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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

- Dinosaur trackway discovery
- Web tool for monitoring forest insect pathogens
- Safety plan for exotic plant control
- Bioblitz success at Biscayne
- Integrating traditional ecological knowledge in resource management

SALT-MARSH MAKEOVER AT GATEWAY

A multiagency program restores marsh islands in Jamaica Bay, but can the causes of marsh loss be reveresed in this urban estuary?

PARKScience
Integrating Research and Resource Management in the National Parks

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From the Editor

What's in a word?

Editors pay attention to words, evaluating the fit, sequence, and strength of each and the role they play in developing a story in a logical, understandable, and enjoyable way. The process of choosing the right words, a partnership of trust between author and editor, is one of exploration and discovery that ultimately blends science and art. With every science writing endeavor we have the opportunity to affect our readers—furthering knowledge, inspiring reflection, prompting action—by choosing our words deliberately so that our story interests and involves the whole person (as Freeman Tilden taught us about good interpretation) and appeals to the curiosity, intellect, emotions, sense of humor, and judgment of our readers.

One word that gets my attention because of its increasingly common use in *Park Science* is "landscape." We are privileged to live and work among some of the most beautiful, awe-inspiring, and relatively undisturbed landscapes in the world. That's a traditional use of the term. But in a park management sense "landscape" is a context that gets to the heart of our capacity to understand and protect heritage resources for the future enjoyment of this nation.

Modern landscapes are a complex combination of biophysical, chemical, social, and geographic processes that interact with each other largely irrespective of park boundaries. Ecology is delving ever deeper into illuminating important patterns and associations among these environmental factors in order to give us a more holistic perspective of the setting in which we strive to sustain park values. Increasing our knowledge of this milieu is fundamental to our ability to protect the integrity of national parks over the long term.

This concept of broad connections on the land is central to several articles in this issue, for example, the article about identifying environmental syndromes affecting trends in the condition of a park's resources. It also figures prominently in the research we review about the relationship of the spatial arrangement of wetlands to bat activity and the consequences it has for bat conservation. Our interview with economist Bruce Peacock highlights the far-reaching influence of human values on natural resource conservation. The landscape perspective shows up in the journal article summary about the ecological costs of pervasive noise to wildlife. Finally, it is evident in the study of factors affecting sage-grouse numbers in Grand Teton National Park and the larger Jackson Hole.

Landscape ecology is not a new science; however, I am pleased to publish articles that explore this important discipline. Though it is just one term among thousands in this issue, "landscape" is a watchword for our time as we strive to fulfill the challenges of our noble mission.

—Jeff Selleck

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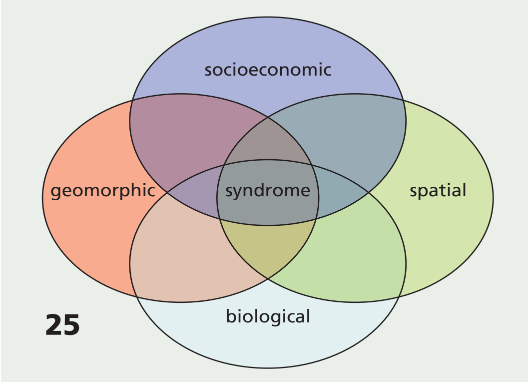
NPS/THOMAS M. STROM

NPS/ROBERT BENNETTS



NPS

DEPARTMENTS

ON THE COVER

Low tide in Jamaica Bay, New York, reveals Elders Point was once a single marsh island; however, most of what was once emergent salt marsh is now subtidal and intertidal mudflat. In this October 2009 image, the light pink color and dark red swirls on the mudflat are caused by *Ulva* (sea lettuce), a green alga that is prevalent in the nutrient-rich waters of Jamaica Bay. Restoration of 15.8 hectares (39 ac) of salt marsh at Elders Point East (island at top center) was conducted in 2006–2007. Elders Point West (see page 4, left photo, at left), prior to restoration, consists of a small area of upland and a band of *Spartina alterniflora*. For more information see the article on page 34.

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U.S. ARMY CORPS OF ENGINEERS

BRYAN BEDROSIAN, CRAIGHEAD BERINGIA SOUTH

USGS/RONALD A. SLOTO

UPCOMING ISSUES

Spring 2011
Climate change research and park management—Adaptation and communication. May release. In production.

Summer 2011
Climate change research and park management—Scientific knowledge. August release. In production.

Fall 2011
Seasonal issue. October release. Contributor's deadline: 15 May 2011.

Winter 2011–2012
January 2012 release. Topical issue: Wilderness research and management. In production.

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RESTORATION JOURNAL

RESEARCH REPORTS

In This Issue

PARKS DISCUSSED IN THIS ISSUE

Abbreviations

Mem	Memorial
MemP	Memorial Parkway
NB	National Battlefield
NHP	National Historical Park
NHS	National Historic Site
NM	National Monument
NP	National Park
NRA	National Recreation Area

Index

Information Crossfile*

SUMMARIES

Information delivery in an information-saturated world

IN TRYING TO MINIMIZE CHANCE, THE SAVVY GAMBLER may learn all he or she can about a horse's breeding and health, the odds of winning, and the conditions of the track by reading tip sheets and trade publications, but only the stable boy knows that Mr. Ed has a slight limp today. In a revealing new evaluation of information transfer, Seavy and Howell (2010) have learned that natural area managers are similarly committed to face-to-face consultations with subject-matter experts because that is what works best. With such vast amounts of knowledge at the fingertips of resource managers today, pinpointing and perfecting how exactly scientific evidence meshes with protected area management experience are more crucial than ever for making truly informed decisions.

Based on a survey of those involved in wetland restoration efforts in California, Seavy and Howell (2010) recommend that one-on-one interaction between ecologists and decision makers be made a priority, despite its relatively high cost. The authors acknowledge that this survey's bias toward bird habitat conservation and its small sample size (86 respondents) limit the applicability of its results. Nevertheless, they succeed in drawing several conclusions about how the ecologist–resource manager–information sharing dynamic can be improved.

Making a comparison to the light-years of advances in medicine brought forth by modern science, the authors discuss how California wetland conservationists are sifting through more than 50 years of ecological insights into natural systems and how they work. This explosion in information presents a tremendous opportunity to incorporate evidence-based knowledge into resource management prescriptions. However, as the authors suggest, "it is not yet clear how to provide information to managers most effectively."

At a time when scientific evidence is pervasive and experience-based information is lacking in decision making, the survey evaluates the variety of high-quality information transfer methods. Seavy and Howell (2010) had the study participants rate the accessibility and importance of five forms of these sources. The authors suggest that "ecologists should not underestimate the importance of publishing their results and contributing to conservation plans," as study participants deemed peer-reviewed publications and synthetic reviews important and available sources. Unpublished reports were moderately important and low in availability. Looking ahead, the authors foresee a need for "well-organized clearinghouses that make this information available to a wide audience" as the body of ecological knowledge grows. Interestingly, Web-based tools were not yet considered important or widely available, at least not for riparian habitat conservation in California. The authors feel the use of Web-based tools would ideally provide managers with "decision support systems" via a library of electronic versions of peer-reviewed and synthetic articles and interactive applications. Making these tools available over the Internet, however, is not enough; managers require training in their use.

Practical advice in an ecologist's work needs to go beyond the typical concluding paragraphs in peer-reviewed manuscripts describing management implications. This study strongly suggests there is a need to apply the human touch and find opportunities for one-on-one interactions between ecologists and managers. Survey respondents rated this type of information transfer as the most important and least available source. In purely economic terms, this also is one of the least efficient methods of information transfer, though it should be done "to ensure that all the information is used effectively." Through these interactions, when information flows freely in both directions, ecological science can be incorporated collaboratively and site-specifically into the decision-making process in resource management. Just as the daily race form gives only the bare essentials of horses at the track, managers should seek out ecologists with their ear to the ground before placing a bet on a resource management decision.

Reference

Seavy, N. E., and C. A. Howell. 2010. How can we improve information delivery to support conservation and restoration decisions? Biodiversity Conservation 19:1261–1267.

—Jonathan Nawn, Amy Stevenson, and Jeff Selleck

■ ■ ■

Improving ecosystem services research for better policy integration

IN EVALUATING ECOSYSTEM SERVICES—THE BENEFITS humans derive from the natural world—complexity is king. All too often, however, this research focuses on patterns alone without understanding the underlying mechanisms of the ecosystem services. This leads to poor predictive power and, therefore, potentially inaccurate policy decisions. In a kind of ecological researcher's call to arms, Nicholson et al. (2009) urge scientists to take an interdisciplinary approach to quantifying ecosystem

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

No study to date has integrated dynamic models of multiple ecosystem services to include feedback between social and ecological components of a system.

services. For a field that is "still based on static analysis and single services, ignoring system dynamics, uncertainty, and feedbacks," ecosystem services research needs to broaden its scope and tackle more intricate and necessarily complex areas of inquiry that are based on process, not just pattern. According to Nicholson et al. (2009), "A social-ecological approach addresses not only the dynamics within each of the social, economic, and ecological components, but also explicitly deals with the linkage and feedbacks between them."

The authors contend that a lack of understanding of many processes that underpin the dynamics of ecosystem services, even at a basic level, significantly hinders the capacity to develop predictive models. According to the authors, no study to date has integrated dynamic models of multiple ecosystem services to include feedback between social and ecological components of a system. For instance, there can be synergies when the increased provision of some services improves provision of others, as when carbon sequestration is benefited by the increased biodiversity of forested areas. Another area of concern is representing uncertainty in a model, a notoriously neglected and difficult dynamic to quantify. The authors contend that the necessary extensive sampling and sophisticated statistical methods employed in ecosystem services quantification research should be used to incorporate uncertainty, or at least acknowledge its complexity, lest policy recommendations be made that are "misleading or flawed."

Nicholson et al. (2009) identify areas of research that are ripe for progress. These include understanding "the linkage between biodiversity and ecosystem function" (an area well suited to national parks), interdependencies among multiple ecosystem services, and the role of economics and human activities in these systems. The authors also highlight the need to detect "potential changes in ecosystem services before it's too late." Managers need to know when the systems in their care are approaching a tipping point, and research may be able to identify indicators that signal impending change. The authors argue that if the challenge of integrating multiple areas of research and crossing traditional communication barriers is met, the result will be potent for effective policy recommendations.

Reference

Nicholson, E., G. M. Mace, P. R. Armsworth, G. Atkinson, S. Buckle, T. Clements, R. M. Ewers, J. E. Fa, T. A. Gardner, J. Gibbons, R. Grenyer, R. Metcalfe, S. Mourato, M. Muuis, D. Osborn, D. C. Reuman, C. Watson, and E. J. Milner-Gulland. 2009. Priority research areas for ecosystem services in a changing world. Journal of Applied Ecology 46:1139–1144.

—Jonathan Nawn, Amy Stevenson, and Jeff Selleck

■ ■ ■

Seeing the trees for the forest: Getting interdisciplinary at the small scale

IF ONLY HUMAN INVASIONS COULD BE SO HUMANE. When the invasive crab species *Hemigrapsus sanguineus*, the Asian shore crab, first landed on the New England shore in the late 1980s and nestled into patches of Atlantic cordgrass (*Spartina alterniflora*) and beds of ribbed mussels (*Guekensia demissa*), there was seemingly little commotion among the native biodiversity. After causing initial concern among biologists with its "high abundance and voracious omnivorous diet," the crab thrived, reaching population density levels even higher than in Asia—all without damaging the native environs. Here is perhaps where the average invasive species study would begin to wrap up. The invasive species' relationship to the native biodiversity would be labeled "positive," conclusions would be drawn, papers would be written, and resource managers would scratch their heads. Altieri et al. (2010), however, argue that the context for such a study, and for many other landmark experiments, is not nearly interdisciplinary enough to warrant ecological significance.

As any cinematographer worth his or her salt will tell you, careful composition of an establishing wide shot will only improve the clarity, drama, and visual punch of the subsequent zoom-in. And as any ecologist will tell you, extending a study's perspective beyond a single species' taxonomic group and particular position in the food chain may lead to more composite data about a landscape.

Altieri et al. (2010) discovered that native cordgrass acted as a foundational species, providing a quality habitat for Asian crab by offering protection from the sun and predators and by providing abundant invertebrate food sources. Moreover, the cordgrass reduced solar stress on mussels and provided an area for mussels to harden the substrate, creating a habitable and shady environment for nonnative crabs and native species alike. Thus, cordgrass was at the core of a facilitation cascade. The authors use the invasion of the Asian shore crab on intertidal New England cobble beaches to examine how single-variable invasive species studies can create

Extending a study's perspective beyond a single species' taxonomic group and particular position in the food chain may lead to more composite data about a landscape.

inconsistencies when resource managers draw large-scale conclusions from small-scale observations.

Using a multitrophic (multiple–food web) approach, Altieri et al. (2010) observed this facilitation cascade, manipulating the native biodiversity to discover its connection to invader population densities. The investigators clipped the cordgrass canopy, reducing shade, shelter, and the stability of the substrate, in order to tease out their separate and interactive effect on densities of Asian shore crabs and the species richness of native organisms. The mussels were also clipped and removed, and the resulting thermal stress and substrate instability were observed. In a crab-tethering experiment, casualties were kept to a minimum. Several crabs were tied down away from cordgrass and left to fend for themselves so that the investigators could study the effects of solar stress, predation, and other causes of mortality.

The findings indicate nonnative Asian shore crabs thrived in areas of high native biodiversity, where the grass was long and green, and where there were mussels; crabs did not thrive in areas where grass and mussels were removed. The authors met their objective to test the hypothesis that a facilitation cascade in cordgrass beds enhances both native diversity and invader abundance, while addressing the inconsistencies that can occur when using small-scale studies to draw large-scale conclusions.

As a result of the experiments, the authors argue that large-scale invasion relationships can be better understood by observing interactions across multiple trophic levels. In particular, facilitation cascades, which too often play "an important but unrecognized role," can "drive patterns of biodiversity, invasive species, and the diversity-invasion relationship."

The authors encourage future research to prioritize conservation efforts by identifying the foundational species that mediate large-scale patterns of community diversity and invasion in natural ecosystems.

Reference

Altieri, A. H., B. K. Van Wesenbeeck, M. D. Bertness, and B. R. Silliman. 2010. Facilitation cascade drives positive relationship between native biodiversity and invasion success. Ecology 91(5):1269–1275.

—Jonathan Nawn and Amy Stevenson

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Playing it by ear: Understanding the costs of noise pollution in protected areas

INVISIBLE, PERVASIVE, THREATENING, AND NOT YET FULLY understood: chronic noise is the other air pollution. Despite a growing foundational literature on noise in natural settings, the unanswered questions and unknown consequences of being noisy neighbors are piling up in ecologists' in-boxes. In a "state-of-knowledge" address to the scientific community, Barber et al. (2009) emphasize that the vast and interconnected nature of the aural landscape of a terrestrial ecosystem, while not yet fully understood, is being substantially altered by anthropogenic noise. When predator footfalls are masked by the ubiquitous dull whoosh of traffic, when shipping noise interrupts a male songbird's aria, when owls and bats cannot efficiently localize prey because of sounds in a specific spectrum, and when that prey cannot perceive the incoming wing beats, animal behavior and possibly populations are altered. In this comprehensive review of the research concerning anthropogenic noise exposure on protected lands, the authors conclude that immediate action is needed to manage America's din, for even in the most remote wilderness, animal habitats can be notably affected by the sounds emanating from adjacent urban development and motorized vehicles on or near the site.

One problem with most studies to date, however, is that they have not separated human activity generally from the effects of noise specifically. Barber et al. (2009) call for greater scrutiny: Is animal vigilance dulled by background noise? Does low-frequency anthropogenic noise inhibit perception of higher-frequency signals? Are sounds made by predators being masked, and is their cognition affected by the masking? Do animals directly perceive human sound as such and associate it with the threat of predation? As humans struggle to converse in a noisy restaurant, so too does chronic noise interfere with the abilities of wildlife to perform efficiently over time. And just as people will adapt by speaking more loudly or smiling in uncertain agreement, some, but not all, animals can adapt.

Chronic noise masks not only deliberate call-and-response soundings that help to maintain community structure but also acoustical eavesdropping of one species on the location and activities of another—a crucial tool in assessing risk for many terrestrial animals. "The acoustical environment is not a collection of private conversations between signaler and receiver but an interconnected landscape of information networks and adventitious sounds," write Barber et al. (2009).

With each investigation, researchers are learning that the soundscape of the natural world is more connected, and the masking effects of anthropogenic noise more destructive, than they may have realized. Among terrestrial animals, clear and substantial changes in reproductive success, density and community structure, and foraging and antipredator behavior have all been observed in response to noise—though birds, primates, and crustaceans have been observed to alter their vocalizations to reduce the effects of masking in an attempt to maintain group cohesion.

"Taken collectively, the preponderance of evidence argues for immediate action to manage noise in protected natural areas," write Barber et al. (2009). Resource managers can begin by targeting highly fragmented and heavily visited locations as the priority for their own experiments in adaptive management. For instance, quieting efforts could begin with the main noise management solution at a resource manager's disposal: increased use of shuttle buses and mass transit into and around the protected area.

With almost 5 trillion vehicle-kilometers (3.1 trillion miles) now traveled on U.S. roads each year, transportation networks are the worst aural offender. As the U.S. population increased by approximately one-third between 1970 and 2007, traffic on U.S. roads nearly tripled. Additionally, aircraft traffic at least tripled between 1981 and 2007. Thus, noise management is now an "emergent" issue for protected lands. Reverberations from the explosive growth of the U.S. transportation network are heard by most, if not all, of its neighbors—especially the ones who cannot call in a noise complaint. To mitigate the effects of chronic noise in protected areas, quieting methods must factor in ecology, wildlife biology, mathematics, and physics. Though noise monitoring and management are a priority of the National Park Service, as the authors attest, great strides still need to be taken to understand the consequences of noise and how to manage fairly for its reduction.

Reference

Barber, J. R., K. R. Crooks, and K. M. Fristrup. 2009. The costs of chronic noise exposure for terrestrial organisms. Trends in Ecology and Evolution 24(3):180–188.

—Jonathan Nawn, Amy Stevenson, and Jeff Selleck

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Efficacy of bison management studied at Badlands

FROM THE BRINK OF EXTINCTION TO ABUNDANCE, the iconic plains bison (*Bison bison*) has rebounded so well in many national and state parks that it has become a potent symbol of conservation in the American West. This recovery is due largely to restoration efforts like the reintroduction of bison into Badlands National Park in 1963, which has been by all accounts a success. As a sort of biological exemplar, or keystone species, that has a "disproportionate" effect on the quality of surrounding flora and fauna, bison have the potential to alter grassland habitats. This is especially true in areas like the 26,000-hectare (64,246 acre) Sage Creek Unit of the Badlands Wilderness Area, a mixed-grass prairie ecosystem where this South Dakota herd is contained by steep cliffs and a fence and lacks natural predators, the wolf and the grizzly bear. In typical ungulate fashion, bison could overpopulate and deplete the native grasslands. Thus, almost every year, resource managers at Badlands National Park have a roundup to remove animals from the herd. In a review of this practice from 2002 to 2007, Pyne et al. (2010) find that managing the herd through annual culling is an effective management strategy.

Over the course of five years and the capture of 3,281 bison, investigators tested various hypotheses related to demographic analysis of the herd and survival rates as they apply to sex and age of individuals; they also reviewed the effects of climatic change on the herd, because management is based on vegetation productivity in drought years. Observing the park's mark-recapture model for maintaining the bison, Pyne et al. (2010) were able to estimate biologically meaningful transition rates, such as the transition from breeding to nonbreeding status, while correcting for recapture rates. This analysis shows that Badlands bison have a high survival rate and high chance of breeding. In other words, the herd is not at "carrying capacity" for the landscape and could be allowed to grow. This is good news for park managers. The park is currently in the process of fencing other areas where bison will be able to expand their range and increase in numbers. Park staff plans to maintain a population of at least 1,000 animals to prevent loss in genetic heterozygosity or diversity. Researchers have found that populations of 1,000 animals sustain genetic health for more than 200 years.

Reference

Pyne, M. L., K. M. Byrne, K. A. Holfelder, L. McManus, M. Buhnerkempe, N. Burch, E. Childers, S. Hamilton, G. Schroeder, and P. F. Doherty. 2010. Survival and breeding transitions for a reintroduced bison population: A multistate approach. Journal of Wildlife Management 74(7):1463–1471.

—Jonathan Nawn, Amy Stevenson, and Jeff Selleck; reviewed by E. Childers

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The effects of wetland networks distribution on bat activity

AS IT TURNS OUT, BATS MAY NOT BE TOO HAPPY ABOUT being stuffed in a belfry—it may just be their best choice for a roost site in a highly fragmented landscape. Additionally, being limited to any one habitat type in a landscape may restrict some bat species' ability to thrive. A new study points out that managing protected areas without consideration of the broader landscape connections is not conducive to the viability of this mobile group of mammals (Lookingbill et al. 2010). True, bats need areas in which to forage and roost, and a "mosaic arrangement of those areas is crucial to maintaining bat activity," note the authors.

In the context of increasing urbanization and wetland depletion, Lookingbill et al. (2010) studied the importance of wetland habitat connectivity in five national parks within the mid-Atlantic United States. The parks chosen for this study combine a variety of land cover types amid a gradient of rural to urban development: Rock Creek Park (forest surrounded by high-density urban development), Monocacy National Battlefield (large tracts of pasture, near the Washington, D.C., metro area), Harpers Ferry National Historical Park (mixture of forest, agricultural, and riverine habitats), Antietam National Battlefield (largely pastureland), and Catoctin Mountain Park (95% forested).

In these parks, five species of bats, all with different feeding habits and behavior, were the focus. Investigators inventoried bat activity levels via acoustic monitoring—96 detection stations in all, located within various land covers. Bat activity was correlated with land cover data captured in satellite imagery and compared with a theoretical network model to graphically illustrate the connectivity of wetland areas.

The authors hypothesized that the spatial distribution of wetlands is critical for allowing bats to use landscapes effectively. They correctly predicted that bat activity would be higher for more connected wetlands than for those that were isolated from one another, and that the importance of these connected landscape features would differ for each bat species. For three of the five species (tri-colored [*Perimyotis subflavus*], eastern red bat [*Lasiurus borealis*], and little brown myotis [*Myotis lucifugus*]), the size of and distance between wetlands were the most important factors for feeding activity. Though wetlands were not correlated with activity of northern myotis (*Myotis septentrionalis*) and were not as strongly correlated as other habitat types with activity levels for big brown bat (*Eptesicus fuscus*), these species' use of many different foraging areas is indicative of the importance of a mixture of habitat types for bats.

The arrangement of wetlands in the landscape in terms of size, distance between wetland patches, the type of connections between those wetlands, and the availability of roosting sites is critically important for bats. Indeed, the authors stress that the area and connectivity of wetland foraging habitat are similarly important to the percentage of urban, forest, and open land cover types and roosting areas in a landscape. If management efforts are to be effective, the foraging movement abilities of each bat species and the spatial distribution of wetlands relative to these movements must be considered. Because one cannot generalize a conservation strategy for wetlands to benefit bats, the authors argue that strategies for protection of bats should be species specific, not focused on bats as a group.

Lookingbill et al. (2010) further assert that future research should focus on integrating detailed information on individual bat flight lines, roosting locations, potential movement barriers, and wetland configuration. So that bats' varied foraging and roosting needs are met, including large connected networks of wetlands, the authors suggest that managers of small parks develop conservation strategies in cooperation with adjacent landowners.

Reference

Lookingbill, T. R., A. J. Elmore, K. A. M. Engelhardt, J. B. Churchill, J. E. Gates, and J. B. Johnson. 2010. Influence of wetland networks on bat activity in mixed-use landscapes. Biological Conservation 143:974–983.

—Jonathan Nawn, Amy Stevenson, and Jeff Selleck; reviewed by T. Lookingbill

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WEB SITE

New journal for protected mountain areas research in Europe

THE AUSTRIAN ACADEMY OF Sciences in conjunction with Innsbruck University Press has launched *EcoMont*, an online journal of research pertinent to the management of protected areas in the Alps, with relevance for mountain area managers worldwide. The journal has similar goals to those of *Park Science*: practical applications of research to protected area management, in this case mountain areas, and publication of best practices based in science. The editors stress the need for a journal focused on protecting and maintaining the rich Alpine natural and cultural heritage in a time when global warming threatens rapid change and strategies for sustainable development are needed more than ever. Articles are written in English and four editions have been published to date. The following sample of recently published articles gives the flavor of this new conservation journal:

- Perceiving changes in biodiversity in daily life
- Hiker use monitoring in the Tatra National Park (Poland)
- Can protected mountain areas serve as refuges for declining amphibian populations? Potential threats of climate change and chytridiomycosis in an alpine amphibian population
- Critical issues in managing protected areas by multistakeholder participation: Analysis of a process in the Swiss Alps
- Turning technical experts into multifunctional managers of protected areas

Article abstracts are available for free; full-text articles cost €5 ($6.74) each. The journal is published at http://www.oeaw.ac.at/ecomont.

