NPS–USGS Collaboration to Support Science and Resource Management in the National Parks

The George Wright Forum

The GWS Journal of Parks, Protected Areas & Cultural Sites
volume 31 number 2 • 2014

GEORGE WRIGHT SOCIETY

Mission

The George Wright Society promotes protected area stewardship by bringing practitioners together to share their expertise.

Our Goal

The Society strives to be the premier organization connecting people, places, knowledge, and ideas to foster excellence in natural and cultural resource management, research, protection, and interpretation in parks and equivalent reserves.

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On the cover: Senator Tim Kaine of Virginia, Secretary of the Interior Sally Jewell, and Representative Jim Moran of Virginia announce wetland restoration funding for Dyke Marsh, George Washington Memorial Parkway (29 October 2013). An NPS–USGS research partnership played a fundamental role in determining the cause of aggressive post-mining erosion at the wetland, leading directly to its currently scheduled restoration. Photos by Tami Heilman (Department of the Interior) and Milan Pavich (USGS). For more information, see the article by Brent W. Steury and colleagues in this issue.

SOCIETY NEWS, NOTES & MAIL

Call for Proposals out for GWS2015; deadline for abstracts October 1

The GWS Conference is coming to the Bay Area! Plan now to join us in Oakland, California, the week of March 29–April 2, 2015, for "Engagement, Education, and Expectations: The Future of Parks and Protected Areas." Our biennial conference is all about reflection, reconnection, and renewal—a week of stimulating discussion about leading-edge research, innovative practices, and foundational values. GWS2015 is your place to engage with colleagues who share your commitment to excellence … to educate yourself about the latest trends and ideas … to raise expectations for yourself and your career.

It's a good investment. In a world where travel and training budgets are down to the bone, we work hard to make sure attending GWS2015 will pay off in new ideas and techniques that you can put to work right away. That's why we are introducing a new results-oriented conference framework for GWS2015: all sessions and individual presentations will spell out the tangible benefits they expect to deliver to you. We invite you to be a part of GWS2015 by submitting a proposal for a session, paper, poster, or exhibit. To submit an abstract, go to **www.georgewright.org/gws2015** and follow the links. The deadline is October 1, 2014.

Nominations being accepted for 2015 round of GWS awards

Do you have a colleague whose work on behalf of parks, protected areas, and cultural sites is worthy of national recognition? If so, please consider nominating that person for a 2015 George Wright Society Award. "Imagine Excellence," the GWS Awards program, recognizes outstanding accomplishments in fields associated with research in, administration and management of, and communication about parks, other kinds of protected areas, cultural sites, and related supporting activities. There are five awards, given every two years at the GWS conferences:

- The George Melendez Wright Award for Excellence (the Society's highest award)
- The GWS Cultural Resource Achievement Award
- The GWS Natural Resource Achievement Award
- The GWS Social Science Achievement Award
- The GWS Communication Award

The next round of awards will be presented during the 2015 GWS Conference. GWS awards consist of a plaque, payment of the winner's expenses to travel to the conference, and a year's complimentary membership in the Society. For a complete description of the five GWS awards, and a link to the online nomination form, go to **www.georgewright.org/awards.** The deadline for nominations is November 1, 2014. Please note: nominations must come from GWS members in good standing. However, the nominees do not have to be GWS members.

Updates: GWS joins CESU, helps prepare for World Parks Congress, more

It's been a busy spring and early summer here at the Society, aside from the usual round of work of publishing *The George Wright Forum* and making advance preparations for the biennial conference. Here's a thumbnail sketch of some of the other things we've been up to:

- In July we were notified that our application to join the Great Lakes–Northern Forest Cooperative Ecosystem Studies Unit, based at the University of Minnesota, had been accepted. CESUs provide research, technical assistance, and education to federal land management, environmental, and research agencies and their partners. By joining the GLNF CESU, we will have additional flexibility to partner with CESU federal agency members and nonfederal CESU member organizations on projects of mutual interest.
- We are taking part in preparations for IUCN's World Parks Congress, coming up in Sydney, Australia, in November 2014. We provided peer review of the manuscript of the forthcoming global guidebook *Protected Area Governance and Management*, sponsored by IUCN and to be published by the Australian National University Press. As another voluntary contribution to the World Parks Congress, we are providing editorial and layout services to a new volume in the IUCN World Commission on Protected Areas' Best Practices Guidelines Series, this one on climate change.
- Working with the National Park Service Northeast Regional Office, we helped conceptualize and organize a successful set of two webinars leading into a one-day symposium on the impacts of climate change on cultural heritage resources in the coastal zone. Over 40 people participated in the two webinars and the symposium. A report of the project is forthcoming.
- We have agreed to help with the organization of the next World Ranger Congress, to be held May 2016 in Estes Park, CO. The congress is the global gathering of rangers/wardens, and is sponsored by the International Ranger Federation and the Association of National Park Rangers.
- We are serving as fiscal administrator for a major grant to a team of consultants from the United Nations Development Program. The grant funds an analysis of the effectiveness of past UNDP grants to the Global Environment Facility.
- We launched the Biosphere Associates chapter of GWS, which is for members who are interested in biosphere reserves. The chapter is being updated on the current UNESCO review of the US biosphere reserve program. Separately, we are moving toward the creation of the first campus-based student chapter of GWS. More on that in the next issue of the *Forum.*

Erratum

Some printed copies of the April 2014 issue (volume 31, number 1) that were sent to members contained an error in Ryan Michelle Scavo's paper "A Mission for Sustainability amidst a Changing Climate." In those copies, a table mistakenly appears in place of Figure 6, which should have depicted a press conference announcing the release of the National Park Service's Green Parks Plan. Other printed copies were unaffected, and the PDF version of the article, available online at www.georgewright.org/311scavo.pdf, is correct.

Professionalism and its Discontents

Diane Barthel-Bouchier

David Harmon's essay in a previous issue of the *Forum* described how National Park Service (NPS) personnel became a target for both political and public animosity during last autumn's government shutdown. Harmon drew our attention to, among other problems, the public's lack of understanding of the professionalism required to keep the parks open. "There is a widespread failure to understand the NPS mission," he noted, "and the basic requirement that national park resources need both protection and professional stewardship."[1]

This sense that one's work is under-appreciated and/or misunderstood is shared by other heritage professionals. In the course of my research for a recent book on cultural heritage and sustainability, the professionals I interviewed or met at conferences frequently expressed similar complaints.[2] Here I argue that these perceptions in fact reflect major changes in the status of professionals in general over the past century and also specific points of tension relating to the public image of heritage professionals in particular. A clearer perception of the deeper issues involved may point the way toward better policies to deal with them.

Let us examine then in turn both the general trends and more specific issues relating to natural and cultural heritage professionals.

General trend #1: From moral leader to scientific expert

Cultural and natural heritage conservation are relatively new professions, but they nonetheless participate in trends affecting the liberal professions as a whole. In his provocative volume *In an Age of Experts: The Changing Role of Professionals in Politics and Public Life*, Steven Brint argues that over the course of the 20th century professionals went from being seen as responsible for setting the moral standards of their communities—that is, as highly qualified people who were placed in a position of trust—to being viewed as scientific experts with no particular ties to communities and no particular moral authority. Brint writes, "From a sociological perspective, expertise is now a resource sold to bidders in the market for skilled labor. It is no longer a resource that requires an extensive sphere of occupational judgment about purposes."[3]

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Both cultural and natural heritage conservation took a decidedly scientific turn during the second half of the 20th century. Overall, it can be said that this scientific approach has served to increase the prestige of heritage professionals and their organizational field: that is, all the organizations active in this area who interact with each other, with the government, and with the public at large.[4] Nonetheless, problems have arisen over the course of the years regarding the use of science as a source of legitimacy for cultural and natural conservation.

The first problem is that, while science is evident in some NPS job titles—ecologist, fish biologist, forestry technician—it is less evident to the public that other job titles—historian, museum professional, or landscape architect—can also be guided by a scientific approach. And what about other jobs, such as human resources specialists or park police? What is their status in the eyes of the public? The second problem is that claims to science do not always impress park visitors. As historian Françoise Choay has written about cultural heritage sites, "The Parthenon, Saint Sophia, Borobudur, and Chartres recall the enchantment of a quest that, in our disenchanted world, is proposed by neither science nor critical analysis."[5] The same might be said of the parks. Some of the earliest parks have achieved near-sacred status: Mount Rushmore, Yellowstone, the Grand Canyon. But what about other, more recent additions? Do all the parks and protected areas within the system truly recall the enchantment of a personal quest or a grand national narrative? Or are they recognized and protected primarily because of their assumed scientific importance, their distinctive landscape or habitats, or their relevance to a specific moment in American history?

Science serves conservation by protecting against the many forms of personal or group prejudice that could bias site selection, protection, and interpretation. Science has also played a key role in creating a system of best practices and shared standards. However, this positive role has its negative counterpart, for the public frequently appears unimpressed with scientific expertise and is suspicious about those who use it to assert the superiority of their position. As David Lowenthal has written, the professionalization of heritage conservation has served more to increase public distrust rather than trust: "With it goes resentment that heritage concerns are dominated by elites and special interest groups, and suspicions of self-interest undermine appreciation of heritage as a public commodity."[6] The National Park Service has sought to fight this impression by becoming increasingly user-friendly. But the great divide still exists between experts and audience, as the budget crisis demonstrated only too clearly.

Overall, the public appears reluctant to view science as holding the key to the global future. Indeed, sociologist Krishan Kumar demonstrates how utopian visions of a future based on the popular image of science have been balanced by *dystopic* visions of a future world dominated by science and deprived of human values.[7] These dystopic visions reflect the fact that scientific approaches often appear ill-suited to the task of resolving problems of social policy, especially those problems that require some measure of prediction of future trends and outcomes.[8] The government shutdown and the protests it engendered reflect just such complicated problems whose solutions are not to be found in pure science but rather in a creative mix of social science approaches and public engagement. Heritage professionals like to claim that heritage conservation is more about people than about places, more about looking toward the future than preserving the past. Yet the act of claiming the status of science *by itself alone* does not appear to be a future-oriented strategy for dealing with the challenges that lie ahead, challenges relating to ecological crisis, economic reversals, and public policy standoffs.

