of prey via the scattering of light) to their advantage, but in underwater habitats, plastic garbage is a source of polarized light pollution. Investigators have identified plastic bags as attractive to sea turtles because of the plastic's transparency and similarity in shape to jellyfish; park literature at Cape Lookout, Canaveral, and Padre Island national seashores highlights such findings (see particular parks at http://www.nps.gov). Horváth et al. (2009) suggest that scattered light through plastic may prompt aquatic organisms to consume inappropriate and dangerous items sensed as prey.

Artificial surfaces that reflect light may easily become polarization signals to which different species are attracted. However, the degree of artificial polarization can far exceed natural levels, disorienting species from native cues in both sky and water.

Cascading effects may result if predators, which initially benefit from the abundance of prey attracted to artificial surfaces, become prey themselves. For instance, nest predators such as magpies (*Pica pica*) that gather near caddisfly (*Hydropsyche pellucidula*) congregations (attracted to vertical glass surfaces) could represent an enhanced predatory risk for the chicks of other bird species that nest in the immediate vicinity of glass buildings. Finally, because artificial surfaces can polarize light more highly than water, aquatic insects prefer to settle and lay eggs upon artificial, horizontally polarizing surfaces, even when there are suitable water bodies nearby. Such maladaptive behavior may result in population declines or alter the structure, diversity, or dynamics of ecological communities.

Although conservation is the primary objective of Horváth and his colleagues, they also supply a provocative alternative hypothesis for the accumulation of life-forms at ancient natural asphalt seeps such as Rancho La Brea in Los Angeles, California. The generally accepted hypothesis is that animals were initially caught when they accidentally stumbled into the tar pits, which may have been camouflaged by dust or leaves (Akersten et al. 1983). Horváth et al. (2009) hypothesize that "these asphalt seeps may sometimes have been covered by rainwater, thus strengthening their polarization signature and attracting polarotactic insects and birds, and initiating a cascading trap for predators attracted to the trapped prey species" (p. 323).

Anthropogenic polarizing surfaces, combined with the occurrence of sensitivity to polarized light in so many animal taxa, suggest that caution in the placement and use of artificial polarizers is warranted from a conservation perspective. According to Horváth et al. (2009), "the ever-increasing levels of polarized light pollution and its ability to negatively affect behaviors and to alter interspecific interactions constitute an important conservation problem, which requires increased attention from conservation professionals and researchers alike" (p. 324).

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—Katie KellerLynn

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Looking at riverbanks in new ways

FLORSHEIM ET AL. (2008) SHOW NEW WAYS OF LOOKING at riverbanks, bank erosion, channel bank infrastructure, and management response to bank erosion, but does the article provide new alternatives? Perhaps the statement in the article's abstract—"Here, we . . . suggest that alternatives to current management approaches are greatly needed"—is an invitation for managers of riparian resources to question their assumptions, take a broader (watershed) look, and think beyond conventional approaches. However, two of the four alternatives the authors provide seem like "floodplain management" repackaged in new terms: "dynamic-process conservation areas" and "erosion easements." Furthermore, the checkerboard ownership of riparian corridors makes the use of these alternatives seem challenging at best. Examples of where and how these alternatives have been (or could be) applied would have added verity to the suggestions. The other two alternatives—"elimination of direct stressors" (e.g., grazing) and "nonstructural approaches" (e.g., planting native vegetation without the inclusion of hard structures such as riprap, gabions, or concrete)—seem practical; that is, simple and effective ways to enhance bank stability (albeit in the short term).

Although alternatives are still needed, the discussion of riverbanks, bank erosion, and channel bank infrastructure in Florsheim et al. (2008) is enlightening. The authors suggest that the pervasive construction of infrastructure to control bank erosion is a result of the assumption that bank erosion is "bad." This notion and the response to it have "greatly diminished natural channel banks, geomorphic processes, and ecology" (p. 527). The authors identify the main geomorphic and ecological effects of channel bank infrastructure, the potential habitat or ecosystem services lost, and examples of organisms affected. The authors highlight riverbanks as ecotones, vital centers of biodiversity in the zone between water and land. These areas, including the dynamic process of erosion within them, provide habitat gradients, setting up

The pervasive construction of infrastructure to control bank erosion is a result of the assumption that bank erosion is "bad." This notion and the response to it have "greatly diminished natural channel banks, geomorphic processes, and ecology."

SUMMARIES CONT'D

Bank erosion is a necessary process that may bring about eventual channel stability in urbanizing areas, and hard structures may prevent the adjustments required for a channel to stabilize on its own and limit future restoration options.

trophic cascades that offer “a greater variety of food sources and physical habitats than do simple plant communities of uniform age and species, which are characteristic of stabilized banks” (p. 523). The authors also point out that bank erosion includes both fluvial (stream-driven) and mass-wasting (gravity-driven) processes, the latter often overlooked at the detriment of engineering solutions. Mass wasting creates both vertical banks and slump deposits, the combination of which increases the heterogeneity of the channel, creating microtopography (for a variety of species) and bare surfaces (for recruitment) at varying elevations above the channel.

Florsheim et al. (2008) suggest that construction of channel bank infrastructure should not be an immediate response to bank erosion, particularly in watersheds with a low level of urban development or where development is in progress. Bank erosion is a necessary process that may bring about eventual channel stability in urbanizing areas, and hard structures may prevent the adjustments required for a channel to stabilize on its own and limit future restoration options. Significantly, the authors point out the general lack of monitoring done to assess the effects or the effectiveness of projects that use channel bank infrastructure, which is ironic in light of the pervasive nature and quick-response applications of riprap, gabions, and concrete. Finally, the authors illustrate that as a management strategy, construction of channel bank infrastructure addresses only one component of watershed management (bank erosion) while ignoring a full spectrum of habitat degradation and environmental problems (e.g., channel incision, removal of riparian vegetation, changes in hydrology, and pollution), as well as the values provided by preserving natural riverbanks.

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—Katie KellerLynn

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Lessons from the mollusk that made headlines

ZEBRA MUSSELS (*DREISSENA POLYMORPHA*) APPEARED in North America in 1988, and the invasion has been well documented; for example, the U.S. Geological Survey (USGS) posts daily updates of sightings in Google Maps (Benson 2009; see fig. 1). Models show that zebra mussels spread by both natural process and human transport. According to Strayer (2009), colonization of North America has proceeded through a combination of long-distance leaps, medium-distance jumps, and short hops. Long-distance leaps include downstream transport through the Mississippi River basin and overland into Lake Mead (Nevada and Arizona). Medium-distance jumps include movement from the Great Lakes to inland lakes, and short hops include the movement between lakes within a regional lake district. Because the most vulnerable bodies of water have already been colonized, spread has slowed in recent years but will presumably continue until the entire potential range is filled (Strayer 2009). Extreme temperatures and inadequate calcium concentrations are the limiting factors to zebra mussel colonization. Hence, zebra mussels are unlikely to spread to the calcium-poor waters found in most of New England and the Pacific Northwest, the very cold waters of northern Canada, or the very warm waters in much of the U.S. Southwest.

Lessons learned for science

Appearance of the zebra mussel, which has become an icon for invasive species study and policy, helped give birth to invasion ecology, now a major part of general ecology. Moreover, as evidenced by the USGS zebra and quagga mussel information resource page (see Benson 2009), much is known about its spread. Furthermore, scientists have identified many ecological impacts of the invasion, most basically the withering of planktonic food webs and the thriving of littoral ones (i.e., organisms that live on, in, or near the seabed or lakebed). The following have decreased as a result of the spread of zebra mussels: phytoplankton and small zooplankton, benthic animals and large zooplankton, native bivalves (some to the point of local extinctions), dissolved oxygen in the water column, and calcium concentrations in freshwater bodies; water clarity, soluble nitrogen and phosphorus, bacteria, and local benthic animal populations have increased. In addition, the zebra mussel invasion has altered the pathways of contaminant cycling. In short, this species has transformed the food webs and biogeochemistry of freshwater habitats throughout North America. Seemingly significant yet unknown impacts include difficult-to-measure (or analyze) responses to the invasion (e.g., fish populations) and the outcome of transforming sediment from mud and sand to shell. Moreover, impacts to large-scale processes and systems are unknown. Strayer (2009) concludes that “scientists and funders working on alien species have preferred to

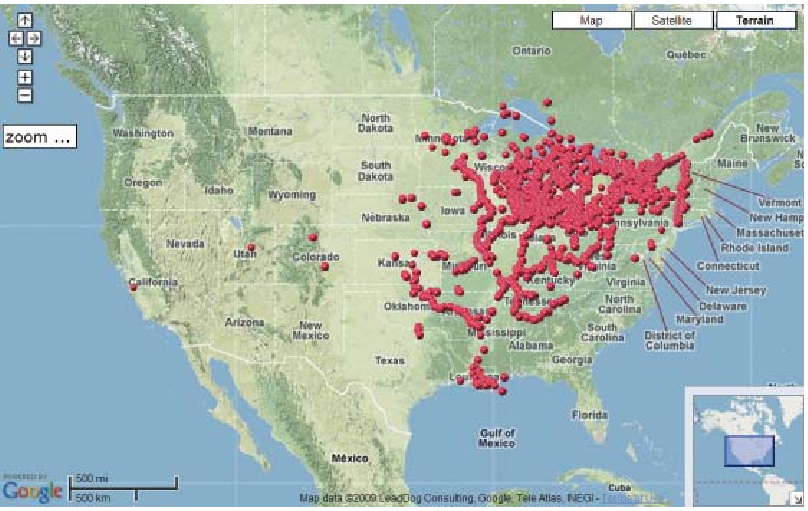

Figure 1. Updated daily on the U.S. Geological Survey's Web site, this map is a compilation of confirmed sightings of zebra mussels (red dots) in the United States and Canada from 1988 through 2009 (Benson 2009). The data shown here are as of 8 December 2009 [see note with Benson (2009) reference]. Each dot does not necessarily represent an established population, but for most locations it does. Reported sightings come from a variety of federal, state, and municipal agencies as well as universities, public utilities, and engineering and private consulting firms.

seek precise answers to small questions, rather than approximate answers to large questions" (p. 138).

Lessons learned for policy

Alarm associated with the appearance of zebra mussels drove advances in control technologies and policies for better prevention and management of species invasions in the United States (Strayer 2009). For instance, the U.S. government passed the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 and its reauthorization as the National Invasive Species Act of 1996, and set up the Aquatic Nuisance Species Task Force (1990) and National Invasive Species Council (1999). In addition, the Lacey Act (1900, amended in 1998) lists zebra mussels as "injurious." However, much remains to be done before the United States has a coordinated and effective policy (Strayer 2009). According to Strayer (2009), even after 20 years, the approach to alien species prevention and control in the United States is a patchwork of inadequate policies that are poorly coordinated, focused on species rather than vectors, slow, and largely reactive rather than proactive. Furthermore, the current approach "does not meet the recommendations of experts on invasive species ecology and management" (Strayer 2009, p. 140).

Lessons learned for economics

Except for rare examples, economic impacts of the zebra mussel invasion are poorly documented at best. Impacts to recreation, commercial fisheries, and commercial shipping seem not to have been studied at all (Strayer 2009). The documented cost to power plants and municipal drinking water plants in North America from 1989 to 2004 was $267 million, which is perhaps surprising, yet according to Strayer, "we are far from having a full appreciation of the economic effects of the zebra mussel invasion, even though this was articulated as an important question at the very beginning of the invasion" (p. 138).

Lessons learned for outreach

Outreach efforts via Web sites, brochures, wallet cards, lectures, and newspaper articles, for example, have resulted in the zebra mussel being the freshwater invertebrate with the highest public profile in North America. As a result, recreationists often provide the first report of spread to new areas. However, the lack of evaluation mechanisms built into outreach efforts has resulted in a lack of understanding of which tools actually work to increase public awareness and change damaging behaviors. Strayer (2009) identifies two challenges to successful public education: (1) overcoming public misconceptions and (2) overcoming the public tendency to see the spread of zebra mussels (and other invasive species) as random, unconnected problems. A primary misconception is that zebra mussels "improve" water clarity (without any acknowledgment of the dangers of moving this species into uninfested waters). For example, in order to improve water clarity, recreational divers likely introduced zebra mussels into two lakes in New Jersey, which had been far outside their established range (Strayer 2009). Zebra mussels are still touted as "the best thing that ever happened" to Dutch Springs, one of these lakes (http://njscuba.net/reefs/chart_pa_dutch_springs.html; accessed 3 December 2009). This example illustrates the deleterious outcome of the public harboring naive ideas about the benefits of zebra mussels (and other invasive species); it also illustrates that although invasions may be inevitable, they are also predictable and potentially controllable consequences of specific human behaviors.

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—Katie KellerLynn

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BOOK REVIEW

The Rising Sea

THE SEA IS RISING! THE SEA IS RISING! Not to be confused with "The sky is falling! The sky is falling!" Poor Chicken Little panicked, but Orrin Pilkey and Rob Young, authors of *The Rising Sea*, take a calm, pragmatic approach to explain sea-level rise. Recognized for his public service by marine, geological, and chemical societies, Pilkey is professor emeritus of earth sciences and founder and director emeritus of the Program for the Study of Developed Shorelines, Nicholas School of the Environment, Duke University, Durham, North Carolina. Young is a nationally recognized expert on wetland ecosystems and coastal environments and is a professor in the Department of Geosciences and Natural Resources at Western Carolina University, Cullowhee, North Carolina. He also serves as director of the Program for the Study of Developed Shorelines. Pilkey and Young "chose to write this book because [they] believe the public needs to have a clear guide to the critical but basic facts about sea level rise and its implications, in order to make intelligent decisions" (p. xii). The final chapter of the book provides recommendations for the societal decisions the authors believe need to be made to begin to address sea-level rise. Decision makers include private citizens, coastal managers, scientists, community planners, national and international government officials, and groups that can provide financial incentives for relocating infrastructure away from the coasts after storm events.

From the authors' perspective—a combined 65 years of studying marine and coastal processes—the effects of global warming are all around us: Venice is drowning. The Netherlands is walled off from the sea. The United States spends hundreds of millions of dollars each year managing beaches that are eroding. From their coastal point of view, there is no need to calculate global temperatures to prove planet Earth is warming, nor is it necessary to argue that the Northern Hemisphere winter of 2007–2008 was the coldest since 2001 (to justify inactivity in the face of climate change). The evidence is clear enough, and *The Rising Sea* provides example after example of the physical outcomes of sea-level rise, many of which are occurring in the National Park System. Consider the following:

Cape Lookout National Seashore. In 1899, Diamond City, North Carolina, was one of the largest towns on the Outer Banks. The now-immersed city is located within the boundary of the national seashore. At the turn of the 19th century, the shoreline was eroding and the protective high dunes began to disappear, probably as a result of sea-level rise. However, a series of storms leading up to and including the nail-in-the-coffin Great Hurricane of 1899 ended this working community of whalers. According to *The Rising Sea*, "today most of the house sites are well out to sea on the continental shelf, the high dunes used by whale spotters [to 'look out'] are completely gone, and the shoreline is retreating at 10 feet (3.0 m) or more per year" (p. 135).

Bering Land Bridge National Preserve. Preserving a long history of sea-level rise, Bering Land Bridge and other Arctic preserves operate "in tandem with greatly increased storm impacts because of longer periods of ice-free conditions on the ocean and melting of beach permafrost" (p. 129). The book pays special attention to the trials and tribulations of the citizens of Shishmaref, whose village and livelihood are threatened by global warming, sea-level rise, and severe beach erosion.

Cape Hatteras National Seashore. Shoreline erosion resulting from sea-level rise on both sides of the barrier-island chain is narrowing the width of the long, low islands off the coast of North Carolina. In 2005 the U.S. Geological Survey published an open-file report about sea-level rise impacts at Cape Hatteras National Seashore (Pendleton et al. 2005). Scientists expect that during a storm of sufficient duration and intensity, many new inlets will open up in the barrier, resulting in the isolation of the eight small tourist villages within the national seashore (Pilkey and Young 2009). The owners of threatened homes and businesses in these oceanfront villages at Cape Hatteras have requested beach nourishment to buffer their properties from the ocean's erosive forces. The National Park Service assisted with the guidance document for this process (Brunner and Beavers 2005).

Everglades National Park. As sea level rises, salt water will intrude on this vast Florida marsh ecosystem, profoundly changing the flora and fauna. The multibillion-dollar restoration that is under way considers a 1-foot (0.3 m) rise over the next century. However, the authors question what "restoration" will mean in the long term because a 3-foot (0.9 m) sea-level rise is likely for this area.

Of particular interest to resource managers may be Chapter 6, "The Living Coasts." The coastal and marine systems highlighted (i.e., coastal wetlands, marshes, mangroves, and corals) in this chapter are facing a future that is truly unprecedented. Throughout geologic history, these systems have migrated back and forth along with changing sea level. Now, as a result of human activities, coastal wetlands and coral reefs have to respond to changes in ocean volume and attendant shoreline movement while responding to anthropogenic changes in the physical environment. Pointing to the sad realization that our coastal towns, cities, and developments leave no room for the future migration of these systems, the authors ask, "When our coastal cities and towns become threatened by rising sea level, will we give these natural ecosystems high enough priority to assure their survival?"