—Editor

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BOOKS

Book analyzes assumptions underlying development of ecological models

YOLANDA WIERSMA, AUTHOR OF A RESEARCH REPORT in our last issue of *Park Science*, is coeditor of a recently published book titled *Predictive Species and Habitat Modeling in Landscape Ecology: Concepts and Applications*. Spatial models are commonly used in landscape ecology to illuminate species-habitat associations. While traditional landscape ecology focused on the evolution of effective data sources, metrics, and statistical approaches that could accurately describe spatial and temporal patterns and processes of interest, this book examines "ecological theories that underpin the assumptions commonly made during species distribution modeling and mapping." Comprising 15 contributed chapters, the book consolidates recent research on various aspects of modeling, case studies, and field surveys of modeling. The editors contend that paying attention to the foundational assumptions underlying the development of models is critical to their applicability to questions of global sustainability. The book is intended to be useful to researchers in landscape ecology, conservation biology, wildlife management, population and community ecology, and general ecology. The book is 314 pages in length and costs $209 (hardcopy). A sample of the text can be viewed at http://www.springer.com/life+sciences/ecology/book/978-1-4419-7389-4.

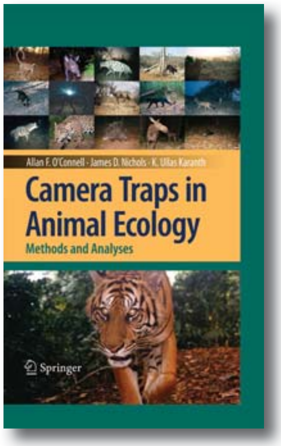
Reference

Drew, C. A., Y. Wiersma, and H. Falks, editors. 2010. Predictive species habitat modeling in landscape ecology. First edition. Springer, New York, New York, USA.

■ ■ ■

Camera traps in animal ecology

EDITORS ALLAN F. O'CONNELL (RESEARCH WILDLIFE ECOLO-gist, USGS), James D. Nichols (senior scientist, USGS), and Ullas K. Karanth (senior conservation scientist, Wildlife Conservation Society Centre for Wildlife Studies, India) have compiled an authoritative guide on the use of remote photography and infrared sensors in sampling wildlife, particularly elusive species. This book is the first volume to describe state-of-the-art techniques for the use of "camera traps" for purposes of high-quality science and effective management. Fourteen contributed chapters explore how to evaluate equipment (coauthored by Don E. Swann, biologist, National Park Service, Saguaro National Park); designs for field sampling; and data analysis for making inferences about the abundance, species richness, and habitat occupancy of target species. Case studies detail the deployment of camera traps for charismatic, endangered, and cryptic species, and newly developed models, such as spatial capture–recapture models, are introduced that will "revolutionize use of camera data to estimate population density." The book is 280 pages in length and costs $189 (hardcover). A sample of the text can be reviewed online at http://www.springer.com/life+sciences/animal+sciences/book/978-4-431-99494-7.



Reference

O'Connell, A. F., J. D. Nichols, and K. U. Karanth, editors. 2011. Camera traps in animal ecology: Methods and analyses. First edition. Springer, New York, New York, USA.

PS

Park Operations

NPS/ADAM THROCKMORTON

Increasing safety for EPMTs working at Bryce Canyon National Park

The Lake Mead Exotic Plant Management Team treats nonnative vegetation at Bryce Canyon in summer 2010.

By Adam Throckmorton and Virginia A. Reams

THE WORK OF EXOTIC PLANT MANagement Teams (EPMTs) is difficult and potentially dangerous. A May 2010 Intermountain Region memorandum called attention to the need for increased safety measures for EPMTs working in parks, stating that they "work under some of the most difficult field conditions and have a high risk of potential safety issues because of the types of chemicals, equipment, and terrain necessary to address invasive species issues." In response to this call for enhanced safety protocols, the Bryce Canyon Vegetation Crew took an innovative approach and adapted Incident Action Plans (IAPs), guidance used on incidents managed through the Incident Command System, for use with the visiting Lake Mead EPMT.

The Lake Mead EPMT provides invasive species treatment assistance to the park. The team visited Bryce Canyon twice in August 2010 to treat smooth brome (*Bromus inermis*) infestations in East Creek Meadow on the first visit and bull thistle

(*Cirsium vulgare*) at the Sheep Creek backcountry campsite on the second. The work involved the combination of two large crews (five and six employees, respectively, on the Lake Mead and Bryce Canyon crews).

Adapting IAPs for EPMT projects

The Bryce Canyon crew developed individual IAPs for each visit using park-specific information and an Operations and Risk Management Plan prepared by the Lake Mead EPMT. The IAPs included two key elements directed in the memo: a safety communication plan and a responsibility outline for reporting incidents to a designated point of contact. Each IAP also included an outline of objectives and assignments for the operational period; maps of the treatment area(s); and a medical plan, which listed the closest hospitals, ambulance services, and helicopters. The project objectives included a general safety message, weather forecast, and alternatives in case of inclement weather.

The crews used the IAPs for both visits. After the first visit, Bryce Canyon staff discussed the effectiveness of the IAPs with EPMT crew members. The crew members appreciated having an IAP in place and noted that they would like to see other partners provide them with a similar safety plan for future activities. The comments included, "The IAP helped me become aware of potential hazards that I otherwise may not have known about" and "Emergency contacts shown clearly, clear instruction on expected work, maps give visual illustration of work." All crew members thought the IAP helped improve efficiency and communications, with one individual commenting, "It would have helped had an incident occurred."

This feedback suggests that the use of Incident Action Plans for EPMT activities in Bryce Canyon addresses many of the concerns in the Intermountain Region memo, helping staff to better understand and manage the risks in their jobs and leading to "increased safety for all staff working in parks." Intermountain Regional Risk Manager David DiTommasso called Bryce Canyon's use of IAPs "a step in the right direction," noting that site-specific safety plans, including a job hazard analysis, are necessary to facilitate the sharing of safety information between parks and traveling EPMTs, which will help protect EPMT crews working in the park. The Bryce Canyon Vegetation Crew plans to continue the use of IAPs when working with any large outside crew that assists with exotic plant treatment.

About the authors

Adam Throckmorton *(adam_throckmorton@nps.gov) was Vegetation Crew lead, Bryce Canyon National Park, in summer 2010. He is now the EPMT crew lead with the Heartland Inventory and Monitoring Network, based at Wilson's Creek National Battlefield, Missouri.* ***Virginia A. Reams*** *is a contributing editor of* Park Science.

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PARKScience

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.

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Profile

NPS/JEFF SELLECK

Bruce Peacock, Chief, NPS Social Science Division, Natural Resource Program Center

Giving natural resources a vote

The Park Science *interview with National Park Service economist Bruce Peacock*

By the editor

Editor's Note: See the table on page 16 for a list of Social Science Program staff and contact information.

***Park Science:* You recently became chief of the Social Science Division. Tell us a little about your programs, products, and plans for the division.**

Bruce Peacock: We're in a planning, growing phase, but we do have a number of ongoing programs (table 1, page 16). These include some familiar acronyms: VSP [Visitor Services Project]—the flagship surveying program of NPS social sciences; also the VSC [Visitor Survey Card], which is our visitor satisfaction survey that we use for GPRA [the Government Performance and Results Act of 1993] reporting and other purposes. Another standard program we have is the Public Use Statistics Office, and that's system-wide visitation statistics. It's perhaps our most widely used product.

Can you distinguish the Visitor Services Project from the Visitor Survey Card for us?

BP: The Visitor Services Project is the park-specific survey program, which is tailored to park needs. We initiate and complete about 15 of these studies in a year. And each of these studies takes three years to complete from design to finish, so at any particular point we have 45 or so of these kinds of studies ongoing. That is a park-specific survey program and helps meet the needs for informing some large park decision document like a general management plan or EIS [environmental impact statement]. Then there's the Visitor Survey Card, and that is generally park-system-wide, covering 330 parks. It is a much more cursory, satisfaction-level survey effort in which we're trying to get a general feel for how satisfied visitors are when they go to a park. From our latest round of surveying I can tell you that 97% of visitors are either satisfied or very satisfied with their experience. We also break that down from just the overall satisfaction level to the satisfaction level with the facilities, interpretive programs, and so forth. This kind of information directly plays into reporting on GPRA goals for visitor satisfaction with the park experience and their understanding of park needs to manage park resources for the future.

What is the Public Use Statistics Office?

BP: When we think of land management agencies, what comes to mind are National Park Service, U.S. Forest Service, Bureau of Land Management, U.S. Army Corps of Engineers—and there may be others—even the Department of Defense operates some recreational facilities. But the National Park Service is the only one with a visitation and statistics program as developed as it is. Visitation data are fed into forms on a Web site that are then used to calculate visitation statistics. For example, when a car rolls over a car counter in a park, that's not one visitor; that's however many people are in the car, two and a half people or whatever, on average. Through those sorts of statistics we're able to calculate total visitation. We're constantly revising how we do that to make sure that we're capturing all of the visitor flows, that we're not double-counting visitors, that we're getting an appropriate count. It is the most advanced visitation recording system in any federal government agency. These are important inputs into budget allocations and they're also very important inputs into calculating regional economic impacts through the Money Generation Model. It's probably the most used product that this division produces.

Tell us about the Money Generation Model (MGM).

BP: The idea behind this program is to quantify how many sales are generated in the [national park] economy, so think of how many dollars are flowing through cash registers and how many jobs are supported by visitors coming into the local area to visit those parks, as well as the local economic inputs generated by park payroll. It's a relatively simple spreadsheet application and it's conservative in its estimates. But it does provide reliable dollar values that indicate how much sales and job activity is going on. These dollars that are spent by visitors, by park employees, and in purchases by the park itself reverberate through the economy in kind of a domino effect of spending. And that just illustrates how visitation within a local area is very important to supporting local businesses, to supporting the local tax base, which supports school districts, road infrastructure, and other necessary and important structures. [Recently we've been in a] recession and everyone is thinking about their jobs, so it's very important information to get out there. The MGM has gone through some improvements over the years and now we're into MGM II. We're looking at ways of making it a little bit more user-friendly and accessible to the public. In fact, in "Flat Hat Chat 10" [Jon Jarvis's regular addresses to NPS staff], the director recently talked about how superintendents should look up the values that are generated by the MGM for their own particular parks so they can talk to local businessmen and chambers of commerce about the economic value of parks.

Is the MGM something a park implements itself?

BP: No. We have a cooperative agreement with Michigan State University that quantifies these kinds of impacts for all of the National Park System, and all of the states and territories system-wide. We produce a report every year, which details how many jobs and how many cash register sales are generated by park visitation.

Are there any aggregated figures on economic impacts of the National Park System as a whole?

BP: In 2006 the National Parks Conservation Association had a consulting firm try to produce the comprehensive value of the National Park System to the American public. And you know, they did a pretty good job. There are some interesting figures, and one of them is that parks in general generate $4 in net economic value for each $1 of tax invested. These net economic values—the value of a scenic view to a visitor, the value of taking a hike in a park, a fishing opportunity—totaled $10.1 billion, and I suspect that's a conservative estimate. For local economic activity that study indicated $13.3 billion in private-sector spending was supported by parks, generating or supporting 267,000 jobs. While I think they're important figures, they don't describe the full nonmarket or market value of parks associated with trade-offs. They don't come anywhere close to talking about some of these intangibles.

Why was the Social Science Program elevated to division status?

BP: A couple of reasons. One was to bring the Social Science Program into a greater area of visibility, certainly within the Natural Resource Program Center [NRPC]. It did not used to be within the NRPC; it was directly supervised by the associate director for Natural Resource Stewardship and Science. And so this brings it into and makes it more accessible to the NRPC, and makes the other divisions more accessible to the Social Science Division. It also increases the consistency of operations within NRPC for the budget, personnel, activities, and that sort of thing. But perhaps more importantly, it takes what are inherently governmental actions, namely information collection and review under the Paperwork Reduction Act, and brings that under federal management as opposed to nonfederal management. [In the past this function had been

Table 1. Social Science Division

Person	Position	Contact
Bruce Peacock	Economist and Chief, Social Science Division, Natural Resource Program Center; Fort Collins, Colorado	(970) 267-2106; bruce_peacock@nps.gov
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Butch Street	Management Analyst, Public Use Statistics Office; Lakewood, Colorado	(303) 343-2704; butch_street@nps.gov

managed by the visiting chief social scientist under a cooperative agreement with Texas A&M University]. So, something as basic and important as reporting on GPRA goals to Congress is now federally managed within the National Park Service, whereas before it was not.

Your background is that of a nonmarket resource economist. How does economics help us do a better job managing parks and protecting their values?

BP: It all comes down to what vote, if you will, natural resources have in public management decisions. If you take a look at an EIS, say from the 1970s, you're not going to find natural resources represented in a value sense in those EISes. In a cost-benefit analysis, which some EISes have and certainly all regulatory actions have, natural resources are going to come up short. If they have no benefit, no dollar amount to represent their benefit, then they don't receive a vote. One of the important applications of economics is to be able to quantify that vote for natural resources.

Give us an example.

BP: I came on board with the National Park Service in 1998 to monetize natural resource damage claims. The one we're thinking of these days is *Deepwater Horizon*. Fortunately, at least to date, we haven't seen the massive amounts of damage that might have been anticipated. Nevertheless, when injury does occur we want to compensate the public for it. The underlying idea here is, if you have a beach that is managed for public use and you're prevented from using it either completely or fully because of some exogenous impact like an oil spill, then that's a public loss because those resources are specifically set aside and managed so that the public may use them. Compensation promotes the restoration of those kinds of resources so that they may be available in greater amounts or in better quality for the future.

How do you determine the monetary value of a park resource?

BP: There's a well-established economics literature that has been around since the 1960s that monetizes these economic values. One technique that's understood by a lot of people is what's called travel cost analysis. While we don't charge visitors for individual park vistas, or each hiking trail they take, or each fishing opportunity they avail themselves of, they do spend money to get to the parks. They pay for gas, hotels, restaurants, and other related expenditures. And so they do demonstrate that they're willing to give something for that opportunity. If we look at the costs they pay for those ancillary goods and services as a price to get at these opportunities, then that gives economists a model to be able to quantify the value. The simple summation of those travel costs is not the value that we calculate but it's a key input into putting a value on those behaviors.

Another technique is simply asking people, through a number of methods, what their values are for certain resources or activities. This technique is what we call stated preference methods. This type of valuation often presents respondents with alternative resource management scenarios and asks them to choose their preferred scenario. And from those choices we're able to elicit those kinds of trade-offs from statistical analysis.

What about putting a value on preserving national parks as a legacy whether or not we ever go there ourselves?

BP: Absolutely. I think there's a correspondence to our mission in the National Park Service: preserving resources and allowing for their enjoyment by current and future visitors. The types of values associated with a day at the beach, hiking, or enjoying scenic views are current visitor uses, and we can put a dollar amount on that experience. But what about preserving those resources for the future? We can put a value on that as well or at least approach that value. Economists call that passive use value. It also goes by other names, such as "nonuse value" and "existence value." But it's the value that people would be willing to pay to know that a resource exists in a given condition and is preserved for the future. Certainly paying taxes is one expression of that; contributing to ecological or environmental causes is another expression of that. We have techniques that are along the state-of-preference idea that I mentioned earlier that actually get at those numbers. An example of this was done for the

Glen Canyon Dam reoperation EIS in the mid-1990s.

Related to water releases through Grand Canyon and on to Lake Mead?

BP: Yes. Before that EIS, the Bureau of Reclamation had been managing water releases to maximize power generation. What happens is, there are peak demand times at which electricity can be sold for higher prices than at low-peak demands. That's during the middle of the day when people flip on the air conditioners during the summer, or perhaps at night when people turn up the heat during winter. They would time the release to maximize flows during those peak demand times. That had direct impacts on the canyon below because it would alter the way in which natural beaches had been formed; it would cause erosion in natural areas, affecting cultural resources and camping opportunities for visitors. Certainly it would affect fishing opportunities for anglers.

The National Park Service was interested in representing those impacts and not just the impacts on hydropower revenues. So a passive use study was done. It was a nationwide study, which quantified what people thought while sitting in their homes about the value of the Grand Canyon being preserved in a favorable condition. As it turned out, it came out to be much higher in value than the corresponding loss of hydropower revenue.

That study was instrumental in the Secretary of the Interior's decision for how to operate the dam, and it resulted in a modified release schedule that moderated those big flows at high-peak electricity demand times. It also included some experimental flood releases to simulate springtime releases of snowmelt to be able to generate more natural conditions down in the canyon. This is an example where through economics we were able to give those impacts and those resources a vote in that decision. I think that's very exciting.

Are there times when monetizing resource values can be counterproductive?

BP: Some values, in my opinion, have no trade-off, and those include perhaps esoteric concepts associated with spirituality, with democracy, with liberty, and a lot of those things that we tie to the national park idea. And those are very important. Economics does not purport to quantify those things for which humans have no trade-offs. We don't talk about, in meaningful ways, the value of the earth, because there is no trade-off for us right now, the earth being a functional, viable biosphere. But what economics does provide is a framework in which we can plug in different factors that should be influential in a decision. Some of those factors may be impacts on the profitability of local businesses, or how much enjoyment visitors receive from their park visit. This framework identifies what we know and don't know about these kinds of decisions and how much of a vote natural resources receive in a decision. The purpose of economics is not necessarily to put a number in every cell of every spreadsheet but rather to help a decision maker identify the value of the information that they have before making a decision.

Some values, in my opinion, have no trade-off, and those include perhaps esoteric concepts associated with spirituality, with democracy, with liberty, and a lot of those things that we tie to the national park idea. And those are very important.

We've heard a lot about ecosystem services lately and how that kind of knowledge can be valuable to park managers. Is economics relevant to understanding the value of ecological services provided by national parks?

BP: Yes, it is. The recent way of thinking about ecosystems and people is to divide these concepts into three broad categories. The first is what we call structure or resources: the number of trees in a forest stand, the quality and quantity of water coursing through a riverway, the geology of a certain park area. We can count these things and inventory them. The next concept is function, and these are interactions of those resources in and among themselves. These are things that can occur whether we like them or not. Take photosynthesis. I could not begin to trace out the chemical interactions that result in transforming sunlight into usable energy for the tree, but it happens. And because it happens, the tree grows and is green, so that is a function. Now, the third concept in this triad is ecosystem services, and those specifically are the beneficial outcomes of either the resources or their functions.

What about replenishment of oxygen to the environment or habitat for wildlife?

BP: Those are functions that occur among resources. But there are certain things about them that I as a human being may appreciate. I appreciate that a viable upland forest reduces downstream flooding of my house and my block. I appreciate that forests sequester carbon, which may have some beneficial impact on the climate change situation.

It helps economists in their analysis of these matters to split these things out, to split function from services.

Does knowledge of ecosystem services help people appreciate the full value of national parks?

BP: It does, and I think it makes our sales job, if you will, for promoting the upkeep of these resources to the public easier. That a forest ecosystem is healthy and functioning, that it has a viable native bird population, that it is performing its watershed functions of flood reduction and contaminant filtering, are functions that I may appreciate in a passive use sense. In other words, not only are they functions within the ecosystem, but they provide a service to me not simply because I have an appreciation for a viable forest stand continuing into the future, but because I also want my kids to play in the forest and understand that's where these interactions occur between wildlife populations. So a function and a service sometimes may be closely related, but that kind of value can be incorporated in a cost-benefit analysis for an important decision and it gives a vote to the continuing existence of those ecosystems.

We've talked a lot about economics, and yet the new division is the Social Science Division. Does the division do research or publish?

BP: We do have a number of operational projects that are ongoing. Though I don't do many damage assessments now, I do provide economic support for them. A recent example is the *Cosco Busan* oil spill at Golden Gate National Recreation Area in California, which generated $20 million of recovery from lost beach use from that oil spill. I also do regulatory economic analyses. I've been associated with the Yellowstone winter use [study] since the year 2000, and it continues. Other projects are what's called "compensatory mitigation scaling" under the Clean Water Act. Section 404 of the act requires a permit from the U.S. Army Corps of Engineers if a developer is going to affect waters of the United States. The National Park Service is not in the business of filling wetlands, but we do have other needs that have some of those effects. For example, right now in Kalaupapa National Historical Park, Hawaii, there is a need to repair their deteriorated dock, which is how they bring in necessary supplies. Just by performing the minimal maintenance work that they do, they will be affecting some coral colonies. I'm helping them calculate how much mitigation they need to offset that, which is a requirement for them to be able to get a permit to do that work.

Is that difficult to quantify?

BP: That type of analysis is relatively simple to conduct. An approach that we use—habitat equivalency analysis—has been used extensively in damage assessment, as in the *Cosco Busan* habitat equivalency analysis. Basically it's a technique that takes existing data and relates them to resources and how they function, examining how long they will be impaired and how long it will take to get other resources functional to replace the ones lost. It's a trade-off analysis, like what economics is, but is relatively straightforward.

Other than the programs you've outlined here, does your division play a role in facilitating social science research in parks?

BP: Our division has very few federal employees and does the vast majority of its work through cooperative agreements with the CESU networks. For example, about a half year ago the USS *Arizona* Memorial in Hawaii opened its new visitor center, which serves a variety of activities in the area, not all operated by the National Park Service: excursions to the USS A*rizona*, the USS *Oklahoma*, an old World War II submarine called the USS *Bowfin*, and the USS *Missouri*, which is famous for being the ship on which the surrender agreement with Japan was signed. And so there's a combination of historical sites to see in Pearl Harbor that go beyond the USS *Arizona*. These new options and this new visitor center have now enabled visitors to schedule all of these different attractions in a much more efficient way than had been possible before. It's always beneficial to cooperate with the partners and generate mutually increased benefits. And so the superintendent wanted an analysis of how people's flow through this new visitor center to these other venues is occurring, how it has changed, and how different demographics use the visitor center. I put the superintendent, Paul DePrey, in contact with one of our cooperators, the Park Studies Unit at the University of Idaho, which runs our VSP and VSC studies. They have now designed a study and are working on funding it and getting it approved and actually will be implementing it this coming year.

How should a park go about requesting your assistance?

BP: They can just give me a call or send me an e-mail [see table 1]. I try to find out what their goals are and then I'll put them in contact with someone who can help. We have a number of cooperators that we have used—certainly the University of Idaho is geared up, but there are others: the University of Wyoming, Texas A&M University, and many others that can be brought to bear. It's a very straightforward matter of using the CESU network to get that information.

What is the process for a park to plan for a visitor survey?

BP: In the division we have the expedited review program for what's called Information Collection Review of Surveys. This is for social science investigations that necessarily or generally involve surveying people, which require review and approval by the Office of Management and Budget [OMB] under the Paperwork Reduction Act. Our program helps speed up that process for some surveys. There are certain thresholds that determine if review and approval are necessary. First, we don't need approval unless we're asking 10 or more people a systematic set of questions. So, an interpretive ranger just walking up to a group of visitors and chatting with them and exchanging ideas is what I would refer to as informal discussion and does not require OMB approval. For parks to collect systematized information from 10 or more people requires that we have a clear understanding of the goals they want to satisfy. That's very important, because another purpose of the Paperwork Reduction Act is to make sure that the information we collect is relevant and useful and not just academic. They also need a design for how they're going to collect this information, not only the questions to get at those goals, but also to make sure it's statistically valid and that we can expand the information we collect to the population we're trying to describe.

Jim Gramann is the visiting chief social scientist for the National Park Service. What are some of his interests?

BP: Jim is the second visiting chief social scientist, following Gary Machlis, now the director's science advisor, who first held this position. Since 2000 or 2001 Jim has been very involved in the information collection review process with OMB, but now is focusing more on some of our higher-end research projects, for example the Comprehensive Survey of the American Public. The first one of these was released in 2001 and we are looking to release a second one a decade later in 2011. This is a nationwide public survey effort—not just of visitors within parks. The term "comprehensive" says it all. Certainly, we're interested in knowing how visitors think about and use the parks, but we're also interested in how nonvisitors think about our parks and what they may perceive about impediments to their visiting, including their attitudes toward parks and the existence of parks.

Reaching nonvisitors is a big concern of the National Park Service these days.