General trend #2: Growing tension between democratization and maintenance of expert control

Cultural and natural heritage conservation has come a long way since the founding days of Britain's National Trust, when heritage was considered quite naturally the preserve of the elite. Robert Hewison recounts how Lady Sylvia Sager, whose great-grandfather and grandfather founded the Dartmoor Preservation Trust, responded to the suggestion that the trust should try to involve more working-class people. For Lady Sylvia, such involvement would mean the "entry of elements that favor unrestricted motoring and caravanning and resent restraints on building or advertising." Dartmoor, she argued, was unique and of national importance, and could "no more be left in the care of local farmers than Oxford's colleges (could) be left in the care of the car workers of Cowley."[9] Indeed the very concept of "trusts" assumes a tutorial relationship between heritage managers and their public, one that puts the public in the position of undisciplined children likely to break the furniture and bother the animals. As Robin Fedden wrote, "In a utopia where a perfect sense of values prevailed there would be no place for a National Trust."[10] Yet the ready mention of "perfect values" reflects an elitist assumption of superiority over those who value heritage less highly.

This state of affairs began to change in the late 1960s and early 1970s with the development of what became known as the New Social History. A younger generation of historians influenced by the sixties no longer wanted to do what they considered "elitist" history or the history of presidents and kings. Instead, women's history, ethnic history, and the history of the working class became the most popular avenues of inquiry, and a range of methods both qualitative and quantitative were put to use to construct history from below. Enthusiasm for this approach rapidly spilled over into the heritage field, even if efforts to preserve the visible reminders of working-class industrial history did not always meet with unanimous approval of the working classes. Tamara Hareven noted that some of the strongest opposition to the preservation of New England textile mills came from the former workers and their families who wanted to forget the past rather than to commemorate it.[11] Similarly, Dominique Vanneste found that residents of 19th-century industrial neighborhoods in Ghent, Belgium, had absolutely no interest in seeing the old textile factories restored, and were more concerned with whether or not restoration would increase traffic in the neighborhood.[12]

Yet it is one thing to try to attract a broader public to cultural or natural heritage, and quite another to resolve tensions between expert control and public expectations. This gap is reflected in the social status of conservation professionals. For sociologist Andrew Abbott, determinants of status differ depending on whether one is a member of a particular profession or of the public it is meant to serve.[13] Within a profession, the further one's activities are separated from actual contact with the public, the higher the status one is accorded by one's colleagues. Thus the purely conceptual architect, or the architect who designs only a few highly emblematic structures, has higher status than the one who works on primary school additions; the university professor who teaches few students has higher status than the one who teaches classes with large enrollments; the scientist engaged in pure research has higher status than the one working on a problem in applied research. Direct and open contact with the public is seen within professions as potentially polluting and even dangerous, and high-status practitioners are often separated from unsolicited contact with the public by layers of administrative support. While professions can and do occasionally reward those members whose work reminds them of their essential public service role, on a day-to-day basis status tends to follow separation from public contact rather than immersion in it.

By contrast, the public tends to be most impressed by professionals who display a willingness to engage on a personal level with relevant issues. Examples would include physicians who appear on television talk shows or lawyers who write advice columns in popular magazines. It would also include professionals who dedicate their talents to solving real-life problems in local communities and who commit for a substantial period of time, rather than just flying in to make guest appearances. In the same way, members of the public appear less concerned with whether or not heritage is a science; they are more concerned with whether heritage conservation adds appreciably to the quality of their lives and that of their communities. These are reasonable concerns, and indeed it can be argued that they are shared by many NPS professionals. But the different starting points of public and professionals reflect more than a problem in communication: they also reveal deeper cultural assumption about how parks contribute to this quality of life, and what happens when access is denied, even temporarily.

Shutdown politics and deep culture

David Harmon's article emphasized the fact that journalists quickly focused on the national parks to illustrate the drama and significance of the government shutdown. The press *could* have used closed IRS offices as their example, but that would only have delighted the public. By contrast, many Americans hold a positive attachment toward the parks as a place of family vacations and outings, of emotional regeneration and spiritual renewal. This, at least, is something to celebrate. In this context, the venting of emotion over their closure is very understandable.

Better understood, the anger expressed by certain members of the public over the closing involved issues of control, and whether the relationship between experts and public is the old tutelary relationship between unequals referred to above, or whether it takes the form of contract relationships between equals, as, for example, when we hire accountants to help with our taxes. NPS has been telling the American public that we are in a contract relationship with them rather than a tutelary one. It tells us that we own the parks and that NPS is there simply to look after them for us, conserving them, interpreting them, and guaranteeing access. If that's the case, then the parks' closure represented a breach of contract. We the public have done our bit by paying our taxes. The fact that contracted services are not being provided makes us begin to wonder what we've been paying for in the first place. If the parks are truly "our property," surely they could make do with a skeleton crew just as the trains do, or as is the case with other businesses when workers go on strike? A few maintenance men could keep things in order until the politicians sort themselves out.

Members of the public rightly suspect that they are not being treated like adults but like children, and that the parks are holding back their candy. The old system of tutelage has never, in fact, gone away. The professional experts are intent on maintaining firm control. That is, after all, their job, and a hard one at that. It is not simply the parks that are being managed, it is also the public. In the words of the cartoon character Pogo, "We have met the enemy, and he is us!" Everyone within NPS is well aware that the parks must constantly battle against acts of vandalism, theft, and other behaviors that endanger both natural and cultural sites. The fact that this control often remains invisible, other than the passing presence of park police, reflects positively on the professionalism of the service. But the public suspects that the wizard is still behind the curtain, pulling switches and levers to manipulate, even if it is said to maximize, the visitor's experience.

This contradiction reflects the deeper malaise that at least some Americans feel toward their government. When local residents oppose the creation of a new national park, a common theme is the loss of control over the land. But the control that concerns them is not over how to deal with invasive insect or plant populations or how to manage staff and provide services. Rather, the loss of control is more a fear of one's self being controlled, of not being allowed to hunt, fish, or picnic when and as one will. This in turn reflects a broader current in American culture, often positively referred to as rugged individualism, negatively as a refusal to respect the claims of the commons. As we have seen in the lamentable shutdown episode, NPS serves as a lightning rod for endemic resentment toward the government as a whole.

What, then, is to be done? If the problem truly reflects a more fundamental discord within the social contract between government and public, it is unreasonable to think that NPS alone can resolve the conflict. All NPS can do is to work toward making the public more aware of the complexity of tasks involved in operating and conserving the national parks and of demystifying the professional expertise necessary to their accomplishment. The public clearly understands and values its right of access to national parks: that much was made clear by the shutdown. What it needs to develop is a better appreciation of the responsibilities involved in their conservation and of its role in contributing toward meeting them.

Conclusion

In this age of ecological crisis, economic cutbacks, and resulting social dislocations, the National Park Service will need a higher public profile and a higher degree of public support. It can achieve this not by disavowing the science ingrained in much of its work or the professionalism that has allowed the accomplishment of many worthy actions. It must do this by finding new visions more in-line with public concerns: visions that can be communicated by a range of media, not just organizational websites and welcome centers. In working toward the goal of achieving more visible and effective outreach, the National Park Service should move beyond *science* to draw more heavily on *social science* and its findings on topics such as how to build trust between experts and publics and how to motivate people to make difficult personal choices and to work toward social change.

Endnotes

1. David Harmon, "Six Shutdown Lessons for the National Park Service and its Supporters," *The George Wright Forum* 30:3 (2013), 242.
2. Diane Barthel-Bouchier, *Cultural Heritage and the Challenge of Sustainability* (Walnut Creek, CA: Left Coast Press, 2013).
3. Steven Brint, *In an Age of Experts: The Changing Role of Professionals in Politics and Public Life* (Princeton, NJ: Princeton University Press, 1994), 15.
4. Paul J. DiMaggio and Walter W. Powell define an organizational field as "those organizations that, in the aggregate, constitute a recognized area of institutional life." See their "The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality," in *The New Institutionalism in Organizational Analysis*, Walter W. Powell and Paul J. DiMaggio, eds. (Chicago: University of Chicago Press, 1991), 64. For more theorizing on organizational fields, see Pierre Bourdieu, *The Field of Cultural Production: Essays on Art and Literature*, Randall Johnson, ed. (New York: Columbia University Press, 1993.
5. Françoise Choay, *L'allégorie du patrimoine*, rev. ed. (Paris: Seuil, 1996), 183.
6. David Lowenthal, "Heritage Stewardship and the Amateur Tradition," *APT Bulletin* 30:2/3 (1999), 7.
7. Krishan Kumar, *Utopia & Anti-Utopia in Modern Times* (Oxford: Blackwell, 1987).
8. In their classic article "Dilemmas in a General Theory of Planning " (*Policy Sciences* 4 (1973), 155–169), Horst W. J. Rittel and Melvin M. Webber identify eight specific traits that make policy-oriented problems unsuited to purely scientific solutions.
9. Robert Hewison, *The Heritage Industry* (London: Methuen, 1987), 140.
10. Robin Fedden, *The Continuing Purpose: A History of the National Trust, its Aims and Work* (London: Longmans, 1968), 53.
11. Tamara K. Hareven, *Amoskeag: Life and Work in an American Factory-City* (New York: Pantheon, 1978).
12. Dominique Vanneste, "Conservation of Built-up and Social Heritage in 19th Century Industrial Neighbourhoods: the Impact of Identity in Some Neighbourhoods in Ghent (Flanders)," in *Conservation in Changing Societies: Heritage and Development*, Teresa Patricio, Koen Van Balen, and Krista De Jonge, eds. (Leuven: Raymond Lemaire International Centre for Conservation, 2006), 305–312.
13. Andrew Delano Abbott, *The System of Professions: An Essay on the Division of Expert Labor* (Chicago: University of Chicago Press, 1988).

Diane Barthel-Bouchier is professor of sociology at Stony Brook University, Stony Brook, New York. A recognized expert in the sociology of heritage, art, and culture, she is the author of *Amana: From Pietist Sect to American Community* (1984), *Putting on Appearances: Gender and Advertising* (1988), and *Historic Preservation: Collective Memory and Historical Identity* (1996), and, most recently, *Cultural Heritage and the Challenge of Sustainability* (2013), as well as over 30 articles published in professional journals and edited volumes.