Another notable discussion in the book is about the Intergovernmental Panel on Climate Change (IPCC) 2007 report, the fourth United Nations–supported assessment of global change. Many researchers, including those in the National Park Service, quote the IPCC prediction of sea-level rise given in this report, and the media now widely accepts that the predicted sea-level rise will be between 7 and 23 inches (18 and 58 cm) by the end of the 21st century. However, the authors point out that this range does not include critical, perhaps catastrophic, increases due to ice sheet melting. According to the IPCC, "models used to date do not include uncertainties in climate–carbon cycle feedback nor do they include the full effects of changes in ice sheet flow, because a basis in published literature is lacking" (IPCC 2007; specifically Summary for Policymakers, p. 14). The 2,500-member IPCC committee chose to include only the causes of sea-level rise that could be predicted with mathematical models; these causes are thermal expansion (increase in ocean volume due to warming) and the melting of the world's mountain glaciers. *The Rising Sea* discusses glaciers and their potential impacts on the rising sea, including the retreating glaciers in Glacier National Park (Montana) and the mountain glaciers in Alaska, such as those in Glacier Bay National Park and Preserve. According to the authors, however, the so-called 800-pound gorilla is the West Antarctic ice sheet. Various investigators have made projections that include ice sheet melting: Rahmstorf et al. (2007) estimate 1.6 to 4.6 feet (0.5 to 1.4 m) in sea-level rise by 2100; Pfeffer et al. (2008) predict slightly less than 3 feet (0.9 m) to a maximum of 6.5 feet (2 m) by the end of the century. Pilkey and Young recommend a "cautious and conservative approach" to coastal management and planning that assumes that ice sheet disintegration will continue and accelerate. For planning purposes, the authors suggest a 7-foot (2 m) rise by the year 2100.

As the sea rises, these authors remain unafraid of getting their feet wet, and they encourage others to do the same. They urge environmental consultants who model erosion rates to venture away from their computers to look at the sediments they are modeling, and engineers who predict shoreline erosion to wade knee-deep in the surf zone in order to provide meaningful estimates to constituents. Applying geologic common sense, Pilkey and Young show that the challenge, difficulty, and even inability to forecast global warming do not mean that global warming is not happening. They show that field data are the most reliable measures of global change, and these data present a compelling case for concern.

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—Katie KellerLynn

Notes from Abroad

COURTESY OF HEIDI BAILEY

Drinking wine in the name of science

By Heidi Bailey

AT A SMALL FAMILY-OWNED winery on the Greek island of Lesvos, Dr. Nickolas Zouros tells a small group of earth scientists why drinking wine will make them better communicators.

The wine is not meant to loosen the scientists' tongues, but rather to demonstrate a way of showing visitors how their everyday lives are touched by geology. The wine is made from grapes, the grapes are grown in soil, and the soil is a reflection of local geology (figs. 1 and 2). Connections like this—between science and culture—are at the heart of a new type of tourist destination known as a "geopark."

The geopark phenomenon

A geopark is a regional partnership of local people and land managers working to promote the geological and cultural heritage of an area through education and sustainable tourism. Dr. Zouros is the director of the Lesvos Petrified Forest Geopark in Greece and a founding member of the international geopark network. He is guiding a field trip for a group of earth scientists who have come from Spain, Poland, Italy, Portugal, Germany, France, Greece, the United Kingdom, and the United States.

The students are here to experience, discuss, and share techniques for communicating earth science concepts to the pub-

COURTESY OF KATARZYNA KOZINA

Figures 1 and 2. The owner of the Lesvos winery holds a piece of gypsum (calcium carbonate), a constituent of the soil that gives the wine from his vineyard (left) a distinct character.

By first enticing visitors with food, wine, art, and architecture, the geopark can engage people in developing an appreciation for the role of science in everyday life.

lic. Perhaps the most innovative technique they learn is how to link the geologic story of a place to the cultural heritage of its people.

Today the students have abandoned their notebooks and pencils to join Dr. Zouros in experiencing the Lesvos Petrified Forest Geopark firsthand (fig. 3, next page). Along with tasting wine, they visit art museums, savor traditional Greek dishes, sample spoon sweets and ouzo liquor, shop for souvenirs, explore a religious monastery and a Turkish fort, stroll along a volcanic beach, listen to tales from Greek mythology, and while away the afternoons in coffee shops.

On this field trip, the students are experiencing what most tourists are looking for in a vacation: relaxation, culture, adventure, and subtle learning experiences. By first enticing visitors with food, wine, art, and architecture, the geopark can engage people in developing an appreciation for the role of science in everyday life.

During their visit, geopark guests discover that the minerals in soil infuse wines with distinctive flavors, a quality known as *terroir*. They see how landscapes have inspired centuries of artists. They realize that the stone walls of monasteries and forts are responsible for preserving history. They find out how geological processes define the borders of countries and contribute to the growth of cultures. For perhaps the first time, visitors see that earth science touches every aspect of their lives.

Geopark guests leave with an understanding that culture and science are forever intertwined. They may not remember rock types or the terms for geological processes, but they carry away the wonder of Earth's heritage. The next time they enjoy a glass of wine, perhaps they will speculate on the minerals that give the wine a distinct quality. The geopark experience is now part of their life experience.

Geopark guests are as diverse as the geology of an area, and the European Geoparks Network, of which the Lesvos Geopark is a member, excels at offering experiences that fit the interests of a variety of visitors. A geopark is a designation similar in concept to a national heritage area, and covers a large region that is home to many smaller parks, protected areas, and local communities. These places are linked thematically to create a unified destination image that centers on striking geology and living culture.

The most appealing aspect of the geopark model is the inclusion of local people as an integral part of the equation. The initiative not only protects and manages geological resources but also spurs sustainable economic development in surrounding areas.

Economic impacts of geoparks

A major part of the geopark initiative's mission is to work with local residents on improving their living conditions and the quality of their environment. While preservation and conservation programs often exclude the needs of the people living in an area, a geopark seeks to balance both.

The ultimate goal of a geopark is to offer solutions to several pressing issues. First, people in small communities often suffer economic losses when traditional industries like mining and agriculture decline. This creates a need for alternative economic development strategies in rural areas.

Second, locals and visitors alike may not recognize the impact of earth science on the existence of ecosystems and the development of cultures. This creates a need for inventive education and interpretive techniques.

Finally, geologic sites and landforms are often ignored or appreciated only for their shape or aesthetic appeal. The names and histories of geological objects may be limited to colloquialisms and mythological tales. Without an understanding of earth science, many people do not see the importance of conserving geologic resources. People accustomed to protecting flourishing plants and charismatic animals may be uninspired by inanimate rocks.

By offering cultural programs, [geoparks] attract visitors who may not … think they are interested in geology or science.

A geopark draws attention to these undervalued places. This, in turn, raises awareness about geodiversity, encourages tourism in rural areas, and builds partnerships between land managers and local people. Since its inception in 2000, the European Geoparks Network has grown in size and popularity and is now inspiring other nations to create their own geoparks.

Worldwide interest in the program prompted UNESCO (the United Nations Educational, Scientific, and Cultural Organization) to form a Global Geoparks Network in 2004. Today, 64 sites in 19 countries are linked under this global umbrella and more are joining each year. The United States is among the nations considering membership.

Geoparks and the United States

Currently, representatives of the National Park Service (NPS), Bureau of Land Management, U.S. Geological Survey, and Geological Society of America are discussing the possibility of the United States joining the Global Geoparks Network.

"We are gathering information on what it would take for the U.S. to join," says Wesley Hill, international secretariat for the Geological Society of America. "This initiative is important because it identifies, links, and recognizes geoheritage sites under one global program. It offers an opportunity to bring together federal and state land management agencies along with scientific experts, nongovernmental organizations, industry, and local people to strengthen earth science conservation, education, and tourism."

In the United States, earth sciences have largely taken a backseat to biological sciences. While "ecotourism" is now a familiar term in the travel industry, geologic tourism (or geotourism) is still relatively unknown. The public has largely viewed geologic features as static backdrops to the plants, animals, and people that live among them.

Geoparks can be an important first step in encouraging people to view geologic sites as dynamic interconnected landscapes similar to ecosystems, habitat corridors,

Figure 3 (left). Earth scientists gather at Lesvos Petrified Forest in Greece to learn about the role of geoparks in highlighting connections between an area's geology and its culture.

COURTESY OF ERDAL GUMUS

and watersheds. In addition to public lands, these areas may include mines, farms, businesses, private fossil sites, historic buildings, and other cultural sites that are tied to the geological story of the area.

"Many sites with great geologic significance are larger than a single park," says Lindsay McClelland of the NPS Geologic Resources Division. "The National Park Service may manage only a small part of the geologically significant area."

"The National Park Service is currently assessing its participation in a U.S. geoparks program," McClelland continued. "Questions from NPS managers include the need for geoparks if the National Park Service is already participating in the [UNESCO] World Heritage Program; the amount of work, including administrative burden required for the process; public opinion; benefits of geopark designation; and demonstration of socioeconomic impacts, such as increased visitation."

In answer to these questions, supporters say the geopark initiative offers a welcome alternative to the World Heritage Program, which operates under strict guidelines that generally exclude multiple-use lands such as those managed by the Bureau of Land Management and the U.S. Forest Service, and awards status only to those areas with outstanding universal value, requiring documentation of international significance. Geopark designations could include a combination of lands managed by the National Park Service and multiple-use agencies to encompass most or all of a nationally significant geologic area. In addition, the intent is for geoparks to be created at the local level and administered by collaborative partnerships rather than by NPS personnel. Socioeconomic impact studies and visitor surveys are being conducted at existing geoparks and the results are forthcoming.

In the meantime, staff from the National Park Service and Geological Society of America are drafting a set of guidelines should the United States choose to join the initiative. In addition, supporters are talking one on one with people who may ultimately benefit from the program: land managers, small-business owners, and local communities.

An example of an NPS site that might benefit from inclusion in a geopark is Florissant Fossil Beds National Monument in Colorado. "We are a small monument located within a large region of geologic significance," says Superintendent Keith Payne. "Our site is already part of the Gold Belt Scenic Byway partnership, which is active in promoting geologic and historic tourism. We are considering the geopark initiative as a way to bring international recognition to this area. We don't want to create something new that requires a lot of time and resources. We are interested in enhancing a wonderful partnership that already exists between numerous public and private sites that are connected by a similar geology."

The power of the geoparks initiative is that it draws attention to places that are relatively undiscovered as tourist destinations. The geopark designation is particularly well suited for smaller parks and monuments such as Florissant Fossil Beds that lack the celebrity status of sites like the Grand Canyon. Geoparks have the potential to draw new visitors in two important ways. First, they will attract international tourists who have visited other sites within the Global Geopark Network. Second, by offering cultural programs, they can attract visitors who may not initially think they are interested in geology or science.

"Many sites in the National Park System do a great job interpreting geology in the context of American culture," says Jim Wood of the NPS Geologic Resources Division. "Several sites interpret gold rushes, including the Klondike Gold Rush in Seattle and Alaska. Other sites, such as Alibates Flint Quarries National Monument in Texas, interpret the connection between American Indian life and geology. Geologic sites such as Scotts Bluff in Nebraska served as signposts to early explorers and frontier people. There is a strong focus on linking history and geology throughout the national parks. The geopark initiative adds to this idea by also linking geology to the cultural value of modern landscapes."

In a geopark, it is not just public land managers that bear the responsibility of protecting and interpreting natural resources. Instead, local businesses—like the winery in Greece—play an important role in earth science education by intertwining geology and culture. For as Dr. Zouros explains to his students while they are drinking their wine, "Geoparks are not just about rocks—they are mainly about people."

For more information

To learn more about the Global Geoparks Network, visit www.globalgeopark.org. To find out more about U.S. involvement in the initiative, e-mail WHill@geosociety.org.

About the author

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PS

State of Science

RYAN VON LINDEN/NEW YORK DEPARTMENT OF ENVIRONMENTAL CONSERVATION

White-nose syndrome in bats:

A primer for resource managers

By Kevin T. Castle and Paul M. Cryan

Abstract

White-nose syndrome emerged as a devastating new disease of North American hibernating bats over the past four winters. The disease has spread more than 1,600 kilometers (1,000 mi) since it was first observed in a small area of upstate New York, and has affected six species of bats in the caves and mines they rely on for winter survival. A newly discovered, cold-loving fungus (*Geomyces destructans*) causes the characteristic skin infection of white-nose syndrome and can infect presumably healthy bats when they hibernate. Although clear links between skin infection by *G. destructans* and death have not yet been established, the fungus is the most plausible cause of the disease. Thousands of caves and mines are administered by the National Park Service. Although bats testing positive for white-nose syndrome have been detected only at two sites in the National Park System thus far, the National Park Service (NPS) has been preparing for the spread and effects of white-nose syndrome through a proactive national program of response coordination, research support and interpretation, and education. National park areas across the nation are uniquely situated to help understand white-nose syndrome and its ecosystem impacts, and assist in the conservation and recovery of affected bat species.

Key words

bats, caves, conservation, disease, federal lands, fungus, management, mines, white-nose syndrome, wildlife disease

WHITE-NOSE SYNDROME (WNS) is a disease responsible for unprecedented mortality in hibernating bats in the eastern United States and Canada. This previously unknown disease has spread very rapidly since its discovery in January 2007, and may pose a considerable threat to hibernating bats throughout North America. As white-nose syndrome spreads, the challenges for understanding and managing the disease are increasing.

History

White-nose syndrome was first observed in four caves near Albany, New York, in the winter of 2006–2007. Before the onset of the disease, decades of winter surveys for hibernating bats that occur in New York indicated healthy and increasing populations (Hicks and Novak 2002). Since 2007, white-nose syndrome has spread more than 1,600 kilometers (1,000 mi) through 11 additional states and devas-

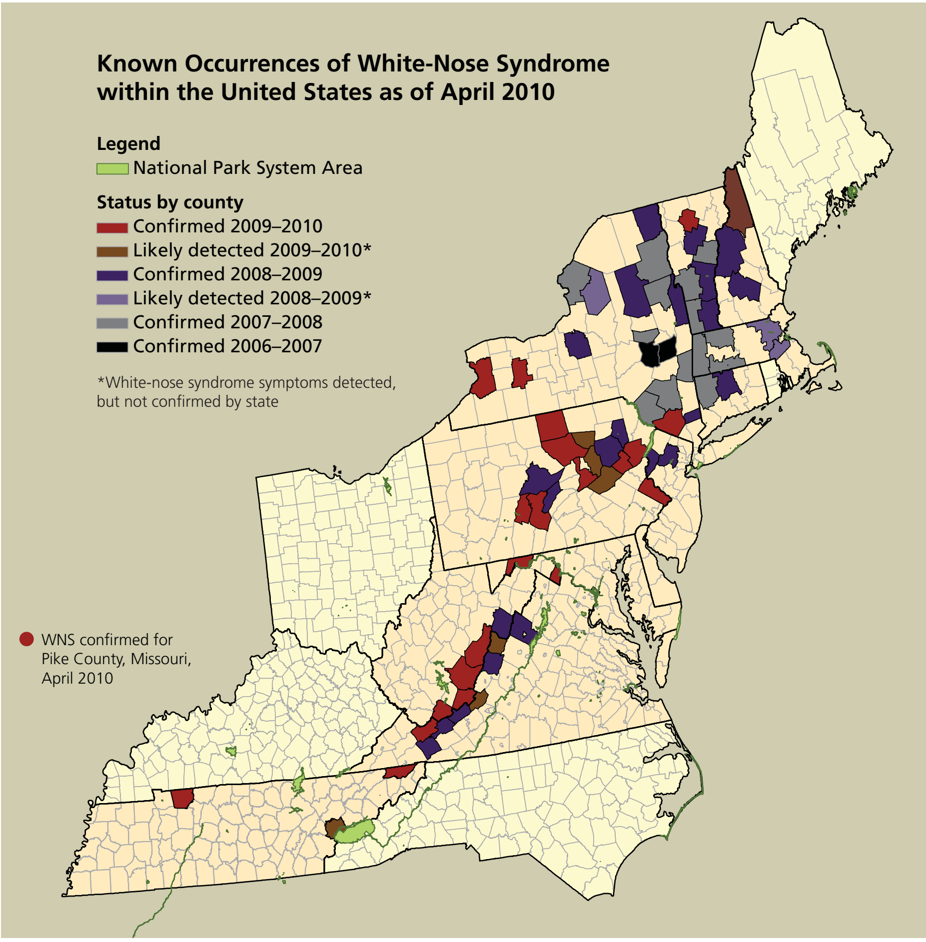

Figure 1. Map of the northeastern United States showing the status of white-nose syndrome occurrence in bats by county.

Figure 2. A close-up of a little brown bat (*Myotis lucifugus*) reveals the white fungal growth associated with white-nose syndrome on its muzzle (facing page) and on its wing and tail membrane (above), New York, October 2008.

Table 1. Hibernating cave bats susceptible to white-nose syndrome

Common Name	Scientific Name
Little brown bat	*Myotis lucifugus*
Northern long-eared bat	*Myotis septentrionalis*
Indiana bat	*Myotis sodalis*
Eastern small-footed bat	*Myotis leibii*
Tricolored bat	*Perimyotis subflavus*
Big brown bat	*Eptesicus fuscus*

tated populations of bats in its path. As of mid-April 2010, white-nose syndrome has been confirmed as far west as St. Louis, Missouri. Overall declines of hibernating colonies at the most closely monitored New York sites reached 75% within two to three years of initial detection (Blehert et al. 2009). As of winter 2009–2010, white-nose syndrome had been detected in six of the seven species of hibernating bats that occur in the affected region (fig. 1). Species affected to date are listed in table 1.