BP: Young people are not visiting parks in the numbers they were in the past. People perceive different needs that we don't offer in parks. For example, social networking, wi-fi in the campgrounds, getting notices about the availability of interpretive programs by tweets. The world has moved on and we need to understand how we can accommodate those changes. The Comprehensive Survey of the American Public is one of those high-end research projects that will help us address these needs. It's a multiyear effort and that's what Jim is working on. He is also finalizing research that we have done from secondary data to analyze the impacts of the Ken Burns TV series that aired in September 2009 on the national parks. These are examples of a couple of different research products that are not our everyday sort of studies that we do, but are more comprehensive and very specialized.

The whole issue of nonvisitors is my single research goal for the coming two fiscal years and will involve a multiphased project with significant funding to look at the nonvisiting public. We want to understand what their needs are and what their perceived hurdles are to visiting parks, so that we can make parks more relevant to people. This is certainly one of the director's four main points—relevancy—and so I'm putting significant effort in.

Much of what you're talking about could be integrated into the communication efforts of the National Park Service, not just for natural resources but more generally.

BP: Absolutely. One of the specialized research topics that Jim Gramman has been spending some time on is the health benefits that parks provide. We all struggle to make time in our busy days for an adequate amount of exercise, and this is one opportunity, a rather enjoyable opportunity, for those living around parks or for those vacationing in parks to be able to take advantage of.

It seems like an exciting time for social sciences and for managers to have an organization to support social sciences that is on better footing within the National Park Service. I'm sure everyone wishes you the best of luck in the job and in building divisional capacity.

BP: It is really exciting because what I would like to do is not only strengthen the existing programs that we have but also to expand the role of social sciences. For example, we talked about economics, and economics has heretofore had very specific applications that may not have been so widely understood as far as the benefits it may provide park managers. I'd like to be able to expand that service more formally to all of the parks.

PS

Science Notes

Fourth annual bioblitz focuses on marine resources at Biscayne National Park

By Astrid Rybeck, Susan Gonshor, Kirsten Leong, and Elaine Leslie

ON 30 APRIL 2010, SCIENTISTS AND CITIZENS converged on Biscayne National Park in southern Florida to take stock of the life-forms inhabiting one of the largest marine parks in the National Park System. This event was the latest installment of the fruitful partnership between the National Park Service and the National Geographic Society, which signed an agreement in 2006 to conduct species inventories in a different park each year for 10 years leading up to the centennial celebration of the National Park Service in 2016. These rapid inventories, or "bioblitzes," log life-forms in an area over a short period of time. The Biscayne event concluded after just 24 hours, resulting in a productive partnership among resource managers, scientists, educators, and the public that advanced the cause for stewardship and preservation of this marine park.

Biscayne National Park is covered by the shallow nursery waters of Biscayne Bay and the coral reef–sustaining waters of the southern Atlantic Ocean. Because this was the first bioblitz to be held in an almost entirely marine-based environment, organizers had many logistical challenges to overcome. National Park Service staff coordinated boat transportation to shuttle hundreds of participants to park islands and underwater inventory sites and managed shuttle buses to accommodate thousands of interested participants in one small visitor parking area. A year's worth of hard work, planning, and creativity resulted in a well-considered network of schedules, routes, buses, and boats to meet these challenges.

NPS/THOMAS M. STROM

Mark Lewis, superintendent of Biscayne National Park, and John Francis, National Geographic Society vice president of research, conservation, and exploration, pass the official bioblitz flag to Darla Sidles, superintendent of Saguaro National Park, hosts of the next National Park Service–National Geographic Society bioblitz in fall 2011. The 24-hour Biscayne bioblitz brought together scientists, students, and the public to explore, inventory, and learn about the park's four major ecosystems.

Species counts

This focused endeavor brought together a record number of more than 170 scientists and experts from numerous disciplines, including National Geographic Explorer-in-Residence and renowned ocean scientist Sylvia Earle, 1,300 students and educators from elementary to university levels, the public, 200 volunteer event "ambassadors," and more than 40 partner organizations that worked to discover, map, and count every living plant and animal species within the 173,000-acre national park.

Water- and land-based science and education activities were conducted throughout the park's four major ecosystems: mangrove shoreline, estuarine bay, islands, and coral reefs. Although species counts and verification continue, scientists and other participants have documented a preliminary (December 2010) tally of 828 species, 324 of which are new listings on the park's official species list, as shown in table 1 (page 22).

Among the most notable and unexpected findings is that made by Dr. William Miller, tardigrade expert from Baker University. Dr. Miller is believed to have discovered a new species of tardigrade, or "water bear," in the park. He is working with park resource managers to confirm and submit his findings for peer review. In addition, the bioblitz afforded the

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The Biscayne bioblitz combined scientific species inventories and identification with citizen science and education activities not only to make new discoveries but also to create lasting connections between participants and the park. Clockwise from top: (1) Students search for life during a marine inventory. (2) A scientist shares stories with students about species collected during water-based inventories. (3) Using a variety of collection techniques, bioblitz participants found 324 species new to the park. (4) Local students from neighboring communities participated in Biodiversity University, an interactive education program created by Biscayne's interpretive staff. Students earned their "diplomas" by completing biodiversity-related activities. (5) A scientist leads students on a plant identification walk.

NPS/THOMAS M. STROM

first opportunity for algae to be specifically surveyed in the park and for numerous rare butterfly and bird species to be recorded.

Student experiences

Complementing the bona fide scientific research, Biscayne's interpretive staff developed a creative, education-based program called "Biodiversity University," which took the classroom outdoors. This hands-on experience encouraged students to "earn" various levels of "degrees" depending on the number of activities they successfully completed. The activities, or "courses," had themes that ranged from understanding the meaning of biodiversity to using mapping and inventory or counting skills to explore patterns between the location and type of habitat and the species that use that habitat. Biodiversity University was so popular that it is being considered as a permanent component of future bioblitzes.

Table 1. Preliminary species count, Biscayne National Park bioblitz

Taxa Group	Total Species	New to Park List
Amphibians	4	
Birds	88	3
Corals	52	26
Fish	163	2
Fungi	7	7
Insects	39	37
Mammals	8	
Nonvascular plants	44	44
Other invertebrates	200	185
Reptiles	9	
Vascular plants	214	20
Total	828	324

Outcome

The scientific, educational, and social benefits resulting from the bioblitz continue to be felt. Teachers, students, and locals went into the field to explore and document park resources with scientists, and many new volunteers were introduced to the diverse service opportunities available at Biscayne National Park. To be sure, these stewards collected useful scientific data, but perhaps more important are the valuable and lasting connections that participants formed with the environment.

Discovering biodiversity in national parks

Bioblitzes conducted in partnership with the National Geographic Society are one type of biodiversity discovery activity the National Park Service uses to engage the public in gaining a solid understanding of the resources this bureau is charged with protecting and of the vast research potential offered by national parks. Other types of activities include the more comprehensive inventories of park biodiversity, known as All-Taxa Biodiversity Inventories (ATBIs), which augment basic inventories conducted by networks of the NPS Inventory and Monitoring Program nationwide.

As part of an NPS commitment to strengthen the connection between science and education and to engage youth in parks, the NPS Natural Resource Program Center recently hired a national coordinator to provide support and technical assistance for biodiversity discovery activities Service-wide, including the next National Geographic/National Park Service–sponsored bioblitz, to be held at Saguaro National Park, Arizona, in fall 2011.

Biodiversity discovery activities put education and citizen science in the forefront of the NPS agenda, connecting youth with nature and history, increasing science literacy, and offering opportunities for the public to “give back” through volunteerism. By widening the public’s understanding of the stewardship role they play in protecting the environment, both within and beyond park boundaries, we are working to advance the national park idea as we enter our second century of existence. The recent bioblitz at Biscayne National Park proved that these goals are attainable—even within a 24-hour period.

About the authors

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PS

NPS/ADAM THROCKMORTON

Experimental control of smooth brome at Bryce Canyon National Park

Figure 1. Biological technicians prepared test plots for the herbicide efficacy experiment in an old roadbed at Bryce Canyon National Park. The tape marks the centerline of the plots, which were installed at 4-meter (13 ft) intervals.

By Adam Throckmorton

RESOURCE MANAGERS AT BRYCE CANYON National Park have been attempting to reduce infestations of smooth brome (*Bromus inermis*), a major invasive species in this 36,000-acre Utah park. In 2009 and 2010 we treated 18 infested acres of the invasive plant species on old roadbeds that cross high-elevation sagebrush meadows near the main park road (fig. 1).

Smooth brome has most commonly been treated with a 3.5% concentration of RoundUp™ (active ingredient glyphosate). However, glyphosate, a nonselective herbicide, has had negative effects on native vegetation and scenic values, as treatment typically causes brown spots on the landscape.

In summer 2010, the Bryce Canyon Vegetation Crew decided to try a grass-specific herbicide: Fusilade II™ (active ingredient fluazifop-P-butyl). A surfactant, Induce™, was added to the Fusilade II at 0.50% concentration. With this grass-specific herbicide, we hoped to reduce impacts to nontarget vegetation and negative impacts to scenic values.

The experiment

We selected an old roadbed infested with *B. inermis* near the visitor center as the research area. A 200-meter (656 ft) line was established and 1,861-square-centimeter (288-square-inch) plots were installed every 4 meters (13 ft), for a total of 50 plots.

The crew conducted stem counts to determine the density of smooth brome and native plants. Plants originating in the plot were counted; plants originating outside the plot with overhanging foliage were not. Stem counts were conducted 7, 14, and 21 days after treatment. According to both RoundUp and Fusillade II labels (Monsanto 2010; Syngenta Professional Products 2010), complete control should be obtained by the 21st day.

We randomly assigned five treatments, as follows: (1) 3.5% RoundUp, (2) 0.25% Fusilade II with 0.50% Induce, (3) 0.50% Fusilade II with 0.50% Induce, (4) 0.75% Fusilade II with 0.50% Induce, and (5) a control in which no herbicide was used. The vegetation crew applied herbicide using 1-liter (approximately 1-quart) bottles and covered smooth brome plants with a fine mist. All herbicide application was conducted by staff with current Utah pesticide applicator licenses.

Results

The Fusilade II plots (treatments 2, 3, and 4) showed little progress by day 21. The 0.25% plots (treatment 2) had an average increase in *B. inermis* of 2%. The 0.50% (treatment 3) and 0.75% (treatment 4) plots had an average decrease in *B. inermis* of 4.5% and 6%, respectively. The 3.5% RoundUp plots (treatment 1) were most effective, with a 92.8% decrease in *B. inermis*. Overall, the control plots showed a 1% decrease in *B. inermis*.

Native species showed an increase in the Fusilade II plots, increasing by 11%, 35%, and 86% respectively in the 0.25% (treatment 2), 0.50% (treatment 3), and 0.75% (treatment 4) plots. The RoundUp plots (treatment 1) had a 10% decrease in native species. Overall, the control plots showed a 14% increase in native species.

Discussion

Fusilade II did not result in as great a reduction in *B. inermis* as did RoundUp. However, with the Fusilade II treatments, nontarget kills were reduced and native growth seemed encouraged. Fusilade II did not have the negative scenic value effect of brown spots, as happened with RoundUp.

One major detriment to this experiment, however, could have been application timing. According to the Fusilade II label (Syngenta Professional Products 2010), "best control is obtained when … applied to actively growing grasses." The first application was made 8 July 2010. Smooth brome starts to grow in early spring and flowers from May to July (Stubbendieck et al. 1997). Thus, our timing may have been too late to treat active growth. Further research with Fusilade II, timed for earlier application, should be conducted for more results.

The Bryce Canyon Vegetation Crew treats *B. inermis* May through September. The best observed results occur when infestations are foliar treated in late summer with a follow-up foliar spot treatment the following spring. Results of this study show that continued use of 3.5% RoundUp for late summer foliar treatment at Bryce Canyon will be more effective than application of Fusilade II. However, if future studies show the effectiveness of spring application of Fusilade II to be comparable to that of RoundUp, then Fusilade II may be preferable for spring treatment, as it has the advantage of causing less impact to native vegetation.

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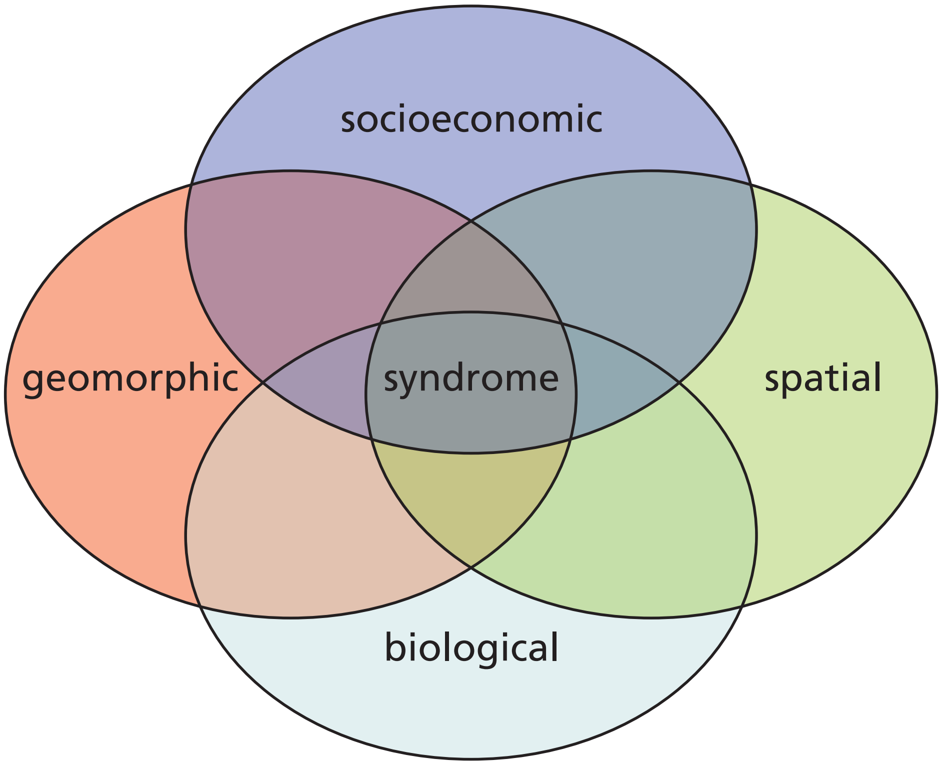
PS

Science Features

Defining resource stressor syndromes in southwestern national parks

By Kristina Monroe Bishop, Lisa J. Graumlich, and William L. Halvorson

RESEARCHERS HAVE INCREASingly focused on the interactions and connections between ecosystems and humans. Through the greater use of resources, increases in pollution, and changes in land use, humans have changed the ecosystems around them. Human activities such as urbanization and intensification of agriculture lead to an increase in road and housing density, oil and gas usage, and necessary infrastructure such as utility transmission corridors. While it is clear that such shifts in land and resource use impact our environment, current research shows that linking the changing population to specific ecosystem change is not simple (Meyer 1996; Harte 2007). Measuring these impacts in protected areas provides an additional layer of complexity, as the source of the ecosystem stress is often found off-site. Although those who manage protected areas, such as the National Park Service (NPS), understand there is a link between encroaching human populations and a change in ecosystem health of the protected area, untangling specific causes of change has proven difficult. With this in mind we aimed to develop a conceptual framework for using available social, economic, and environmental indicators to give land managers new tools for understanding the potential ecological ramifications (effects) to park resources of adjacent socioeconomic stressors (causes). What emerged from this process was the "syndromes" approach. This is a new method for categorizing impacts to park ecosystems that moves away from trying to find one-to-one relationships between socioeconomic factors and ecosystem changes in protected areas. Establishing such relationships is extremely difficult and we therefore suggest this holistic approach to gaining insight into how socioeconomic factors effect park ecosystem changes. When one or more syndromes are found to be influencing a protected area, the protected area would benefit by monitoring the factors involved, such as encroaching development, mining, ranching, and public use.



The Syndromes concept

Syndromes approach

The National Park Service is charged with protecting national park lands and resources by such means as will leave them unimpaired for future generations. To achieve this goal, park managers need to understand not only the condition of their parks, but also the kinds of factors that may be contributing to that condition. Rather than being unique to each park, these stressors often share a common set of elements or characteristics that allow them to be broadly categorized. The syndromes approach to classifying those stressors involves examining a collection of biological, socioeconomic, geomorphic, and spatial elements that work together to create a larger ecological condition (see diagram, above). Because it is necessary to consider how ecological and social systems are working together in order to fully understand an ecological situation, taking this sort of holistic approach will help park managers make well-informed decisions. Schellnhuber et al. (1997) introduced the concept of using syndromes to examine the interconnection of ecological and social factors. Others have followed up with this concept at global and local scales (Ludeke et al. 2004; Manuel-Navarrete et al. 2007).

In the national parks, biological stressors include changes in the range of certain species through habitat reduction or exotic species invasion. Socioeconomic stressors related to the national parks include nearby population growth, urban buildup, infrastructure, primary production (agriculture and mining), and land use change, as well as visitor use and other anthropogenic influences that can change the ecological system. Geomorphic stressors include changes in the land itself, such as local-scale erosion and alterations to fire and flood regimes, as well as shifts due to larger-scale factors, such as climate change. The spatial element of the syndromes approach identifies where stress is occurring (within the park, near the park, or far off-site), which is useful for understanding how managers might deal with the stressors and their effects.

The syndromes identified by the research team (table 1) came out of coding the Sonoran Desert Network (SODN) Vital Signs Monitoring Plan Stressor Survey Results (NPS 2005). When the researchers coded the stressed resources and their stressors, trends were uncovered, leading to the identification of eight syndromes. To fit a syndrome a park need not have all the symptoms, and it is possible for a park to exhibit more than one syndrome. The eight syndromes we identified are (1) Encroaching Urbanism, (2) Distant Degradation, (3) Intensive Extraction, (4) Extensive Consumption, (5) Excursionist Strain, (6) Desperado, (7) Shifting Terrain, and (8) Remote Bliss (see corresponding figures).

NPS/ROBERT BENNETTS (8)

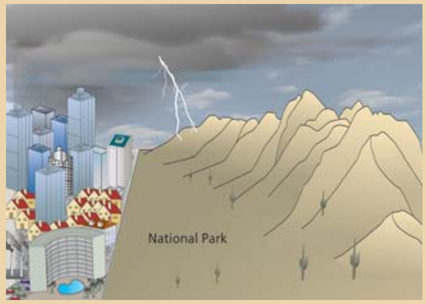


Figure 1: Encroaching Urbanism

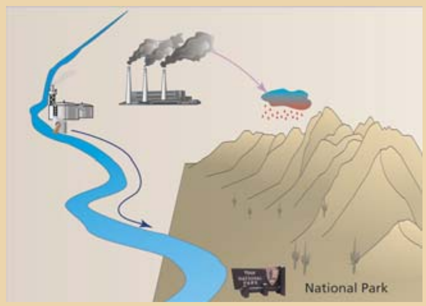


Figure 2: Distant Degradation

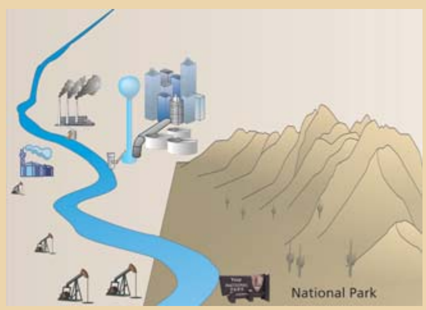


Figure 3: Intensive Extraction

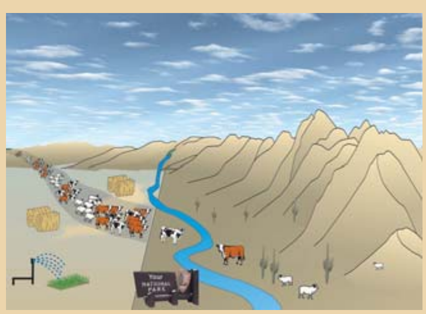


Figure 4: Extensive Consumption

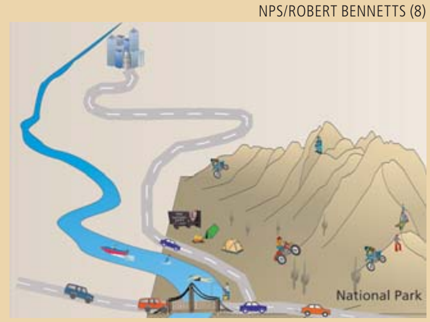


Figure 5: Excursionist Strain

Figure 6: Desperado

Figure 7: Shifting Terrain

Figure 8: Remote Bliss

Implications

The syndromes are intended to help managers identify the suite of effects that may result from the various stressor symptoms common to units of the National Park System. If managers detect the stressors of a syndrome whose origin is primarily outside the unit boundaries, they may seek to establish collaborative relationships with appropriate state, local, or federal governmental representatives and private landowners and entrepreneurs, with the goal of either curbing the presence or impact of the stressors or devising and implementing mitigation of their effects. If managers detect the stressors of a syndrome whose origin is primarily inside the unit boundaries, they may wish to reassess the types of uses permitted in the area with the goal of mitigating the undesired effects.

Table 1. The syndromes facing units of the National Park System

Syndrome	Description	Symptoms	Selected Examples of Possible Effects	Location
Encroaching Urbanism	A large urban population center is located very close to the park and is growing in either population size or area.	• Increase in population • Increase in nearby housing, industry, or retail development • Increase in construction of utility corridors and roads	• Increase in invasive species • Light and noise pollution • Groundwater depletion • Increase in human-animal interactions • Increase in dust and smog • Increase in roadkill • Habitat fragmentation/loss	Adjacent to park
Distant Degradation	There is an off-site, nonlocal source of stress, such as a pollution source upstream, that is brought in by a vector or transport line.	• Major highway nearby • Air traffic • Upstream or upwind factory, industry, utility plant, or mine	• Water/air/noise pollution • Soil toxicity • Vibration • Species loss • Dust and smog	Source far outside park with a “transport” line into or near the park
Intensive Extraction	There is intensive resource extraction or use very close to the park, such as a mine, wells, or agriculture.	• Nearby wells/mines • Nearby intensive agriculture • Chemical runoff	• Water depletion/pollution • Soil toxicity • Air pollution • Increase in invasive species • Habitat fragmentation/loss	Adjacent to park
Extensive Consumption	There is a large-scale, dispersed, extensive use of resources or source of disturbance.	• Cattle grazing near or in park • Extensive agriculture • Off-road vehicle use or horseback riding within buffer zone of park	• Trampling • Habitat degradation • Loss of habitat for native species • Erosion • Water pollution	Adjacent or in park
Excursionist Strain	There is overuse or abuse by the visitors in the park.	• Unusually high numbers of visitors over a sustained period • Established uses whose potential for resource impacts exceeds that of leave-no-trace activities • Extensive off-trail use • Overuse or abuse of park facilities or resources • Insufficient maintenance budget	• Trampling • Noise pollution • Litter • Habitat disturbance • Increase in direct take of resources by visitors • Damage to geological features • Increase in human-animal interactions • Decrease in visitor satisfaction	Adjacent or in park
Desperado	Numerous illegal activities, such as the trafficking of drugs or people are occurring in the park.	• Poaching • Proximity to international border • Known or possible drug farms • Human migration and smuggling through park	• Increase in direct take of resources • Danger to park personnel and visitors • Trash and human waste • Park infrastructure damage • Water drawdown and pollution from chemical runoff	Adjacent or in park
Shifting Terrain	There is a significant change in the disturbance regimes of the park, such as an increase or decrease in fires, floods, or drought.	• Dike or dam affecting waterways • Increase in impermeable surface in or near park (such as roads) • Increase in invasive species • Ineffective fire management regime • Climate change	• Increase in floods/fires • Species reduction • Change in water runoff pattern/erosion • Habitat fragmentation/loss • Smoke	Adjacent or in park
Remote Bliss	This park has few unwanted stressors.	• Low nearby population • Limited visitor disturbance • Limited intensive use of land outside park • Unaltered or minimally altered disturbance regimes	• Low pollution • Sustainable water supply • Visitor satisfaction • Healthy habitats	Adjacent or in park

One approach to dealing with the concerns of a particular syndrome may be to engage with NPS managers from other units with the same syndrome. These other units may not be geographically near each other, but may be facing many of the same issues. Such interaction, whether through informal conversation or formalized meetings and conferences, could lead to creative solutions. This may also hold true for managers of other types of protected areas (e.g., state parks, wildlife refuges, and Nature Conservancy lands).

In addition, the NPS I&M networks already have a Geographic Information System (GIS) for their units, including the NPScape program, which "provides landscape-level data, tools, and evaluations for natural resource management" (NPS 2011), yet it might be helpful for the networks to expand the GIS so that information about each of the symptoms listed in table 1 can be organized by syndrome. Programs that only detail GIS data on the interior of the park are no longer sufficient to understand the greater issues that protected natural areas are facing. Data such as surrounding land use, population density, and sources of pollution are also required. The networks' GIS will need to cover an area large enough for the symptoms included in distant degradation to be mapped for each natural area.