Letter from Woodstock

Rolf Diamant

An Urban Parks Agenda for Everyone?

I begin my eighth Letter from Woodstock by expanding upon a previous one ("Stewards of Our Heritage," March 2013) that referenced preparations for the 2016 centennial of the National Park Service (NPS). In that Letter I suggested "broadening the emphasis beyond the parks themselves—to also highlight the many ways national parks and programs 'preserve and support' the well-being and aspirations of communities and people who use them." I intentionally used the word *broadening* because an essential challenge facing NPS and almost all park and protected area systems is how to deliver high-quality public services and consistent stewardship but also be adaptable enough to remain relevant and responsive to the urgent needs and concerns of contemporary life. There is also a subtle shift in perspective: *broadening* a conversation that is often centered on *what is best for the future of parks* to a conversation that is expanded to include *what is best for a larger set of social and environmental objectives* and ways that parks, in collaboration with other institutions, can help achieve those objectives.

Former NPS Director Roger Kennedy spoke of the "usefulness" of national parks in the context, for example, of how they played an outsized role in emergency conservation, employment, and recreation projects during the Great Depression. The national park system also represented a popular national institution in a time of profound social demoralization. I would suggest that NPS continues to play a unifying role today in a country that seems pulled so in many different directions. The 2009 National Parks Second Century Commission Report described the national parks "as community builders, creating an enlightened society committed to a sustainable world." The current National Park System Advisory Board,

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building on the National Parks Second Century Commission, articulates this higher purpose for NPS: "actively working to advance national goals for education, the economy, and public health, as well as conservation."

I don't take for granted (though I certainly won't be around to see) that there will be a national park system to celebrate a third century in 2116. Though I am not inclined to either pessimistic or dystopian thinking, I have come to believe that nothing can be taken for granted; good work that has been done can also be undone. (As I write this, the Australian government, only a few months before the World Parks Congress convenes in Sydney, is *repealing* landmark legislation to reduce greenhouse gas emissions.). NPS, like many other public institutions, will continue to be subject to a variety of stress tests, evaluating things like resiliency and adaptability, purpose and meaningfulness, ecosystem and cultural services, collaborative relationships, and their overall relevancy to what people care deeply about. That is why the work being undertaken by the advisory board and by a number of national parks and partner organizations to broaden the usefulness and relevancy of the national park system is so vitally important. Here are a few examples.

NPS, New York City, and a consortium of research institutions are using the Jamaica Bay unit of Gateway National Recreation Area as a living laboratory for testing new approaches for building climate change resiliency in urban coastal ecosystems. This is not the only place in the national park system where there is new thinking and research about climate resiliency, but given the devastation that Hurricane Sandy inflicted on the densely populated barrier islands of the metropolitan New York/New Jersey area, there is a particular sense of urgency to the Jamaica Bay project.

I have described in a previous Letter how the partnership between the Presidio Trust, NPS, and Golden Gate National Parks Conservancy is breaking new ground on integrating sustainable city living, historic preservation, and park design at the Presidio of San Francisco, including the first national historic landmark property to be certified by the US Green Building Council as "LEED for Neighborhood Development" for "smart growth, urbanism and green building." This ambitious re-purposing of vast military holdings for public benefit and use is only part of the story. Concurrent with this great transformation, an extraordinary bond is being forged between these national parks and people and communities of the San Francisco Bay Area, drawing the attention of park and protected area managers from all over the world.

On a very different scale, there is the interesting example of New Bedford Whaling National Historical Park's Youth Ambassador Program (YAP!), a partnership project between NPS and Third Eye Youth Empowerment, a nonprofit dedicated to "building community and national pride through a series of learning experiences, skill development and real projects … to improve the community, centered on the principles of economic and social equality." The mission of the Youth Ambassadors is to "unite young people, utilizing Hip Hop, a common cultural art form and voice for the people, to engage and empower youth to positively change themselves and their community." Working with New Bedford Whaling National Historical Park, the Youth Ambassadors are producing a series of music videos, including their powerful hip-hop video "54," about the 54th Massachusetts, the African-American regiment recruited by Frederick Douglass during the Civil War. The young performers infuse the narrative with their own distinct voice and message using an evocative, if unorthodox, interpretive format, making this compelling "Civil War to Civil Rights" story accessible to their friends and peers.

NPS is embarking on a landmark systemwide effort to develop what is being called an "urban agenda." This urban agenda, is in part, an outgrowth of the 2012 conference titled "Greater & Greener: Re-Imagining Parks for 21st Century Cities," organized by the City Parks Alliance in partnership with the New York City Department of Parks & Recreation. An "affinity caucus" of NPS conference attendees, mostly from urban national parks, joined NPS Director Jon Jarvis to initiate an ongoing participatory process for identifying policy changes that will enable NPS urban parks and programs to "step into their power" with the intent of becoming a larger, more relevant part of urban life in America.

The scale of current NPS urban activities may come as a surprise to many people. Beginning in the early 1930s, Congress has gradually expanded the urban footprint of the National Park Service, establishing new units of the national park system in 40 of the country's 50 most-populated metropolitan areas. Today, these national parks make up nearly one-third of the entire park system and draw approximately 40% of all national park users. The NPS National Capital Region and its 34 national parks in and around Washington, DC, for example, serve an urban population of more than five million people. Congress has also authorized more than two dozen different NPS programs providing urban communities with a wide range of services, including historic preservation tax credits, recreation grants, and conservation technical assistance.

Throughout this process of developing the urban agenda, the NPS Stewardship Institute (formerly the Conservation Study Institute) has been coordinating and documenting a series of webinar conversations with "communities of practice"—self-selecting groups of urban park practitioners—focusing on specific subjects such as urban innovation, economic revitalization, connecting youth to nature, and urban parks as portals for diversity. Attention tended to focus on what I might call "nuts and bolts" problems: how to streamline the use of legal authorities for leasing and cooperative agreements and how to align NPS funding and program priorities to concentrate available resources for greater impact. Lessons learned are shared for a variety of relatively new NPS-sponsored, community-based programs dealing with public transportation, safe routes to school, urban gardening, and partnerships with health providers. There is also an imperative to build a stronger "culture of collaboration" in which NPS operates as one partner among many. Underpinning all these discussions is the implicit vision of NPS as a "catalyst for civic renewal" consistent with the overall direction of Second Century Commission, the NPS director's Call to Action, and the work of the National Park System Advisory Board.

The urban agenda is still very much a work in progress that will have to surmount competing interests and priorities, political jockeying, and bureaucratic inertia. There is also a danger that 2016 NPS centennial activities and a looming national election may, in effect, swamp it. There may also be internal resistance. Some may choose to interpret relevancy primarily in terms of making a fixed set of traditional park experiences more widely accessible rather than exploring ways to expand those experiences in order to engage a broader cross-section of the public (think "54"). Nearly 40 years ago, while I was working on the startup of the Golden Gate national parks, I clipped a *Sierra Club Bulletin* commentary by Jonathan Ela hammering NPS and other administraton officials for reversing previous support for urban national parks and testifying *against* making Cuyahoga Valley, located between the cities of Cleveland and Akron, Ohio, part of the national park system. Contending that NPS personnel appeared at that time more comfortable with park users that looked and acted just like they did, Ela illustrated his article with this drawing by Steven M. Johnson (reproduced with permission of the artist). Decades later, Bill Gwaltney (formerly with NPS—now with the Smithsonian), while working on diversifying the NPS workforce, would remind his colleagues that "people feel better [using parks] when they think their reality, their experiences, their culture, their expectations are on some levels mirrored in their national parks."

National parks may also come to over-rely on their social media and marketing as substitutes for personal engagement and the patient hard work and risk-taking that builds trust and meaningful long-term relationships between parks and communities. Protecting parklands within clearly defined boundaries has always been a core function of the agency and it will no doubt be a challenge getting people to see an investment in "civic renewal," particularly as budgets contract, as a central strategy for the long-term survival of national parks.

Even under the most favorable circumstances, moving an urban agenda forward will be difficult. There is a recurring concern that any reform, however desirable, might set a precedent that unintentionally provides an opening for parties with interests inimical to national parks to do harm. Such concerns deserve careful consideration, and risk-taking must be judicious, yet the alternative of always playing it safe and resisting change has significant downstream dangers.

Let us hope that the newly established Urban Committee of the National Park System Advisory Board may be able to advance an NPS urban agenda, and, in the face of these obstacles, help sustain its momentum. Those working on the urban agenda understand that a system of national parks and programs that is perceived as being accessible, engaged, and resourceful will be a system that is ultimately valued, supported, and strengthened over time. This is what an earlier Advisory Board report, *Rethinking National Parks in the 21st Century*, envisioned when it advocated that parks reach "broader segments of society in ways that make them more meaningful in the life of the nation" and help build "a citizenry that is committed to conserving its heritage and its home on earth."

A 21st-century agenda for urban national parks is, in many fundamental ways, an agenda for all national parks.

Our Shared Conservation Legacy: Past, Present, and Future—The First Legacy Organization Workshop

Ryan L. Sharp

From April 11–13, 2014, an ambitious group of 26 conservation organizations gathered at the US Fish and Wildlife National Conservation Training Center (NCTC) in Shepherdstown, West Virginia. Specific legacy organizations were invited whose missions include interpreting and extending our national legacy of conservation. Organizations such as the Aldo Leopold Foundation, the Ding Darling Wildlife Society, the Murie Center, and the George Wright Society came together, for the first time, to examine the past, share current achievements and challenges, and discover pathways to the future.