The disease appears primarily to affect insectivorous bats while they are hibernating, and hibernators comprise the majority of the 45 species of bats that occur in the United States. Most bats living in cold temperate zones survive the harsh conditions of winter by moving to cold places, where they lower their body temperature to save energy and metabolize stored body fat until insect food becomes available again (Ransome 1990). These flying insect predators are long-lived (approximately 5–15 years or more) and reproduce slowly. Like other top mammalian predators, such as polar bears and mountain lions, numbers of hibernating bats do not fluctuate widely over time, and populations affected by white-nose syndrome will likely take a very long time to recover.

White-nose syndrome was initially named “fuzzy muzzle” by some biologists, for the visible presence of a white fungal growth around the muzzles, ears, and wing membranes of affected bats (fig. 2). In summer 2009, scientists identified a previously unknown species of cold-loving fungus (*Geomyces destructans*) as a consistent pathogen causing skin infection in bats at affected sites (Gargas et al. 2009). This fungus thrives in low temperatures (5–14°C; 40–55°F) and high levels of humidity (>90%), conditions that are characteristic of both the bodies of hibernating bats and the caves and mines in which they hibernate (fig. 3, next page). Chronic disturbance of hibernating bats can cause high rates of winter mortality through loss of fat and possibly water, and effects associated with skin infection by *G. destructans* may also cause bats to consume critical fat and water reserves too

Figure 3. Hibernating Indiana bats (*Myotis sodalis*) form a cluster in a New York cave. The density of bats, which may be as high as 300 individuals per square foot, could enhance the spread of white-nose syndrome. ALAN HICKS, NEW YORK DEPARTMENT OF ENVIRONMENTAL CONSERVATION

quickly during winter. Aberrant behaviors observed at sites affected by white-nose syndrome can include (1) large numbers of bats moving within hibernacula to roosts near entrances or to unusually cold areas; (2) large numbers of bats flying during the day outside of hibernacula in midwinter; (3) general unresponsiveness to human disturbance; and (4) large numbers of fatalities, either inside hibernacula or near their entrances. Not all of these behaviors may occur at affected hibernacula; this is particularly true of mortality early in the disease onset. Skin infection by *G. destructans* is a plausible primary cause of mortality associated with the disease. However, the exact processes by which skin infection leads to death remain undetermined and it is unclear whether other underlying conditions contribute to mortality (Meteyer et al. 2009).

One of the greatest mysteries surrounding white-nose syndrome was its rapid appearance. Biologists in North America had never reported white fungus on the muzzles of living bats in winter, yet reports from European scientists indicated that similar fungal growth had been seen on hibernating European bats since the mid-1980s. However, there are no reports of bat mortality associated with such fungal infections in Europe. A recent publication compared small portions of the genome of *G. destructans* from North America with fungal samples recovered from a French bat (*Myotis myotis*), and found that the two were identical (Puechmaille et al. 2010). Additional genetic research is being conducted in Europe and the United States to further compare these fungal isolates, to determine if and when *G. destructans* may have spread from Europe to North America, and to determine why European bats seem less prone to mortality. Bats do not naturally migrate between Europe and North America, so if *G. destructans* was recently introduced to the United States, it is highly unlikely that it arrived here on the wings of a bat without human assistance.

Spread of the disease

Bats undoubtedly play a major role in spreading the disease from one area to another through local movements and long-distance migration. Laboratory experiments have shown that *G. destructans* can be transmitted among diseased and presumably healthy bats through physical contact (USGS 2009). Studies are ongoing to determine whether *G. destructans* persists in cave or mine environments and infects bats that subsequently come into contact with it, although preliminary evidence suggests sites can remain infectious. Humans may also unwittingly transmit the fungus from one place to another. There is circumstantial evidence to support the potential for this mode of transmission among popular recreational caving sites (USGS 2009). The fact that the same fungus exists on two continents provides compelling evidence of long-distance, human-assisted spread.

NPS-protected resources at stake?

Caves

Nearly 4,000 caves are administered by the National Park Service in roughly 85 different units of the National Park System. In addition, approximately 126 park units have mines, which total almost 3,100 in number. Among the most well-known parks with caves are Mammoth Cave and Carlsbad Caverns national parks and Jewel Cave and Timpanogos Cave national monuments. Mammoth and Jewel are the world's two longest caves, with surveyed lengths of 580 kilometers (360 mi) and 241 kilometers (150 mi), respectively. Although some caves exhibit extraordinary geologic, hydrologic, and biologic features, all caves in the National Park System are classified as "significant" by the Federal Cave Resources Protection Act. Mines are not generally afforded the same level of resource protection, although some contain significant bat populations. Many NPS-administered caves and mines provide important refuge for bats by serving as winter hibernacula or summer maternity roosts.

Bats do not naturally migrate between Europe and North America, so if* G. destructans *was recently introduced to the United States, it is highly unlikely that it arrived here on the wings of a bat without human assistance.

Figure 4. Biologists from the National Park Service and U.S. Geological Survey have installed remotely triggered infrared cameras in a cave at Cumberland Gap National Historical Park in Kentucky, to help document and investigate how white-nose syndrome might lead to bat mortality.

NPS/KEVIN CASTLE

Throughout the National Park System, caves and mines also provide habitat for rare or unique life-forms in addition to bats.

Bats

More than 40 bat species are found in the National Park System in the contiguous 48 states. A majority are insectivorous, cave-dwelling species that hibernate and are, therefore, susceptible to white-nose syndrome. A number of national park areas (e.g., Mammoth Cave, Great Smoky Mountains, Cumberland Gap) contain hibernacula or maternity colonies of one or more of the four hibernating bat species and subspecies that are federally listed as threatened or endangered (T&E species) under the U.S. Endangered Species Act. Those and other parks are also home to large colonies of non-T&E species that could be severely affected by white-nose syndrome. In the temperate zones of North America, bats are the major, and sometimes only, predators of night-flying insects. Hibernating bats have always been an important part of both natural and human-modified ecosystems in the United States and certainly have beneficial effects on our lives. For example, many of the crops grown in the United States and Canada are likely protected from night-flying insect pests by bats (e.g., Cleveland et al. 2009). White-nose syndrome has the potential to alter these "secret alliances" in ways that are difficult to predict.

Visitors

Each year approximately 1.7 million recreational visits are recorded at parks such as Mammoth Cave, Carlsbad Caverns, Jewel Cave, Timpanogos Cave, and Wind Cave, where cave resources are primary features. Roughly 2.4 million visits are recorded annually at Cumberland Gap National Historical Park, Great Basin National Park, and Ozark National Scenic Riverways, where caves are important but not primary features. If caves were closed year-round to all visitation because of the impacts of white-nose syndrome on bats inhabiting those caves, visitor enjoyment of those areas would be greatly diminished. In addition, the economic impacts on parks and gateway communities could be severe. The high number of visitors to our national parks gives the National Park Service an unmatched opportunity to educate people about white-nose syndrome and to ask for their assistance in controlling the spread of this disease.

NPS roles

The NPS Wildlife Management and Health Program (Biological Resource Management Division) leads an NPS white-nose syndrome working group made up of cave and bat ecologists, regional biologists, and a park superintendent. The primary objectives of the working group are to disseminate information among parks and regions and to help interpret general management recommendations made by non-NPS agencies in light of NPS policies. The Wildlife Management and Health Program remains involved in interagency working groups, including a team developing national guidance on white-nose syndrome.

In February 2009, three dead bats found near an abandoned mine at Delaware Water Gap National Recreation Area in Pennsylvania were submitted for WNS testing and were positive for *G. destructans* and white-nose syndrome. In early April 2010, bats from Great Smoky Mountains National Park tested positive for the fungus. Despite the proximity of a number of additional park units to WNS-positive hibernacula (see fig. 1), Delaware Water Gap and Great Smoky Mountains are the only sites in the National Park System with bats that have tested positive for white-nose syndrome. Active surveillance for endangered species in national parks such as Mammoth Cave is typically conducted biannually, and additional surveys have been conducted at national parks by federal and state biologists to monitor the spread of white-nose syndrome. As of February 2010, surveys at Mammoth Cave have revealed normal bat numbers and activity levels but no indication of white-nose syndrome.

Research

Many national park area caves with significant bat populations or other significant resources are already off-limits to research, except to those who have proper permits. In response to the WNS threat, many more caves in national park areas have been closed. The National Park Service is assisting the investigation of white-nose syndrome by helping to identify knowledge gaps and by supporting research to better understand the disease. There is a largely unmet need for research to determine basic information about white-nose syndrome before effective management strategies can be invoked, including routes and rates of transmission, biology of *G. destructans*, pathogenesis, control methods, bat species susceptibility or resistance, and effects on other animal species. An overarching NPS goal is to ensure that scientists working in national parks engage in research and management activities that do not make things worse for the bats or the ecosystems of which they are an integral part. To minimize the potential for humans to introduce white-nose syndrome into bat caves, a number of parks have obtained park-specific caving and bat-capturing equipment or have purchased washing machines and dryers so that researchers and others with a need to enter caves or handle bats do not risk spreading the disease. Scientists from the U.S. Geological Survey and the National Park Service are collaborating on a project at Cumberland Gap in Kentucky to monitor hibernating bats using remotely triggered infrared cameras so bat disturbance is minimized (fig. 4). Although white-nose syndrome has not yet reached this park, the objective of the camera project is to document normal bat behaviors during hibernation so that aberrant behaviors that occur in the presence of the disease can be evaluated.

Education

National park staffs have an excellent opportunity to educate millions of people about white-nose syndrome because of the large number of visitors they contact. A number of national park areas have developed education materials, including interactive Internet pages, brochures, bulletin boards, and "live" information booths staffed by NPS interpretive and education personnel. Mammoth Cave, for example, uses all of the education materials mentioned and has combined a visitor footwear decontamination area with a WNS educational booth.

Recovery and conservation

A critical role for the National Park Service is to minimize disturbance of bats that hibernate or roost on its lands. It can be difficult to balance the need for information gained by directly observing bats with the need to minimize stress when bats are weakened or debilitated by disease. Caves and other areas in national parks where bats congregate may ultimately serve as refuges for bats that survive white-nose syndrome, because the National Park Service has a mandate to protect resources on its lands and can limit access to significant hibernacula and roosts. White-nose syndrome may render historical hibernacula and roosts unsuitable or unappealing for bat use and bats may begin to use other natural or artificial sites that have not been used before, including those on lands administered by the National Park Service.

National leadership role

National Park Service personnel have been involved with national WNS coordination efforts since March 2008. Since then, NPS wildlife veterinarians and cave and bat biologists have regularly attended national and regional WNS meetings. In autumn 2009 a multiagency effort to formalize a national plan for WNS investigation and management was initiated. Wildlife veterinarians with the National Park Service have an active role on the plan steering committee and the writing team.

What should national park staffs do?

In response to white-nose syndrome, the U.S. Fish and Wildlife Service and other federal agencies have recommended cave closures, decontamination procedures, and other management actions if the disease continues to spread. On 17 April 2009 the National Park Service issued guidance concerning white-nose syndrome in the national parks to help clarify the NPS position. The primary message of that memorandum and subsequent recommendations from the NPS Washington Office is that field-based staffs continue to make WNS management decisions based on the best science available and in accordance with the NPS mission, policies, and park enabling legislation. Recommendations include:

- Restrict access to caves serving as bat hibernacula or maternity roosts.
- In unaffected areas, ensure that gear entering caves has not been used in affected areas.
- Ensure proper decontamination of gear that is moved within affected areas.
- Review all cave-use permit requests, and approve only requests for scientific or educational purposes whose benefits outweigh the risk of potentially spreading white-nose syndrome.
- Collect and submit samples of dead bats to the appropriate diagnostic laboratories, following standard carcass submission procedures and safe work practices (found on the InsideNPS intranet site).
- Although there does not appear to be a direct human health risk related to white-nose syndrome, the NPS

Office of Public Health recommends that people handling bats use safe work practices and personal protective equipment to minimize exposure to, and spread of, infectious or toxic agents.

- Participate in public awareness and education to inform park visitors about white-nose syndrome and its threat to bat conservation.

Conclusions

White nose syndrome is an unprecedented danger to bat populations in the eastern United States and possibly to bat populations throughout North America. More than half of the 45 species of bats that occur in the United States rely entirely on hibernation as a winter survival strategy, when temperatures drop below freezing and insect prey is not available. Although the potential for *G. destructans* to continue to spread through hibernating bat populations is unknown, the implications of it undermining the survival strategy of so many bat species are enormous. We are just beginning to appreciate the important roles bats play as nocturnal flying predators in North American ecosystems. The unprecedented loss of bat populations in the wake of white-nose syndrome has the potential to alter the function of ecosystems and adversely impact the global economy through cascading effects, such as when crop- or forest-damaging insects typically eaten by bats are left unchecked. As with any wildlife disease that causes wide-scale mortality, understanding and managing white-nose syndrome will not be an easy task and the veterinary creed "first do no harm" must be followed. White-nose syndrome does not respect state or regional borders. National park areas across the nation are uniquely situated to help understand white-nose syndrome and its ecosystem impacts, and to assist with the conservation and recovery of affected bat species.

The National Park Service will be broadcasting a Service-wide white-nose syndrome Web-based seminar on Wednesday, 9 June 2010. All NPS personnel are invited to participate.

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Links for more information

NPS Wildlife Health Program
http://www1.nrintra.nps.gov/BRMD/Wildlife_Health_Management/Wildlife_Health/White_Nose_Syndrome.cfm

U.S. Fish and Wildlife Service
http://www.fws.gov/northeast/white_nose.html

USGS Fort Collins Science Center
http://www.fort.usgs.gov/WNS/

USGS National Wildlife Health Center
http://www.nwhc.usgs.gov/disease_information/white-nose_syndrome/index.jsp

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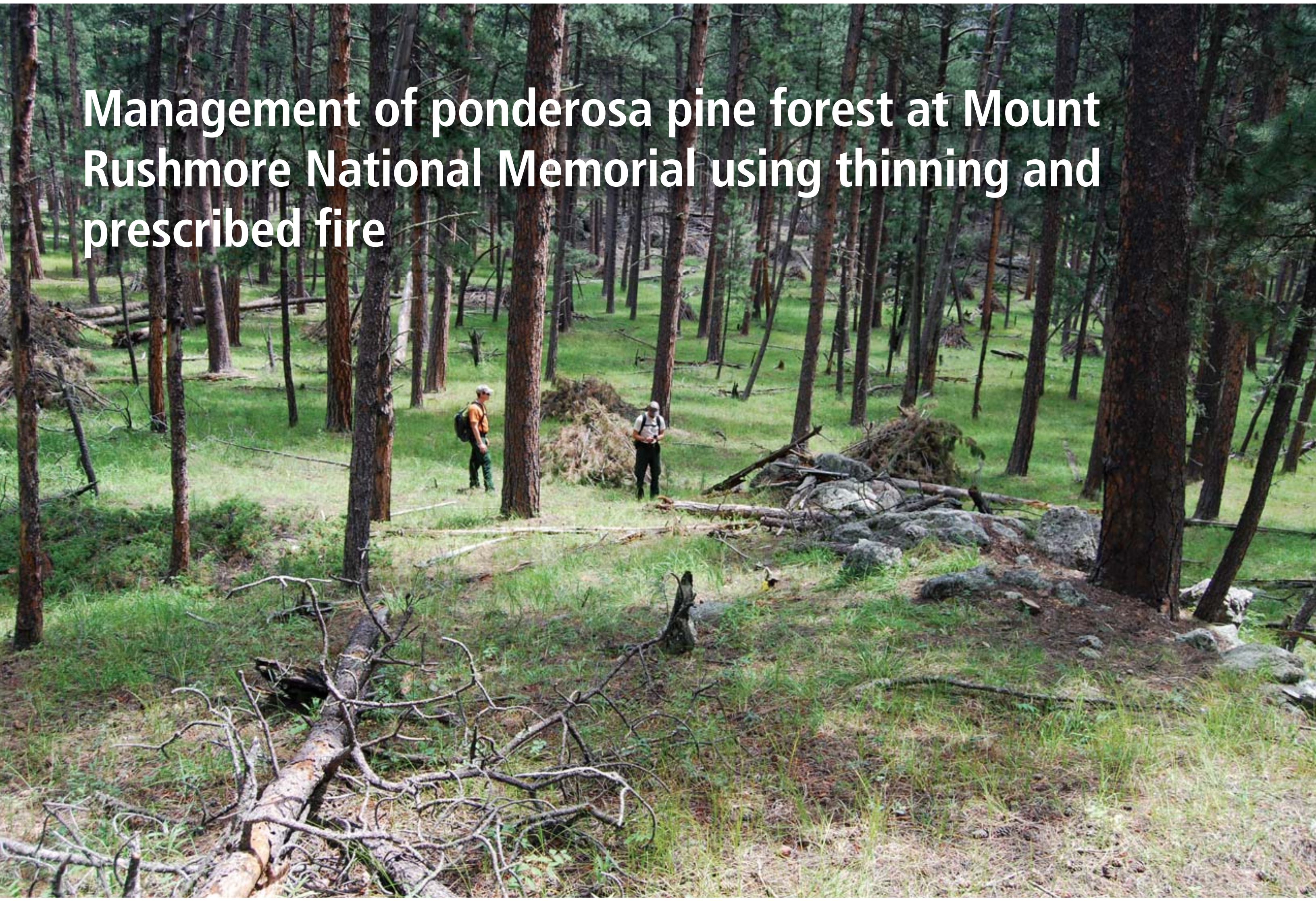
Science Feature

Management of ponderosa pine forest at Mount Rushmore National Memorial using thinning and prescribed fire



By Cody Wienk

MOUNT RUSHMORE UNderstandably has become synonymous with South Dakota. References to the massive granite sculpture of Presidents Washington, Jefferson, Roosevelt, and Lincoln are in the state nickname, on the license plate, and on the state-themed quarter. The memorial is known around the world and millions of people visit every year. Yet, I imagine few visitors appreciate the significance of the natural resources that surround the famous sculpture. For example, a research project completed in 2005 highlighted the value of the ponderosa pine (*Pinus ponderosa*) forest at Mount Rushmore. Symstad and Bynum (2007) reported that 66% of the memorial (850 acres [344 ha]) is covered by old-growth ponderosa pine forest and that it comprises "the second largest contiguous area of old growth within the Black Hills."