The networks could also explore a relationship with outside organizations, such as the Western Governors' Association, which is developing programs to address wildlife corridors and crucial habitat, or the Western Region Partnership (http://wrpinfo.org) and its committees on (1) Wildlife Corridors, Critical Habitat, Threatened and Endangered Species; (2) GIS/Mapping; and (3) Land Use. The National Park Service could work with these organizations on land management issues surrounding its units.

Next steps

We developed this as a holistic approach to conceptualizing social and environmental interactions. The issues facing all protected natural areas are complex, and it will take a comprehensive, integrated, landscape-scale strategy to manage them. Though this study was done specifically for the National Park Service, the results should be considered by managers of all protected natural areas.

The usefulness of this theoretical approach can only be known through its application to real-life situations in the field. We hope this article will help us locate natural area managers who are willing to work with us to develop such case studies. We believe that the syndromes approach is an additional tool for managers to assess factors in the condition of protected area resources and to anticipate what future changes are likely to occur. Our research shows that finding one-to-one relationships between external stressors and changes in internal ecosystem factors is a limited approach, as few one-to-one relationships likely exist and most ecosystem change is the result of numerous stresses. Thus, we propose this holistic approach and look forward to working with managers to test its usefulness in specific areas.

Acknowledgments

We would like to thank Robert Bennetts for the pictograms; Tonya Raymond for help with library research and analysis of park stressors; and Robert Bennetts, Andy Hubbard, and Alice Wondrak-Biel for their ideas on this project and editing of the manuscript.

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PS

On the application of the cyberinfrastructure model for efficiently monitoring invasive exotic species

By Kurt Lewis Helf

INVASIVE EXOTIC INSECT FOREST pests and pathogens (IFPs) pose a serious, permanent threat to natural and cultural resources in parks administered by the National Park Service (NPS). Though the attrition of these immigrant species is undoubtedly great, the few populations that survive are, de facto, part of the affected community, and can have a profound influence at the population, community, and ecosystem levels (Mack et al. 2000). Oak (*Quercus* sp.), the most abundant tree genus in many forested southeastern units of the National Park System (NatureServe, R. White, ecologist, personal communication, August 2009), is under constant threat from multiple IFPs (fig. 1). A serious outbreak of an exotic species with a wide host range (e.g., European gypsy moth, *Lymantria dispar*) could affect energy and nutrient flux in the short term (Fajvan and Wood 1996; Lovett et al. 2006). A potent exotic invasive (e.g., hemlock woolly adelgid, *Adelges tsugae*) could, by killing dominant tree species, alter the hydrologic processes and successional dynamics of an entire ecosystem over the long term (Ellison et al. 2005; Stadler et al. 2006; Ford and Vose 2007; Nuckolls et al. 2008). Further, IFPs' effect on forested areas is approximately 45 times greater than wildfire because the damage is incurred over a greater area, relatively synchronous, and continuous over a period of years (Dale et al. 2001). Interactions between stressors such as IFPs and global climate change could lead to compounded effects that further increase the likelihood of long-term, unpredictable alterations to forest ecosystems (Paine et al. 1998; Hansen et al. 2001; Walther et al. 2002). Finally, their estimated annual aggregate economic damage is estimated in the billions of dollars (Pimentel et al. 2000; Dale et al. 2001). The environmental and economic damage caused by IFPs justifies their monitoring by numerous federal and state agencies, universities, and nongovernmental organizations.

Cyberinfrastructure stimulus

Numerous entities acquire and publish valuable IFP information on the Internet and so collectively constitute a robust cyberinfrastructure to be harnessed as an adjunct to monitoring in the field. To be effective as an NPS monitoring tool, the IFP cyberinfrastructure should at least (1) provide data on their characteristics and location, (2) provide watch lists for new and established IFPs at several scales, (3) send early detection alerts, (4) model the current and predicted extent of an IFP's range, and (5) provide information on best management practices for rapid responses to new invasions (Graham et al. 2008; Galaz et al. 2010). The prompt dissemination of such information enables NPS park managers to plan a response in advance of when an IFP is detected within a park. Rapid response to the early stages of an outbreak is critical to stopping its spread and minimizing its impact on native ecosystems (Liebhold and Tobin 2008). However, conventional Web searches would be tedious and inefficient in that the user would have to filter out verified information, such as USDA–Forest Service data, from among hundreds of thousands of hits (e.g., the search term "gypsy moths" yields more than 700,000 hits). A number of group efforts (e.g., the Global Invasive Species Information Network, http://www.gisinetwork.org/) are aimed at realizing a relatively self-contained invasive species cyberinfrastructure wherein data could be efficiently acquired (fig. 2, next page); limited funding decreases the likelihood that these goals will be met with alacrity. However, the recent introduction of tools that exploit Web 2.0 enables concerned individuals to efficiently acquire data on IFPs from extant cyberinfrastructure.

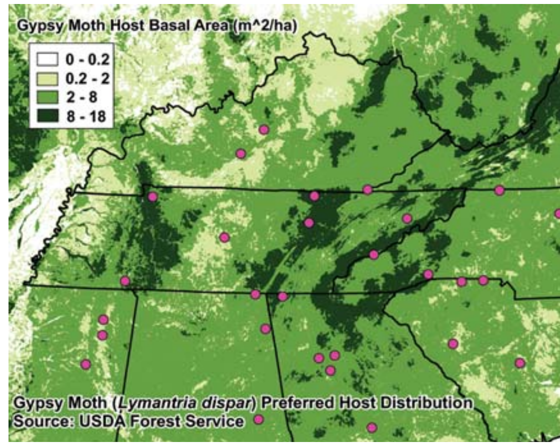


Figure 1. Distribution of white oak (*Quercus alba*), the gypsy moth's preferred host species, by basal area (m^2/ha). Basal area is closely correlated with foliage cover. Dots indicate locations of national parks in the Southeast Region.

Web 2.0 refers to those Web sites that allow users to contribute, share, and ma-

Rapid response to the early stages of an outbreak is critical to stopping its spread and minimizing its impact on native ecosystems.

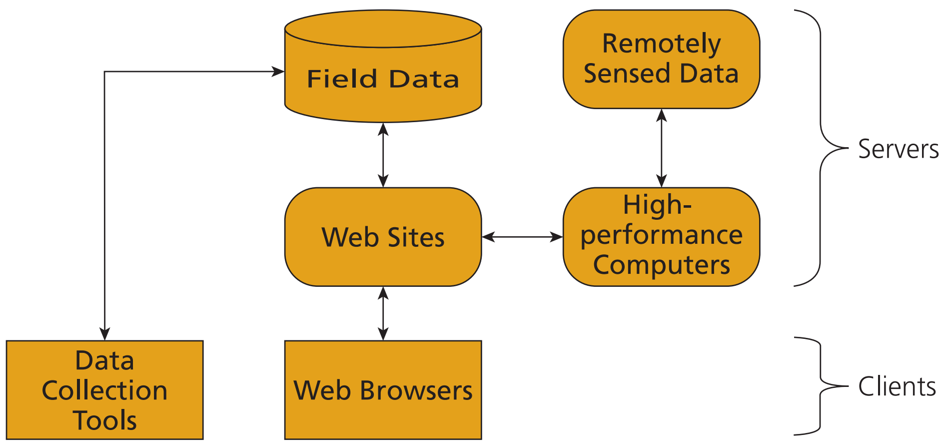


Figure 2 (above). Model for invasive species cyberinfrastructure (from Graham et al. 2008 with permission).

nipulate (or "mash up") data rather than passively viewing or retrieving it. Since the software applications that provide this functionality are run entirely through Web browsers, users avoid expending their own scant resources. Web feed formats such as Really Simple Syndication (RSS) are the key to efficiently using cyberinfrastructure to access IFP data on federal, state, and nongovernmental Web sites. The nearly ubiquitous RSS icon (fig. 3) indicates that a Web site contains a feed, to which viewers can subscribe, that displays frequently updated content in a standard format. The feed displays Web content (e.g., news stories, videos) that typically includes a title, a summary, and a link to the source. Content is usually displayed in chronological order but can be sorted by title. Some feeds enable users to search for specific content and filter it by category (fig. 4). Thus users can manipulate a feed's content to reflect their interests. However, a feed's most convenient function allows users to receive syndicated content automatically by subscription. Subscribers can view the feed page on any electronic device that supports a Web browser (e.g., a smart phone), or even receive it as an e-mail.

Occasionally, a useful IFP Web page is not syndicated via an RSS feed. In these cases, Feedity.com provides a service that lets users generate RSS feeds from almost any Web page. For example, the North American Plant Protection Organization, a group of North American countries that promotes protection of plant resources while facilitating trade, posts pest reports on its Web site and disseminates them via e-mail, but does not syndicate their reports via RSS. Using Feedity.com, I created an RSS feed of their Official Pest Reports, information compliant with the Food and Agriculture Organization of the United Nations' International Plant Protection Convention Standard on Pest Reporting, to serve as another convenient, official source of early detection data on exotic invasive species.

Distilled information

A topic as important as insect forest pests and pathogens generates a large amount of Web content, and each source potentially has its own subscribable RSS feed. Thus, the large number of RSS feeds to which one could subscribe would quickly become unwieldy and reduce their utility. However, a number of free, Web-based services (e.g., Yahoo! Pipes, FeedRinse, feed.informer) enable their users to "work smarter not harder" (Farley 2008). For example, Yahoo! Pipes is a free, Web-based application that enables users without programming experience to sign up and collect and manipulate content from multiple RSS feeds and Web pages (fig. 5). With a Yahoo! Pipes account (hereafter, "Pipes") users can aggregate content in which they are interested from multiple RSS feeds and distill it into a single digest. Simple Pipes can be constructed in minutes but the learning curve for constructing more elaborate Pipes is steep; fortunately there are a number of instructional Web sites, including a Yahoo! Pipes developer's forum, as well several "how to" books (Loton 2008).

Pipes are created in the Pipes Editor by dragging and dropping preprogrammed modules from the Library pane onto the Canvas pane and linking their terminals (fig. 6). These modules are what make Pipes such a powerful, efficient filter, because they allow users to access a wide range of data from the cyberinfrastructure, such as data formatted in comma-separated values, images, and text. The modules can even translate RSS feeds into English from 12 different languages. Furthermore, users may configure search parameters and input/ouput fields in most modules and thereby specify the information extracted by the Pipe. Users can test the functionality of their customized Pipe by clicking the Pipe Output module and examining the results in the Debugger pane (fig. 6).

Dual wield

While constructing elaborate Pipes requires knowledge of Web programming languages, users can search for Pipes made by those adept in Web programming by topic or function, "clone" the pipe, and easily adapt it to suit their purposes (fig. 7). There are two obvious applications to IFP monitoring: (1) the "formal user," the project leader, could employ Pipes as a sort

[Formatting languages] such as Really Simple Syndication (RSS) are the key to efficiently using extant cyberinfrastructure to access IFP data on federal, state, and nongovernmental Web sites.

Figure 3. RSS icon.

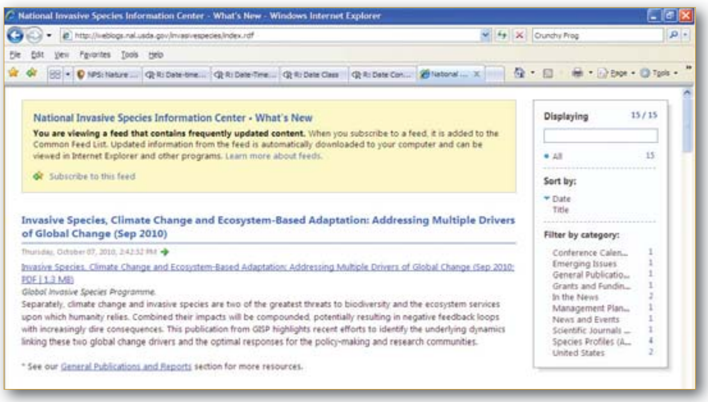


Figure 4. USDA National Invasive Species Information Center feed page. Feed pages enable users to subscribe to the feed and thereby receive automatically updated content. The additional functions to manipulate and customize displayed Web content are at right.

Figure 5. Yahoo! Pipes home page. Yahoo! Pipes can be used with Internet Explorer and Firefox Web browsers. In the Firefox Web browser the RSS feed symbol is located in the URL window.

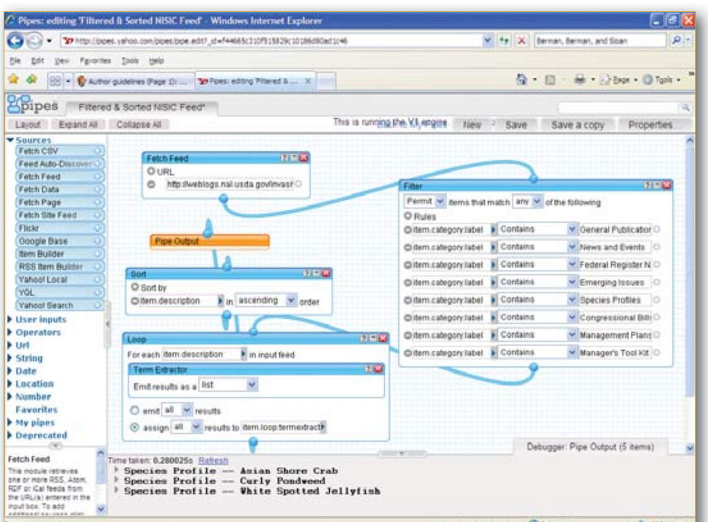


Figure 6. Pipe Editor screen in Yahoo! Pipes. Clockwise from "Fetch Feed" module at the top of the screen: each module, linked at the module's terminals, enables users to download, filter, configure, sort, and emit Web content. Individual modules (in this case, "Fetch Feed") are defined by example in the lower left pane. The "Debugger: Pipe Output" pane at the bottom enables the user to test the Pipe's functionality by clicking on the "Pipe Output" module.

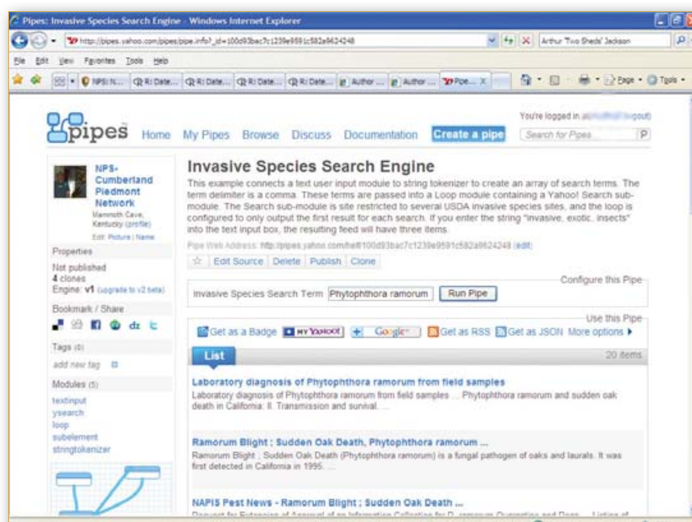
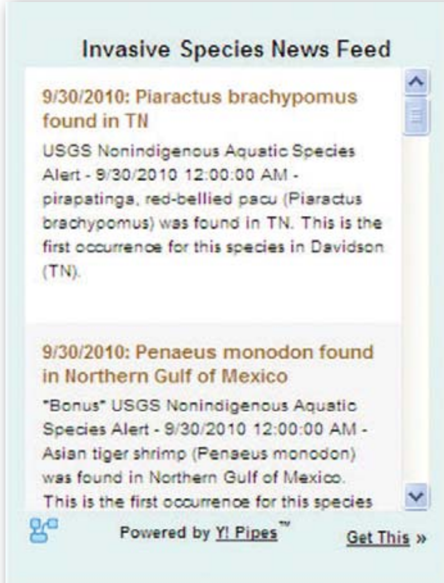


Figure 7. This searchable Pipe was "cloned" from a Pipe constructed by a more adept user and modified to suit my purpose: a Pipe that searches state and federal databases for IFP information. This Pipe emitted 20 items regarding *Phytophthora ramorum*, the fungal organism that causes sudden oak death.



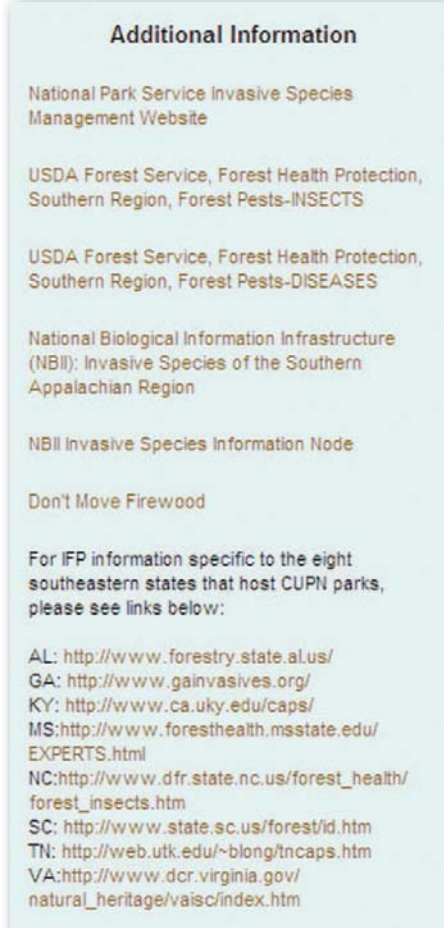


Figure 8. Examples of a badge with customized invasive species news feed (above), a third-party widget (left), and links to state and federal Web sites with information about southeastern invasive species (right) posted on the Cumberland Piedmont Network Forest Pest Web page. The "Get This" link at the bottom right of the news feed badge allows viewers to add the badge to their own Web pages.

of black box for collecting, synthesizing, and reporting information to NPS resource managers; and (2) Pipes' output could be widely disseminated or "opened up" to the "informal user," or the public (Farley 2008). This latter application is yet another avenue for providing the interested public, in addition to resource managers, with up-to-date information about this important topic.

One of the most intriguing ways to distribute customized information emitted from Pipes is to post it as a widget or "badge" on a Web site (figs. 8 and 9). Depending on the content of the custom Pipe feeds, badges can be configured in a number of ways, such as a simple list of items, a slide show of available images, or a map with geocoded locations of specific items (e.g., earthquakes). Furthermore, Pipes badges have a "Get This" link that enables viewers to add the badge to their own Web page and so disseminate the information to a different audience (fig. 8).

Practical application

The Cumberland Piedmont Network's (CUPN) forest pest Web page (http://bit.ly/9rhUZQ) uses various Web 2.0 applications that serve both NPS resource managers and the public as a clearinghouse from which verified information from reliable sources can be conveniently accessed (figs. 8 and 9). One badge posted there, a cloned and customized Pipe titled "Invasive Species News Feed," searches multiple RSS feeds from the U.S. Department of Agriculture (USDA) and the Department of the Interior, for national and international news media stories, in addition to official alerts about invasive species (fig. 8). The "Invasive Species of the Week" widget, which links to a digital (PDF) fact sheet, was provided by the Invasive Species Specialist Group, a global network of scientific and policy experts on invasive species. The widget was designed to raise awareness of the impacts of invasive species on native biodiversity and threatened ecosystems. More conventionally, the CUPN Forest Pest Web page also hosts multiple links to state and federal government Web sites with information about IFPs affecting the Southeast (fig. 8). Finally, another cloned, customized Pipe, the "Invasive Species Search Engine" badge, enables interested parties to simultaneously search multiple USDA RSS feeds for news media stories, official species profiles, survey data, distribution maps, management plans, and grants (fig. 9). This badge also searches feeds from both the North American Plant Protection Organization's Phytosanitary Alert System and the United States Geological Survey's Nonindigenous Aquatic Species Alert System for official reports on exotic insect and aquatic species, respectively. After users conduct a search, they can click on "Subscribe to this feed" to begin receiving a custom RSS feed based on the results of their search (fig. 9).

Conclusion

Efficiencies realized by using the cyberinfrastructure to mine, synthesize, and disseminate IFP data should have positive repercussions for inventory and monitor-

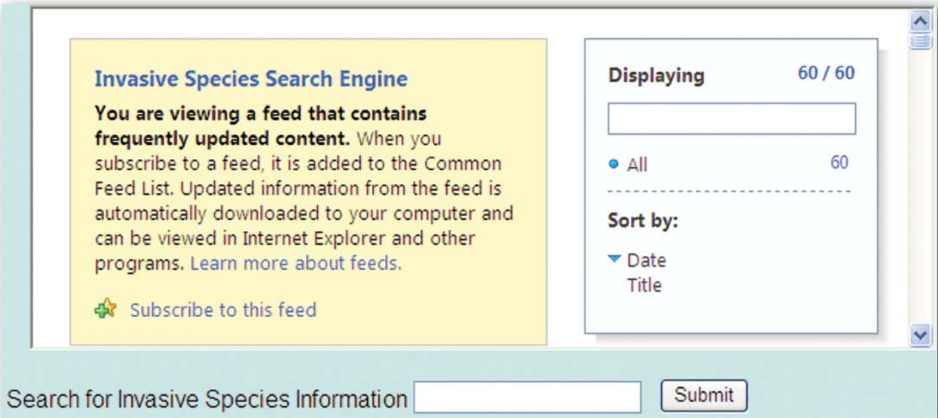


Figure 9. Searchable custom badge posted on the Cumberland Piedmont Network's Forest Pest Web page.

ing programs. These efficiencies should allow resource managers to reduce preparation time for management assistance requests in response to IFP outbreaks. Rapid response is critical to stopping IFP spread and minimizing their impact on native communities. The National Park Service will also realize cost savings by mining data collected by other governmental and nongovernmental agencies. Using these tools presents an opportunity to better inform the public of NPS efforts to monitor IFPs. Keeping the interested public informed about this vital sign, or indicator of an ecosystem's health, will buttress early detection efforts by increasing awareness and volunteer recruitment. However, the uses and research topics to which the Web 2.0 tools detailed in this article could be applied are manifold.

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Restoration Journal

Building partnerships to restore an urban marsh ecosystem at Gateway National Recreation Area

GALVIN BROTHERS, INC.

Elders East, Gateway National Recreation Area

By Patricia Rafferty, JoAnne Castagna, and Doug Adamo

THE JAMAICA BAY ESTUARY IS LOcated on the western end of Long Island, New York (fig. 1), and most of the bay is part of the Jamaica Bay Unit of Gateway National Recreation Area. Historically the bay was known for an abundance and diversity of shellfish. In addition, with extensive marsh islands, tidal creeks, mudflats, and brackish water, the bay has served as an important nursery and feeding ground for many species of birds and fish. However, over time the Jamaica Bay ecosystem has been altered. Urban development has caused widespread changes in the quantity and quality of bay waters and much of the bay shoreline has been hardened and modified. The natural flow of water and sediment into the bay has been affected by channel dredging, stormwater runoff diversion, sewage treatment plant operations, and causeway construction. In addition, the Rockaway Inlet, on the bay's southern shore, has migrated to the west over many years and has constricted flow into the bay. The bay also has experienced the conversion of more than 60% of the vegetated salt-marsh islands to intertidal and subtidal mudflats. Between 1951 and 2008, 647.5 hectares (1,600 ac) of salt marsh were lost; the current rate of loss is 7.7 hectares (19 ac) per year.