A primary goal of the meeting was to engage youth representatives of invited legacy organizations to provide input about how to include this demographic in the future of conservation. The discussions carried out during this roundtable were enlightening, and provided a few key points to consider for organizations like the George Wright Society. Many of the youth representatives expressed a need to celebrate achievement, and emphasize hope when discussing conservation. It can be easy to take on a "gloom and doom" type of attitude with so many challenges present on the conservation front. Listening and inviting youth to the table was also stressed as an important avenue to engagement. Many young people may already be practicing conservation, but are not calling it that; understanding the younger generation's perspective can help bring more into the fold. One suggestion to achieve this is to begin collecting stories from youth about their conservation-related activities, and by doing so, display that there are several avenues to the common goal of protecting our natural and cultural heritage. Also, in terms of legacy organizations, finding ways to make them more accessible by changing the narratives commonly told; specifically, make the story less dense, and more relatable to youth. It was suggested that more focus be placed on conservation values, or the significance of the place, and less on the story of the individual.

The youth roundtable also had a lengthy conversation about how to best utilize social media. The importance of a website or "landing page" was stressed, which can act not only as a source of information, but also as a place to connect with the organization's Facebook, Twit-

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ter, or Instagram (to name a few) accounts. It is not enough to just have these accounts, they must be maintained and updated to attract interest in the organization. Social media outlets can be used to show what youth are doing related to conservation. Stories and pictures can be shared that will connect a diverse collection of youth engaged in conservation activities (which as mentioned above, may have varying definitions). These stories and pictures will also give those considering involvement in conservation organizations a place to see how they would fit in, or provide them with someone to ask questions about the organization. The importance of social media cannot be denied, but the members of this youth discussion group also emphasized that face-to-face contact cannot be replaced and time needs to be set aside for this.

This first meeting of conservation legacy organizations led to many fruitful conversations and ideas for the future. Not only did we have a great exchange about how to include the next generation of conservationists, but we also shared how we can work together towards a common goal. We discussed the value of making this an annual meeting to ensure the momentum established during the short two days does not dissipate. On the first night of the meeting we watched a biography of J.N. "Ding" Darling, the famous cartoonist and conservationist. The movie provided our mantra for the remainder of the meeting. Ding Darling stated that "eleven million horses running wild couldn't pull a rubber-tired baby buggy to town unless there was a harness to hook them to the load." These words provide an important reminder that conservation organizations working together are more powerful and efficient in meeting our shared conservation goals than each working in isolation.

Board member Ryan L. Sharp attended the meeting as the GWS representative.

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NPS–USGS Collaboration to Support Science and Resource Management in the National Parks

Vincent L. Santucci, guest editor

Introduction

Vincent L. Santucci

In 2016, the US National Park Service (NPS) will celebrate the agency's centennial and one hundred years of resource stewardship and public service in the parks. Throughout this history, the mission of the bureau as defined in the National Park Service Organic Act (1916) has endured and flourished into a system of parks and protected areas across the American landscape. The management strategies and practices implemented for and in the parks have undergone some evolution and maturation based upon new laws, advancing technology, and a wide variety of changing social, political, economic, and environmental priorities.

In order to effectively meet the demands of a growing park system and the expanding public use of the parks, NPS ventured into public and private partnerships, recognized the benefits of philanthropy and volunteerism, and engaged in opportunities for scientific collaboration. The need to integrate more science into park planning and decision-making was becoming increasingly more apparent and is well chronicled by NPS historian Richard West Sellars in his book *Preserving Nature in the National Parks: A History* (Sellars 1997). The need for science in park management is clearly evident today in the attempts to understand the impacts of climate change on parks, protecting air and water resources, and evaluating the health of marine and terrestrial ecosystems. NPS is not working alone on these critical science issues and collaborates with many other government agencies, scientific institutions and organizations, and other groups to understand and address them.

The US Geological Survey (USGS) is one of the principal entities collaborating with NPS on scientific issues. A few examples of NPS–USGS collaboration are presented in this special issue of *The George Wright Forum*. The science-focused mission of USGS supporting the diverse needs of the Department of Interior bureaus is reflected in the 2010 USGS Science Strategy. The new USGS organization is aligned into seven mission areas that provide

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the professional support and capacity to address the science needs of the nation and Department of the Interior agencies.

The historical relationship between NPS and USGS is well documented in the administrative histories for both bureaus. These agency connections were initially forged during the post-Civil War era before either USGS or NPS were established as federal bureaus. The government's interest in the resources of the American West led the Department of Interior to embark on four great geological and geographical surveys of the western territories in 1869. One survey, led by Ferdinand V. Hayden into the Yellowstone area, compiled information, photographs, and paintings which soon inspired the American people and Congress to establish Yellowstone National Park on March 1, 1872. After USGS was established in 1879, mappers and scientists conducted work in the early parks that were established prior to the creation of the National Park Service in 1916 (Rabbitt 1989).

Today, collaboration between NPS and USGS involves hundreds of science and resource management projects in the parks. Collectively, this collaboration helps to inform managers and the public about the condition of park resources and the science needed to support informed decision-making. The interagency cooperation and sharing of new and state-of-the-art technologies have enabled evaluation and study of parks and their resources that could never be contemplated when NPS was founded in 1916.

We dedicate this special issue of *The George Wright Forum* to all NPS and USGS employees who have recognized and fostered interagency collaboration, which supports the highest levels of science and stewardship in the management of our national parks.

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Interagency Partnership to Assess and Restore a Degraded Urban Riverine Wetland: Dyke Marsh Wildlife Preserve, Virginia

Brent W. Steury, Ronald J. Litwin, Erik T. Oberg, Joseph P. Smoot, Milan J. Pavich, Geoffrey Sanders, and Vincent L. Santucci

Introduction

The narrow-leaved cattail wetland (Hopfensperger and Engelhardt 2007) known as Dyke Marsh formally became a land holding of George Washington Memorial Parkway (GWMP, a unit of the national park system) in 1959, along with a congressional directive to honor a newly-let 30-year commercial sand and gravel dredge-mining lease at the site (Litwin et al. 2013; Figure 1). Dredging continued until 1974 when Public Law 93-251 called for the National Park Service and the United States Army Corps of Engineers to "implement restoration of the historical and ecological values of Dyke Marsh." By that time, about 83 acres of the marsh remained, and no congressional funding accompanied the passage of the law to effect any immediate conservation or restoration. Decades of dredge mining had severely altered the surface area of Dyke Marsh, the extent of its tidal creek system, and the shallow river bottom of the Potomac River abutting the marsh. Further, mining destabilized the marsh, causing persistent erosion, shoreline retreat, and tidal channel widening after mining ceased (Litwin et al. 2013). Erosion has continued unchecked until the present; approximately 50 acres of the original marsh are now estimated to remain (Figure 2). The specific cause of persistent erosion had been unknown prior to this collaborative study (Litwin et al. 2013) but previously was assumed to be due to flooding by the Potomac River.

GWMP needed to (1) quantify the magnitude of acreage loss, (2) determine the most significant causal agents of marsh erosion, and (3) understand the initial environmental conditions in place prior to dredging, in order to comply with Public Law 93-251 and restore Dyke Marsh to a more naturally sustainable geological and biological system. In 2009, the National Park Service (NPS) entered into partnership with the US Geological Survey (USGS) to investigate the causes and rates of unabated marsh erosion; the results of that part-

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Figure 1. Aerial photos of Dyke Marsh, within George Washington Memorial Parkway. All were taken at approximately low tide conditions. (A) 1938 photo of marsh showing its historical "pre-mining" configuration. By 1940 deep-water access had been dredged from the Potomac River's main channel to the promontory (the approximate initiation of shoreface mining; Litwin et al. 2013, their Appendix 1F). By 1949 the promontory and its wetland forest were mined out (Litwin et al. 2013, their Figure 3). A white line showing the 1902 marsh boundary is overlain on this photo for comparison, to illustrate "pre-mining" landform stability at the marsh. Tidal creeks (mouths) are numbered north to south; the original positions of those creek mouths are shown in all four photos. Black boxes indicate first dredge barges (mining) along periphery of Dyke Marsh. Black arrows indicate direction of Potomac River flow (southward). (B) 1959 photo showing the initial mining-out of the promontory that formed the southern shoreline of tidal creek #4, Hog Island Gut. The locality of the first samples ever analyzed (1963) to estimate marsh age is starred, along tidal creek #2. This is the marsh configuration that existed when the NPS was first delegated oversight of this wetland by Congress. (C) 1987 photo showing marsh conditions about one decade after commercial dredging ended at the marsh. The tidal creek networks are mostly mined out. Black boxes indicate several land areas that disappeared since 1987. (D) 2006 photo showing continued erosion along its southern and western shorelines (Hog Island Gut and its tributaries are now eroding the marsh. The four island remnants of the once-intact wetland also are aggressively eroding away. Figure modified from Litwin et al. 2013.

nership (hereafter referred to as the "interagency study") are the subject of this paper. USGS took the lead on geological research (Litwin et al. 2013) that provided a synthesis of existing knowledge and yielded new data on historical marsh configuration, function, and degrada-

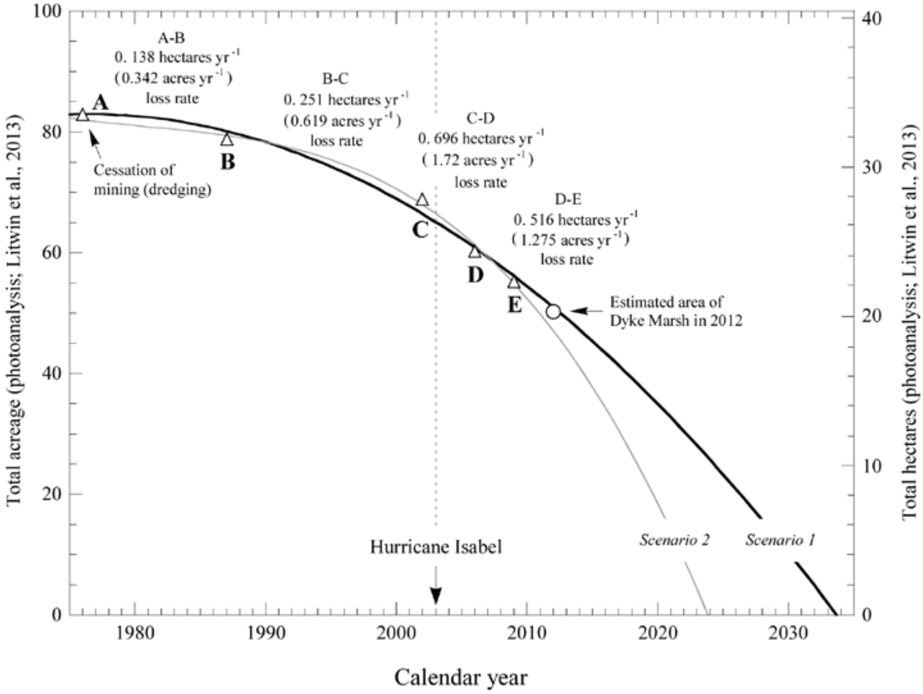

Figure 2. Photo-based acreage estimates of Dyke Marsh (1976–2009), showing marsh size versus time. Note that marsh loss rate is nonlinear. Two equally valid numerically modeled solutions (scenarios 1 and 2) suggest that, without NPS land management remediation, acreage loss rates will increase and lead to the demise of this wetland by 2035 at the latest. Figure from Litwin et al. 2013.

tion. That interagency study focused on (1) quantifying the historical and present-day rates of marsh erosion, (2) determining the natural ("post-mining") causes of marsh erosion, and (3) identifying any human-induced causes that contributed to marsh destabilization and ultimately, to erosional loss of wetland acreage and adjacent river bottom. In turn, NPS provided NRPP (Natural Resource Preservation Program) funding towards the research and logistical support (boat access and GWMP natural resources personnel) to facilitate the necessary site work.