Even though the ponderosa pine stands of the memorial maintain many old-growth characteristics, their structure has changed significantly over the past century. Protection from timber harvest has maintained the large, old trees in the memorial, but fire suppression has allowed a dramatic increase in smaller-diameter pine trees (fig. 1a). These dense thickets of pine regeneration can act as ladder fuel and in the event of a fire, can carry fire into the overstory, resulting in a crown fire. These conditions make the forest susceptible to severe wildfires and insect outbreaks (Shepperd and Battaglia 2002; Brown and Cook 2006). The National Park Service (NPS) Northern Great Plains Fire Management Office has undertaken a combination of research and fire management projects in an attempt to restore the historical structure to these forest stands and make them less susceptible to stand-replacing disturbances (fig. 2). This article describes some of the significant forest management studies and actions designed to achieve this goal.

Figure 1a (above). Before thinning, the Old Growth project area is typical of forested areas in the Black Hills, characterized by dense growth of small-diameter trees with relatively few larger, older trees. **Figure 1b (facing page).** After thinning, the forest in the Old Growth project area is more open, fuel loads are reduced, and sunlight penetrates to the forest floor, stimulating vegetation growth.

NPS/NORTHERN GREAT PLAINS FIRE ECOLOGY PROGRAM (2)

NPS/MIDWEST REGION FIRE ECOLOGY PROGRAM, AUGUST 2009

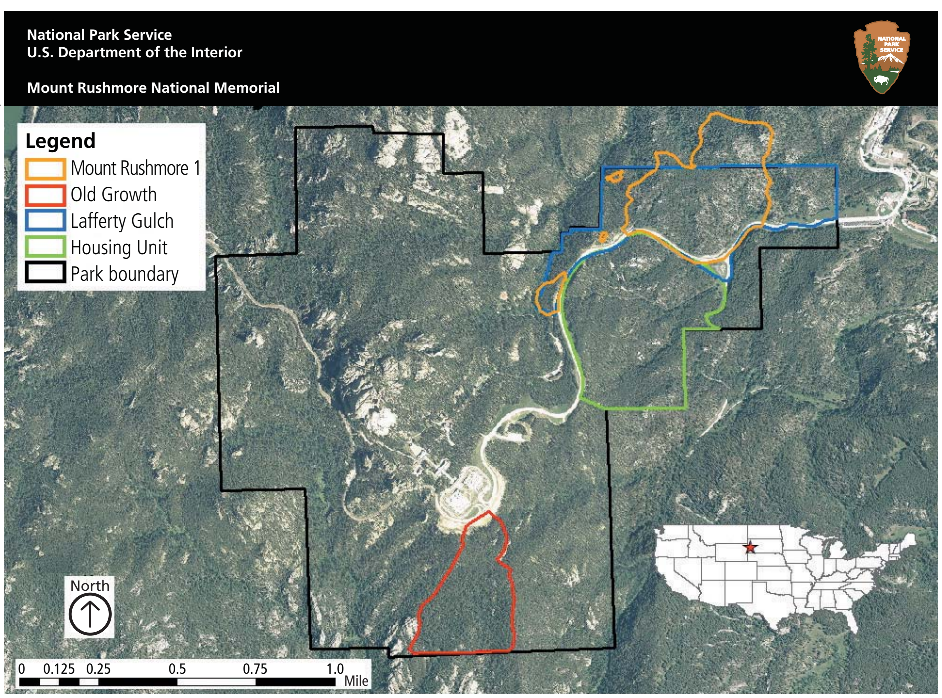


Figure 2. Recent forest thinning and restoration projects at Mount Rushmore National Memorial.

Mechanical thinning and an unplanned wildfire

In 2003 the Northern Great Plains Fire Management Office initiated a mechanical thinning project in Lafferty Gulch (see fig. 2). The office's Fire Ecology Program established monitoring plots throughout the area to document changes in the ponderosa pine stands and to assess the success of the treatments. The project involved mechanical removal of most ponderosa pine trees smaller than 6 inches (15 cm) in diameter, which reduced pole-sized trees by more than 90% (see fig. 1b). The material was then stacked by hand into an estimated 3,500 piles on the 115-acre (46 ha) treatment area. Crews burned the piles starting in January 2004 when snow cover was adequate to keep the fires from spreading. However, after about two weeks of burning, on the night of 27 February 2006, a chinook wind moved across the area. The warm winds rapidly reduced the snow cover and allowed the smoldering piles to creep into surrounding litter and duff, starting a wildfire called the Mount Rushmore 1 fire. Firefighters contained the fire after it burned approximately 100 acres (41 ha) on the memorial and neighboring USDA Forest Service land. Although it was unintended, the wildfire resulted in some positive benefits. Total fuel load across the burned area decreased by more than 70% and tree density was further reduced because the fire was hot enough to kill some of the overstory or larger, more mature trees (fig. 3, next page).

Research and old-growth restoration potential

I collaborated with Peter Brown, director of Rocky Mountain Tree-ring Research, on a research project funded by the Joint

Fire Sciences Program. This program is an interagency research partnership between the U.S. Department of the Interior and the U.S. Department of Agriculture that funds wildland fire research. We initiated the project in fall 2005 at Mount Rushmore with the goal of using tree-ring data to document changes in the historical fire regime[1] and forest structure[2] over the past several centuries, and to estimate crown fire risk and the effects of potential mitigation measures. Brown's team collected data from 1,000 living trees, snags, stumps, and logs throughout the memorial. The research results indicated that between the years 1600 and 1900, fires burned across the memorial an average of every 17 years. However, the last wildfire to burn here was in 1893, before fire suppression began to be commonplace in the Black Hills (Shepperd and Battaglia 2002).

Historically, the Mount Rushmore forests would have been dominated by large, old ponderosa pines with few seedling- and pole-sized trees and a rich understory of shrubs and herbs. When fires started under these conditions, it most often would have been a surface fire and few large trees would have been killed. Primarily because of fire suppression, today's forest contains more small-diameter trees, fewer large trees, and higher fuel loads (Brown et al. 2008). These conditions leave the forest susceptible to stand-replacing crown fire. However, many stands at Mount Rushmore maintain many large, old trees as well as remnant understory vegetation that should flourish once the pole-sized trees are removed to allow much needed sunlight and moisture to reach the forest floor. This condition makes restoration to historical stand structure very feasible.

[1] **Fire regime:** A combination of frequency, seasonality, severity (impact as measured by organic matter loss), intensity (amount of energy released from a fire), and scale of wildland fire across a landscape.

[2] **Forest structure:** The horizontal and vertical distribution of layers in a forest, including height, diameter, density, and species present.

NPS/ CODY WIENK

Figure 3. The Mount Rushmore 1 wildfire started in late winter 2006 when fire from slow-burning slash piles from a mechanical forest-thinning project increased in intensity following warm weather. Seventeen months after the fire, this view reveals brown trees killed by the wildfire. The town of Keystone is visible at the center.

Thus, the Mount Rushmore area could be a valuable reference landscape for Black Hills old-growth forest.

The principal investigator presented his findings to park and fire management staffs at the memorial in May 2007. He recommended mechanically thinning smaller-diameter trees and then using prescribed fire to reduce litter and duff accumulations. He also suggested that NPS Northern Great Plains Fire Management staff (stationed nearby at Wind Cave National Park) initiate thinning treatments in the remnant old-growth stands of the memorial. As a direct result of this research and the recommendations, fire management staff began to restore old-growth forest in the southern part of the memorial in fall 2008 (see fig. 1). Using chain saws, crews removed most ponderosa pine trees 5 inches in diameter and smaller and stacked the resulting fuel in piles by hand. They thinned approximately 30 acres (12 ha) that fall and completed an additional 25 acres (10 ha) in summer 2009. At least 2,000 debris piles were created during this project and will be burned over the next couple of winters when weather conditions permit.

Chipping: Another tool in the management toolbox?

The traditional approach to thinning ponderosa pine stands includes mechanically removing smaller trees, consolidating the resulting material, and burning the slash piles while there is snow cover. Since winter snow is often unreliable in the central and southern Black Hills, managers were interested in exploring alternatives to this method. Chipping the thinned material and broadcasting the chips on-site is an alternative that has been used in western forests (Wolk and Rocca 2009; Miller and Seastedt 2009). However, resource managers in western U.S. national parks are hesitant to use this method because of uncertainties about impacts of this type of treatment to herbaceous vegetation and soil.

The National Park Service funded and initiated research in 2008 to assess the impacts of thinning, chipping, and use of heavy machinery on herbaceous vegetation and soils of Black Hills ponderosa pine forests. Researchers established plots in the 125-acre (51 ha) Housing project area (see fig. 1) to determine pretreatment conditions of the study sites. During 2009, crews used chain saws to remove most trees smaller than 6 inches in diameter, and used a remotely controlled, tracked chipper to cut the material into fragments (figs. 4 and 5). The study is ongoing and focuses on depth of the wood chips, ground disturbance, and changes in herbaceous vegetation and soil chemistry. The research plots will be revisited over the next two years to evaluate changes to the site. Managers also hope to apply prescribed fire to the chipped areas to determine how the wood chips affect fire behavior in the forest.

NPS/KATE CUENO

Figure 4. An alternative to burning slash piles, chipping reduces forest debris to small wood fragments spread on the forest floor. Research in the Housing project area is investigating the effects of chipping on soil chemistry, ground disturbance, and vegetation.

NPS/KATE CUENO

Figure 5. This forest stand in the Housing project area has been thinned and chipped.

Conclusions

The recent research and fire management projects have both resulted from and contributed to increased awareness of the significance of the natural resources at Mount Rushmore. This is just the first step, however, since only a small percentage of the memorial has been thinned. Moreover, park managers hope that prescribed fire can be applied over a large portion of the memorial once thinning is completed. The goal is to restore the old-growth forest structural characteristics, which should lead to an increase in abundance and diversity of understory vegetation such as roughleaf ricegrass (*Oryzopsis asperifolia*), upland sedges (*Carex* spp.), pasqueflower

[The goal of the research was to use] tree-ring data to document changes in the historical fire regime and forest structure [at the memorial] over the past several centuries, and to estimate crown fire risk and the effects of potential mitigation measures.

(*Pulsatilla patens*), raspberry (*Rubus* spp.), and current (*Ribes* spp.). This should also make the stands less susceptible to intense, stand-replacing fires and more resilient to mountain pine beetle outbreaks. These treatments may be put to the test because a mountain pine beetle outbreak is occurring on USDA Forest Service land adjacent to the memorial. Northern Great Plains Fire Management and Mount Rushmore staffs are currently collaborating on plans to apply restoration treatments to many of the remaining forest stands at the memorial.

Acknowledgments

Many people have been critical in the completion of the research and fire management projects at Mount Rushmore. Peter Brown (Rocky Mountain Tree-ring Research), Amy Symstad (U.S. Geological Survey), Mike Bynum (NPS Northern Great Plains Inventory and Monitoring Program), Kate Cueno (Colorado State University), and Monique Rocca (Colorado State University) have led the research efforts. The fire management and monitoring projects have been accomplished by the collaborative work of Dan Morford, Steve Ipswitch, Jim McMahill, Eric Allen, Andy Thorstenson, Dan Swanson, and Jon Freeman. Andy Thorstenson, Jon Freeman, Jim McMahill, Dan Swanson, Kate Cueno, Blaine Kortemeyer, and J. Michael Johnson provided helpful comments to develop this article.

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PS

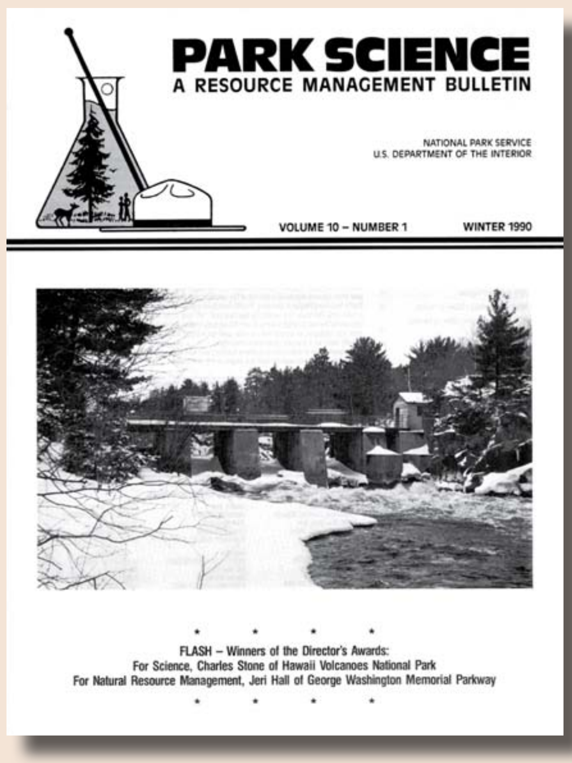
20 Years Ago in Park Science

National Academy of Sciences to study NPS science programs

THE NPS SIGNED A COOPERATIVE AGREEMENT WITH the National Academy of Sciences (NAS) to conduct a study on "Improving the Environmental Science and Technology Programs of the National Park Service." Congress asked for the study because it believed the science program "gives the appearance of being developed in a haphazard fashion in response to specific problems and absent any general framework."

The project, to last 18 months, will be carried out by the Board on Environmental Studies and Toxicology (BEST) of the Commission on Physical Sciences, Mathematics, and Resources of the Natural Resource Council. . . .

The study will address "historical development and evolution of (science and technology) programs within the NPS; the range and scope of environmental problems of concern to the NPS; the scope and organization of the current NPS science and technology programs; the extent of coordination of these programs with other NPS programs and missions; the need for monitoring, inventories and related studies to determine the status of the parks and the effects of internal and external stresses; budget and financial programming aspects of NPS science and technology programs; systems for quality control and quality assurance of research activities; NPS outreach efforts and collaboration with the external scientific community; and options for enhancing productivity, efficiency, quality, and management relevance of the NPS science programs."



PARK SCIENCE
A RESOURCE MANAGEMENT BULLETIN

NATIONAL PARK SERVICE
U.S. DEPARTMENT OF THE INTERIOR

VOLUME 10 – NUMBER 1 WINTER 1990

FLASH – Winners of the Director's Awards:
For Science, Charles Stone of Hawaii Volcanoes National Park
For Natural Resource Management, Jeri Hall of George Washington Memorial Parkway

Reference

Shelton, N. 1990. National Academy of Sciences to study NPS science programs. Park Science 10(1):17.

Case Studies

Water quality in southeastern coastal national parks

Is "fair" good enough?

By Eva M. DiDonato, Virginia D. Engle, and Lisa M. Smith

Figure 1. Timucuan Ecological and Historic Preserve was established in 1988. Approximately 70% of this 46,000-acre (18,630 ha) urban preserve is either open water or wetlands. Good water quality is critical to these ecosystems, and in turn critical to visitor experience at the park.

NPS/RICHARD BRYANT

WITH DEVELOPMENT OF THE 2006 Ocean Park Stewardship Action Plan and formation of the Ocean and Coastal Resources Branch in the Natural Resource Program Center, the National Park Service is focusing more effort on issues beyond park shorelines. Estuaries are one of the habitats of concern to resource managers in coastal parks (fig. 1). These areas are nursery grounds for many species of recreational and commercial importance and they contribute significantly to visitor experience (e.g., boating, fishing, wildlife viewing) at coastal parks. Compromised estuarine water quality often results from regional population growth and local development. Most stressors of coastal water quality originate from beyond park boundaries, so understanding the regional perspective is critical to successful management of park coastal waters.