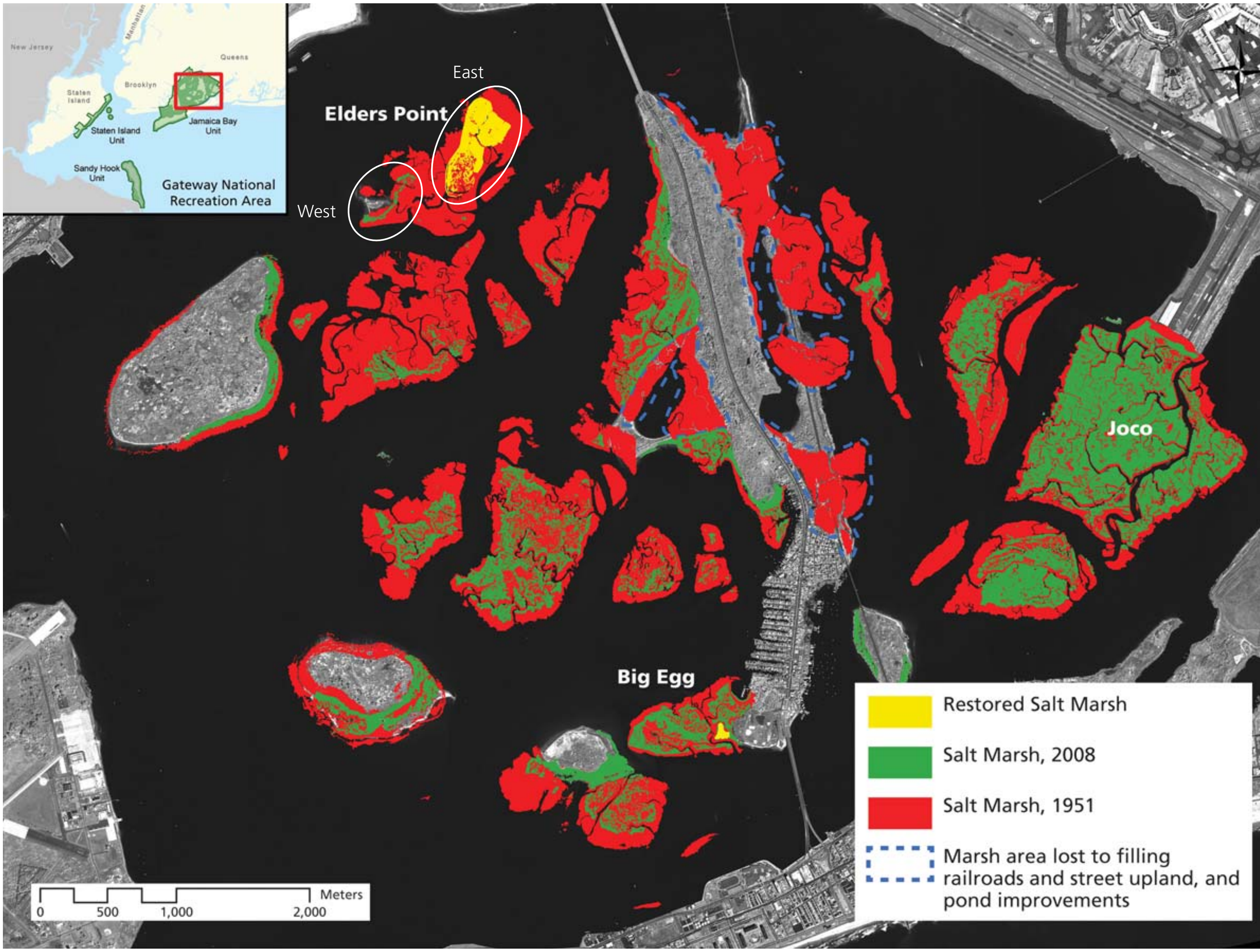

Figure 1. Change in salt-marsh islands in Jamaica Bay, New York, from 1951 to 2008. Change analysis is based upon heads-up digitizing of 1951 aerial photographs (minimum mapping unit = 20 sq m or 23.9 sq yd) and unsupervised classification of 2008 QuickBird satellite imagery (minimum mapping unit approximately 2 sq m (2.4 sq yd). Big Egg and Elders Point East marsh restorations, as well as the JoCo control marsh, are labeled. Elders Point West restoration (constructed in 2010) is not depicted in this analysis.

CHANGE ANALYSIS: M. CHRISTIANO AND K. MELLANDER , GATEWAY NATIONAL RECREATION AREA; FIGURE COURTESY OF M. CHRISTIANO, GATEWAY NATIONAL RECREATION AREA

Causes of marsh loss in Jamaica Bay

Understanding, managing, and reversing the causes of marsh loss are key to the long-term success of restoration efforts in Jamaica Bay. The National Park Service has worked with university and federal partners to identify and understand the causes of marsh loss in this urban estuary.

Increases in the frequency and duration of marsh flooding due to anthropogenic changes in tidal range have likely contributed to the loss of vegetated salt-marsh islands within Jamaica Bay (Swanson and Wilson 2008). Channel dredging, completed in the first half of the 20th century, increased the volume of the bay by 350% (NYCDEP 2007) and the mean depth from approximately 1 to 5 meters (3.3–16.4 ft) (Swanson et al. 1992). Historical increases in tidal range have resulted in high-tide water levels today that are 56–78% greater than increases due to sea level rise (Swanson and Wilson 2008).

Working with partners has been key to advancing our understanding of marsh loss in Jamaica Bay as well as implementing marsh restoration and monitoring.

In addition, sediment is trapped in deep pits that were excavated in the bay bottom to provide fill for development in the bay's fringing wetlands. Hydrodynamic modeling indicates that there is little deposition of sediment within dredged navigation channels; however, deep pits, such as Grassy Bay, may serve as sinks for fine sediments (Wilson and Flagg 2008) that could otherwise be transported to the marsh surface. Inorganic sediments are moved by tides through the inlet and deposited in the western bay. During storm events, sediments are subsequently transported to the eastern portion of the bay, including Grassy Bay (Renfro et al. 2010).

Sediment supply to marshes may be insufficient to maintain marsh elevation. Marsh elevation is controlled by the deposition or removal of sediment from the surface of the marsh and subsurface processes such as peat accumulation, decomposition, pore-water storage, and subsidence. The inorganic mass of marsh sediments has decreased in Jamaica Bay marshes since European settlement (Peteet et al. 2008) while organic matter has increased over the same period (Peteet et al. 2004). Despite this historical decrease in inorganic sediment availability, long- (over the past 100 years) (Kolker 2005) and short-term (since 2003) (U.S. Geological Survey, Patuxent Wildlife Research Center, D. Cahoon, research ecologist, personal communication, 22 October 2008) marsh surface sediment accumulation rates in Jamaica Bay exceed the rate of long-term regional sea level rise at the Battery, New York (0.28 centimeters or 0.11 inches per year); however, recent rates of sediment accumulation in some marshes are not sufficient to maintain marsh elevation given the combined rates of shallow subsidence and regional sea level rise (U.S. Geological Survey, Patuxent Wildlife Research Center, D. Cahoon, research ecologist, personal communication, 1 December 2010). Many of the marsh islands are submerging or getting wetter.

High nutrient levels in the bay may increase the rate of shallow subsidence. Jamaica Bay is frequently referred to as having a "sewershed" since the primary source of freshwater is four New York City Water Pollution Control facilities and numerous combined sewer overflow pipes. Nitrogen loading in Jamaica Bay has increased by more than 400% in the past 110 years from an estimated 35.6 kilograms (78 lb) of nitrogen per day, which entered the bay via submarine groundwater discharge, to 15,785 kilograms (34,800 lb) of nitrogen per day that enters the bay via wastewater discharge, subway dewatering, landfill leachate, submarine groundwater discharge, and atmospheric deposition (Benotti et al. 2007). Smooth cordgrass (*Spartina alterniflora*) is the dominant vegetation in salt marshes along the Atlantic and Gulf coasts of North America. High nutrient loading may decrease root production in *S. alterniflora* (Valiela et al. 1976; Morris and Bradley 1999; Turner et al. 2009) and/or increase the rate of peat decomposition (Valiela et al. 1985). *S. alterniflora* belowground biomass contributes to marsh elevation (Valiela et al. 1976; DeLaune et al. 1994; Morris and Bradley 1999) and its roots bind sediments and slow sediment compaction (Redfield 1972; DeLaune et al. 1994; Rybczyk and Cahoon 2002). The U.S. Environmental Protection Agency is conducting research to evaluate soil respiration, above- and belowground biomass, and root structure at numerous marshes in Jamaica Bay and across Long Island (Wigand et al. 2008). In 2009, the National Park Service initiated research to evaluate the role of nutrient enrichment (eutrophication) in the allocation of resources between above- and belowground biomass at three marshes in Jamaica Bay.

Fresh organic carbon from combined sewer overflows and algal blooms may also contribute to marsh loss by fueling sulfate reduction in marsh sediments and causing elevated pore-water sulfide concentrations. In greenhouse studies, prolonged exposure of *S. alterniflora* to moderate and high pore-water sulfides caused stunted growth and death, respectively (Koch and Mendelssohn 1989). Pore-water sulfide concentrations that are consid-

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Figure 2. Experimental salt-marsh restoration in Jamaica Bay has relied upon increasing elevation by the placement of clean sediment. At Big Egg, top, a swing-ladder dredge was used to spray sediment onto the marsh surface. At Elders Point East (page 34) and West, above at bottom, slurried sediments were pumped onto the restoration site and mechanically moved and graded.

ered stressful to *S. alterniflora* have been observed in Jamaica Bay marshes (Cochran et al. 2009).

Experimental marsh restoration

In response to the rapid loss of salt-marsh islands in Jamaica Bay, Gateway National Recreation Area embarked on an experimental restoration project at Big Egg Marsh. In September 2003, a self-propelled swing-ladder dredge (fig. 2) sprayed a layer of sand slurry on 0.8 hectare (2 ac) of severely degraded salt marsh to achieve an elevation suitable for the planting, growth, and survival of *S. alterniflora*. Monitoring of vegetation, benthos (benthic organisms), insects, birds, and sediment elevation was conducted at the restoration and control sites from 2003 to 2008 to evaluate the restoration. In addition, this experimental restoration site provided public access for volunteer participation in restoration planting and monitoring as well as education and outreach.

In 2006, construction of a much larger 15.8-hectare (39 ac) experimental salt-marsh restoration project was initiated at Elders Point East (fig. 2). This multiagency effort was led by the U.S. Army Corps of Engineers, New York District, and was the result of years of interagency collaboration, environmental planning, and engineering by the U.S. Army Corps of Engineers, Port Authority of New York and New Jersey (the nonfederal cost-share partner), New York State Department of Environmental Conservation, New York City Department of Environmental Protection, New York State Department of State, U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, and National Park Service. Restoration of Elders Point East was funded by and fulfilled mitigation requirements of the New York Harbor Deepening Project.

This multiagency team continues to work collaboratively toward restoration of the Jamaica Bay ecosystem, including salt-marsh island restoration. In 2010, building upon the lessons learned at Big Egg and Elders Point East, the team completed construction for the restoration of an additional 13.4 hectares (33.2 ac) of salt marsh at Elders Point West (fig. 2). The U.S. Army Corps of Engineers, New York City Department of Environmental Protection, and New York State Department of Environmental Conservation provided funding for the 2010 restoration and will also share in the cost of restoring three additional marsh islands in Jamaica Bay. Design plans and specifications for the three islands are under development, and construction is targeted for federal fiscal year 2012.

In addition to agency staff resources, these restoration projects represent a substantial financial commitment. Planning and construction costs ($315,536) for the Big Egg experimental restoration were funded by the National Park Service. The addition of in-kind contributions, including park staff time and volunteer participation, more than doubles the

The goal of the monitoring is to determine factors contributing to the success or failure of the restoration, test various Spartina *planting techniques, justify adaptive management actions, and better understand factors contributing to marsh loss throughout Jamaica Bay.*

cost of the project. U.S. Army Corps of Engineers and local cost-share partners have funded restoration at Elders Point East and West. Planning, design, and engineering costs for Elders East and West exceeded $3 million; however, planning, design, and engineering costs of subsequent projects are expected to be less than $400,000 per project. Construction costs at Elders East and West were $12,941,569 and $11,936,100, respectively.

Marsh restoration monitoring

This multiagency team has also developed and implemented a comprehensive monitoring and adaptive management program for the restoration of Elders Point East and West. The monitoring program was based in part on experiences from the Big Egg marsh restoration. The goal of monitoring is to determine factors contributing to the success or failure of the restoration, test various *Spartina* planting techniques, justify adaptive management actions, and better understand factors contributing to marsh loss throughout Jamaica Bay. Monitoring of vegetation, nekton, birds, benthos, sediment elevation, habitat, and landscape parameters at the treatment and reference marshes was conducted prior to restoration (2005) and will continue for at least five years after restoration. Construction of the restored marsh at Elders East was completed in 2006–2007 and at Elders West in 2010. The monitoring program has been funded by the U.S. Army Corps of Engineers and the local cost-share partners (Port Authority of New York and New Jersey, New York State Department of Environmental Conservation, and New York City Department of Environmental Protection) and is managed and implemented by the National Park Service. Annual monitoring costs for each restoration project have been approximately $200,000.

This monitoring plan employs a BACI (Before, After, Control, Impact) design. Monitoring has been conducted at the restored marshes as well as at a control (JoCo) marsh, both "before" and "after" the restoration. The placement of dredge material and planting was the "Impact" and the undisturbed reference marsh (JoCo) was the "Control." The control marsh is representative of the target condition. We present and discuss planting treatments and results for some vegetation monitoring parameters at Elders East in this article.

Methods

Planting treatments

To expedite the establishment of salt-marsh vegetation at the restored marsh, vegetation plugs were planted and fertilized in 2006. In addition, some existing vegetation (hummocks) had to be relocated to accommodate project drainage and the delivery of fill at the project site. The hummocks and sediment were removed with intact root system and benthic communities by a skid loader and immediately placed in areas that had been filled to the design elevation (fig. 3). The objective was to evaluate the effectiveness of relocated hummocks for vegetative propagation.

Sampling design

Vegetation plots (1 square meter [1.2 sq yd]) were established along transects in 2005 (JoCo and pre-restoration Elders East) and 2006 (Elders East planted treatment and Elders East hummock relocation). The locations of each transect and of plots along each transect were established by a random-systematic design. At each plot, canopy

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Figure 3. Approximately 0.6 hectare (1.5 ac) of smooth cordgrass was the only vegetation remaining at Elders Point West before restoration. This species, which existed as hummocks, was excavated and distributed across 9.7 hectares (24 ac) during restoration construction, thus conserving the vegetation and associated benthos. The objective of this planting technique is to achieve revegetation of the restoration site via vegetative propagation and to accelerate the establishment of the marsh benthic community.

cover, species composition and abundance, total stem count, and plant height were measured. Paired with alternate vegetation plots, a clip plot and a soil core were collected to evaluate above- and belowground biomass. To evaluate net annual belowground production, in-growth cores were deployed in 2007–2009 and harvested during the subsequent fall; however, only data for samples harvested in 2008 are reported here. Because of the small size of the hummock relocation areas, no destructive sampling (clip plots or cores) was conducted for that treatment. All vegetation data and samples were collected during peak biomass (mid-August to October) each year.

Results and discussion

Planted plugs treatment (restored compared with reference marsh)

Vegetation monitoring at the restoration and reference marsh seeks to evaluate the response of vegetation to restoration and to determine if vegetation communities at the two marshes are converging. By 2008 total live vegetated cover (fig. 4, next page) and annual belowground production (table 1, next page) were equivalent. Furthermore, the project's interagency Monitoring and Adaptive Management Team had established a presumptive threshold of 50% vegetative cover by 2009; however, this goal was achieved by 2008. Failure to achieve the threshold would have triggered an evaluation and possible implementation of management actions to achieve the restoration goals. While total standing aboveground biomass and stem density did not differ between sites, on average, *S. alterniflora* plants are taller at the restoration site than at JoCo, the reference site. In addition, as it is a mature marsh, macro-organic matter at JoCo represents the long-term accumulation of belowground organic material; we observe that macro-organic matter at JoCo is greater than at Elders East.

Hummock relocation (Elders East planted treatment vs. Elders East relocation treatment)

The relocation of hummocks during restoration construction provided an opportunity to evaluate a method of vegetative propagation that also provides for the conservation of existing marsh vegetation and intact benthic communities while increasing the elevation at which the vegetation is growing. An additional year was required to achieve 50% canopy cover via vegetative propagation as compared with planting; however, by 2009, there was no difference

Table 1. Mean 2008 belowground biomass production[1] at two depth intervals at reference and restoration marshes

Depth	Reference (JoCo)	Restoration (Elders East Planted)
Belowground 0–10 cm (0–3.9 in)	262 ± SD 224 (n = 10)	274 ± SD 229 (n = 10)
Belowground 10–20 cm (3.9–7.9 in)	90 ± SD 193 (n = 11)	123 ± SD 146 (n = 10)

[1]Production measurements are in grams per square meter per year.
SD = Standard deviation

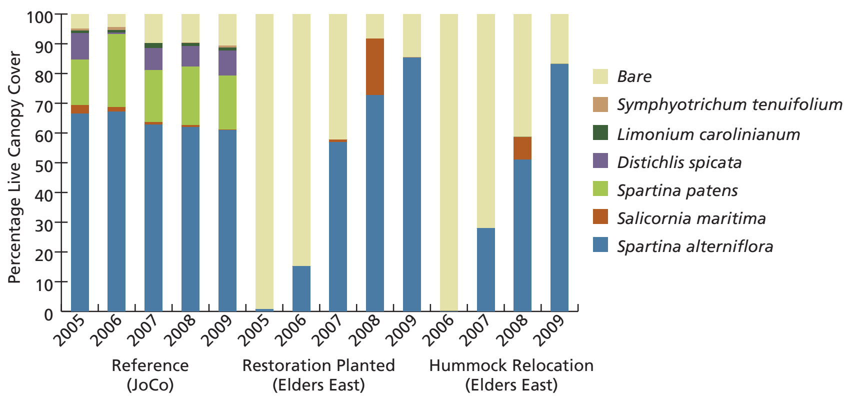

Figure 4. Mean live vegetative and bare canopy cover (as percentage of total canopy cover) by year for reference (JoCo treatment [n= 27]) and restored (Elders East planted treatment [n = 31]; Elders East relocation [n = 12]) marshes.

in canopy cover (fig. 4) or vegetative species composition, richness, or diversity.

Successes and lessons learned

As a result of the success of the limited hummock relocation at Elders East, hummock relocation was the planting technique employed over a 9.7-hectare (24 ac) area of the Elders West restoration (fig. 3, previous page). In addition, 1.7 hectares (4.2 ac) was planted in high marsh species (*S. patens* and *Distichlis spicata*), 1.6 hectares (4 ac) was left unvegetated to evaluate natural seedling success, and 0.4 hectare (1 ac) was seeded with *S. alterniflora*. Monitoring at Elders Point West will evaluate the efficacy of these planting methods for the establishment of vegetation and benthic communities. If natural recruitment or seeding proves successful in establishing vegetation at Elders West, then these methods can be used for future restoration projects in Jamaica Bay, eliminating the costs of *S. alterniflora* plant propagation, planting, or hummock relocation.

Both Big Egg and Elders Point East have demonstrated that we can successfully restore the saltmarsh form (i.e., the vegetation) in Jamaica Bay; however, it may be decades before we are able to determine if we have successfully restored marsh functions such as food web support and carbon sequestration. In addition, it is unclear whether or not Jamaica Bay marshes can be self-sustaining in the face of sea level rise, eutrophication, and inadequate sediment supply to the marsh surface. While much of the bay is within Gateway National Recreation Area, most of the impacts are historical or result from activities beyond park boundaries.

A principal success of the Jamaica Bay marsh restoration has been the development of a strong multiagency partnership that is working to restore the Jamaica Bay ecosystem. Working with partners has been key to advancing our understanding of marsh loss in Jamaica Bay as well as implementing marsh restoration and monitoring. Although multiple impacts associated with urbanization have reduced water quality, salt marshes, and other aquatic habitats, the bay's resilience provides an opportunity to focus on restoration of functions that are critical to ecosystem sustainability.

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Research Reports

Greater sage-grouse of Grand Teton National Park: Where do they roam?

BRYAN BEDROSIAN, CRAIGHEAD BERINGIA SOUTH

By Geneva W. Chong, William C. Wetzel, and Matthew J. Holloran

Figure 1. Male greater sage-grouse in flight during winter.

IN GENERAL, SPECIES ARE LOCATED WITHIN A BROADLY defined range, but they use only specific habitats within their range, often seasonally. For example, in a field guide to birds you will often see a map showing seasonal ranges and migration areas with text describing which areas, such as wetlands, are most used within the range. Recent research maps historical and current greater sage-grouse (*Centrocercus urophasianus*; fig. 1; hereafter sage-grouse) range, which has been reduced about 50% since European settlement (Schroeder et al. 2004). The loss of sagebrush (*Artemisia* spp.) habitat is the main cause of the current decline in sage-grouse, and the sage-grouse was recently found "warranted but precluded" for listing as endangered under the Endangered Species Act (U.S. Fish and Wildlife Service 2010). Natural resource managers need to understand how sage-grouse populations use existing habitat to persist so that landscapes can be managed to prevent the listing of the species as endangered.

Studies that have used landscape-scale, spatial approaches to examine sage-grouse habitat selection (Homer et al. 1993; Aldridge and Boyce 2007; Moynahan et al. 2007; Carpenter et al. 2010) generally confirm the importance of well-developed sagebrush stands. Within sagebrush habitat, however, sage-grouse further refine their habitat selection. In general, studies show that relative to random sagebrush locations, sage-grouse select habitats with

Abstract

Greater sage-grouse (*Centrocercus urophasianus*) population declines may be caused by range-wide degradation of sagebrush (woody *Artemisia* spp.) steppe ecosystems. Understanding how greater sage-grouse use the landscape is essential for successful management. We assessed greater sage-grouse habitat selection on a landscape level in Jackson Hole, Wyoming. We used a Geographic Information System (GIS) and radio-collared sage-grouse to compare habitat used and the total available landscape. Greater sage-grouse selected mountain big sagebrush (*A. tridentata* var. *vaseyana*) communities or mixed mountain big sagebrush–antelope bitterbrush (*Purshia tridentata*) communities and avoided low-sagebrush (*A. arbuscula*) dwarf shrubland. In spring and summer, sage-grouse primarily used sagebrush-dominated habitats on the valley floor and did not concentrate in mesic areas later in the summer as is typical of the species. The diversity of habitats used in winter exceeds that reported in the literature. In winter, Jackson Hole greater sage-grouse moved to hills, where they used various communities in proportion to their availability, including tall deciduous shrublands, cottonwood (*Populus angustifolia*) stands, exposed hillsides, and aspen (*P. tremuloides*) stands. Because seasonal habitat selection is not necessarily consistent across populations residing in different landscapes, habitat management should be specific to each population and landscape. This sage-grouse population provides an example that may offer insight into other species with seasonal habitat needs.

Key words: *Centrocercus urophasianus*, Grand Teton National Park, greater sage-grouse, Greater Yellowstone Ecosystem, habitat selection, sagebrush

greater sagebrush height and cover (Crawford et al. 2004; Hagen et al. 2007). In winter, sage-grouse prefer sagebrush exposed approximately 25–35 centimeters (9.8–13.8 in) above snow, often on south- and west-facing slopes (Connelly et al. 2000; Crawford et al. 2004; Hagen et al. 2007). For nesting and early brood-rearing, sage-grouse prefer relatively tall (40–80 cm or 15.7–31.5 in) sagebrush of moderate to high canopy cover (15–25%) with a well-developed grass and forb understory (Connelly et al. 2000; Hagen et al. 2007). As forbs dry through the summer, female sage-grouse and their broods are found in increasingly moist and even riparian habitats (Wallestad 1971). During nesting and brood-rearing, sage-grouse avoid cropland, oil wells, other anthropogenic habitats, badland-type habitats, loamy upland sites, and habitat edges, but select habitats with a rich grass component (Aldridge and Boyce 2007; Moynahan et al. 2007).

In Wyoming, an area with relatively intact sagebrush habitat, male breeding-ground attendance dropped 50% from 1965 to 2003 (Connelly et al. 2004). Population declines in areas with intact habitats suggest that degradation of remaining habitats may be an important cause of sage-grouse population declines (Braun 1998; Connelly et al. 2000). The Jackson Hole, Wyoming, sage-grouse provide a unique opportunity to study a population that exists in a complex landscape with much less homogenous sagebrush than is typically found in areas occupied by sage-grouse, and which may be limited by winter habitat availability (USRBSGWG 2008). Our work provides an example of how habitat use can be studied to describe fine-scale, individual, seasonal selection within a larger landscape—whether for other sage-grouse populations or other species. This type of information may be used by natural resource managers to conserve critical habitats such as winter habitat.

The Jackson Hole, Wyoming, sage-grouse provide a unique opportunity to study a population that exists in a complex landscape with much less homogenous sagebrush than is typically found in areas occupied by sage-grouse, and which may be limited by winter habitat availability.

We investigated three main questions about sage-grouse habitat use across the Jackson Hole area: (1) which habitats do sage-grouse use? (2) how does habitat selection vary seasonally? and (3) how does habitat selection in a complex landscape differ from selection in sagebrush-dominated landscapes more typical of the species?