The interagency study integrated radiometric dating, sedimentary textural analysis, field examination of erosional features, analysis of past vegetation (pollen analysis), photoanalysis of past marsh photographic datums, and comparison of navigation maps versus instrumental bathymetry records (i.e., maps from1862 to 2010, versus sonar bathymetry from 1992 and 2009).

The overall research results put into context several geologic factors that likely could diminish the ongoing erosion at the wetland. It also helped park managers to understand the increasing pace of marsh erosion (Figure 3), as well as all of its attendant geologic and ecologic consequences.

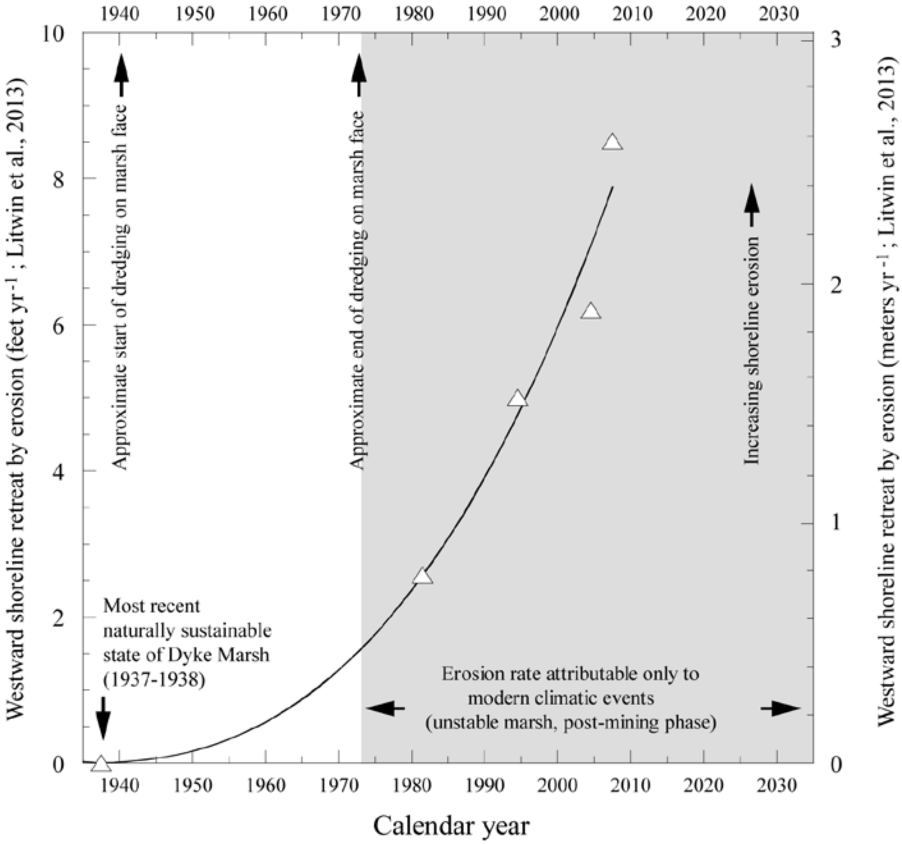

Figure 3. Westward shoreline erosion rates at Dyke Marsh, based on median values measured along 25 fixed reference stations for each of four analyzed time intervals after mining ceased (1976–1987, 1987–2002, 2002–2006, and 2006–2009), with comparison to naturally sustainable "pre-mining" shoreline (1937–1938). This quantifies the increasing erosion of the face of the marsh by northbound storms tracking up the Potomac River valley. Figure from Litwin et al. 2013.

Collaborative study findings

Estimated natural marsh longevity. NPS needed to understand accurately the longevity of the marsh as a persistent landscape feature and the variation in its resident floral communities through time to gain insight on the marsh's past ability to respond to changes in environmental conditions. The first study to estimate the longevity of this wetland (Myrick and Leopold 1963) primarily characterized tidal creek hydrology in the northern half of the marsh. In that study, Estella Leopold[1] analyzed pollen from subsurface channel-bank samples taken from that same tidal creek (creek #2, Figure 1B, indicated by star). The report noted that her field samples yielded pollen assemblages that were similar in character to those found in a Delaware marsh (and which previously had been dated by radiocarbon evidence as 5,000 to 7,000 years old; Myrick and Leopold 1963). This informal comparison became the only known estimate of marsh longevity, and stood for over 40 years, as it was founded on the best available evidence at that time.

USGS researchers took shallow and deep sediment core samples across Dyke Marsh transects, and dated multiple organic samples taken directly from those same cores to get a best approximate age of marsh establishment at the site. The oldest radiometric evidence was obtained from a percussion core taken from the southern marsh, which indicated that marsh probably had developed at this site by the Early Woodland Period (~2,200 BP, or late Holocene). This refined the initial age estimate (Myrick and Leopold 1963), and gave the park updated knowledge of how long the marsh had been in existence and responding naturally to fluctuating environmental conditions. A follow-up high-resolution study of the marsh's paleoclimate history (vegetation response to climate shifts) is in progress. Preliminary results suggest that the forest structure surrounding the marsh has been highly sensitive to climatic warmings and coolings during the past millennium, at short time-scales. In addition, preliminary results suggest the presently observed dominance of narrow-leaf cattail in the Dyke Marsh wetland likely first developed < 1,000 years ago.

Natural and human-induced stressors to the Dyke Marsh tidal wetland system. Multiple factors were implicated in determining why Dyke Marsh is eroding aggressively today, but did so less visibly prior to 1938, based on archival photographic and cartographic evidence. First, the study found no correlation between historical Potomac River flooding frequency and marsh erosion, as had been suspected initially. The study instead determined that other natural processes contributed to the observed persistent marsh erosion. The study noted that by 1949, a long-forested promontory that had existed immediately south of the marsh had been fully removed by the dredge mining. This promontory was underlain by high-quality sand and pea-gravel, making it among the first areas within Dyke Marsh to be targeted for commercial dredging. The study found that elimination of this adjacent forested promontory consequently exposed the marsh to wave energy generated by episodic cyclonic storms (tropical storms and hurricanes) tracking upriver from the south. Prior to 1940, under "pre-mining" conditions and with an intact southern promontory, the maximum linear fetch[2] that potentially would permit waves propagating from the south to be delivered (shoaled) against the southern marsh was close to zero. By 1949, southerly linear fetch exceeded 3 miles, because the promontory that protected the south end of the marsh had been mined out. The removal of the promontory as a buffer gave wind fields of subsequent northbound storm systems a much greater travel path (and opportunity) to build surface waves, and therefore enabled greater potential wave energy to be expended directly against the marsh's southern shoreface.

Prior to dredging, wave energy from the south also had been partly dissipated by the shallow western river bottom along the Potomac River, immediately south of the wetland; historical shallow river depths were confirmed by bathymetry (navigation) maps dating back to 1862. The collaborative study therefore also examined the effects of dredging on the Potomac river bottom adjacent to and south of the marsh. The study found that dredging during the mining phase had occurred to depths extending 30 feet below mean low water in areas that were formerly shallow (2-to-4-foot) river bottom and even previously emergent wetland. This significant change in the depth profile of the Potomac River adjacent to Dyke Marsh continues to have a large impact on how wind-driven waves approach the shoreface of the marsh. On the "pre-mining" marsh the broad shelf of shallow water in conjunction with the forested promontory acted as dual erosion buffers, by causing larger waves to crest and to shoal well before reaching the marsh shoreface. By contrast, the "post-mining" Potomac River bottom profile provides little to no wave-base barrier for maximum-sized waves to shoal against until they reach the marsh shoreface. Furthermore, the 30-foot-deep submerged mining scars within the historical GWMP boundary, observed in recent park bathymetry surveys, are now the loci of aggressive river bottom scour, destabilizing the previously shallow river bottom. As a result, the marsh is increasingly unable to absorb and dissipate storm energy, specifically the wind-driven wave energy from northward-tracking cyclonic summer storms (and probably also cold-season northeasterly storm events, i.e., winter nor'easters).