Working with partners, the Ocean and Coastal Resources Branch has completed 30 Watershed Condition Assessments for ocean and Great Lakes parks and several more are under way (http://www.nature.nps.gov/water/watershed_reports/WSCondRpts.cfm). These reports provide an overview of coastal resource issues and identify potential sources of impairment for park coastal habitats and processes. In southeastern coastal parks, for example, water quality concerns include high nutrient loading, low dissolved oxygen, and excessive fecal bacteria, while sediment quality concerns include metals contamination (e.g., iron, copper, nickel, lead, mercury) and toxic compounds derived from industry, Superfund sites, and other sources. These issues can impact human and ecosystem health, resulting in beach swimming and fishery closures, seafood consumption advisories, alteration of seagrass habitat, algal blooms, and other habitat consequences.

This article presents an approach to understanding water quality in national parks by using data collected within and beyond park boundaries. Combining park and regional water quality data with national assessment criteria gives park managers a broader perspective on water quality issues in their parks and can help them identify potential management

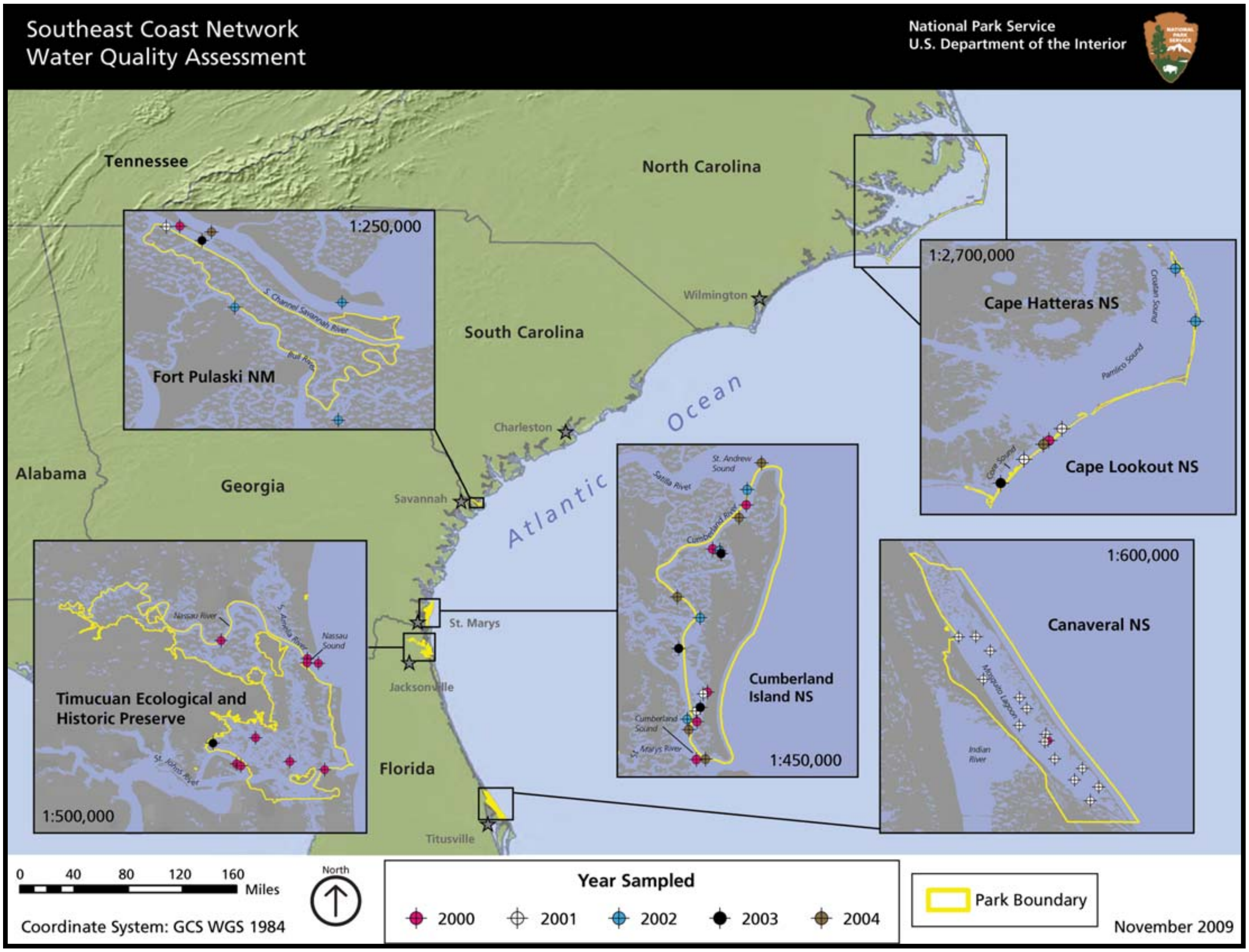


Figure 2. USEPA National Coastal Assessment sample sites in southeastern coastal national parks (2000–2004).

actions. The successful partnership with USEPA described in this article for southeastern coastal parks can serve as an example for future NPS efforts.

A partnership with USEPA

The U.S. Environmental Protection Agency's (USEPA) National Coastal Assessment (NCA) was initiated in 2000 as an integrated, comprehensive, coastal monitoring program across all U.S. coastal states and many of the island territories. The NCA survey design assesses spatially variable and geographically unique coastal and estuarine resources using multiple sampling intensities. Because the NCA uses an unbiased survey design and comparable sampling methods for all coastal resources regardless of spatial or temporal scale, the data provide an excellent baseline and can be used to interpret site-specific or local water quality monitoring efforts within a broader spatial context.

A study was conducted in southeastern coastal parks using existing NCA water quality data from 2000 to 2004 to determine the relative condition of park coastal waters (fig. 2). Water quality at sites inside and outside park boundaries was rated according to USEPA assessment criteria as good, fair, or poor (table 1). Within park boundaries, 34% of the sites had good water quality while 65% of sites were rated fair (table 2). Outside park boundaries, 18% of sites had good water quality, 65% had fair, and 16% had poor. The probability of a site within a park receiving a good water quality rating was significantly higher than that of a site located outside of a park.

Table 1. U.S. Environmental Protection Agency assessment criteria for water quality in the southeastern United States

Parameter	Good	Fair	Poor
Dissolved oxygen (mg/L)	>5	2–5	<2
Chlorophyll *a* (µg/L)	<5	5–20	>20
Dissolved inorganic nitrogen (mg/L)	<0.1	0.1–0.5	>0.5
Dissolved inorganic phosphorus (mg/L)	<0.01	0.01–0.05	>0.05
Water clarity (% surface light at 1 m [3.3 ft])			
Supporting SAV (submerged aquatic vegetation)	>40%	20–40%	<20%
Naturally turbid	>10%	5–10%	<5%
All other	>20%	10–20%	<10%

Table 2. Criteria used by the U.S. Environmental Protection Agency to determine the Water Quality Index Rating by site

Rating[1]	Criteria
Good	No component indicators rated poor; maximum of one rated fair.
Fair	One component indicator rated poor; or two or more indicators rated fair.
Poor	Two or more component indicators rated poor.

[1]Water quality components: dissolved inorganic nitrogen, dissolved inorganic phosphorus, chlorophyll *a*, water clarity, dissolved oxygen.

Information for park managers

Most park sites (65%) were still fair, which raises the question: Is fair water quality acceptable for our coastal national parks? Given that national parks represent some of our nation's most outstanding coastal areas, the answer to this question is no! Especially as climate changes, resource managers are trying to reduce water quality stressors to increase the resilience and adaptability of coastal ecosystems (Hansen et al. 2003). Scientific information about park resources and partnership opportunities with federal, state, and local agencies are key components for park managers to meet this challenge.

At Timucuan Ecological and Historic Preserve (see fig. 1), Resource Management Specialist Richard Bryant took immediate action after learning the results of the southeastern pilot study:

> When we learned the water quality was only fair, we decided to increase our cooperation with local neighboring agencies who deal with water quality issues. . . . The park was one of the founding members of the Three River Conservation Coalition. This formal partnership with other land management agencies, regulatory agencies, and nonprofits has a primary mission to monitor water quality and actively work to improve water quality in the vicinity of [the preserve] by supporting low-impact developments, and by sharing efforts to ensure water quality information is collected [and reported] on a timely basis . . . so park managers can fully comprehend what is occurring inside and outside the park boundaries.

In 2000 the National Park Service implemented a Service-wide inventory and monitoring program to "improve park management through greater reliance on scientific knowledge" (NPS I&M 2008). The Southeast Coast Network (SECN) and Northeast Coastal and Barrier Network (NCBN) of parks monitor coastal water quality in part by using the USEPA's National Coastal Assessment protocols. These protocols permit complete park-wide water and sediment quality assessments (fig. 3). The Southeast Coast Network, for example, samples each coastal park using a spatially balanced random sampling design developed according to NCA standards once every five years on a rotating basis. John Stiner (personal communication), resource management specialist at Canaveral National Seashore in Florida, will use data from these surveys in the following ways:

- Identify water quality problem areas in the 40,000-acre (16,200 ha) Mosquito Lagoon that warrant intensified monitoring or a proactive management response.
- Track the disturbing increase in nutrient (nitrogen and phosphorus) levels in Mosquito Lagoon.
- Assess long-term effects of natural events on water quality, such as storms and weather patterns.
- Aid in tracking and quantifying pollutants and assessing the impacts of septic tank effluents in a hydrologic model of Mosquito Lagoon.

Beginning in 2010, the USEPA is surveying Great Lakes and estuarine waters nationwide every five years (http://www.epa.gov/owow/monitoring/nationalsurveys.html). Since the Southeast Coast Net-

Figure 3. A team from the University of Georgia, Marine Extension Office, collects sediment samples at Canaveral National Seashore in 2009. These samples are taken as part of the Southeast Coast Network monitoring program following USEPA protocols for water quality.

NPS PHOTO

work uses USEPA protocols, these data are directly comparable and can provide a regional perspective to park-specific assessments. In addition, under the current Great Lakes Restoration Initiative, the National Park Service is partnering with the U.S. Environmental Protection Agency to assess water quality in our Great Lakes parks (Apostle Islands, Indiana Dunes, Pictured Rocks, and Sleeping Bear Dunes national lakeshores; Grand Portage National Monument; and Isle Royale National Park). The National Park Service, Water Resources Division worked with the U.S. Environmental Protection Agency to develop sampling designs for Lake Superior and Lake Michigan parks (figs. 4 and 5, next pages), which will allow us to assess water and sediment quality within parks relative to coastal waters in each of the lakes. It is our hope that this partnership with USEPA will expand to other coastal regions, allowing interpretation of park water quality data within a regional perspective.

According to the U.S. Environmental Protection Agency (USEPA 2004, USEPA 2006, USEPA 2008), the Southeast has the best water quality in the continental United States (Alaska and Hawaii have good water quality). The overall condition of water quality inside, compared with outside, park boundaries in other regions is unknown, although this can be determined by an analysis similar to that conducted for the SECN parks. The Ocean and Coastal Resources Branch of the Water Resources Division recognizes pollution, water quality, and watershed management as priority issues. At a recent ocean and coastal park workshop, natural resource managers from across the country identified the need for legislative and regulatory revisions; partnerships with local, state, and federal agencies; and several operational solutions to help coastal parks better manage their water quality. Robust data from these regional surveys will assist the National Park Service as we focus more on coastal management and issues that transcend park boundaries.

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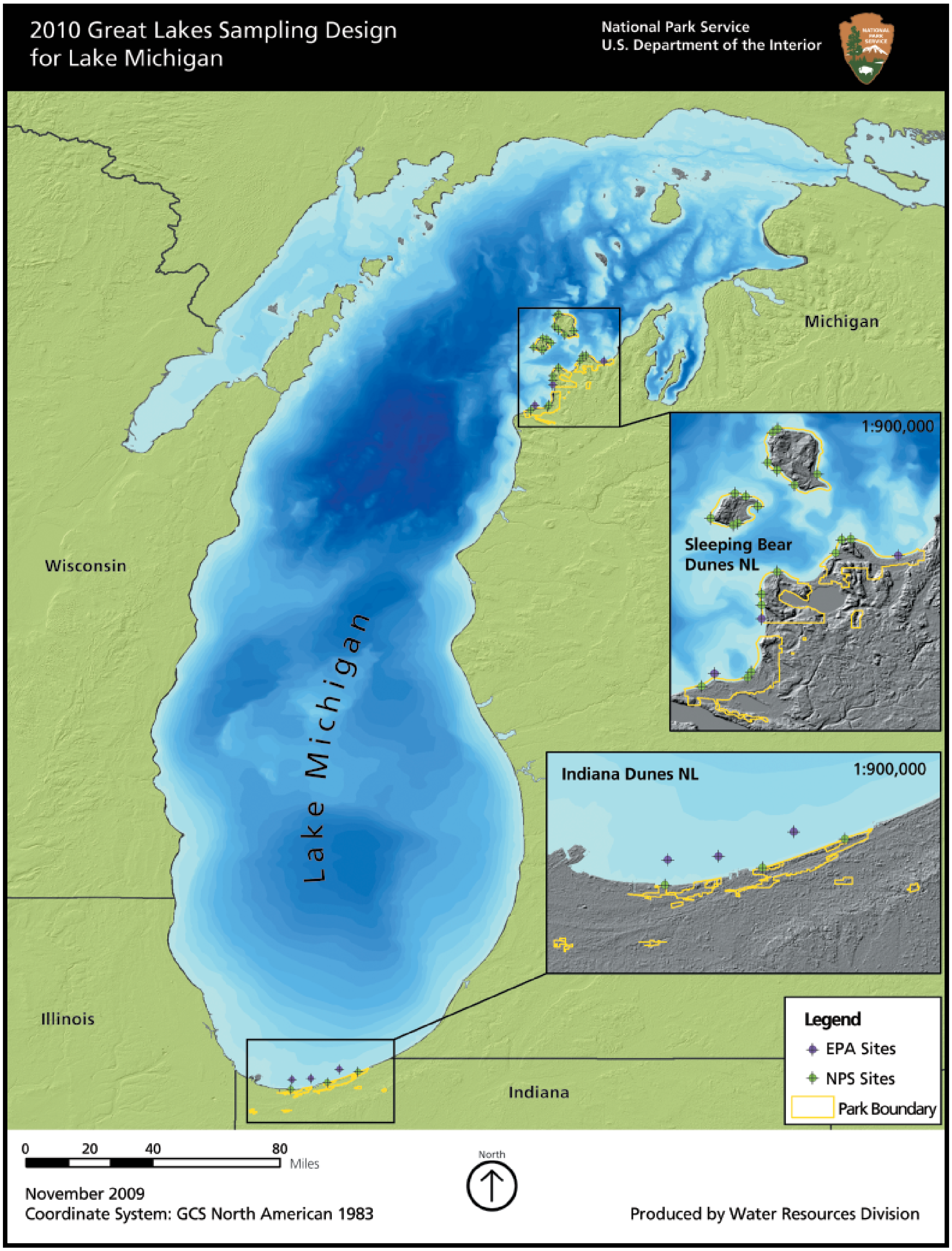
Figure 4. 2010 Sampling design for Lake Michigan. Sites shown within park insets will be used as part of the NPS assessment for Lake Michigan parks. This design will allow the National Park Service to assess and compare water and sediment quality inside and outside park boundaries.



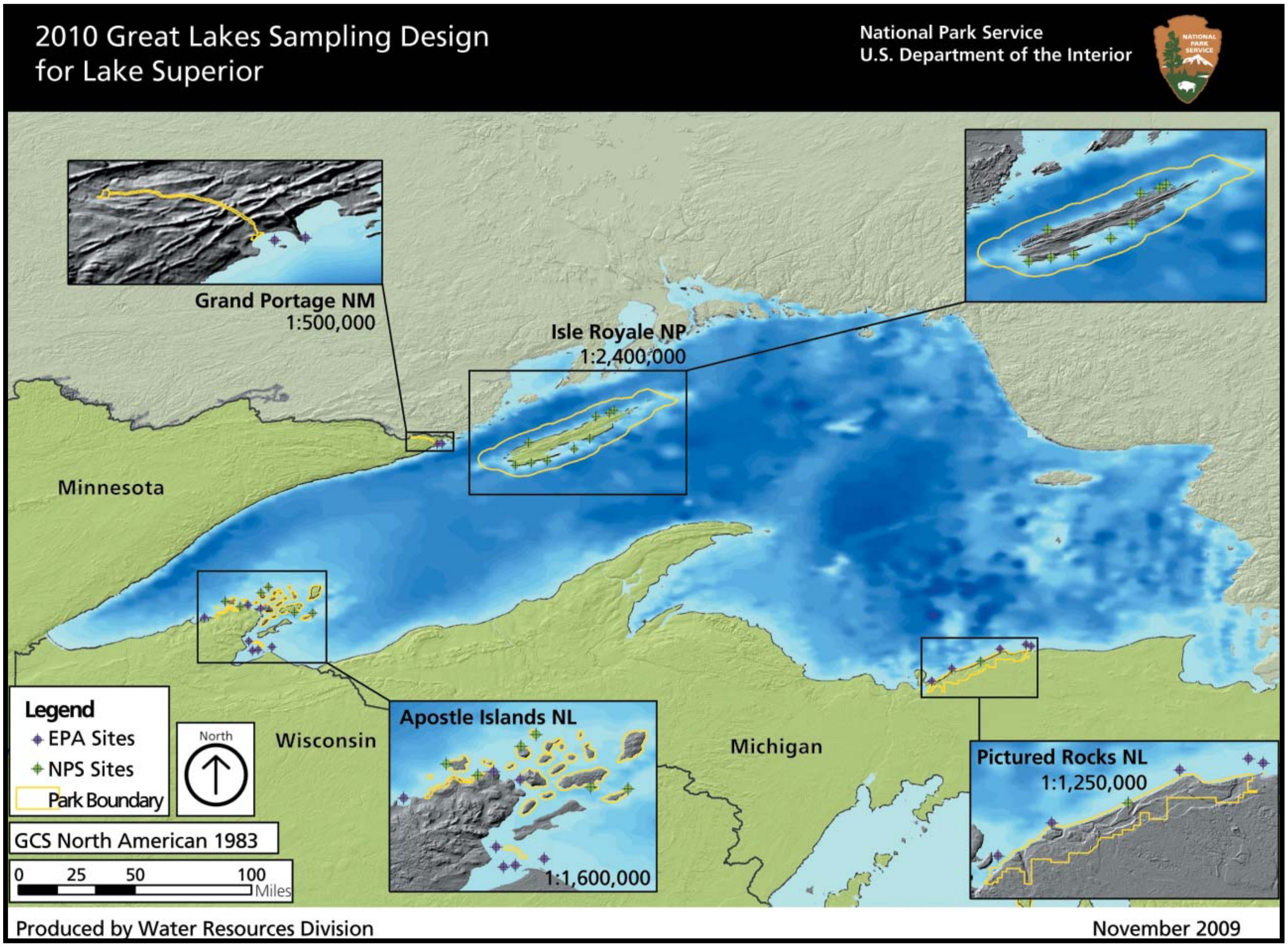


Figure 5. 2010 Sampling design for Lake Superior. Sites shown within park insets will be used as part of the NPS assessment for Lake Superior parks. This design will allow the National Park Service to assess and compare water and sediment quality inside and outside park boundaries.