Methods

We assessed landscape-level, sage-grouse habitat selection (Manly et al. 2002; Calenge and Dufour 2006) in and around Grand Teton National Park, Wyoming (1,255 sq km or 484 sq mi, 44° N, 110° W), within the Greater Yellowstone Ecosystem (Marston and Anderson 1991) using radiotelemetry data (Holloran and Anderson 2004). The many available habitats in the topographically complex landscape (e.g., elevation ranges from the 2,070-meter [6,792 ft] Snake River valley to the 4,197-meter [13,770 ft] summit of the Grand Teton) used by the Jackson Hole sage-grouse population allowed us to observe whether sage-grouse would use habitat not widespread in the species' typical, more homogenous sagebrush range. The analyses we employed have been used on a variety of

Table 1. Habitat classifications used in habitat selection analyses for greater sage-grouse in and surrounding Grand Teton National Park, Wyoming, 1999–2003

Habitat[a]	Description	% Study Area[b]	% Home Range[c]
Low sagebrush	*Artemisia arbuscula* dwarf shrubland	0.5	0.2
Mixed sagebrush–shrubby cinquefoil	*Artemisia* spp.–*Dasiphora fruticosa* mesic shrubland	1.1	0.8
Mixed big sagebrush–bitterbrush	*Artemisia tridentata–Purshia tridentata* mixed shrubland; sagebrush is predominantly mountain big sagebrush (*A. tridentata* ssp. vaseyana)	1.6	14.2
Big sagebrush	Artemisia tridentata dry shrubland; sagebrush is predominantly mountain big sagebrush (*A. tridentata* ssp. *vaseyana*)	10.8	58.5
Conifer forests	*Abies lasiocarpa–Picea engelmannii*, *Picea pungens*, *Pinus contorta*, and *Pseudotsuga menziesii* forests	33.9	0.9
Forb	Montane xeric and mesic forb herbaceous vegetation	3.2	1.5
Low hillside vegetation	Exposed hillside sparse vegetation	0.7	0.9
Disturbed	Human disturbed: canals, mixed urban, mineral extraction, and transportation	1.0	2.5
Grassland	Mixed herbaceous grassland	4.7	6.7
Cottonwood	*Populus angustifolia–P. balsamifera* riparian forest	1.0	3.6
Aspen	*Populus tremuloides* forest and woodland regeneration	2.6	2.6
Riparian	Lake shoreline, flooded wet meadow, *Salix* spp. shrubland, sand areas, stream deposits, and streams	5.7	3.7
Deciduous shrub	Mixed tall deciduous shrubland	1.3	3.1
Other	Habitat classes lacking sage-grouse relocations; e.g., alpine and subalpine vegetation, cliff, talus, and agricultural land	31.8	0.7

Notes: Habitat classifications are based on the Grand Teton National Park Vegetation Map (Cogan et al. 2005).

[a]Habitat names are as used in text and figures.

[b]Study area percentages are of the area covered by the Grand Teton National Park Vegetation Map (Cogan et al. 2005), which includes the park and surrounding areas.

[c]Home range percentages are of combined winter and summer 85% probability home ranges.

wildlife species (Johnson 1980; Manly et al. 2002; Alldredge and Griswold 2006), but rarely on sage-grouse.

Four main sagebrush communities available to this sage-grouse population were mountain big sagebrush (*A. tridentata* var. *vaseyana*) shrubland, low-sagebrush (*A. arbuscula*) dwarf shrubland, mixed mountain big sagebrush–antelope bitterbrush (*Purshia tridentata*) shrubland, and mixed sagebrush–shrubby cinquefoil (*Dasiphora fruticosa*) (table 1). Other shrubs present at varied densities throughout sagebrush communities included yellow and rubber rabbitbrush (*Chrysothamnus viscidiflorus* and *Ericameria nauseosa*) and snowberry (*Symphoricarpos* spp.). Cottonwoods (*Populus* spp.) occurred along riparian areas. At higher elevations, aspen (*Populus tremuloides*) woodlands occupied mesic, north-facing hollows, and mixed conifer forests (e.g., *Pinus contorta*, *Pinus flexilis*, *Picea engelmannii*, *Pseudotsuga menziesii*, *Abies lasiocarpa*) populated the hills and mountains (table 1).

We captured 15 male and 20 female sage-grouse at or near breeding grounds (leks) from mid-March through April 1999–2002 and fitted them with ≤25-gram (0.9 oz) radio transmitter necklaces (19% of the estimated population during 1999–2003; Advanced Telemetry Systems Inc., Isanti, Minnesota). We used the radio-collar data collected from 1999 to 2003 (Holloran and Anderson 2004; fig. 2) and Wyoming Game and Fish Department visual observation records from 1978 to 2006 to examine habitat use defined by observed sage-grouse locations.

In 2005 the U.S. Geological Survey and the National Park Service completed a digital vegetation map for Grand Teton National Park, John D. Rockefeller, Jr. Memorial Parkway, and surrounding areas (hereafter "the study area"; fig. 2; Cogan et al. 2005). The map covers 222,612 hectares (550,074 ac), with a mean polygon size of 7 hectares (17.3 ac) and a minimum effective unit of 0.5 hectare (1.2 ac). It has 52 land classes, 42 of which are vegetation types. We divided the land classes into 14 habitat groups based on ecological and structural similarity (table 1). To compare abiotic variables across habitats, we extracted data, including elevation and slope, from 1,747 field plots used to build and assess the map (Cogan et al. 2005).

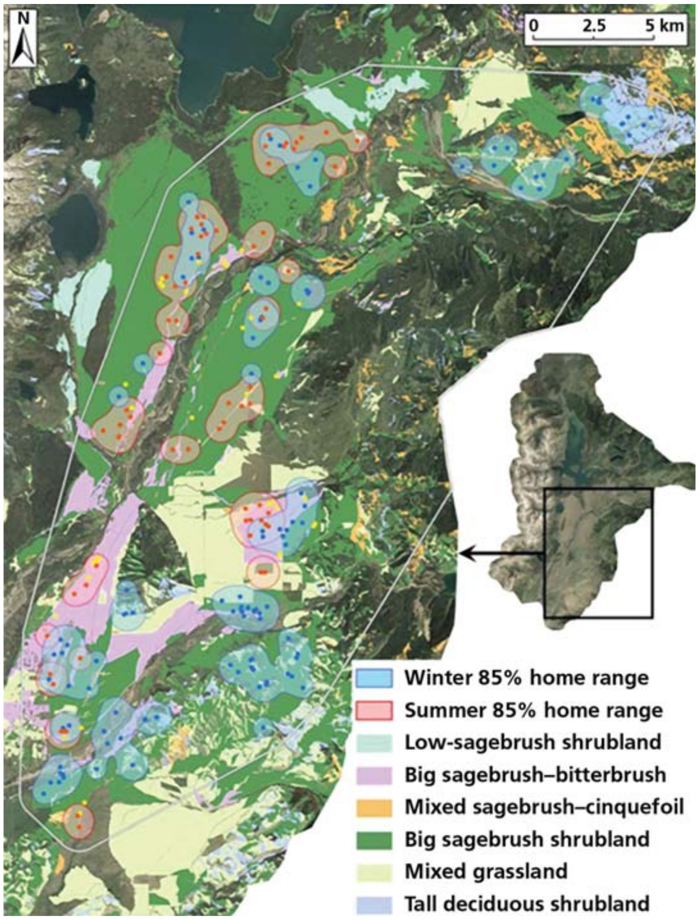

Figure 2. Orthophotos of Grand Teton National Park, Wyoming, including select vegetation types from the Grand Teton National Park Vegetation Map (Cogan et al. 2005) and sage-grouse relocation points from 1999–2003 (Holloran and Anderson 2004). Inset photo is of the entire study area (Grand Teton National Park Vegetation Map coverage area). Main image is Jackson Hole, Wyoming, the area used by greater sage-grouse. Red points are summer relocations, blue points are winter relocations, and yellow points are nest locations.

We used individual bird locations (n = 35 birds) to ask: (1) does each bird use the same habitat? and (2) do birds use habitat in proportion to its availability (Manly et al. 2002: 50; Calenge and Dufour 2006)? If each bird used different habitat, we would not be able to generalize their preferences, and if all habitats were used equally in proportion to their availability, we would not be able to identify preferred or critical habitats. Because of our small number of collared birds, we were conservative when deciding the significance of our findings (Cherry 1996; Payton et al. 2003), so our findings are robust.

We defined habitat use in two ways: (1) a bird uses the habitat class that encloses a radio-collar relocation point; and (2) a bird uses all classes within a 200-meter (656 ft) radius buffer of a relocation point proportionally to the area of the classes within the circle. The buffer definition of resource use emphasizes the importance of habitat mosaics and acknowledges that animals may select one habitat type because it is adjacent to another (Dickson and Beier 2002). We compared habitat use by each individual with habitat we defined to be available to the entire population (design 2; Thomas and Taylor 1990, 2006). Defining availability on the population level made biological sense because sage-grouse are gregarious and not territorial (Crawford et al. 2004).

We used the R statistical programming language (R Project 2007) for statistical analyses and graphing. Package Adehabitat (Calenge 2006) and its supporting package Ade4 (Chessel et al. 2004) provided functions for compositional analysis, selection ratio analyses, and eigenanalysis (Calenge and Dufour 2006). We used ArcMap™ (ESRI 2006) with Spatial Analyst Tools and Hawth's Analysis Tools (Beyer 2007) for spatial calculations and analyses.

Results

As expected, chi-square statistical tests supported the hypothesis that individual collared birds used habitat the same way as all the other collared birds, so we can make generalizations about habitat selection. Similarly, mean sage-grouse habitat use differed from random (when random is use in proportion to availability) for summer, winter, and nest relocation groups at the study area scale, which supports the hypothesis that sage-grouse select habitats with desirable characteristics for them.

For sage-grouse, not all sagebrush community types in the study area are equal (fig. 3, next page). Big sagebrush and mixed big sagebrush–bitterbrush habitats were preferred by all relocation groups. At all scales, big sagebrush–bitterbrush (mean across seasons and scales $S = 7.08$) had higher mean selection ratios than big sagebrush (mean $S = 2.63$, but not significant because of high variance, standard deviation = 9.04, and our conservative 95% confidence interval). Low-sagebrush dwarf shrublands were never used in the winter, so they had winter selection ratios of zero. Nine birds used sagebrush–shrubby cinquefoil but infrequently and generally only as a small proportion of a relocation's 200-meter (656 ft) buffer.

Sage-grouse avoid habitat differently during different seasons. For example, the only habitats that were significantly avoided at any scale in the winter were low-sagebrush ($S = 0$), big sagebrush–shrubby cinquefoil ($S = 0.46$), conifer forest ($S = 0.32$), aspen woodland ($S = 0.86$), and the unused habitats ($S = 0$). In addition, cottonwood riparian was the only non-sagebrush habitat class

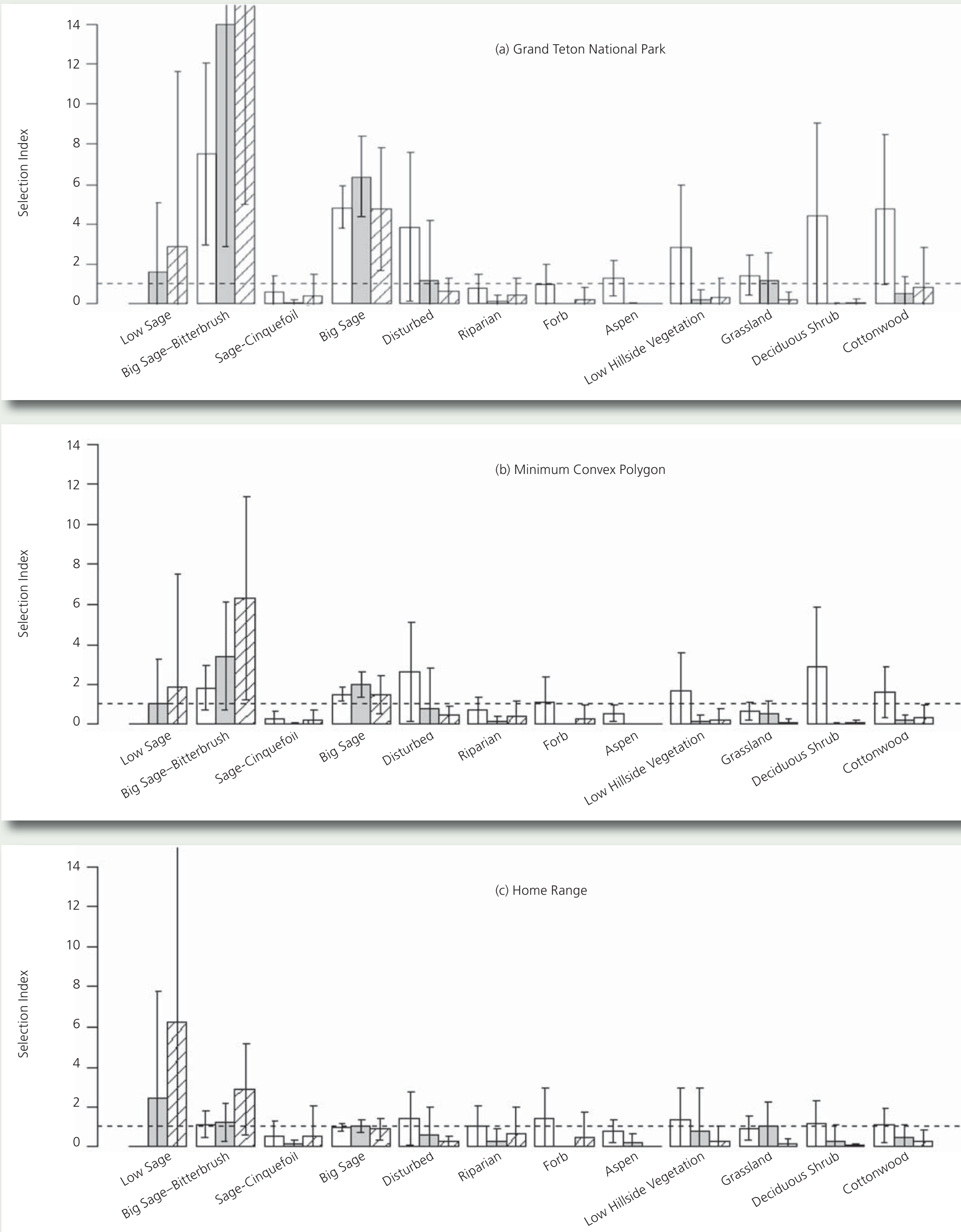
(a) Grand Teton National Park
(b) Minimum Convex Polygon
(c) Home Range
Selection Index
0
2
4
6
8
10
12
14
Low Sage
Big Sage–Bitterbrush
Sage-Cinquefoil
Big Sage
Disturbed
Riparian
Forb
Aspen
Low Hillside Vegetation
Grassland
Deciduous Shrub
Cottonwood

Figure 3 (left). Mean sage-grouse selection indices (observed/expected) for 12 habitat types at (a) study area (Grand Teton and surrounding areas), (b) minimum convex polygon, and (c) home-range scales in Grand Teton National Park, 1999–2003. White bars represent winter selection, shaded bars represent summer selection, and hatched bars represent nest site selection. Error bars show 95% confidence intervals. The dotted line at selection index = 1 represents the point at which observed use is in proportion to availability. The nesting habitat selection at the GRTE scale for big sage–bitterbrush continues beyond the figure to a selection index of 26.1. The upper limit of the 95% CI for summer big sage–bitterbrush at the GRTE scale extends beyond the figure to a selection index of 25.2.

Surprisingly, our population wintered in hills with a wide range of shrubby habitats and near trees, rather than in the homogenous sagebrush winter habitat reported in the literature.

with a significant positive selection ratio (S = 4.73), and this occurred in the winter season.

In summer, sage-grouse used only 4 of the 14 habitat classes proportionally to their availability. We used eigenanalysis (Calenge and Dufour 2006) to statistically describe habitat selection based on individuals' locations. The summer eigenanalysis, for example, explained 95% of the variation in habitat selection with only two habitat classes: big sagebrush and big sagebrush–bitterbrush. Because more habitats were used in the winter, the winter eigenanalysis at the same scale accounted for only 55% of the variation and yielded, in addition to big sagebrush and big sagebrush–bitterbrush, three other influential habitat classes: tall deciduous shrubland, exposed hillside, and human disturbed, all of which, though insignificant, had selection ratios greater than 1.

Nesting habitat was more uniform than winter or summer habitat (fig. 3). Mixed big sagebrush–bitterbrush (S = 26.07) and big sagebrush (S = 4.76) dominated nesting habitat, whereas other vegetation classes were only minimally present in the 200-meter (656 ft) buffers. Avoidance of non-sagebrush habitats typified nesting habitat selection (S = 0.21).

The minimum convex polygon (MCP) encompasses the entire landscape used by the population, and we built it using all 221 relocations. The MCP covered 47,278 hectares (116,824 ac) primarily in the valley floor but also up into the hills to the east and south of the main valley (fig. 2, page 45). Year-round home range (combined summer, winter, and nesting home range) spanned 9,414 hectares (23,262 ac). Winter home range (6,321 hectares [15,619 ac]) overlapped only 28% of the summer home range (4,366 hectares [10,788 ac]), indicating a difference between the seasonal habitats (fig. 2). Summer home range predominantly occupied the sagebrush flats in the center of the valley, whereas winter-use core areas were partially spread outward onto the hills that surround the valley floor. Slope measurements made in Grand Teton National Park vegetation plots were, on average, 96% steeper in sage-grouse winter home range than in summer home range (10% and 5%; Wilcoxon rank-sum test, $P < 0.01$).

Discussion

The pictures of sage-grouse habitat use provided by this study are an important starting point for research that connects habitat selection with fitness and population dynamics (e.g., Aldridge and Boyce 2007). In summer, the study area population avoided nearly all non-sagebrush habitats, which indicates that during our study period they did not need to seek resources in more moist or riparian areas. Surprisingly, our population wintered in hills with a wide range of shrubby habitats and near trees, rather than in the homogenous sagebrush winter habitat reported in the literature (Crawford et al. 2004; Carpenter et al. 2010). These results support the hypothesis that traditional, suitable winter habitat may be limiting in the study area, and further suggest that sage-grouse prefer to remain in sagebrush-dominated habitats but will seek required resources where they exist.

During our study period the Jackson Hole sage-grouse population selected atypical habitats in winter probably in search of exposed sagebrush for food, topography for shelter, or both, and this population's need for these resources superseded the usual avoidance of trees, which can contain raptor predators (Beck 1977; Connelly et al. 2004; Doherty et al. 2008). The hilly vegetation mosaic selected by wintering grouse, although not dominated by sagebrush, likely contained the only exposed patches of sagebrush. Wintering sage-grouse have been found to select for low sagebrush because of its high palatability (Connelly et al. 2004; Rosentreter 2005), but in the study area low sagebrush is likely snow-covered and unavailable during the winter.

Regardless of which resource birds were seeking when selecting nontraditional habitats, it does not reduce the fact that sage-grouse survived winters in a mosaic of vegetation types, including cottonwood riparian forest, mixed tall deciduous shrubland, exposed hillside sparse vegetation, aspen forest and mixed grassland, as well as big sagebrush and bitterbrush shrublands. This suggests that sage-grouse may be able to use a wider range of habitats than previously thought (Connelly et al. 2004), but also demonstrates how dependent the species is on sagebrush and suggests that ideal sagebrush winter habitat may be limited in the study area.

Whether studying sage-grouse or other species with potential seasonally limited habitat, this research reminds us to include a large landscape scale such as the minimum convex polygon and to avoid preconceptions of habitat use.

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USGS/RONALD A. SLOTO

An innovative method for nondestructive analysis of cast iron artifacts at Hopewell Furnace National Historic Site, Pennsylvania

Figure 1. The cast house encloses the furnace at Hopewell Furnace National Historic Site. The stone stack of the furnace is visible on the left side of the cast house. In the foreground, part of the furnace slag pile is exposed and makes up the left bank of French Creek.

By Ronald A. Sloto and Martin F. Helmke

THE U.S. GEOLOGICAL SURVEY (USGS) IS CONDUCTING research at Hopewell Furnace National Historic Site (fig. 1; see sidebar, page 53) in southeastern Pennsylvania to determine the fate of trace metals, such as arsenic, cobalt, and lead, released into the environment during the iron-smelting process. Arsenic is a carcinogen, cobalt is a suspected carcinogen, and lead can cause severe health problems.

Iron ore containing elevated quantities of trace metals was smelted at Hopewell Furnace during its 113 years of operation (1771–1883). The ore used at Hopewell Furnace was obtained from local mines, mainly the Jones and Hopewell mines, which were within 5 miles (8 km) of the furnace. The iron ore deposits were formed during the early Jurassic period about 200 million years ago. The deposits are mineralogically similar and contain abundant magnetite, the chief iron mineral, and accessory minerals enriched in arsenic, cobalt, copper, and other metals.

The study

For this study, we sampled iron ore, cast iron furnace products, slag, soil, groundwater, streamflow, and streambed sediment. It was important for us to determine which trace metals from the smelted ore were incorporated into the cast iron in order to provide a complete picture of the fate of those metals. It was the only missing piece of information after all other media were sampled. Standard techniques were used to sample and analyze all media except cast iron. Standard techniques require collecting samples in the field, shipping them to a laboratory, and performing a destructive analysis. We needed a nonstandard approach for analysis of the cast iron artifacts.

Sampling cast iron produced by the furnace posed two problems. First, verification that the iron was actually cast at Hopewell Furnace was necessary, as some iron objects found at Hopewell may not have originated there. This was accomplished by using artifacts on display at the Hopewell visitor center (fig. 2). All artifacts on display have been positively attributed to the furnace, and

Abstract

Iron ore containing elevated concentrations of trace metals was smelted at Hopewell Furnace during its 113 years of operation (1771–1883). For this study, we sampled iron ore, cast iron furnace products, slag, soil, groundwater, streamflow, and streambed sediment to determine the fate of trace metals released into the environment during the iron-smelting process. Standard techniques were used to sample and analyze all media except cast iron. We analyzed the trace-metal content of the cast iron using a portable X-ray fluorescence spectrometer, which provided rapid, on-site, nondestructive analyses for 23 elements. The artifacts analyzed included eight cast iron stoves, a footed pot, and a kettle in the Hopewell Furnace museum. We measured elevated concentrations of arsenic, copper, lead, and zinc in the cast iron. Lead concentrations as great as 3,150 parts per million were measured in the stoves. Cobalt was detectable but not quantifiable because of interference with iron. Our study found that arsenic, cobalt, and lead were not released to soil or slag, which could pose a significant health risk to visitors and employees. Instead, our study demonstrates these heavy metals remained with the cast iron and were removed from the site.

Key words: arsenic, cobalt, lead, trace metals, iron smelting, cast iron, X-ray fluorescence

USGS/RONALD A. SLOTO

Figure 2. Stoves cast at Hopewell Furnace are on display in the Hopewell Furnace National Historic Site visitor center. These stoves were analyzed for trace metal content. This style of stove was cast in the 1820s and 1830s.

USGS/RONALD A. SLOTO

Figure 3. Martin Helmke analyzes the trace metal content of a cast iron stove using a portable X-ray fluorescence spectrometer. This stove was cast at Hopewell Furnace in 1772 and is the finest known example of a rococo sand casting.

stoves produced by the furnace are easily recognized by the name "Hopewell" cast into them. The second problem was the analysis of the trace metal content of the cast iron, because it was not possible to break off part of a historically important artifact and send it to a laboratory for analysis. This problem was solved when the USGS collaborated with West Chester University, which owns a portable X-ray fluorescence (XRF) spectrometer.

Methods

We analyzed the trace metal content of cast iron produced by Hopewell Furnace using a portable XRF spectrometer (Innov-X Systems Avenger™). This was an ideal tool because it could perform on-site, nondestructive, real-time analysis. This instrument employs a silver-anode, 10–40 keV (kilo-electron volt), 5–50 mA (milliampere) X-ray tube as an excitation source and a silicon PIN diode detector. It is a handheld instrument (fig. 3) that provides analytical results for 23 elements in less than one minute. Data are displayed on a screen on the instrument as well as stored for later uploading to a computer.

The portable XRF spectrometer contains a miniature X-ray tube that emits high-energy primary X-rays, which strike the sample. The X-ray photons have enough energy to knock electrons out of an atom's inner orbital shells. When this occurs, the atoms become ions, which are unstable. The atom regains stability when an electron from an outer orbital shell moves into the newly vacant space in the inner orbital. As it does so, it emits an energy known as a secondary X-ray photon or fluorescent X-ray. The X-ray emission wavelength or energy of the fluorescent X-ray is characteristic of a specific element, and the amount of the element present is determined by the intensity of the emission.