But even non-storm conditions at the marsh now contribute to persistent erosion. Dredging altered the hydrology by destroying most of the tidal channel network that historically existed on the marsh (based on archival aerial photographs, Figure 1). This original channel network had developed to be approximately in balance for dissipating the energy delivered by daily (non-storm) tides on the Potomac (presently ~3-foot tide range). The "pre-mining" tidal channel network on the marsh directed rising tides and their suspended sediments back into and onto the interior marsh surface through highly sinuous, dendritic, and shallow tidal channels, dissipating that tidal energy, and consequently trapping that formerly suspended sediment onto the marsh surface with each successive tidal cycle. By this process, riverine wetlands along the Potomac served as important natural filters to improve water quality, in conjunction with the tidal cycles. Since dredging began on the marsh, normal tidal flows increasingly exceeded the diminishing marsh remnant's ability to dissipate this non-storm tidal energy and to trap its incoming suspended sediment load. As a result, marsh acreage growth was progressively inhibited. This relatively constant diurnal tidal energy is now being expended across a rapidly diminishing (eroding) marsh acreage, which steadily and notably increases the marsh-tide imbalance, and increasingly impedes the marsh's ability to conserve its acreage. As a result, non-storm tidal energy is now slowly stripping sediment from the interior of the marsh and from its distributaries, rather than adding sediment, as would be predicted under undisturbed and balanced tidal marsh conditions. This non-storm sediment loss is confirmed by modern field observations of deepening and widening tidal channels, tidal channel bank steepening, and shallow nickpoint[3] erosion at the heads of the distributaries, along with surface erosion scour on the interior marsh platform. The USGS study noted that the rate of acreage loss and shoreline loss is now nonlinear, and has become an accelerating feedback loop. The study determined that marsh shoreline erosion (measured due westward) was occurring at a rate of approximately 6–8 feet per year just prior to 2010, and is increasing (Figure 3). From 1976 to 2009, overall marsh acreage loss to erosion has increased from 0.3 acres per year to over 1.2 acres per year, and also is increasing (Figure 2). As a consequence, the study determined that Dyke Marsh likely will disappear within the next 20 years if marsh-tide equilibrium is not restored. These Dyke Marsh wetland erosion rates were unexpectedly high, and found to be comparable in magnitude to wetland erosion rates documented directly along marine coasts of the Mid-Atlantic region, the latter of which suffer the initial impact of landfall hurricanes and tropical storm systems in this area.

Discussion

Other ongoing research at Dyke Marsh (NPS National Capital Region Office of Natural Resources and Science) is yielding independent results that are consistent with these findings, especially regarding an increasing loss of acreage. Since 2006, NPS has been actively monitoring permanent rod surface elevation tables (RSETs; per Cahoon et al. 2002) across the marsh: (1) along the marsh shoreface, (2) along the marsh tidal channels, and (3) on the undissected interior marsh platform (a total of 9 stations). These permanently fixed stations measure the total elevation change of the marsh surface, relative to the bottom of the deep benchmark to which they are attached. The RSET locations also incorporate feldspar marker horizons[4] (Cahoon and Turner 1989) as time datums, along with "frozen-finger"[5] technology (Cahoon et al. 1996) to penetrate the marsh and to get accurate serial measurements of vertical marsh growth due to tides and flood depositional events. Data analyzed to date suggest that average elevation change (including vertical aggradation) of the marsh surface has been keeping pace with relative sea level increases in the Mid-Atlantic region over the past ~80-year trend (NOAA 2014; G. Sanders unpublished data 2014). However, two of the three permanent RSET stations placed parallel to—but inland of—the marsh shoreface are now *at* the retreating edge of the marsh shoreline, and soon will be unusable for monitoring due to aggressive shoreline erosion.

NPS site remediation planning. A restoration and long-term management plan / environmental impact statement (EIS) currently is in final draft form and its completion is anticipated in late 2014. This will provide the National Environmental Policy Act documentation that will guide the site restoration process. The National Park Service and the US Army Corps of Engineers will collaborate on the design and construction of the marsh restoration, with USGS as a scientific advisory partner. The most desirable restoration scenario is to re-balance any natural depositional processes that enable Dyke Marsh to sustain itself in a resilient state. The USGS research helped NPS to understand the geologic processes that build and erode the marsh, and the geologic consequences of human modifications to the marsh's historical configuration. This enabled NPS to select the most effective strategies to mitigate shoreline erosion, as well as strategies to abate the storm-induced degradation and persistent foreshortening of the marsh's largest remaining tidal channel remnant that dissipates tidal energy at this wetland (Hog Island Gut).

Replacement of a promontory in its historical position along the south shore of Hog Island Gut, which had been completely removed by mining between 1938 and 1949 (Litwin et al. 2013), should provide significant protection and stabilization to the marsh, enabling any natural marsh-building processes to increase in effectiveness. Reconstruction of the promontory is a common feature among all alternatives presented in the EIS. It is considered to be an essential requirement for any restoration scenario. The plan includes placing heavy, deep-water fill in the dredge scars near the marsh edge, creating a breakwater at the site of the promontory that was lost to dredging, installing containment cells that will be filled with dredge material to elevations proper for supporting marsh vegetation, and planting native wetland species within those containment cells. Highly sinuous and shallow tidal distributaries for dissipating tidal energy will be created on the new graded surface as part of the remediation, along with continued monitoring of natural sediment deposition rates on the marsh. The active NPS monitoring stations (RSETs) will provide important data on changes in the marsh's ability to trap sediment and to aggrade naturally, as the marsh's acreage and tidal channel network are restored.

The National Capital Region (NCR) of the NPS proposed to Ronald Reagan Washington National Airport in 2013 that Dyke Marsh reconstruction could serve as an acceptable mitigation to counterbalance the loss of ~2 acres of Potomac River bottom upriver (within NCR boundaries), slated to be removed in an upcoming runway extension. The FAA is in favor of this proposed NPS "improvements-in-kind" offer, and has now included that task formally in the airport runway extension project.

Present-day ecosystem services. Despite the erosion and destabilization that currently affects Dyke Marsh, the remaining ~50 acres still provide valuable ecosystem services. Dyke Marsh is located along the scenic GWMP (on the route to Mount Vernon). Approximately 7.4 million vehicles travel the parkway annually (2012 figures), making it a major transportation corridor within the Washington metropolitan area, and it crosses the western edge of the marsh. The marsh acts as a physical storm buffer between the Potomac River and the parkway. At the same time, it provides important green space within a densely populated urban area. GWMP trails at the marsh receive more than 438,000 day-users (foot traffic) annually. Dyke Marsh provides opportunities to enhance the economic productivity of the region through boating, bird watching, fishing, hiking, jogging, biking, and nearby hunting activities. A popular marina and sailing school exists just north of Dyke Marsh. Restoration of this urban wetland will improve each of these diverse public-use services.

Such freshwater wetlands are diminishing nationally as a public and natural resource. Dyke Marsh is the last large remnant of a series of once extensive and numerous tidal freshwater marshes that were lost to expanding development of the Washington area (Updegraff et al. 1954). It has been the focus of many studies of marsh biodiversity and ecology (e.g., Hopfensperger et al. 2006; Mitchell et al. 2007; Barrows et al. 2008; Hopfensperger and Engelhardt 2008; Hopfensperger and Baldwin 2009; Kjar 2009; Steury 2011; Steury et al. 2012, 2013; Cavey et al. 2013; Palinkas et al. 2013). Even in its diminishing state, Dyke Marsh hosts the only breeding population of marsh wrens in the Washington area and provides habitat for a breeding population of the least bittern (rare in the state of Virginia) and state-rare plant species such as river bulrush and rough avens.

Additionally, ~239 species of birds (site nesters, extralocal residents, and transcontinental migratory species) have been documented at this wetland (Johnston 2000; GWMP unpublished data 2014), a diversity that is similar to that observed at other Mid-Atlantic Region coastal sites along the Atlantic Flyway. For example, Prime Hook and Bombay Hook national wildlife refuges (in Delaware, under the jurisdiction of the US Fish and Wildlife Service) document approximately 288 total bird species and 274 total bird species, respectively. If diversity comparisons are made only among total "migratory" (extralocal and non-nesting) species at these three sites, Dyke Marsh hosts ~166 non-nesting species, Prime Hook ~174, and Bombay Hook ~171. By that measure, Dyke Marsh appears to support a *minimum* of ~95–97% of the total non-nesting bird diversity observed at Prime Hook or Bombay Hook, which are two major migratory habitats along the Atlantic Flyway. Preliminary comparisons to Chincoteague National Wildlife Refuge and Assateague Island National Seashore (Virginia), also located along the Atlantic Flyway, yield similar results. Chincoteague hosts ~295 total species (excluding their exceptionally rare taxa such as puffin and jaeger) and ~204 non-nesting species. Assateague hosts ~294 total species, of which 46 taxa are not unequivocally documented and therefore are not counted here (note: nesting species data were unavailable from that site). Based on currently available figures, Dyke Marsh hosts ~81% of the total non-nesting diversity observed at Chincoteague, and ~96% of the presently *confirmed total species* diversity at Assateague. Although the actual component species differ among these five sites, these "non-nesting species diversity" comparisons provide evidence that Dyke Marsh is a similarly significant migratory resource (and urban corridor habitat) along the Atlantic Flyway in the Mid-Atlantic Region.

Impacts of study collaboration

The impacts of this successful NPS–USGS collaboration are grouped into long- and short-term categories below, yielding multiple tangible results from this interagency effort within the US Department of Interior.

Improved ecosystem services. Long-term impacts of restoring Dyke Marsh will include stabilizing two miles of Potomac River shoreline (including along the GWMP, which is, as noted above, a major metropolitan transportation corridor), protecting ~50 acres of existing freshwater tidal wetland, and adding 150 acres of restored wetland in areas where it was lost to dredging. Restoration will help in attenuating tidal energy on the wetland to re-enable natural marsh deposition and in buffering storm energy (to help protect adjacent park and private real estate interests); creating additional economic opportunities for local businesses. Other positive impacts include restoring "urban corridor" wildlife habitat, restoring and increasing historical refugial habitat for endangered species, improving spawning and nursery grounds for (game and bait) fish, and restoring historical habitat for migratory waterfowl (including Arctic-wintering and -migratory species such as the tundra swan and lesser scaup, which have been documented at the marsh). Societal impacts include (1) enhancing natural water filtration along the Potomac River (the source of drinking water for over 4 million people) and in the Chesapeake Bay, (2) increasing natural vegetation-driven denitrification processes to help increase water quality and diminish eutrophication within the Potomac River (Brush 2009; Hopfensperger et al. 2009), (3) helping to reduce sediment transport towards the Chesapeake Bay, (4) increasing local metropolitan carbon storage (carbon sequestration), and (5) improving public recreation and youth natural-science field education opportunities. In these ways, restoration of Dyke Marsh will improve multiple regional-scale ecosystem services and address the NPS Call to Action's Goal #32 ("Crystal Clear").[6]

Restoration appropriations. Short-term impacts include several funding allocations resulting from this research, appropriations that followed an invited congressional briefing by the NPS–USGS collaborators (January 2012) and our published study (Litwin et al. 2013). The initial funds planned for Dyke Marsh reconstruction, as 'improvements-in-kind' in association with upcoming Reagan National Airport runway expansion, will total between $1.7

and 2.5 million. On 29 October 2013, Secretary Jewell held a national press conference at GWMP, announcing that NPS is to receive an additional $24.9 million in Dyke Marsh restoration funds through a competitive grant administered by the Department of the Interior, as part of the 2013 Disaster Relief Appropriations Act (see photo on the cover of this issue). The Dyke Marsh fiscal component alone comprised fully 15% of the national total of $165 million in this storm-relief funding package. These two allocations collectively will enable the restoration of the Dyke Marsh wetland landscape to approximate its "pre-mining" configuration along the Potomac River, and will help to restore part of the extensive riverine wetlands that historically once lined the tidal portions of the Potomac River. Restoring Dyke Marsh's degraded and destroyed wetlands also will help NPS meet the longer-term goal of net gain of wetlands across the national park system (NPS Environmental Policies 2006, section 4.6.5, "Wetlands").