Acknowledgments

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Management of plague at Wind Cave National Park

A case study in the application of the One Health concept of disease management

By Daniel S. Licht, Kevin T. Castle, Daniel E. Roddy, and Barbara L. Muenchau

NEW AND EMERGING WILDLIFE DISEASES will likely be one of the greatest challenges confronting the National Park Service (NPS) this century. As the world "gets smaller," and people and animals move more frequently and over greater distances, diseases will likely spread. Furthermore, disease severity can be exacerbated by environmental degradation, such as pollution, climate change, species invasions, and changes in land use. Increased prevalence and severity of disease may have ominous consequences for people, wildlife, and the ecosystems upon which they both depend. In fact, many of these incipient diseases can affect both humans and wildlife. Diseases that are transmitted between humans and nonhuman animals are known as "zoonotic" diseases. The increased occurrence of such diseases may affect NPS operations more than most government bureaus, because the National Park Service provides for human safety and well-being while also conserving wildlife and ecological integrity. In this article we briefly describe the "One Health" concept of disease management, and we present a case study of the application of this framework at Wind Cave National Park, South Dakota.

One Health

The One Health concept is based on the premise that the health of people, animals, and our environments is inextricably interconnected. Specifically, One Health advocates for "the establishment of closer professional interactions, collaborations, and educational opportunities across the health sciences professions, together with their related disciplines, to improve the health of people, animals, and our environment" (One Health Commission 2010). This interdisciplinary approach is an exciting and potentially powerful model for health and disease management for veterinarians, physicians, public health officials, wildlife managers, and others.

The concept of One Health is not new; in fact, it was espoused by Rudolf Virchow and William Osler in the 19th and early 20th centuries. However, it was not until recently that the model received a renewed interest. In 2007 the American Veterinary Medical Association, behind the leadership of Dr. Roger Mahr, created a One Health Initiative Task Force to "study the feasibility of an initiative that would facilitate interdisciplinary collaboration to implement *One Health* principles." As a result of the task force report, a national One Health Joint Steering Committee was formed, with the National Park Service as a founding member. The steering committee has now become the national One Health Commission (http://www.OneHealthCommission.org), which has garnered support from multiple organizations and agencies, including the American Medical Association, American Veterinary Medical Association, and the Centers for Disease Control.

The National Park Service has been a leader in implementing the One Health approach by improving coordination, communication, and collaboration between the bureau's Wildlife Health Program (Biological Resource Management Division, Natural Resource Program Center) and its Office of Public Health. The two programs have worked side by side to investigate a number of disease issues over the last several years, including the death of a wildlife biologist from plague, a Boy Scout who was diagnosed with plague after visiting a national park and surrounding national forest,[1] a rabies outbreak near several national park units in Arizona, and unexplained deaths of coyotes and domestic dogs in a national park unit in Texas. In October 2008, the two programs formalized their collaboration by creating a joint disease outbreak investigation team to study human and wildlife disease issues in national parks. Core members of the team are a medical epidemiologist and environmental health specialist from the Office of Public Health, and a wildlife veterinarian from the Wildlife Health Program.

While it is true that in some cases an illness or disease may be isolated to people or to animals with little relevance to the other group, in many cases there is a nexus between human and wildlife health. Consider that 75% of the recent emerging infectious diseases affecting humans are of animal origin (Taylor et al. 2001). In many cases a disease can be

Figure 1. A keystone species of the Great Plains, prairie dogs are susceptible to plague, caused by a nonnative bacterium carried by fleas. Outbreaks of the disease can devastate prairie dog colonies and have ramifications for many other species and for human health.

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[1]The investigation revealed that the Scout probably was not exposed while visiting the park.

In many cases a disease [of animal origin] can be fatal to both people and animals, and it can have a life history and a remedy that require input from ecologists, veterinarians, physicians, environmental scientists, and others.

fatal to both people and animals, and it can have a life history and a remedy that require input from ecologists, veterinarians, physicians, environmental scientists, and others. Plague is an example of such a disease.

Plague

Plague is caused by a bacterium, *Yersinia pestis*. The microorganism's life cycle requires both a flea and a mammal host. Rodents and lagomorphs (rabbits and hares) are the most typical mammal hosts, but carnivores and other mammals can be infected as well. *Yersinia pestis* was responsible for the notorious "Black Death" in Europe in the Middle Ages and is a classic zoonotic disease. In the case of the Black Death it was rats—ubiquitous because of poor sanitation at the time—and their fleas that played a key role in transmitting the disease to humans.

The plague bacterium likely was brought to North America via San Francisco around the beginning of the 20th century (Cully et at. 2006). From there it spread east to about the 104th meridian, or the Wyoming–South Dakota border. For the latter half of the last century the spread of the disease stalled at this imaginary line for reasons that are still unknown. Early this century, the disease was documented in southwestern South Dakota. (Interestingly, the disease moved into South Dakota at the end of a long and severe drought, suggesting that climate played a role in the eastward expansion.) The year 2007 was marked by several large die-offs of prairie dogs on the Pine Ridge Indian Reservation in southwestern South Dakota. In 2008 the disease was confirmed in prairie dog towns in the Conata Basin physiographic area just south of Badlands National Park and in prairie dog colonies about 20 miles (32 km) southeast of Wind Cave National Park.

Prairie dogs appear to have little if any immunity to plague, which is not surprising because plague is exotic to North America and thus prairie dogs did not evolve with it (Biggins and Kosoy 2001). Once a prairie dog colony becomes infected, the consequences can be catastrophic, with almost 100% mortality within a week or two in many instances (Cully et al. 2006). This can devastate the ecosystem because prairie dogs, and especially black-tailed prairie dogs (*Cynomys ludovicianus*), are keystone wildlife species (fig. 1, page 38; Kotliar et al. 2006). Among other functions, prairie dogs are prey for many predators, their burrows provide shelter, their soil-disturbing activities enhance soil health, and they maintain nutritious and diverse forage for grazing animals. When prairie dogs disappear or populations are greatly reduced, a negative ripple effect can occur throughout the system with disastrous impacts to black-footed ferrets (*Mustela nigripes*), burrowing owls (*Athene cunicularia*), swift fox (*Vulpes velox*), and other species. Although prairie dog die-offs are perhaps the most notable wildlife impact from the disease in North America, plague is known to be fatal to a wide range of species, from various mice and voles to mountain lions. Little is known about the severity of the disease in populations of these species and the impacts on the ecosystems in which they reside.

On average, 10 to 20 cases of human plague are documented every year in the United States and about 14% of these cases are fatal (Centers for Disease Control 2009). The most likely form of transmission to humans is flea bites. People often come in contact with fleas by handling live or recently dead wildlife, the nesting material of such mammals, or placing their hands in areas where fleas may reside, such as burrows. Family pets such as cats and dogs, especially those that investigate burrows, may also play a role in bringing infected fleas into contact with people. Many recent human plague cases were linked to pet cats that had become ill and then infected their owners or veterinarians (Gage et al. 2000). Less frequently, people can become infected by inhaling the bacterium or when it enters through openings in the skin. The symptoms of a plague infection in people are often flu-like at first, which can lead to misdiagnosis, with deadly results. Another common symptom is the formation of "buboes," or swollen, painful lymph nodes, which gave rise to the common name "bubonic" plague. The Centers for Disease Control and Prevention (2009) identifies "ecology-based prevention and control" as an important strategy for managing the disease, a concept that is consistent with the One Health model.

One Health, plague, and Wind Cave National Park

Wind Cave National Park is one of America's premier wildlife parks. In fact, it was established to preserve wildlife populations in addition to the cave. Since its establishment in 1903, the park has restored numerous species, including bison, elk, and pronghorn. In summer 2007 the park restored the endangered, and still extremely rare, black-footed ferret (fig. 2). This member of the weasel family is dependent on large areas of prairie dog colonies for its existence, as it relies almost entirely on prairie dogs for food and shelter.

As plague approached to within 20 miles (32 km) of Wind Cave National Park in summer 2008, park staff was faced with a series of critical and complex decisions, the most prominent of which was whether the park should proactively "dust" prairie dog towns with insecticide in the hope of killing the fleas that may spread the disease, and thereby prevent a prairie dog epizootic[2] (Cully et al. 2006). Dusting would also reduce the risk of plague infection in humans. However, broad use of insecticides on NPS lands is not common, in part because such treatment is often expensive and the nontarget impacts are not well-known. Furthermore, dusting may provide only one year of plague control. For Wind Cave National Park the approach was untested; however, its application also offered an opportunity for research, such as a study of the nontarget impacts. The following steps were part of plague management at Wind Cave National Park.

[2]An outbreak of disease in wildlife.

Figure 2. A television crew films the release of a black-footed ferret in Wind Cave National Park. An outbreak of plague could jeopardize restoration of this endangered species, which relies on prairie dogs for food and shelter.

Figure 3. Biologist Dan Licht collects fleas from a prairie dog burrow at Wind Cave. A DNA test will be used to determine if the plague bacterium is present in the gut of the collected fleas. For safety, Licht wears rubber gloves, has taped his pant leg to his boot, and has sprayed his boots and socks with insect repellent.

NPS/DANIEL S. LICHT

Assess the risk

How plague is spread and maintained across the landscape is not well understood, and this information gap was a significant shortcoming in assessing the risk to park wildlife and to human health. The nearest known plague epizootic in prairie dogs was about 20 miles (32 km) away, which is a modest distance for a dispersing coyote (*Canis latrans*) or bobcat (*Lynx rufus*) or other potential carriers of the disease. It was possible that plague would occur at the park that summer, or not for another 10 years, if ever. It was even plausible that plague was already present at the park in 2008, but at low levels that had not yet caused an epizootic in prairie dogs. Therefore, one of the park's first steps was to collect flea samples and have them analyzed for the plague bacterium. Because of the risks to human health, biologists collecting samples followed safe work practices, wearing rubber gloves and spraying insect repellent (DEET) on shoes and socks (fig. 3). The University of South Dakota quickly analyzed the fleas and reported that it did not detect plague DNA in the samples. However, the sample sizes were very small and therefore the results were statistically inconclusive. Nevertheless, the information was another piece of the puzzle the park used to determine whether to dust.

Another important factor in the decision-making process was that the park had just spent considerable money and effort in restoring endangered black-footed ferrets. The presence of plague would likely end that effort because the disease kills ferrets directly or indirectly by eliminating their food source, prairie dogs.

Conversely, a strong argument for not dusting was the time commitment, labor, and cost of such an undertaking. Dusting just one-third of the prairie dog acreage in the park would cost approximately $15,000 for supplies and other items, and require a crew of five for approximately 30 days. In addition, there were significant unknowns regarding the ecological impacts of using the insecticide deltamethrin to kill the host fleas. A wide range of species, such as tiger salamanders (*Ambystoma tigrinum*), toads, snakes, and insects, reside in prairie dog burrows where the insecticide would be applied. Even though plague is carried by a nonnative bacterium, the fleas themselves are a native species and—according to NPS policies—worthy of protection and conservation as a component of the ecosystem.

A third consideration was the human element. The dust itself, which can remain active in the burrow entrance for a year or more, could conceivably be touched or ingested by curious and unsuspecting people. A fourth concern was that the sight of park personnel driving all-terrain vehicles (ATVs) across the prairie while wearing head-to-toe protective gear could disturb visitors and leave a negative impression of park management. Yet if plague did occur in the park, and people became infected, the consequences would be very serious indeed. After reviewing the literature, conferring with experts, assessing park resources and objectives, and establishing priorities, park managers determined that dusting prairie dog burrows was the prudent course of action.

Plan for the action, including environmental compliance and job hazard analysis

In the years before the plague outbreak, the park had completed both prairie dog and black-footed ferret management plans (Wind Cave National Park 2006a, 2006b). Unfortunately, neither document adequately considered plague management and, therefore, they were inadequate for compliance with the National Environmental Policy Act (NEPA). To satisfy NEPA and minimize environmental impacts, the park completed an environmental screening form and determined that a categorical exclusion was appropriate for this action (Sec. 3.4 E[3], "Removal of individual members of a non-threatened/endangered species or populations of pests and exotic plants that pose an imminent danger to visitors or an immediate threat to park resources"). Dusting to control plague outbreaks involves spraying deltamethrin powder into prairie dog burrow entrances. Prior to using any pesticide, NPS personnel must consult with the NPS Integrated Pest Management program and obtain approval through the Pesticide Use Proposal System, and must make sure NPS staff applying the pesticide are certified for its use within their state. To reduce the likelihood of injury or harm to personnel applying the insecticide, park staff followed recommended safety procedures, namely, wearing protective clothing such as long sleeves, gloves, and eye protection. Those applying the insecticide were trained and certified in ATV use by the ATV Safety Institute so that they could safely and efficiently navigate the treatment sites (fig. 4).

Implement treatment actions

In summer and fall 2008 the park treated approximately 1,100 acres (445 ha) of prairie dog colonies with deltamethrin in hopes of preventing a plague epizootic. This area amounted to about 40% of all prairie dog acreage in the park. The great majority of the treated area included colonies used by restored black-footed ferrets. The park also opted not to treat approximately 100 acres (41 ha) of a prairie dog colony that had a small wetland (about 1 acre [0.4 ha]) in the middle of it (fig. 5). Previous studies had documented a high density of tiger salamanders using the prairie dog burrows near the wetland. By leaving this site as an undusted refugium the park reduced the risk of accidentally extirpating nontarget organisms. In 2009 the park re-treated 725 of the acres (294 ha) treated in the prior year.

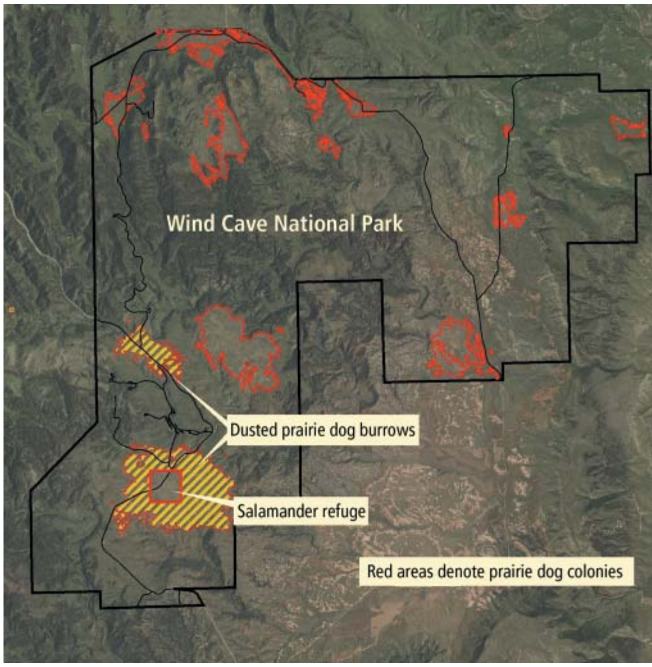
Monitoring

The concept of adaptive management requires post-treatment monitoring to test and document whether project goals are being met. As part of this approach, the park continues to collect flea samples from non-dusted colonies in an effort to determine if plague is present. The samples will be analyzed by the University of South Dakota. The university will also study the genetics of the fleas to better understand flea movement within and outside the park. The park also monitors its prairie dog colonies for evidence of plague and periodically maps the distribution of the colonies. Monitoring for outbreaks of the disease consists primarily of determining whether prairie dogs are present or absent, because plague can kill nearly all members of a colony. Although dusting is a common practice in some areas,

Figure 4. Biological Science Technician Barb Muenchau dusts a prairie dog burrow with insecticide in order to kill fleas that may be carrying the nonnative plague bacterium.