Table 1. Range and mean concentrations of elements measured in cast iron products from Hopewell Furnace by X-ray fluorescence spectroscopy

Element Analyzed	Stoves		Footed Pot		Kettle	
	Range	Median	Range	Median	Range	Median
Antimony	ND	ND	ND	ND	ND	ND
Arsenic	ND–1,330	438	607–1,440	988	ND	ND
Barium	ND	ND	ND	ND	ND	ND
Bromine	89–429	299	142–396	237	353–373	357
Cadmium	ND	ND	ND–5	ND[1]	ND	ND
Chromium	ND	ND	ND	ND	ND	ND
Cobalt	ND–17,720	11,300	ND–7,640	ND[1]	ND	ND
Copper	ND–4,790	1,860	ND	ND	ND	ND
Gold	81–400	265	178–385	298	259–323	264
Iron	>900,000	>900,000	>900,000	>900,000	>900,000	>900,000
Lead	ND–3,150	319[2]	469–6,270	2,720	401–540	536
Manganese	ND–7,000	ND[3]	ND	ND	5,240–6,120	5,480
Mercury	ND	ND	ND	ND	ND	ND
Molybdenum	37–112	76	69–108	92	41–70	50
Nickel	ND	ND	ND	ND	ND	ND
Rubidium	ND–258	ND[4]	ND	ND	ND	ND
Selenium	ND–9	ND	ND	ND	ND	ND
Silver	ND	ND	ND	ND	ND	ND
Strontium	30–233	64	23 E–41	31	ND–45	33
Tin	ND	ND	ND	ND	ND	ND
Titanium	ND	ND	ND	ND	ND	ND
Zinc	ND–8,220	834	348–2,450	964	376–1,270	785
Zirconium	ND–47	25[5]	ND–44	ND[6]	ND	ND

Notes: ND, value below detection limit; >, greater than.
[1]One detection in 6 samples.
[2]Twenty-seven detections in 48 samples.
[3]Seven detections in 48 samples.
[4]Three detections in 48 samples.
[5]Twenty-six detections in 48 samples.
[6]Two detections in 6 samples.

The Hopewell Furnace artifacts analyzed included eight cast iron stoves, a footed pot, and a kettle. One stove was cast in 1772 and the others were cast between 1820 and 1840. In addition, we sampled a stove cast at the Rock Furnace in Lancaster County, Pennsylvania, which was on display. Each stove was sampled three times on the ash lip and three times on the top. The pot was sampled three times on the inside and three times on the outside, and the kettle was sampled three times on the outside.

Discussion

The range and median concentrations of the 23 elements analyzed by XRF spectroscopy are summarized in table 1. The median arsenic concentration for stoves cast at Hopewell Furnace was 438 parts per million (ppm), and the median concentration measured for the pot was 988 ppm. Arsenic was not detected in the kettle. Lead concentrations as great as 3,150 ppm were measured in the stoves. Median lead concentrations were 319 ppm for the stoves, 2,720 ppm for the pot, and 536 ppm for the kettle. The implications of arsenic and lead in cooking utensils cast at Hopewell Furnace may warrant further study. Elevated cobalt concentration likely was caused by interference with high iron concentrations. Cobalt was detectable but not quantifiable in all stoves sampled. Cobalt was detected in only one of six samples from the pot and was not detected in the kettle.

Hopewell Furnace

Built by Mark Bird in 1770–1771, Hopewell was one of the last of the charcoal-burning, cold-blast iron furnaces operated in Pennsylvania. It continued in operation long after most charcoal furnaces were replaced by more modern ones. The most productive years for Hopewell Furnace were 1830 to 1837. Castings were the most profitable product, especially the popular Hopewell Stove (fig. 2). More than 80,000 stoves were cast at Hopewell, which produced as many as 23 types and sizes of cooking and heating stoves. Beginning in the 1840s, the iron industry shifted to large-scale, steam-driven coke and anthracite furnaces. Despite a short reprieve during the Civil War, Hopewell could not compete against the new iron and Bessemer steel industries. When the iron and steel industries consolidated in urban manufacturing centers like Pittsburgh, Bethlehem, and Chicago, small independent rural enterprises like Hopewell could no longer compete, and the furnace ceased operations in 1883 (Kurjack 1954).

We measured two other elements, copper and zinc, in elevated concentrations in cast iron. The median copper concentration for the stoves was 1,860 ppm. The stove cast at Rock Furnace did not have detectable levels of copper. Iron ore from the Jones mine is particularly rich in copper. Copper was not detected in samples from the pot and kettle. Median zinc concentrations were 834 ppm for the stoves, 964 ppm for the pot, and 785 ppm for the kettle.

An interesting finding from this study was the presence of gold in the cast iron. Median gold concentrations were 265 ppm for the stoves, 298 ppm for the pot, and 264 ppm for the kettle. Each stove may contain up to an ounce of gold. Gold was not analyzed in other media; however, gold concentrations up to 3.25 ppm were reported in ore samples from iron mines in southeastern Pennsylvania by Smith et al. (1988: 330).

Antimony, barium, chromium, mercury, nickel, silver, tin, and titanium were not detected in any sample of cast iron. Cadmium, manganese, rubidium, and selenium were rarely detected. When zirconium was detected, concentrations were low. Concentrations of bromine, molybdenum, and strontium were low.

Variability in trace metal concentration in the cast iron is caused, in part, by use of ore from different mines and by the percentage of sulfide minerals included with the magnetite. However, because the iron deposits had a similar origin, they have similar trace metal concentrations. The stove that was cast in 1772 had about the same concentration of trace metals as those cast between 1820 and 1840.

Conclusions

We found the portable XRF spectrometer to be a valuable tool in determining the fate of trace metals in iron ore smelted at Hopewell Furnace. The spectrometer provided rapid, on-site, nondestructive analyses for 23 elements in cast iron artifacts in the Hopewell Furnace museum. There was no other practical way these data could be obtained. Using this instrument, we filled a data gap and provided key information in understanding the fate of trace metals at Hopewell Furnace National Historic Site.

Our study found that arsenic, cobalt, and lead were not released to soil or slag, which could pose a significant health risk to visitors and employees. Instead, our study demonstrates that these heavy metals remained with the cast iron and were removed from the site or are now safely housed in the visitor center museum.

Acknowledgments

The cooperation of Hopewell Furnace National Historic Site personnel is greatly appreciated in granting access and providing assistance. Rebecca Ross, the park cultural resource manager, was especially helpful by providing assistance and the history of Hopewell Furnace artifacts.

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PS

Integrating traditional ecological knowledge (TEK) into natural resource management

Perspectives and projects in western U.S. national parks

By Moran Henn, David Ostergren, and Erik Nielsen

Editor's note: National Park Service policy for use of the best available science and the integration of traditional ecological knowledge in natural resource management are discussed in *NPS Management Policies 2006*, particularly at sections 4.1, 4.2.1, 5.1.1, and 5.2.

Abstract

A growing interest in traditional ecological knowledge (TEK) in the National Park Service (NPS) is emerging out of an understanding that the original peoples of the land and their unique knowledge have much to offer modern land management. While little information exists regarding the nature, location, and outcomes of TEK integrated projects, even less information exists regarding the perceptions of its integration among managers in the world's first protected area system, the U.S. National Park System. With many parks now managing lands that were inhabited for centuries by native tribes, understanding the nature of TEK-integrated projects is especially important. Using an online survey focusing on the Intermountain and Pacific West regions of the National Park System, we assessed the perspectives of NPS employees on TEK integration. We hope to shed light on the perceived benefits, obstacles, and attitudes toward TEK integration within the National Park Service, as well as to provide a preliminary map describing the location and nature of these projects.

Key words: traditional ecological knowledge, tribes, Native Americans, comanagement, public involvement, natural resource management

NOT LONG AGO IN A REMOTE GRASSLAND, A GROUP OF tribal elders, accompanied by a national park fire chief, botanist, and resource chief, gave a short prayer before setting fire to the meadow to help restore native vegetation and fight off invasive species. This fire was started and maintained with traditional methods, the same methods used by the tribe long before the designation of the park, or even the National Park Service. In another park unit more than 1,000 miles (1,609 km) away, selected park employees slog through a swamp, treading on Wapato (*Sagittaria latifolia*), a flowering plant also known as Indian potato that grows in shallow wetlands. To the uninformed spectator this act might seem ambiguous at best, but this activity is thousands of years old. Local tribal women shared the method with park employees to help propagate Wapato, now a threatened species in the park.

These two restoration projects are part of the National Park Service's attempts to integrate traditional ecological knowledge to improve natural resource management. This research investigates the status and perceptions of TEK, an emerging and, we believe, underused source of knowledge that can help managers maintain natural resources and engage in meaningful tribal partnerships, especially in park units with a long history of tribal affiliation.

Background

Though there is no single definition of TEK (Houde 2007), it is usually accepted as a "cumulative body of knowledge, practice, and belief, evolving by adaptive process, and handed down through generations by cultural transmission, about the relationship of living beings with one another and their environment" (Berkes 1993:8). It is knowledge based on long-term observation and interactions with the natural world associated with societies who have a strong connection to a geographic location and historical continuity in resource use and management practices (Berkes 1993).

After more than two centuries of Western science guiding natural resource management, many agencies are now realizing that Western science is sometimes limited and cannot solve resource issues alone (Bowers 2005). A growing number of park managers realize that resource-based peoples have tremendous insight and offer additional perspectives. Global examples of integrating TEK include (1) using TEK as baseline data of pre-European or pre-industrialized ecological conditions; (2) providing alternative perspectives, classification systems, and management methods; (3) providing information about past and current uses of resources; and (4) aiding in formulating research methods, questions, and hypotheses (Berkes et al. 2000). TEK also has the potential to facilitate reconciliation between indigenous peoples and governments (Cronin and Ostergren 2007).

While, in some cases, TEK integration has proven beneficial in improving resource management, some challenges have been identified, including a basic lack of trust, institutional barriers, mission conflicts, cultural differences, and the ambiguity of terms (Berkes et al. 2000). To successfully integrate TEK, these challenges must be understood and addressed (Cronin and Ostergren 2007).

With the exception of Alaska, relatively little information is available regarding such endeavors in the National Park System. This study sheds light on TEK projects in the western United States and describes perceptions and attitudes of a broad sample of NPS resource managers.

Methods

For the purpose of this study we focused on NPS projects that use TEK for conservation or management of a natural resource. Native American Graves Protection and Repatriation Act (NAGPRA) consultations and interpretive projects were excluded from this analysis. We selected the Pacific and Intermountain West regions because 75% of these parks are historically and culturally connected to tribes, and most park units are within 50 miles (80 km) of reservation lands. We collected data from a sample of NPS resource managers, scientists, and superintendents.

Interviews and survey

We employed a mixed-methods methodology with semistructured interviews and an online survey to explore perceptions and experiences with TEK, as well as the status of TEK that is integrated into natural resource projects.

In 2008 we began conducting exploratory semistructured interviews (Berg 2007) with relevant NPS employees (n = 6) using chain referrals (snowballing) to learn about the nature and outcomes of TEK integrated projects. We used qualitative coding to analyze the responses and develop key themes related to TEK. Based on thorough literature review and major themes that emerged during the exploratory interviews, we developed an online survey using Survey Gizmo (online survey software). The survey included open-ended, multiple-choice, and Likert scale questions addressing individual perceptions of TEK, involvement in TEK projects, and perceived outcomes, benefits, and challenges of TEK projects. We coded multiple-choice and Likert scale questions as discrete variables and used open coding, and later focused coding (as used in qualitative analysis), for open-ended questions (Lofland et al. 2006). In 2009 we sent the survey to a contact list of NPS resource managers and superintendents from park units in the Pacific and Intermountain West (n = 512). The contact list was generated through the Colorado Plateau Cooperative Ecosystem Studies Unit (CPCESU) at Northern Arizona University. Participants received an e-mail explaining the study and ensuring confidentiality and a link to the questionnaire. Following Dillman (2007), participants received two reminder e-mails. We then conducted six follow-up interviews selected from a pool of 23 survey respondents who agreed to participate. In addition we interviewed five tribal representatives or former tribal government employees selected through chain referrals. The interviews clarified our survey results and allowed us to either confirm conclusions or reject speculation.

A growing number of park managers realize that resource-based peoples have tremendous insight and offer additional perspectives [to Western science].

Results

Participant characteristics

We had a 34% response rate representing 69 different parks—65% of western parks with affiliated tribes. Some parks were represented by more than one respondent. Natural resource managers and supervisory-level scientists accounted for 35% of respondents, cultural resource managers and professionals accounted for 26%, superintendents and deputies accounted for 23%, and 16% identified themselves as both natural and cultural resource managers. Most respondents (70%) worked for the National Park Service for over 10 years. Self-reporting personal experience levels working with tribes ranged from no experience (6%), to little experience (14%), some experience (43%), much experience (23%), and extensive experience (14%).

Knowledge and perceptions of TEK

When asked about familiarity with the terminology and concept of TEK, 23.6% reported that they were very familiar with both the term and concept, 28.5% reported that they were somewhat familiar with the term and concept, 33.3% were familiar with the concept but *not* the term, and 14.6% were not familiar with the term and concept. More important, a majority of survey respondents indicated they believe TEK has a place in NPS management (see table 1, page 56).

TEK project involvement

Less than half (42.5%) of respondents said they are involved in TEK-related projects, and 43.7% know about TEK projects. From the 51 respondents who reported being involved or knowing about TEK-integrated projects, we identified 44 projects in 37 parks (fig. 1, page 56; table 2, pages 57–58). Three parks had more than one project, five projects were reported numerous times, and 11 projects did not provide the location or park unit name. We filtered the data to avoid counting the same project twice.

Table 1. Perceptions of incorporation of TEK in NPS management (n = 122)

Statement	Strongly Agree	Somewhat Agree	Neither	Somewhat Disagree	Strongly Disagree
It is important to incorporate TEK within the National Park Service.	43%	38%	12%	5%	2%
Incorporating TEK improves conservation/management of natural resources.	25%	35%	32.5%	6%	1.5%
The National Park Service must make it a top priority to incorporate TEK into its management objectives.	16%	32%	37%	10%	5%

TEK project information

Respondents were asked to provide information about goals, TEK use, benefits, and challenges to TEK integrated projects. The results are summarized in tables 3 and 4 (page 59).

In all, only 45% (n = 20) of projects dealt directly with conservation and restoration of natural resources. TEK was often used for adding knowledge diversity and historical context (44%; n = 15) or understanding resource uses (25%; n = 11), but not for direct natural resource management decisions. A biologist explained, "Incorporating TEK into natural resource issues is just low-priority, and that is why it is rarely used when making natural resource management decisions." Understanding current resource use, however, was emphasized by many respondents and was repeatedly expressed in the interviews. A superintendent stated, "We must know what is being collected and where."

Figure 1. The study identified 44 TEK integrated projects in 37 western U.S. park units (map displays 26 of the identified parks with TEK projects).

Project challenges

Respondents identified "difficulties in obtaining TEK" as a major challenge (fig. 2, page 59). This refers to a lack of employee knowledge and training in the process of obtaining TEK, lack of collaboration with tribes, and a belief held by some participants that the knowledge is lost. A superintendent explained, "We were not always sure whom to speak with, how to approach the tribe, what is appropriate, whether our behavior is acceptable." A cultural resource manager added, "Since the tribes have been removed from the park for over 100 years, very little knowledge actually exists."

"Institutional barriers" included a lack of support and resource allocation for TEK projects as well as institutional inertia. A resource chief stated, "Getting enough financial support . . . this is an ongoing problem." However, two tribal interviewees regarded this issue not as a lack of resources but as a lack of prioritization. One stated, "There is no shortage of money or people . . . it is all about priorities . . . it just takes will from management."

"Cultural differences" referred to personal differences in beliefs, attitudes, and actions, specifically differences in ideology, cosmology, and epistemology. A superintended explained, "My experience has been, as any time when people of different backgrounds and cultures try to jointly conduct a project, the groups bring their own distinct ideas to the process."

"Lack of trust" referred to instances where NPS employees felt a lack of trust from tribal representatives and governments. A resource chief explained, "They just don't trust us; why would they?"

Table 2. National park management projects using traditional ecological knowledge (TEK)

Park	Description	Type	How TEK Was Used
Anonymous (i.e., park name not provided/requested to remain anonymous)	American Indian students share TEK as seasonal interpreters	Interpretation	Knowledge diversity and historical context
Anonymous	Determine population status of a threatened plant species	Restoration and conservation	Knowledge diversity and historical context
Anonymous	Vegetation management and traditional use identification of plants	Restoration and conservation	Knowledge diversity and historical context
Anonymous	Obtain resource information for creation of a new park	Interpretation	Knowledge diversity and historical context
Anonymous	Collect native seed for reseeding disturbed areas	Restoration and conservation	Traditional management techniques
Anonymous		Interpretation	Resource use
Anonymous	Improve/develop relationships between tribes and park. Major emphasis on past, present, and future resources use	Relations	Resource use
Anonymous	Tribal involvement	Resource use	Resource use
Anonymous	Restoration of native forest	Restoration and conservation	Resource use
Anonymous	Update of fishing regulations	EIS consultation	
Anonymous	Watershed analysis	EIS consultation	
Bandelier NM	Fire management and ecological restoration	Restoration and conservation	Resource use
Bent's Old Fort NHS/Sand Creek Massacre NHS	Ethnobotanical survey	Restoration and conservation	Baseline data
Big Bend NP	Monitor plant species	Resource monitoring and research	
Big Hole NB	Camas citizen science monitoring program	Interpretation	Knowledge diversity and historical context
Canyon de Chelly NM	Gathering rights	Resource use	
Death Valley NP	Mesquite and pinyon monitoring	Resource monitoring and research	Traditional management techniques
Devils Tower NM	Develop a recreational management plan for a traditional cultural property	Sacred sites management	Knowledge diversity and historical context
Glen Canyon NRA	Provide emergency access to lake	EIS consultation	Knowledge diversity and historical context
Golden Gate NRA	Restoration of Crissy Field tidal mMarsh in the Presidio	Restoration and conservation	Baseline data
Golden Gate NRA	Redwood Creek restoration at Muir Beach (wetland and creek restoration)	Restoration and conservation	Baseline data
Grand Canyon NP	Colorado River management (both NPS plan and Bureau of Reclamation plan for operation of Glen Canyon Dam)	EIS consultation	Traditional management techniques
Great Sand Dunes NP&P	Prescribed fire	Restoration and conservation	Traditional management techniques
Great Sand Dunes NP&P	Identify traditional uses of plants	Resource use	
Joshua Tree NP	Install a traditional use demonstration garden	Interpretation	Knowledge diversity and historical context
Lake Mead NRA	Cultural landscapes, traditional tribal properties (compliance-related consultations)	EIS consultation	Knowledge diversity and historical context
Lake Mead NRA	Restoration of natural resources in a traditional cultural property	Restoration and conservation	Knowledge diversity and historical context
Lake Mead NRA	Eradicate invasive plant species within the park	Restoration and conservation	Baseline data and resource use
Lake Roosevelt NRA	Fire management	Restoration and conservation	Resource use
Lava Beds NM	Inventory cave cultural and natural resources	EIS consultation	Knowledge diversity and historical context

CONTINUES >>

Table 2 (continued)

Park	Description	Type	How TEK was used
Lewis and Clark NHP	Reintroduce Wapato (*sagittaria latifolia*), an indigenous food staple, to the ecosystem	Restoration and conservation	Traditional management techniques
Mount Rainier NP	Manage fisheries and tribal uses of plants and access to sacred sites	Resource use	Resource use
Mount Rainier NP	Information about tribal use of plant material	Resource use	Resource use
Nez Perce NHP	Restore camas lily to Weippe Prairie (camas citizen science monitoring program)	Restoration and conservation	Baseline data, knowledge diversity, and historical context
Olympic NP	Elwha River ecosystem restoration	Restoration and conservation	Baseline data
Olympic NP	Changes in fishing regulations	EIS consultation	
Redwood NP	Study the feasibility of reintroducing California condor to tribal and national park lands	Restoration and conservation	Knowledge diversity and historical context
Redwood NP	Management (protection and restoration) of bear grass on traditional use sites	Restoration and conservation	Resource use and traditional management techniques
Rocky Mountain NP	Senior Ranger Corps and Next Generation program	Interpretation	Knowledge diversity and historical context
Tuzigoot NM	Restore a marsh	Restoration and conservation	Resource use
Whiskeytown NRA	Develop trails within the park	EIS consultation	Value
Yellowstone NP	Conserve Yellowstone bison	Restoration and conservation	Knowledge diversity and historical context
Yosemite NP	Burn meadow for both cultural and natural resource values	Restoration and conservation	Traditional management techniques
Zion NP	Incorporate cultural harvesting of plants into resource management efforts	Resource use	Resource use

Abbreviations: NB = national battlefield, NHP = national historical park, NHS = national historic site, NM = national monument, NP = national park, NP&P = national park and preserve, NRA = national recreation area.

"Ambiguity with the term and the knowledge" referred to lack of a clear definition of TEK and conflicting or unclear information provided by tribes.

"NPS attitudes" referred to a spectrum of answers, ranging from perceived racism and prejudice to a lack of interest or desire to work with TEK or tribes. These attitudinal problems, however, did not emerge as challenges in our postsurvey interviews.

"TEK-NPS conflicts" referred to situations where NPS participants felt that TEK contradicts NPS values and mission. This was especially true for the collection and harvest of threatened or sensitive species. Although a request to collect an endangered species is a rare event, it is a worst-case scenario that elicits strong reactions in both groups.

"Unrelated challenges" referred to problems dealing with the resources or conditions themselves, including adverse weather conditions and broken machinery.

"Public opinion" referred to problems of perceived favoritism toward Native Americans in privileging their knowledge and input into resource management.

"TEK-science conflicts" referred to situations where NPS participants felt that the best available science contradicts TEK. In our postsurvey interviews, a tribal representative commented on this point and said that "in many cases it [TEK] strengthens Western science. But we need to understand it is also a science and should be evaluated as such."

Project benefits

Respondents identified "park-tribal relations" most frequently (39%) as a benefit of TEK integration (fig. 3). Tribal interviewees did not discuss relations as a TEK benefit but rather as a prerequisite. A former tribal resource manager explained, "For TEK projects to be successful the NPS must first create strong relationships with tribes and build trust."

Table 3. Distribution of TEK projects (n = 44) in western units of the National Park System

Project (categories based on goals)	(n = 44)	Details
Improving natural resource management	20 (45%)	Restoration and conservation
Environmental impact statement and consultation	9 (20%)	National Environmental Policy Act (NEPA), Endangered Species Act (ESA), cultural consultations
Resource use	6 (14.5%)	Monitoring, understanding, and regulating historic and current uses
Interpretation	6 (14.5%)	Educational displays, talks, trails
Resource monitoring and research	2 (4.5%)	Resource inventory
Sacred sites management	1 (2%)	Resolving sacred site issues

Table 4. Distribution of how TEK was used in identified projects (n = 44)

Uses	(n = 44)	Details
Knowledge diversity and historical context	15 (44%)	Cultural value given to specific resources and ethnographies
Resource use	11 (25%)	Current and historical harvest, collection, and hunting
No explanation	7 (16%)	Gave no explanation of how TEK was used
Traditional management techniques	6 (12%)	Executing alternative management and restoration actions based on traditional methods
Baseline data	5 (3%)	Information for restoring pre-European conditions to a site, such as vegetation pallets

Figure 2. Distribution of perceived challenges (n = 77) of TEK integration into natural resource projects in western U.S. parks.