Conclusions

Geology, climatology and meteorology, ecology, and biology are best understood when approached as integrated disciplines. This collaboration was successful because we combined agency expertise, thereby allowing us to understand the interaction of the physical and biological components of this wetland ecosystem. The success of this study also resulted from regular communication with other federal, state, district, local, and nongovernmental entities, including private citizens' groups (e.g., Friends of Dyke Marsh). All were stakeholders in this effort to determine the underlying problems affecting this imperiled wetland. This collaboration demonstrated that a fundamental understanding of geological processes was an important prerequisite to understanding marsh system function (and dysfunction) at this site. Understanding the geologic processes at work on the present marsh remnant helped USGS and NPS to identify appropriate and effective ways to resolve causal problems, rather than only addressing the problematic symptoms generated by a persistently eroding natural, cultural, and recreational resource. Most importantly, this effort highlights the practical value of applying interagency cooperative science to public land management issues, and underscores the benefits of engaging other federal, state, and local stakeholders during that process.

Acknowledgments

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Wildlife Refuge. We thank Larry Cartwright, Kurt Gaskill, Katherine Wychulis, and Ed Eder (Friends of Dyke Marsh) for verification of bird diversity data at Dyke Marsh.

Endnotes

1. Daughter of late naturalist Aldo Leopold, and sister of the 1963 study's coauthor.
2. The distance across open water over which surface waves can be generated by sustained winds.
3. The point of abrupt slope change in the longitudinal profile of a stream or tributary.
4. Powdered white feldspar is applied to the marsh surface, and is buried in place with sediment supplied by consecutive incoming tides.
5. Liquid nitrogen is dispensed into a hollow probe driven directly downward into the moist marsh surface at the SET station each year. The mud in contact with the tube freezes from the liquid nitrogen, and the probe is pulled; the bright white feldspar (now buried, but visible along the probe) allows vertical deposition on the marsh to be measured (per unit time).
6. "Protect the health of our watersheds by improving water quality, aquatic habitat, and ensuring adequate flows for public enjoyment …" (http://inside.nps.gov/calltoaction/pdf/C2A_2013_screen.pdf).

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USGS Ecosystem Research for the Next Decade: Advancing Discovery and Application in Parks and Protected Areas through Collaboration

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Introduction

Ecosystems within parks and protected areas in the United States and throughout the world are being transformed at an unprecedented rate. Changes associated with natural hazards, invasive species, greenhouse gas emissions, and increasing demands for water, food, land, energy and mineral resources are placing urgency on sound decision-making that will help sustain our nation's economic and environmental well-being (Millennium Ecosystem Assessment 2005). In recognition of the importance of science in making these decisions, in 2007 the US Geological Survey (USGS) identified ecosystem science as one of six science directions included in a comprehensive decadal strategy (USGS 2007). The Ecosystems Mission Area was identified as essential for integrating activity within USGS and as a key to enhanced integration with other federal and private-sector research and resource management organizations (Myers at al. 2007).

This paper focuses on benefits to parks and protected areas from the USGS Ecosystems Mission Area, which expanded the scope of the original 2007 science strategy to identify the bureau's work in ecosystem science over the next decade (Williams et al. 2013). The plan describes a framework that encompasses both basic and applied science and allows USGS to continue to contribute meaningfully to conservation and management issues related to the nation's parks, protected areas, and ecological resources. This framework relies on maintaining long-standing, collaborative relationships with partners, both in conducting science and applying scientific results. Here we summarize the major components of the USGS Ecosystems Science Strategy, articulating the vision, goals, and strategic approaches, then outlining some of the proposed actions that will ultimately prove useful to those managing parks and

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protected areas. We end with a discussion on the future of ecosystem science for USGS and how it can be used to evaluate ecosystem change and the associated consequences to management of our nation's resources.

Vision for USGS ecosystem science

As a federal science agency, USGS is charged with providing scientific understanding to the Department of Interior (DOI) and the nation to help foster better informed decision-making about our natural resources. The ecosystem science envisioned by the strategy's framework encompasses studies of organisms and their environments across scales from genes to biomes, and over time periods from short term through the long view provided by the geologic past, and into projected futures. It requires studies across multiple spatial scales to better understand the interaction of local features of landscapes (such as water diversions) with global processes (such as climate oscillations). Exploration of human activity, such as park visitation and ecosystem services, as integral to ecosystem function is also an important component of the framework.

Discovery and application

To adequately address causes of ecosystem change and its consequences for parks and protected areas, over the coming decades science will be faced with integrating system responses to drivers of change including climate variability, landscape alterations, and effects of water and energy development. To help guide effective management of protected areas and to address problems that will increasingly affect humans, USGS will be required to integrate scientific discovery and application. The bureau's research will need to combine efforts to discover how ecosystems function, and apply these discoveries to better inform decisions faced by park and protected area managers.

Science enables the discovery of new knowledge that can be applied to problems of social importance (Stokes 1997). In this feedback system, applications of new knowledge by resource managers can lead to the identification of new science needs, and thus focus investigations that lead to the discovery of yet more new knowledge (Figure 1a). While this relationship between science and park management has been well established (Sellars 1997), as society moves into the 21st century an enhanced relationship between discovery and application is needed in which new knowledge originates from the application of existing knowledge, as well as from basic and applied research that is being conducted in parks and protected areas (Figure 1b). Thus, science does inform, but can in turn also be informed by, park resource management, with discovery and application overlapping rather than being mutually exclusive. The overlap of the two activities represents simultaneous application of knowledge and discovery of new knowledge, such as when science-based interventions are used to address park management goals as well as to obtain new knowledge (Martin et al. 2011; van Riper et al. 2013). This approach is efficient in focusing science on questions and key uncertainties of primary importance to management decisions, and will serve as a cornerstone for future USGS ecosystem science efforts.

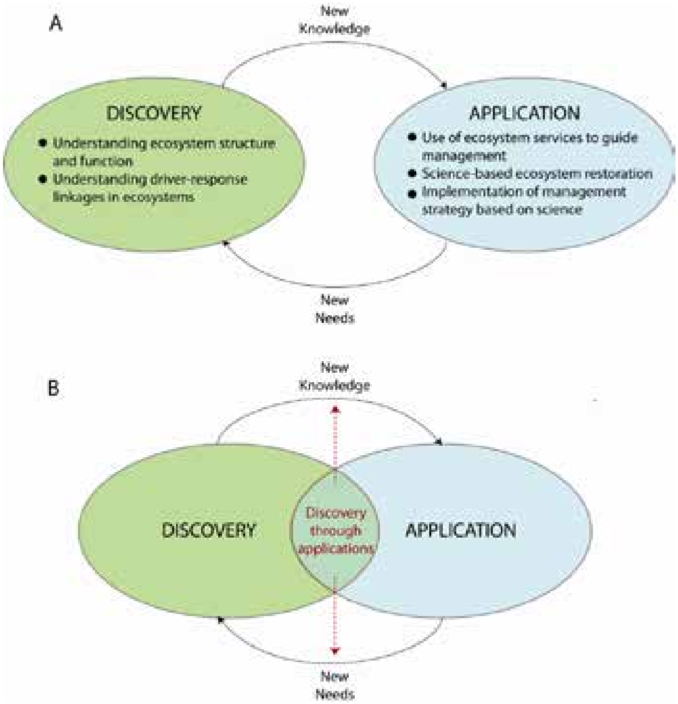

Figure 1. The relationship between discovery and application in ecosystem science. (A) Scientific discovery of new knowledge is applied to ecological problems while application in turn leads to focus on additional questions for discovery. (B) Application of new scientific knowledge by park and protected area managers can itself generate new knowledge.

Advancing science through collaboration

USGS is known for its multidisciplinary expertise and comprehensive, integrative research that is only further strengthened through collaborations and partnerships with the National Park Service (NPS) and other agencies. Strong collaborations enable science resources to be used efficiently and thus better support the information needs that protected area management agencies face. USGS has a highly distributed infrastructure with science centers and cooperative research units found in most every state; many are co-located with universities or within the facilities of other collaborators such as national parks. This geographic structure enhances the ability of USGS scientists to work with partners at all levels—local, territorial, state, tribal, federal, and non-governmental. Cooperative ventures that promote ecosystem-based management are expected to grow. Such ventures include the DOI Landscape Conservation Cooperatives, Cooperative Research Units, National Phenology Network, NPS inventory and monitoring programs, Cooperative Ecosystem Studies Units, National Ecological Observatory Network (NEON), Long Term Ecological Research programs, and

National Climate Science Centers. At a time of tightening budgets, it is critical for USGS to pursue research approaches that build on the strengths of complementary organizations.

Goals of USGS Ecosystems Science Strategy

The strategy is structured around five complementary and interconnected goals that reinforce a vision of science that addresses priority societal issues.