NPS/TOM FARRELL

Figure 5. In 2008, Wind Cave staff treated approximately 40% of all prairie dog colonies with the insecticide deltamethrin in hopes of preventing a plague epizootic. A 100-acre (41 ha) area with a small wetland in it was left untreated so that it could serve as a refugium for tiger salamanders.



though dusting is a common practice in some areas, little information is available about its effects on nontarget species. The potential nontarget impacts were of great concern to the park in part because of the NPS mission to conserve all flora and fauna. Therefore, the park left a portion of one prairie dog colony undusted to serve as a study site and to provide refugia for nontarget species. To better understand nontarget impacts of dusting, park staff identified the tiger salamander as an indicator species and a study subject. This salamander species resides in prairie dog burrows during the day and moves to the burrow entrances at night to feed on the rich insect community associated with prairie dog colonies (fig. 6). It is conceivable that salamanders could be harmed directly by the insecticide or indirectly through a reduction in food items. Therefore, staff conducted salamander surveys on undusted (i.e., control) and dusted (i.e., treatment) plots. Preliminary results suggested no significant impact to salamanders as a result of applying the insecticide, but additional surveys and testing are needed. The park is developing an agreement with Black Hills State University to conduct a more thorough analysis of impacts to tiger salamanders. Even if the insecticide turns out to be harmful to salamanders, the population should still persist thanks to the undusted refugia. Similarly, other organisms that could be killed by the insecticide (e.g., beetles) should persist in the refugia and be able to recolonize treated areas once the insecticide is no longer effective.

Communicate with stakeholders and partners

Accurate and timely communication with the public was deemed critical to the success of the project. Therefore, park natural resource managers worked closely with interpreters to ensure that appropriate messages were developed and went out to the public. Visitor center staff and patrol rangers were all kept in the loop, as they were on the front lines in communicating with the public. This was extremely important because field crews wearing protective gear were often visible to the public. Messages about the treatment explained that prairie dogs were the victims of plague and not the cause, and that the disease was brought to America by humans. This was very important as prairie dogs are often viewed as pests by landowners, who remove them from their land. Suggesting that prairie dogs were the cause of the disease would exacerbate that situation. The park took other steps to minimize the spread of plague, such as diligently enforcing rules regarding pets, as a dog or cat that had recently been in the western United States could be harboring plague-infected fleas from that region that could be transmitted to park wildlife.

Summary

How the National Park Service manages plague will vary from park to park because all parks differ in their goals, priorities, and environments. For example, methods used to control plague in parks with black-tailed prairie dogs (e.g., dusting burrows) may not be suitable for parks where rock squirrels or other rodents are the primary mammalian host of the disease, because their burrows are not as easily identified. And within parks that have plague, backcountry areas may be managed differently from areas with high human use. Costs will always be a consideration in determining management options.

Yersinia pestis is an exotic bacterium, and therefore its control and eradication would be supported by NPS management policies. However, eliminating the disease from North America, let alone the 25 or so units of the National Park System that host it, is

Figure 6. Tiger salamanders reside in prairie dog burrows in the vicinity of a small wetland within one of the treatment areas at Wind Cave. Staff, therefore, decided not to treat 100 acres in this area in order to create a refugium for the species.

infeasible. Therefore, a more realistic management goal is to take actions that decrease the likelihood of wildlife epizootics and minimize the risk of human infection. Current intervention methods unfortunately still trade protection of the health of one or two species for that of others. These interventions have been devised based on our old paradigm of "separate health." Future progress toward true One Health approaches to conservation management depends on research to better understand ecosystems and variables that detract from or support the balanced health of all species. We advocate that there is a great need for this type of research in order to provide for informed One Health interventions.

To meet these goals, park biologists and managers will need to use an approach that incorporates the science, tools, and methods of the wildlife, human, and environmental health professions and that acknowledges the interconnectedness of human, animal, and environmental health. That is the essence of the NPS One Health approach.

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Research Reports

The benefits of stakeholder involvement in the development of social science research

By Robert B. Powell and Wade M. Vagias

Abstract

Collaboration among park managers, researchers, and stakeholders can reduce tension, develop support for research activities, and assist in meeting management objectives. While frequently promoted, providing meaningful stakeholder involvement can be a challenging task for researchers and managers. The purpose of this article is to discuss the potential benefits of stakeholder involvement in social science research development and explore specific steps to accomplish this goal. In 2008, researchers and NPS managers sought ORV (off-road vehicle) stakeholders' involvement and support for a study to be conducted at Big Cypress National Preserve (Big Cypress) in Florida that examines the use of education for reducing ORV impacts. Off-road vehicle management is very contentious at Big Cypress so stakeholder involvement was considered essential. The specific steps undertaken to develop support and involvement included public presentations and discussions as well as collaborative review and refinement of the research. The theoretical benefits of stakeholder involvement in the development of social science research include enhanced trust, organizational commitment, and science literacy as well as improved support for the research and its results.

Key words

public involvement, social science research, survey research

Introduction: Collaboration and public involvement in park management

NATIONAL PARKS AND PROTECTED AREAS ARE NOW SEEN as one dynamic, complex, interrelated, and interdependent socioeconomic and ecologic system (e.g., Folke et al. 2002). Because of this complexity and uncertainty, managers of national parks are moving beyond a traditional "parks as islands" paradigm and are now applying an ecosystem-wide approach that embraces adaptation, participation, and collaboration (e.g., Meffe et al. 2002). This collaborative approach requires a high degree of public involvement and the development of public understanding and science literacy to support learning and adaptive processes (Lee 1993; Force and Forester 2001; Holling 1995). Currently the National Park Service (NPS) uses research to enhance understanding of park resources and to provide usable information that supports effective management decisions. In particular, social science research can provide insight into public attitudes, beliefs, and behaviors regarding park resources and issues facing NPS management as well as evaluate current NPS programs. However, managers and researchers tasked with conducting social science research often overlook the benefits of stakeholder involvement in the design and development process. The purpose of this article is to discuss these potential benefits of stakeholder involvement in social science research development and explore specific steps to accomplish this goal.

Theoretical benefits of collaboration and stakeholder involvement in the development of social science research

Social scientists have identified the following theoretical benefits of stakeholder involvement during the formative stages of social science research:

1. Improves research (public involvement and review can improve the validity, clarity, and appropriateness of research) (e.g., Babbie 2001).
2. Ensures the utility of the results for managers and stakeholders (e.g., Patton 1996).
3. Builds trust through informal and formal communication processes (e.g., Schoemaker and Jonker 2005).
4. Enhances organizational commitment to the sponsoring agency (by internal and external stakeholders) (e.g., Mowday et al. 1982).
5. Notifies and informs the public regarding the purpose of the study and improves support for research (including heightened participation if the study is seen as valid) (e.g., Force and Forester 2001).

6. Builds acceptance of scientific results by internal and external audiences (if seen as legitimate and defensible) (e.g., Weeks and Packard 1997).

7. Builds public understanding and science literacy (through active public involvement and partnerships) (e.g., Lee 1993; Force and Forester 2001; Holling 1995).

8. Supports adaptive ecosystem management (facilitates the use of results for adaptive management) (e.g., Meffe et al. 2002; Margoluis and Salafsky 1998).

Utilizing multiple theoretical approaches in conducting social science evaluation research

Involving the public in the development of social science research is challenging and requires a departure from traditional theoretical approaches to research. In situations where stakeholder involvement is deemed important, researchers need to embrace multiple theoretical approaches for conducting social science. Traditionally, social science research conducted by and for the National Park Service can be described as theory-driven research and evaluation (e.g., Campbell and Stanley 1963; Rossi and Freeman 1993; Weiss 1998; Suchman 1967), which emphasizes that research is theoretically based, is methodologically rigorous, is scientifically objective, and uses valid and reliable data collection instruments. This ensures the defensibility of the results but may overlook their utility and the public's perception regarding their validity (e.g., Ziman 1991). To ensure the utility of the results for the funding organization, some researchers now use a more collaborative and participatory development process that is referred to as utilization-focused research and evaluation (e.g., Patton 1996). This utilization-focused approach requires involvement in the formative stages of the study by members of the funding organization. To enhance public perception regarding the utility and validity of the results, researchers also may employ a "consumer-based research and evaluation" approach (e.g., Scriven 1972; Bledsoe and Graham 2005). This requires meaningful involvement of an organization's external stakeholders in the development and review of research to capture their informational needs and to ensure the utility of results for a broader external audience. Involving stakeholders in the research development process also encourages the development of goodwill, trust, and commitment between key groups and the sponsoring organization (the National Park Service in this case) (e.g., Powell et al. 2006).

By using multiple approaches, social science researchers emphasize the primary purpose and benefits of each approach while mitigating their potential weaknesses. In other words, by using multiple approaches, researchers may maintain the rigorous and scientific nature of their work to ensure defensibility, but they also may improve the utility and acceptability of the results to both internal and external stakeholders by employing participatory processes during the developmental stages.

A case study of public involvement in the development of social science research: Big Cypress National Preserve and the TL! Education Evaluation

Formally adopted by the National Park Service in 1998, the "Tread Lightly!" (TL!) off-road vehicle (ORV) skills and ethics education program is based on five "best practices" or principles that support resource stewardship. However, no research has examined the effectiveness of this educational campaign or mechanisms for its improvement. In response to this need, the Wilderness Stewardship Division, NPS Washington Office, funded a study designed to help understand both the effectiveness of the TL! message and to identify salient factors that can be used to explain ORV operator attitudes toward TL! recommended practices. Three sites were selected for the study, one of which was Big Cypress National Preserve in Florida, which has a long history of ORV recreation (fig. 1, next page).

Early in the research development process, we asked senior managers at Big Cypress for their willingness to participate in the study. These managers and the researchers then scheduled meetings to discuss the goals of the study to ensure that the results would be useful to Big Cypress. In addition, because ORV management is a contentious issue in Big Cypress, the senior managers at the preserve requested that we present an overview of the study at a Big Cypress ORV Advisory Committee (ORVAC) public meeting at Everglades City, Florida. Members of ORVAC represent Big Cypress ORV stakeholders, including environmental organizations, ORV clubs, local residents, hunters, outdoor enthusiasts, and private land inholders. This presentation served several purposes, including notification and clarification regarding the purpose of the study (fig. 2, next page). After the presentation, ORVAC voted to form a subcommittee to collaborate with the researchers and the National Park Service by reviewing and commenting on the research methods and survey instruments. Participants felt this collaboration was particularly important because the ORV community has a level of mistrust toward the National Park Service and NPS-sponsored research. According to sev-

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Figure 1. Swamp buggies are a popular means for hunters and other outdoors people to navigate the subtropical wetlands of Big Cypress National Preserve. The National Park Service is using social science research developed in conjunction with stakeholders to evaluate the effectiveness of education to reduce off-road vehicle impacts on park resources.

NPS PHOTO

Figure 2. The first author presents an overview of the social science research to be conducted at Big Cypress. In attendance at the public meeting are members of the Big Cypress ORV Advisory Committee, which subsequently participated in fine-tuning the survey used in the study.

eral members of ORVAC, this mistrust has arisen from perceived misrepresentations of past research results and the view that public opinion has been ignored by Big Cypress managers in the past.

Shortly after formation, the ORVAC subcommittee and the researchers developed a work plan and action items. First, the subcommittee undertook a thorough review of the survey that initially focused on identifying questions that could be interpreted as inflammatory, could elicit socially desirable answers, or were confusing or poorly worded. During this process the researchers also discussed survey design and other social science research methods to develop the capacity of the ORV advisory board subcommittee for evaluating the soundness of the research, understanding the limitations of social science research, and interpreting future results. We reviewed the comments and then clarified them with each subcommittee member. Subsequently, we revised the survey based on their comments and added questions to collect more data deemed important by the stakeholders. We then repeated the process with the goal of addressing all concerns and reaching consensus on the appropriateness of the survey instrument. The subcommittee then reported to the full ORVAC regarding the process and the acceptability of the survey. The ORVAC then issued full support for the study. A summary of stakeholder involvement steps can be found in table 1.

Conclusion

The purpose of this article was to discuss the potential benefits of stakeholder involvement in social science research development and explore specific steps to accomplish this goal. The activities undertaken sought to improve the survey instrument, ensure the research will provide useful results to both the National Park Service and the public, strengthen stakeholder-NPS relationships, and enhance trust in the research process and the results of the study. Although the TL! evaluation study is ongoing, and evaluating the full benefits of this public participation process is outside the scope of the current research project, the stakeholder involvement process did appear to increase participants' awareness and understanding of social science research methods and supported the process of developing a science-literate public. Public involvement also appeared vital to the continued building of trust between Big Cypress management and the ORV Advisory Committee. Ultimately, public involvement, even in social science research development, appears important for effective ecosystem-wide management and stewardship of resources managed by the National Park Service.

Table 1. Process of stakeholder involvement in the development of social science research at Big Cypress National Preserve
1. Meetings and collaboration with Big Cypress staff (utilization-focused evaluation steps)
2. Public meeting (notification and clarification of research purpose)
3. Invitation to collaborate (review and comment regarding research)
4. Consultation (addition of questions important to both internal and external stakeholders)
5. Development of stakeholder subcommittee to review the draft instrument (similar to cognitive testing), focusing on identifying questions that could be interpreted as inflammatory, could elicit socially desirable answers, or were confusing or poorly worded
6. Incorporation of comments (builds trust by listening and responding to concerns and suggestions of stakeholders)

Managers and researchers tasked with conducting social science research often overlook the benefits of stakeholder involvement in the design and development process.

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PS

Survival of the western prairie fringed orchid at Pipestone National Monument

By Gary D. Willson and F. Adnan Akyuz

Abstract

A small population of the threatened western prairie fringed orchid (*Platanthera praeclara*) occurs at Pipestone National Monument, Minnesota, in a tallgrass prairie with shallow soil and altered hydrology. During dry years, the population at Pipestone may be subject to greater moisture stress and lower survival than plants growing in other orchid habitat with deeper soils and intact hydrology. For a nine-year period we monitored the survival of 30 flowering plants at marked locations at Pipestone and compared the results with those from another monitoring study of orchid survival in unaltered habitat at Sheyenne National Grassland, North Dakota. We found plants were short-lived at both Pipestone and Sheyenne (half-lives of one to two years) and few surviving plants flowered again after the second year at Pipestone. The low survival of flowering orchids at Sheyenne following one dry year suggests that even in habitats with intact hydrology, below-normal precipitation can substantially lower survival in this species. Following a very dry year or series of dry years, survival of plants at Pipestone could be very low. Restoration of the natural hydrology at Pipestone might enhance survival but is unlikely considering the costs and likely opposition. We recommend the suspension of prescription burns at Pipestone during extended dry periods to avoid possible further lowering of survival.

Key words

western prairie fringed orchid, Pipestone National Monument, hydrology, prescribed fire, restoration

THE WESTERN PRAIRIE FRINGED ORCHID (*PLATANTHERA praeclara*) is an erect perennial herb with a showy inflorescence or flower stalk reaching up to 75 centimeters (29.6 in.) in height and producing 5–25 white flowers (Sheviak and Bowles 1986) (fig. 1). The orchid once grew throughout the western tallgrass prairie but is now restricted to remnant sites in six states and southern Canada. It has declined because of the drainage and direct loss of habitat resulting from agricultural expansion, and was listed as a federal threatened species in 1986 (U.S. Fish and Wildlife Service 1996).

Extant populations of the western prairie fringed orchid are usually found in mesic (relatively good drainage but high moisture during most of the growing season) to wet tallgrass prairie habitats that are often subirrigated (moisture in the subsoil from a groundwater source). In these habitats, soil moisture is a critical determinant of the growth and flowering of orchid plants. Drought depresses this flowering and decreases survival (Sather 2000; Ashley 2001; Willson et al. 2006). Likewise, flooding or moisture-saturated soil depresses flowering and, if prolonged, kills orchid plants (Sieg and Wolken 1999; Willson et al. 2006). Prescribed burning of orchid habitat also influences flowering of the orchid and ultimately its survival. In a dry spring, burning can exacerbate soil moisture loss in tallgrass prairie (Knapp 1985), which causes orchid plants to abort flowers (Pleasants 1995).

Pipestone National Monument in southwestern Minnesota protects outcrops of pipestone or catlinite that American Indians have quarried from prehistoric times to the present (fig. 2). A small, isolated population of the western prairie fringed orchid occurs in the monument in mesic tallgrass prairie habitat of shallow soil overlying Sioux quartzite bedrock (Morey 1983). The orchid habitat is periodically prescription burned in spring to control invasive cool-season grasses, primarily smooth brome (*Bromus inermis*), but is not grazed by bison or cattle. Historical (1890s) photographs of the area that later became the monument show water flowing over a ridge of Sioux quartzite into the orchid habitat from multiple overflow channels of Pipestone Creek (fig. 3, page 52). In the early 1900s the creek bed was lowered about 3 meters (10 ft) at Winnewissa Falls on Pipestone Creek (fig. 4, page 52) and the channel upstream was straightened, which reduced surface flow of water into the orchid habitat.