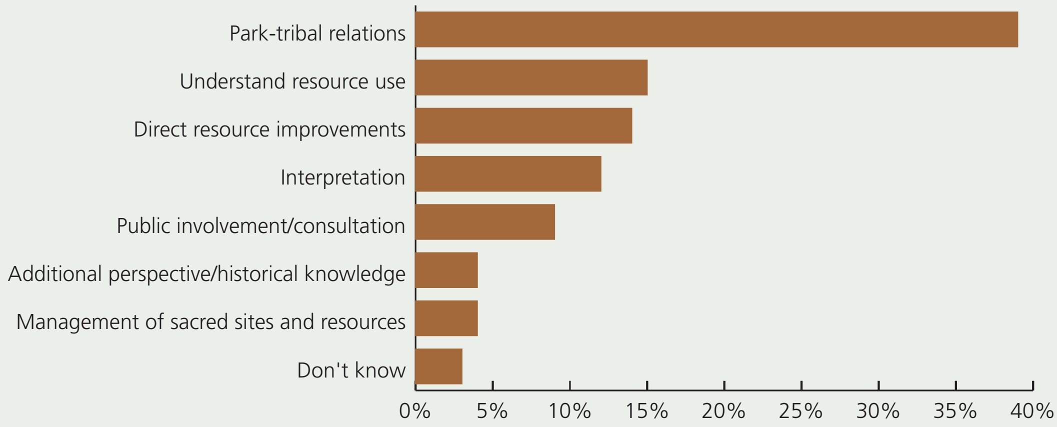
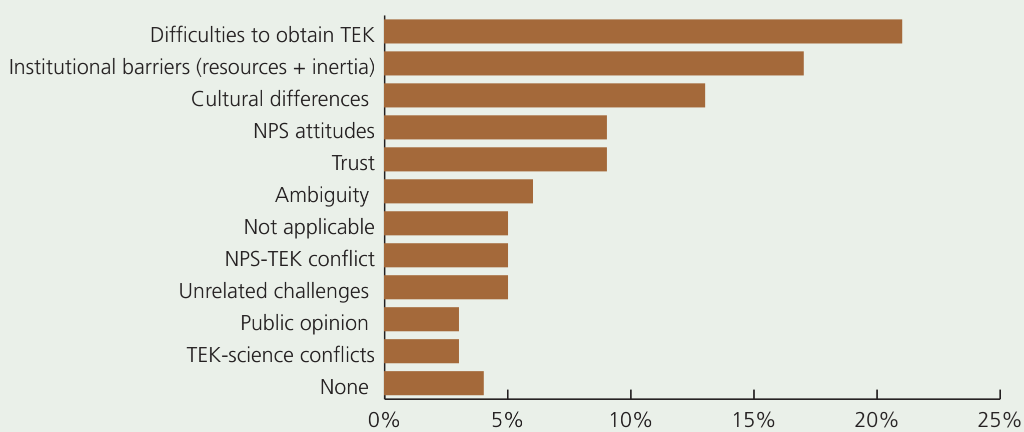


Figure 3. Distribution of positive outcomes and benefits (n = 46) from TEK integration to natural resource projects.



"Understanding resource use" (15%) referred to both historical and current harvesting, hunting, and collection of resources by Native Americans. An NPS resource manager stated, "It helps us better manage the resources if we know how they are being used and by whom."

"Direct resource improvements" referred to active management of natural resources, especially restoration, using methods guided by TEK. These include propagation of plants and burning methods. A biologist explained that "the greatest benefit from integrating TEK was preventing loss of a sensitive plant population."

"Interpretation" referred to interpretive displays, talks, and other educational programs. Even though we were not looking to capture TEK integration into interpretive projects, it was a common use and benefit mentioned by respondents.

"Public involvement and consultations" referred to the official NPS mandate of public involvement and consultations such as NEPA and NAGPRA.

"Additional perspective/historic knowledge" referred to general positive comments about TEK, or its value in adding knowledge diversity to a predominantly scientific knowledge base. A resource chief indicated that "while TEK might not have concrete benefits, using it adds a historical and cultural perspective."

"Management of Native American sacred sites and resources" referred to using TEK to improve management of these locations and resources.

Additional project details

The majority (73%) agreed that integrating TEK into natural resource management improved relations between tribes involved and the park unit and (70.1%) directly helped to conserve resources and improve natural resource management. However, just over half (60%) agreed that their park unit will continue to incorporate TEK for natural resource management.

Conclusion and implications

Incorporating TEK into resource management is not just the collection of specific information (or individual facts) about natural resources from tribal members. Rather, integrating TEK is a process of working in collaboration with tribes to assess the potential for using the TEK to manage culturally and ecologically important resources. Park staff can use participatory social science methods to elucidate and document this knowledge. Traditional ecological knowledge should be regarded as a body of information about ecosystems gleaned over generations that is as useful and informative as Western sources of knowledge. As such, it can contribute to informed decision making using the best available science and knowledge. If conflicts arise, then managers need to weigh the evidence and make the best decision they can with the available data—as in all management decisions. More likely the integration will provide complementary information to guide decisions (Huntington 2000; Ruppert 2003).

Throughout the world, managers are beginning to recognize the tremendous value of TEK, whereby tribes bring in their unique, long-term, local knowledge to complement Western science. In our study several respondents also reported that NPS TEK projects have improved natural resource conditions, and the majority of respondents reported that joint projects help build stronger relationships with tribes. The majority of respondents were familiar with TEK and felt that the National Park Service should use it more. That most of the respondents are in decision-making positions and have been in the National Park Service more than 10 years suggests a positive trend for future integration of knowledge and joint projects.

However, out of 69 parks in which 44 projects were identified, only 20 parks reported integrating TEK into natural resource management projects; 20% of respondents had little to no experience working with tribes; 14.6% were unfamiliar with TEK; the majority reported institutional inertia and cultural differences as barriers to TEK; and less than half (48%) reported that the National Park Service should prioritize TEK integration. These results raise the question, "Can the NPS culture embrace the use of TEK to improve natural resource management?" There will always be a place for the National Park Service to undertake projects to "strengthen relations with tribes" and "regulate resource use." But in order to work through institutional barriers and cultural differences to value and incorporate TEK into resource management decisions, the National Park Service will have to dedicate resources for training and implement policies that support and cultivate a culture of awareness and respect for TEK. As more park managers explore and evaluate the utility of TEK for specific resource management questions and then attempt to integrate it, the efficacy of these efforts will be the ultimate measure for broader applications. Future research should focus on documenting these applications and their outcomes for resource management and building partnerships with American Indian tribes.

Incorporating TEK into resource management is not just the collection of specific information (or individual facts) about natural resources from tribal members. Rather, integrating TEK is a process of working in collaboration with tribes to assess the potential for using the TEK to manage culturally and ecologically important resources.

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The benefits of live interpretive programs to Great Smoky Mountains National Park

FINLEY-HOLIDAY/RODNEY CAMAUFF, PHOTOGRAPHER (2)

Figure 1. Costumed interpretation and ranger-led walks are among the interpretive activities that visitors to Great Smoky Mountains National Park described as important to their park visit.

By Marc J. Stern, Robert B. Powell, and Cathleen Cook

LIVE INTERPRETIVE PROGRAMS AT NATIONAL PARKS serve multiple functions (fig. 1). They help to reveal to park visitors the deeper meanings associated with parks' cultural and natural resources (Ham 1992; Tilden 1977). They can enhance visitors' enjoyment by providing entertaining experiences or better orientation to the available sights, resources, and activities (Moscardo 1999). They can effect emotional connections to landscapes, to animal or plant life, and to the history being interpreted (Tilden 1977). They can influence visitors' attitudes to the park they are visiting, toward the National Park Service, or toward an ecosystem, a historical event, a social movement, or the environment or nature in general (e.g., Powell et al. 2009). Research and theory also suggest that interpretation can influence visitors' behaviors both during their visits and after they have left the park (Ham 2009).

In conjunction with a study designed to learn why visitors attend (or do not attend) ranger-led interpretive programs at Great Smoky Mountains National Park, we set out to address three additional research questions that provide the focus of this report:

- How many visitors attend a ranger-led interpretive program? While general visitor surveys conducted by the Park Studies Unit at the University of Idaho typically ask visitors whether they have attended a ranger-led interpretive program on the particular visit during which they were contacted by the survey team, we sought to find out how many visitors had attended a program in the park when multiple visits are considered.
- How do visitors feel about ranger-led interpretive programs, regardless of their attendance? We sought to understand how visitors value the existence of ranger-led interpretive programs as well as their opinions of programs they had attended.
- What impacts do ranger-led interpretive programs appear to have on attendees? We gauged program impacts on a number of attitudes and intentions relevant to park management.

Methods overview

This study was an initiative of Virginia Tech and Clemson University, and it was funded by the Friends of Great Smoky Mountains National Park.[1] We conducted a survey with a representative sample of visitors to the areas of Great Smoky Mountains National Park where most interpretive programs are offered. The survey explored attendance patterns and asked multiple questions about visitors' reasons for attending or not attending ranger-led interpretive programs[2] in the park. It also asked about

[1] While the study was permitted by Great Smoky Mountains National Park and discussed with its staff, park staff did not participate in the research directly.

[2] We described ranger-led programs in the following manner: "Great Smoky Mountains National Park offers a number of ranger-led programs for park visitors. These include campfire programs, guided walks and hikes, cultural demonstrations, junior ranger programs, and numerous other activities."

Abstract
We conducted a visitor survey at Great Smoky Mountains National Park, Tennessee and North Carolina, to investigate attendance at live (ranger-led) interpretive programs, visitors' attitudes toward those programs, and the impacts of the programs on visitors' appreciation and awareness of park resources. We found that more than a quarter of the park visitors we contacted during the nine-day study had attended a ranger-led program at the park, either on this or a prior visit. This is substantially more than the most recent general visitor survey at the park in the prior year, which considered only the current visit. Results suggest that visitors to Great Smoky Mountains National Park highly value ranger-led interpretive experiences regardless of their direct participation in them. Most program attendees also suggested that the programs had increased their appreciation of this national park and the National Park Service (NPS), increased the likelihood that they would donate to the park if asked, and made them more aware of this country's cultural heritage and environmental issues and concerns. The study affirms the importance of live interpretive programs for enhancing the visitor experience and promoting positive attitudes toward Great Smoky Mountains National Park and the National Park Service.

Key words: interpretation, visitation, evaluation, survey research

group characteristics, prior experiences, motivations for visiting the park in general, quality assessments of programs for those who had attended, information sources for finding out about programs, and general opinions about ranger-led programs, the national park, and the National Park Service. This report focuses on patterns in program attendance, opinions about ranger-led programs, and the programs' impacts on participants. Additional results are reported elsewhere (Stern et al. 2010).

Contacts with visitors were made from 25 July 2009 to 2 August 2009. Respondents were briefly told about the purpose of the survey and were invited to participate. If they agreed to participate, they were handed a postcard with instructions for accessing a survey online, along with a personal identification number (PIN). The PINs were used primarily to associate responses with data collected on-site and to maintain respondents' confidentiality. One e-mail reminder was sent 10 days after the on-site recruitment period to those who provided an e-mail address and had not yet completed the survey. We also printed 200 mail-back surveys with return envelopes and postage for those without Internet access or who stated a preference for the paper survey.

More than 80% of respondents viewed ranger-led programs as important to the mission of the National Park Service.

Results

Of the 2,064 visitors approached, a total of 1,830 visitors accepted either the postcard or one of the 200 mail-back paper surveys. We received 617 completed surveys, indicating a 34% response rate. The demographics and trip characteristics of our survey respondents matched those of the most recent general visitor survey (Papadogiannaki and Hollenhorst 2008), suggesting that we achieved a representative sample of visitors to the park.

Program attendance

Sixty-three percent of respondents were aware that the park offered ranger-led interpretive programs. Of the 617 respondents, 82 (13.3%) reported attending a ranger-led program on this particular visit. Of those who expressed an awareness of program existence, 21.1% attended a program on this visit. Ranger talks were the most commonly attended programs (table 1, next page).

We also asked respondents whether they had ever attended a ranger-led program at Great Smoky Mountains National Park, either on this visit or a prior one. More than a quarter (26.4%) of respondents reported having attended a ranger-led program at the park at least once when multiple visits are considered. Nearly half (42%) of those who expressed awareness of these programs reported attending at least one interpretive program on this or a previous visit.

Visitor opinions

All respondents were asked their opinions of park management and whether ranger-led interpretive programs are important to the mission of the National Park Service. Respondents who were not aware that the park offered these programs were asked whether these programs should be offered (table 2, next page). Those who were aware of programs were asked additional questions about their value (table 3, next page). Respondents were asked to rate their answers to the questions on a five-point scale, reflecting their level of agreement with each statement (1 = strongly disagree; 5 = strongly agree). Opinions of the park and of the importance of ranger-led programs were high for each group. More than 80% of respondents viewed ranger-led programs as important to the mission of the National Park Service.

Table 1. Survey respondents' attendance at interpretive programs

Program	Total Sample (n = 617)	Those Aware of Any Ranger Program (n = 388)
Talk by a ranger	8.4%	13.4%
Cultural or craft demonstration	6.0%	9.5%
Junior ranger program	2.6%	4.1%
Guided daytime walk or hike	2.4%	3.9%
Amphitheatre program	1.9%	3.1%
Night hike	1.0%	1.5%
Campfire program	0.0%	0.1%

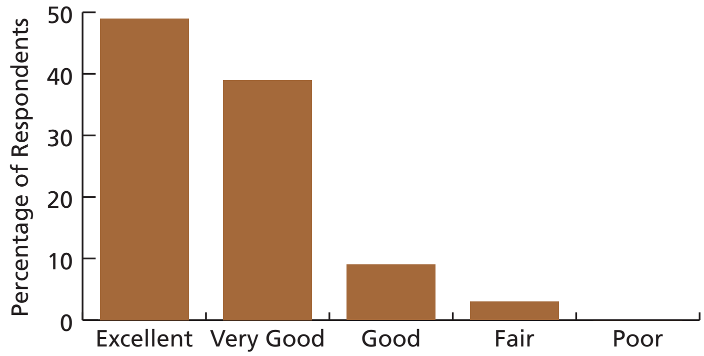

Figure 2. Opinions of ranger-led program quality for those who attended a program on this park visit.

Table 2. Opinions about the park and interpretive programs of those unaware of the existence of ranger-led programs

Statement	Disagree or Strongly Disagree	Neutral	Agree or Strongly Agree
Great Smoky Mountains National Park is well managed.	4.6%	9.3%	86.1%
The park should offer ranger-led programs.	1.2%	13.6%	85.2%
Ranger-led programs are important to the mission of the National Park Service.	2.8%	15.0%	82.3%

Table 3. Opinions about the park and interpretive programs of those aware of the existence of ranger-led programs

Statement	Disagree or Strongly Disagree	Neutral	Agree or Strongly Agree
Great Smoky Mountains National Park is well managed.	2.0%	7.8%	91.2%
Ranger-led programs are important to me.	6.7%	45.2%	48.1%
Ranger-led programs are important to the mission of the National Park Service.	2.3%	13.6%	84.7%
If ranger-led programs did not exist, I would be disappointed.	8.7%	38.2%	53.2%
If ranger-led programs did not exist, it would lower my opinion of the National Park Service.	22.6%	27.2%	50.1%
If ranger-led programs did not exist, it would lower my opinion of Great Smoky Mountains National Park.	27.5%	27.8%	44.6%

Table 4. Comparisons of opinions about the park and ranger-led programs for those who had ever attended a live program vs. those who had not

Statement	Ever Attended?	Mean	Mean Difference
Great Smoky Mountains National Park is well managed.	Yes No	4.26 4.21	0.05
Ranger-led programs are important to me.	Yes No	3.88 3.29	0.59*
Ranger-led programs are important to the mission of the National Park Service.	Yes No	4.31 4.02	0.29*
If ranger-led programs did not exist, I would be disappointed.	Yes No	3.82 3.39	0.43*
If ranger-led programs did not exist, it would lower my opinion of the National Park Service.	Yes No	3.68 3.13	0.55*
If ranger-led programs did not exist, it would lower my opinion of Great Smoky Mountains National Park.	Yes No	3.45 3.00	0.45*

*Statistically significant difference ($p < 0.001$).

Table 5. Impacts of ranger-led programs on attendees' attitudes

Participating in a ranger-led program(s) has . . .	Disagree or Strongly Disagree	Neutral	Agree or Strongly Agree
Increased my appreciation of Great Smoky Mountains National Park (n = 77).	2.6%	9.1%	88.3%
Increased my appreciation of the National Park Service (n = 76).	2.6%	9.2%	88.2%
Increased the likelihood that I would donate to the park if asked (n = 75).	6.7%	34.7%	58.7%
Made me more aware of environmental issues and concerns (n = 75).	9.1%	29.9%	61.0%
Made me more aware of this country's cultural heritage (n = 77).	9.1%	16.9%	74.0%

Respondents who attended a program (either on this or a prior visit; n = 163) were also asked about the quality of the ranger-led programs they had attended. Respondents were asked to rate the overall quality of their ranger-led programs on a scale from 1 to 5 (1 = poor; 2 = fair; 3 = good; 4 = very good; 5 = excellent). Respondents were also provided an option to report the quality of programs as "mixed (some good, some not)." No respondents selected this category. None rated the program(s) they had attended as poor, and 88.6% rated the program(s) as excellent or very good (fig. 2). The overall average score was 4.35.

Impacts of programs

To gauge the impact of attending an interpretive program, we divided the sample into those who attended a program (either on this or a prior visit; n = 163) and those who had not (n = 464). We then compared the two groups' mean scores for each attitudinal statement (table 4). While opinions about the management of the park were not significantly different between the two groups, opinions about the importance of ranger-led programs were more positive for those who had attended one.

Respondents were also asked about the extent to which the program(s) they had attended on this visit impacted their appreciation of Great Smoky Mountains National Park and the National Park Service, their awareness of environmental issues and this country's cultural heritage, and their likelihood of donating to the park if asked (table 5). The results suggest that the programs had a strong positive impact on most respondents. Nearly 90% of respondents reported that attending a ranger-led program increased their appreciation of Great Smoky Mountains National Park and the National Park Service. More than 60% of respondents indicated that their awareness of environmental issues and this country's cultural heritage increased. More than half reported that their attendance increased the likelihood that they would donate to the park if asked.

[No respondents] rated the program(s) they had attended as poor, and 88.6% rated the program(s) as excellent or very good.

Summary

Results from this survey show that more visitors have attended interpretive programs in the park (26.4%) than accounted for in the most recent general visitor survey, which found that approximately 9% of visitors attended an interpretive program on the specific visit during which their participation in the survey was solicited (Papadogiannaki and Hollenhorst 2008). By accounting for multiple visits, our research suggests that interpretive programs may be attended by a larger portion of visitors than previously assumed, particularly at parks where repeat visitation is common, such as Great Smoky Mountains National Park.

Visitors highly value ranger-led interpretive experiences regardless of their direct participation in them. More than 80% agreed that ranger-led programs are important to the mission of the National Park Service. Just over half of those who were aware of the existence of ranger-led programs suggested that their absence would lower their opinion of the National Park Service.

Program attendees rated highly those programs they had attended, and most suggested that these programs had increased their appreciation of Great Smoky Mountains National Park and the National Park Service, increased the likelihood that they would donate to the park if asked, and made them more aware of this country's cultural heritage and environmental issues and concerns.

Nearly 90% of respondents reported that attending a ranger-led program increased their appreciation of Great Smoky Mountains National Park and the National Park Service. More than 60% of respondents indicated that their awareness of environmental issues and this country's cultural heritage increased.

In conclusion, the study affirms the importance of interpretive programs for enhancing the visitor experience at Great Smoky Mountains National Park, promoting positive attitudes toward this park and the National Park Service, increasing awareness, and building constituencies for achieving the NPS mission.

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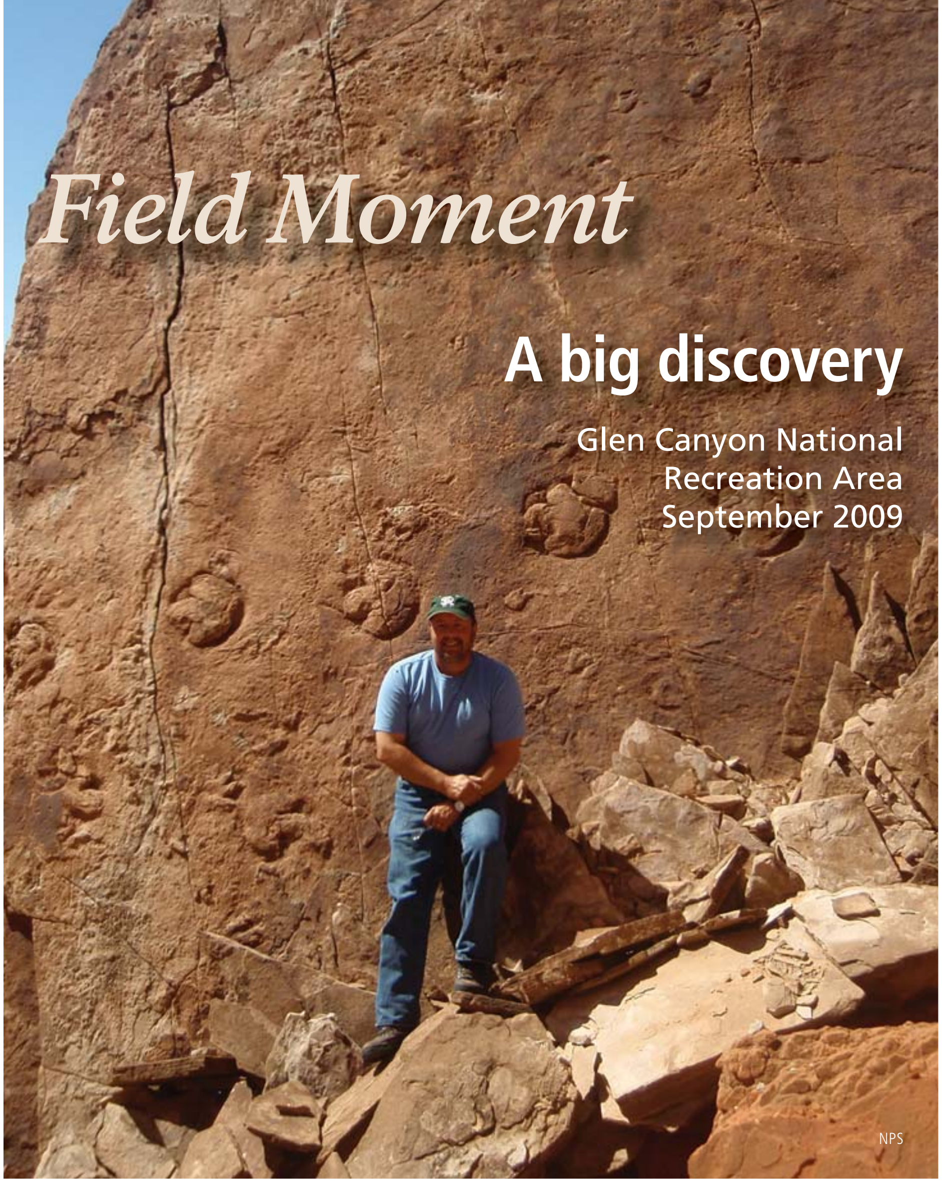
PS

Field Moment

A big discovery

Glen Canyon National Recreation Area
September 2009



NPS

GEORGE WASHINGTON Memorial Parkway chief ranger (and paleontologist by training) Vincent Santucci and a team of National Park Service and Utah Geological Survey fossil experts were performing "houseboat paleontology" on Lake Powell in Glen Canyon National Recreation Area. They were working on a pilot paleontological resource monitoring program that would yield information regarding the condition and stability of in situ fossil localities and lead to greater protection of fossil sites both at Glen Canyon and across the National Park System. Notified by visitors of possible dinosaur tracks in an area of towering Navajo Sandstone blocks at the edge of the lake, they navigated to the site, secured the boat, and set out on a short hike. As they turned a corner, they saw not just one or two tracks but seven fossil prints stretching horizontally across the burnt-orange cliffs. "We were in awe of what we were looking at," said Santucci, who recognized immediately that "this was not just another track locality."

The trackway is both significant and puzzling. It has more value than a single footprint: multiple tracks reveal information about the animal's size, gait, and behavior. Also, these tracks are exceedingly large and seemingly out of place in the Early Jurassic rocks. There are no known fossil remains of an animal alive at that time that would leave tracks of this morphology or size. In addition, the tracks are unusual for the Navajo paleoecosystem, which was composed of wind-driven sand dunes with pockets of wetlands (or lakes) in low areas between dune crests. Santucci explains, "We would not expect to find a large bipedal reptile in such an environment." The tracks appear to have been left by an ornithopod (bird-footed dinosaur), a creature unknown from the Early Jurassic.

To unearth this mystery and determine whether it is an ornithopod or some other unknown dinosaur, the National Park Service will consult with leading experts on dinosaurs and dinosaur tracks. If the tracks are determined to have been made by an ornithopod, this discovery may move back the known existence of this group of dinosaurs by 25–30 million years. In addition, the ancient sandstone block contains tracks of smaller dinosaurs that may tell us about the contemporaries of the mysterious creature.

Discoveries such as the trackway at Glen Canyon demonstrate the importance of national parks in preserving the fossil record. Since the inception of the NPS paleontological inventory program in 2001, scientists have gathered baseline information about fossil resources in parks. Paleontological inventories have greatly expanded the knowledge of the scope, significance, diversity, and distribution of fossils across the National Park System. Before the effort began, 110 parks were known to have fossils; today that number has grown to more than 230.

Each field season, our knowledge and understanding of the fossil record increase—a reminder, says Santucci, that most of what is to be learned about the history of life on Earth remains to be discovered. By adopting active management and monitoring strategies for paleontological resources in national parks, we can help preserve this fossil record, enabling future discoveries such as the mysterious track-maker in Glen Canyon.

—*Virginia A. Reams*

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