Because of the shallow soil and altered hydrology of its habitat in Pipestone National Monument, the western prairie fringed orchid may be prone to greater moisture stress and lower survival than plants growing in other orchid habitat with deeper soils and intact hydrology. To determine if lower survival of orchid plants occurs in the monument, we compared the survival of orchid plants at Pipestone with the survival of another population of these plants at Sheyenne National Grassland in southeastern North Dakota (Sieg and King 1995). Sheyenne National Grassland protects one of the largest populations of the orchid in deep-soiled habitat that is usually wet but can be dry or flooded. Pipestone and Sheyenne are similar in general soil type (mesic loam), climate (total amount and distribution of precipitation), and management (prescribed burns and no cattle grazing in orchid habitat); they differ in soil depth and hydrology. Lower survival of orchid plants at Pipestone than that at Sheyenne would suggest the population at Pipestone would benefit from restoration of the natural hydrology. However, because of the extent and depth of channelization of Pipestone Creek in the monument and upstream, the only feasible response may be changes to the management regime (e.g., prescribed fire) in the orchid habitat.

Pipestone National Monument

Pipestone National Monument includes about 114 hectares (281 acres) of native and restored tallgrass prairie. In the monument, the western prairie fringed orchid is found in a diverse plant

ADNAN AKYUZ

Figure 1. The showy flower of the western prairie fringed orchid is a unique resource at Pipestone National Monument, where a small population of this threatened plant species persists. Scientists and managers are striving to understand factors affecting preservation of the orchid, including hydrology, precipitation, and prescription burns.

NPS ILLUSTRATION 2007

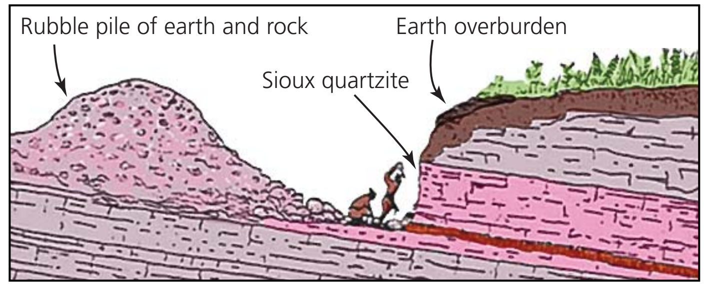


Figure 2. American Indians quarry pipestone, a red-colored rock layer interbedded in Sioux quartzite bedrock. The quarries are located near the orchid habitat and expose the thin layer of soil that lies above the bedrock.

community that is dominated by little bluestem (*Schizachyrium scoparium*) and other native grasses (Becker 1986). The soil where the orchid occurs is a silty clay loam developed on loess (windblown silt) with a depth to bedrock of 2 to 3 meters (3.3 to 6.6 ft) (U.S. Soil Conservation Service 1975) (see fig. 2). The annual precipitation averages about 65.4 centimeters (25.8 in.) with 78% or 51.0 centimeters (20.1 in.) falling as rain in April through September (Midwest Regional Climate Center 2004). Since 1972, the prairie habitat of the orchid has been prescription burned, on average every three to four years, usually in early May.

Erratic growth patterns of the orchid make it difficult to monitor. In some years an orchid may produce a tall, visible flower stalk, while in other years it produces only one to three basal leaves (vegetative stage) (fig. 5, page 52) or no aboveground growth. In 1993 the monument began an annual, mid-July count of flowering plants, the orchid's most detectable life-stage (Willson 2000). In addition, the distribution of flowering plants was mapped during the annual counts. From 1993 to 2008, the number of flowering plants varied considerably, with annual counts ranging from 0 to 221 (table 1, page 53). The distribution of flowering plants also varied from year to year but, when flowering plants were present, most were clustered in the wetter portion of the habitat (fig. 6, page 53).

Sheyenne National Grassland

Sheyenne National Grassland encompasses about 27,244 hectares (67,269 acres) of stabilized dunes associated with the glacial Sheyenne Delta. The western prairie fringed orchid occurs in lowland depressions or swales, where it grows in association with mesic plants such as woolly sedge (*Carex lanuginosa*), Baltic rush (*Juncus arcticus*), and northern reed grass (*Calamagrostis stricta*) (Sieg and King 1995). A layer of silt interbedded with clay located up to 30 meters (98 ft) below the soil surface impedes drainage, which results in the relatively high water level in the swales (Baker and Paulson 1967). Sandy loam and loamy sand are the most common soils in the swales (U.S. Soil Conservation Service 1975). The mean annual precipitation is 49.7 centimeters (19.6 in.), most of which falls as rain during the April–September growing season (High Plains Regional Climate Center 2009). Most of the grassland is managed for cattle production under three regimes—grazed-rotational, grazed–season long, and grazed–prescription burned—but some areas are ungrazed or ungrazed–prescription burned.

In 1987 at Sheyenne, Sieg and King (1995) established three belt transects (10 × 30–80 meters [33 × 98.4–262.5 ft]) in an ungrazed–prescription burned exclosure that encompassed three swales. They permanently marked the location of a total of 10 flowering orchid plants on each of the three transects and, from 1988 through 1994, resurveyed these locations each year, noting if plants were present or absent during peak flowering in late June through early July.

NPS/PIPESTONE NATIONAL MONUMENT HISTORICAL PHOTO COLLECTION

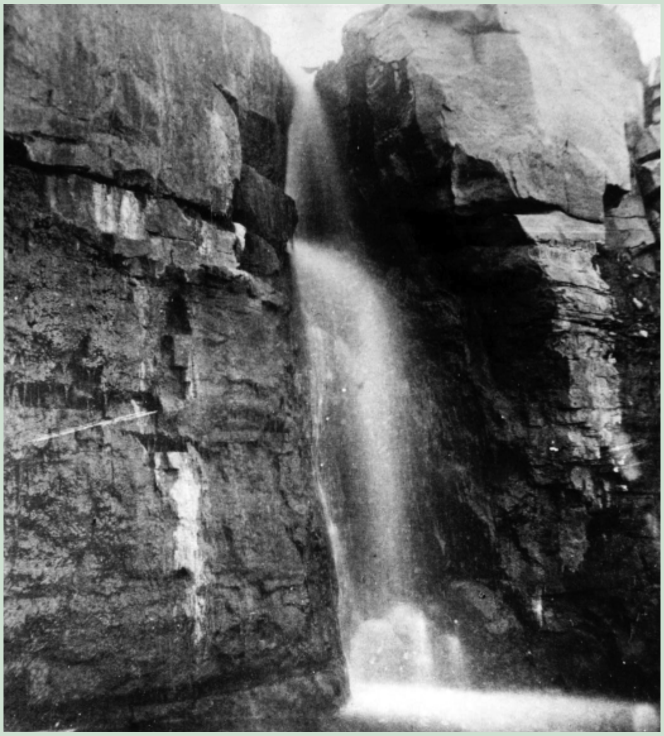
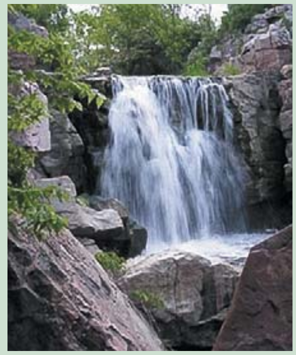


Figure 3. Overflow channel and falls of Pipestone Creek, 1890s.

NPS/NATHAN KING



NPS/GARY WILLSON

Figure 4 (above left). Pipestone Creek plunges over a cliff of Sioux quartzite as Winnewissa Falls. The creek bed was altered above and below the falls in the early 1900s, reducing the amount of surface water reaching orchid habitat.

Figure 5 (above right). Erratic growth patterns make the orchid difficult to monitor. In some years an orchid may produce a tall, visible flower stalk (see fig. 1), while in others it produces only one to three basal leaves (the vegetative stage shown here) or no aboveground growth.

Methods

In July 1995, as part of the annual census of flowering orchids in Pipestone National Monument, we permanently marked the locations of the 37 flowering western prairie fringed orchids counted that year. For the next nine years (1996–2004), we revisited the marked locations during the July census. At each location, we recorded the life stage of each orchid as flowering, vegetative, or absent. In 1997, seven markers were inadvertently removed after the habitat was prescription burned. We compared the survival of the remaining 30 orchid plants in this population with that of 30 orchid plants that Sieg and King tracked in ungrazed–prescription burned habitat at Sheyenne National Grassland. The orchid habitats at Pipestone and Sheyenne were generally similar in climate, soil type, and management but substantively different in soil depth and hydrology. We assumed the age distribution of the flowering plants at both locations was similar, although the ages of the flowering plants were unknown (i.e., plants were first encountered as flowering individuals of unknown age, not as seedlings).

Results

Appendix A (page 55) shows the status (i.e., flowering, vegetative, or absent) of orchid plants for each year of the nine-year monitoring record at Pipestone National Monument, and table 2 (page 54) shows a summary of these data. Table 3 (page 54) shows the number of orchid plants surviving in each year of monitoring at Pipestone and Sheyenne.

Year-to-year survival of plants at marked locations was similar in the Pipestone and Sheyenne populations, except for the first year of monitoring (1988 at Sheyenne and 1996 at Pipestone), when survival was 50% at Sheyenne and 83% at Pipestone. At the end of the nine-year monitoring period at Pipestone we found that two plants had survived—one flowered and the other was vegetative—that year, whereas at the end of the seven-year monitoring period at Sheyenne, Sieg and King found six plants had survived. At Pipestone, we found only two orchids had flowered in the second year of monitoring (1997), although three had flowered in the fifth and sixth years. Furthermore, only two orchid plants flowered for three consecutive years. Sieg and King did not report these data for the plants they monitored.

Discussion

Half-life is the period of time during which half of the individuals in a population die (as used by Hutchings 1989). At Sheyenne, Sieg and King (1995) found orchid plants were short-lived, with a

Table 1. Flowering western prairie fringed orchid plants at Pipestone National Monument, 1993–2008

Year	Number of Flowering Plants
1993	33
1994	18
1995	37
1996	55
1997	3
1998	0
1999	16
2000	125
2001	95
2002	124
2003	221
2004	146
2005	149
2006	101
2007	1
2008	10

half-life of one year in the ungrazed-burned habitat. Most orchid species have half-lives that are longer than five years (Hutchings 1989). Such a short half-life may have been the result of very dry conditions (50% of long-term average precipitation) in 1987 at the beginning of their monitoring (Sieg and King 1995). At Pipestone we found survival of the orchid was somewhat longer, but still very short with a half-life of about one to two years. Precipitation at Pipestone was also below normal in one year during the monitoring period, but that year—1997—was the second year and was only moderately dry (70% of normal precipitation).

The low survival of flowering orchids at Sheyenne following one dry year suggests that even in habitats with intact hydrology (in this case subirrigated), below normal precipitation can substantially lower survival. Although we did not monitor the survival of flowering plants following a very dry year at Pipestone, we believe the altered hydrology and shallow soil there may compound the negative effect of low precipitation on orchid survival. Following a very dry year, or a series of dry years, orchid survival at Pipestone may be as low as or lower than the first-year survival of flowering plants that were monitored at Sheyenne. Very low survival of the orchid plants, very low flowering of surviving plants, and a short-lived seed bank (Alexander 2006; Batty et al. 2000) could lead to extinction of the small population at Pipestone following a prolonged drought. Recolonization would be very unlikely, considering the next closest western prairie fringed orchid population is about 29 kilometers (18 mi) away.

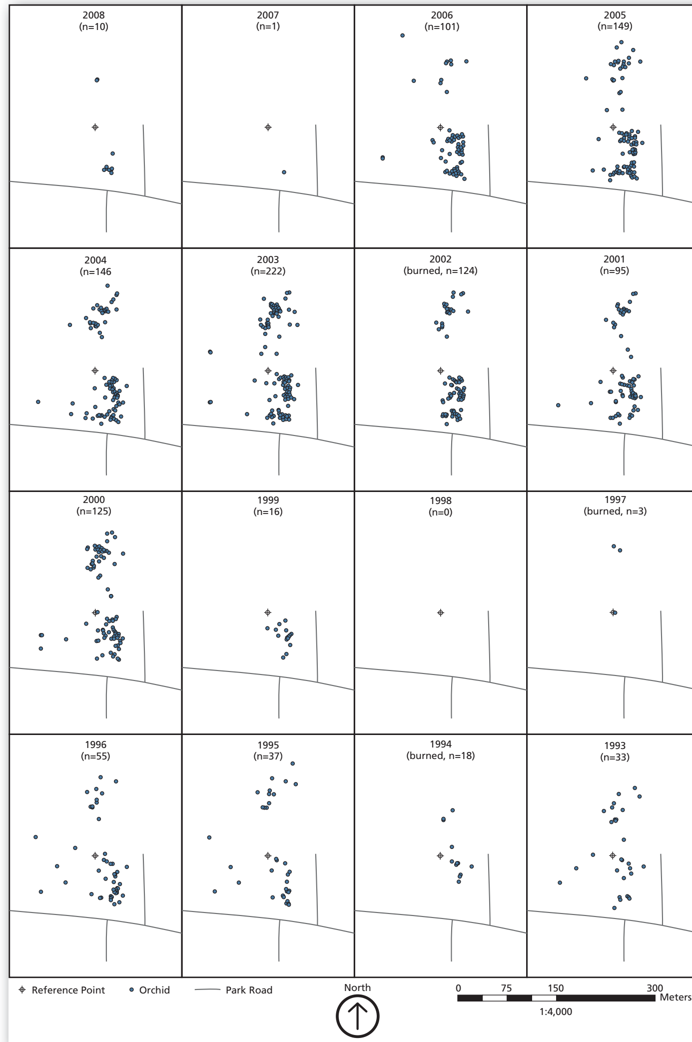


Figure 6. Distribution of flowering western prairie fringed orchid plants at Pipestone National Monument, 1993–2008.

SOURCE: YOUNG ET AL. 2008. *NOTE:* ORCHID LOCATIONS ARE APPROXIMATE.

Restoration of the natural flow of Pipestone Creek might supplement soil moisture in the orchid habitat and mitigate the effects of reduced precipitation in dry years, but restoration is unlikely considering the cost and opposition from upstream urban and agricultural interests. In addition, surface flow of water into the orchid habitat would likely contain agricultural chemicals that might affect orchid flowering and survival. The only practical strategy may be changes in resource management, primarily the use of prescription burns. We recommend not burning the orchid habitat during an extended dry period when burning may increase soil moisture loss and further reduce the survival of plants and the ability of surviving plants to flower (Pleasants 1995; Willson et al. 2006).

Table 2. Number of flowering, vegetative, and absent western prairie fringed orchid plants at permanently marked locations at Pipestone National Monument, 1995–2004

	Year									
Stage	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Flowering	30	18	2	0	0	3	3	1	1	1
Vegetative	0	7	10	8	11	5	4	2	0	1
Absent	0	5	18	22	19	22	23	27	29	28

Table 3. Survival of western prairie fringed orchid plants at marked locations during 1987–1994 at Sheyenne National Grassland and during 1995–2004 at Pipestone National Monument

	Year (Sheyenne/Pipestone) and Number of Plants									
Site	**1987/ 1995**	**1988/ 1996**	**1989/ 1997**	**1990/ 1998**	**1991/ 1999**	**1992/ 2000**	**1993/ 2001**	**1994/ 2002**	**—[1]/ 2003**	**—[1]/ 2004**
Sheyenne (1987–1994)	30	15	13	8	7	9	7	6	—[1]	—[1]
Pipestone (1995–2004)	30	25	12	8	11	8	7	3	1	2

[1]Monitoring at Sheyenne ended in 1994.

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Appendix A: Annual monitoring results at marked locations where western prairie fringed orchid plants flowered at Pipestone National Monument in 1995

	Year									
ID	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
9501	2	1	1	1	1	1	2	0	0	0
9502	2	2	0	0	0	0	0	0	0	0
9503	2	2	0	0	1	0	0	0	0	0
9504	2	2	0	0	0	0	0	0	0	0
9505	2	0	0	0	0	0	0	0	0	0
9506	2	2	0	1	1	0	1	0	0	0
9507	2	2	0	0	1	0	0	0	0	0
9508	2	2	0	1	1	1	2	2	0	2
9510	2	2	1	0	0	1	0	0	0	0
9511	2	1	0	0	0	0	0	0	0	0
9514	2	2	1	1	1	0	0	0	0	0
9516	2	1	0	0	1	1	0	0	0	0
9517	2	2	0	0	0	0	0	0	0	0
9518	2	1	0	0	1	0	1	0	2	0
9519	2	2	0	0	0	0	0	0	0	0
9521	2	0	1	0	1	1	0	0	0	0
9522	2	1	1	0	0	0	0	0	0	0
9523	2	2	0	0	0	0	0	0	0	0
9524	2	2	0	0	0	0	0	0	0	0
9525	2	2	2	0	0	0	0	0	0	0
9526	2	1	0	0	0	0	0	0	0	0
9527	2	2	2	0	0	0	0	0	0	0
9528	2	0	1	0	0	0	0	0	0	0
9529	2	2	1	1	1	0	0	0	0	0
9530	2	1	1	1	1	2	1	1	0	1
9531	2	0	0	0	0	0	0	0	0	0
9532	2	0	0	0	0	0	0	0	0	0
9533	2	2	1	1	0	2	0	0	0	0
9534	2	2	1	1	0	0	1	1	0	0
9536	2	2	0	0	0	2	2	0	0	0

2 = Flowering
1 = Vegetative
0 = Absent

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