1. ***Improve understanding of ecosystem structure, function, and processes***. This goal focuses on developing an understanding of how ecosystems work, including the dynamics of species, their populations, interactions, and genetics, and how they vary across spatial and temporal scales.
2. ***Advance understanding of how drivers influence ecosystem change.*** The challenges here are explaining the drivers of ecosystem change; their spatiotemporal patterns, uncertainties and interactions; and their influence on protected area ecosystem processes and dynamics.
3. ***Improve understanding of the services that ecosystems provide to society.*** Here the emphasis is on the measurement of environmental capital and ecosystem services in protected areas, and the identification of sources and patterns of their change in space and time.
4. ***Develop tools, technologies, and capabilities to inform decision-making about ecosystems.*** This includes developing new technologies and approaches for conducting applications-oriented ecosystem science that will benefit resource management. A principal challenge will be how to quantify uncertainty and incorporate it into decision analysis.
5. ***Apply science to enhance strategies for management, conservation, and restoration of ecosystems.*** This goal encourages an advisory role in which USGS ecosystem science is brought to bear directly on issues related to management and conservation of protected areas, with scientists working directly with park management to identify critical challenges, including development of novel approaches to monitoring, assessment, and restoration of ecosystems; new methods to address species of concern and communities at risk; and innovations in decision analysis and support to address imminent ecosystem changes and those already underway.

These goals collectively promote enhanced partnerships within and outside the USGS and emphasize the linkages between discovery and application (Figure 2).

Strategic approaches

Closely integrated with the five goals are four strategic approaches that provide a path forward for USGS ecosystem science. These approaches cut across all of the goals and are viewed as essential to the implementation of this strategy.

1. ***Assess information needs for ecosystem science through enhanced partnerships.*** Work with DOI and other agencies, practitioners, and institutions to identify, design, and implement priority decision-driven research.

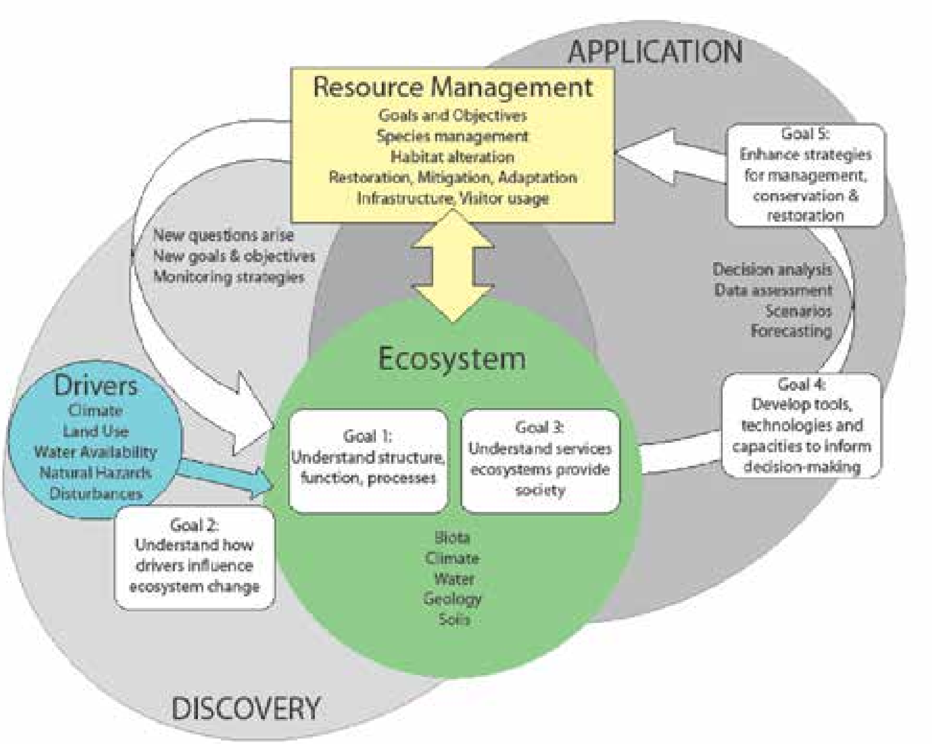

Figure 2. Integration of the USGS Ecosystem Science Strategy goals with scientific discovery and application. Strategic goals are shown along a continuum between discovery and application with links to other drivers. Disturbances include but are not limited to contaminants, fire, visitation, pollutants, pathogens, and resource utilization.

2. ***Promote the use of interdisciplinary ecosystem science.*** Design and conduct interdisciplinary process-oriented research in ecosystem science.
3. ***Enhance modeling and forecasting.*** Develop models to forecast ecosystem change, assess future management scenarios, and reduce uncertainties through an adaptive learning process.
4. ***Support decision-making.*** Use quantitative approaches to assess the vulnerabilities of ecosystems, habitats, and species, and evaluate strategies for adaptation, restoration, and sustainable management of protected areas.

These strategic approaches focus on the study of ecosystems and the drivers influencing their dynamics, while engaging protected area managers. Each approach can serve as a standalone program or as a scientific component of larger decision processes for conservation and management of our nation's ecosystems into which parks and protected areas are embedded.

The strategic approaches also define institutional processes that will serve to continually test science directions and renew priorities as needed to maintain responsive and relevant science that addresses protected area needs. Institutionalized collaboration within USGS and with external partners will assure applications of the latest techniques, information, assessments, maps, and decision-support tools that are needed to address ecosystem management issues that affect parks and protected areas. In addition, these strategic approaches provide flexibility in identifying both the systems to be studied and the scientific approaches to be used. Importantly, these approaches also are interconnected and can be effectively pursued simultaneously.

Proposed actions

Proposed actions put forward in the Ecosystems Science Strategy address some of the most pressing environmental information needs of parks and protected areas (Williams et al. 2013). These actions range from ongoing mission-critical to long-term strategic activities, and focus on interdisciplinary science. Through collaboration with partners and application to decision-making, these proposed efforts will provide scientific information that can be utilized to enhance management of parks and protected areas. The following list provides a small sample of what USGS scientists are presently undertaking, and illustrate the depth and breadth of USGS ecosystem science.

- Improving our understanding of the impacts of alternative energy development on ecosystems.
- Incorporating understanding of past patterns of environmental variability into forecasting future efforts of ecosystem restoration and management.
- Improving our ability to predict the occurrence and consequences of fire across protected area landscapes.
- Investigating the impacts of acidification on ecosystems.
- Working with resource managers to develop science-based restoration performance measures and targets.
- Implementing quick-response teams to investigate the scale and effects of environmental disasters.
- Developing integrated models for forecasting the consequences of climate change to parks and protected areas, within larger ecosystem contexts.
- Designing innovative approaches to study interactions between hydrology and ecology for establishment of hydrologic flow criteria aimed at ecosystem sustainability.
- Developing robust approaches to natural resource decision-making in the face of climate change.
- Developing the capacity of USGS scientists to become engaged in design and execution of adaptive management projects.

Future of USGS ecosystem science

The USGS Ecosystems Science Strategy is intended to guide the bureau over the next decade. Two aspects of the strategy are designed to ensure relevance as we move forward. First, it emphasizes integration of five goals, from discovery to application, that can be used in real-time resource management and decision-making. This emphasis means that USGS ecosystems science will continue to be driven by the need to transform fundamental scientific understanding into relevant, actionable information, and to aid in the application of that information by protected area managers and practitioners into decision making. Second, the strategy will endure because of a commitment to communication and collaboration with other natural resource agencies and organizations. Through this commitment, USGS will continually evaluate and redefine ecosystem science directions to keep pace with information needs and emerging technologies, while seeking to maximize the value of collaborations. The strategy recognizes that USGS is one of many entities pursuing ecosystem science and that the greatest benefit to protected areas, society, and the nation will come from complementary applications of resources and talent.

Ecosystem science is interdisciplinary by nature and requires the incorporation of information technology and the biological, chemical, physical, and social sciences to address important and complex ecosystem issues. USGS includes scientists from many disciplines who can work together to better understand the components of and interactions within ecosystems. Thus, there already exists a strong framework for applying USGS interdisciplinary expertise to collaborative efforts with scientists from within and outside the bureau.

Similar to most strategic plans, the USGS Ecosystems Science Strategy contains goals, objectives and actions. Unlike many plans, however, it also contains a commitment to a new perspective on integrating discovery and application in ecosystem science, and a commitment to an ongoing process of communication and collaboration with outside organizations. These processes can serve to keep USGS ecosystem science current, flexible, and relevant to our nation's protected area needs.

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Climate Change and Plant Community Composition in National Parks of the Southwestern US: Forecasting Regional, Long-term Effects to Meet Management Needs

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Introduction

The National Park Service (NPS) is charged with conserving natural resources unimpaired for the enjoyment of future generations. Understanding the current status of resources, and anticipating how these resources may change in the future, will help NPS manage their parks more effectively. To monitor the status and long-term trends of selected natural resources, NPS has organized more than 270 parks with significant natural resources into 32 Inventory and Monitoring (I&M) Networks (NPS 2014). All 32 networks have prioritized and selected a set of "vital signs" that are being used to track the condition of selected natural resources. Vital signs are physical, chemical, and biological elements and processes of park ecosystems that represent the overall health or condition of the park, known or hypothesized effects of stressors, or elements that have important human values. Understanding the dynamic nature of park ecosystems and forecasting their future trajectories requires synthesis of biotic and abiotic data generated by vital signs monitoring, natural resource inventories, and historical park data that predate the I&M program.

Climate is a fundamental vital sign being monitored across all I&M networks and is critical to interpreting past ecosystem changes, as well as forecasting future changes, in national parks. Most ecological processes and species respond to variation in climate. However, human-induced climate change poses enormous challenges to natural resource managers because it will likely occur more rapidly than the speed at which ecosystems can adapt

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(Christensen et al. 2007). This may result in a shift in the composition and spatial extent of ecosystems, such that parks may be uninhabitable by the species, habitats, and communities they were designed to protect (Peters and Darling 1985). If these transitions occur, then the consequences of climate change will make it difficult for park managers to preserve ecosystems unimpaired for future generations.

Plant cover and community composition are also vital signs that are monitored across all I&M networks. The abundance, distribution, and interaction of many plant species and functional types are likely to respond differently to future changes in precipitation and temperature, creating novel communities. Shifts in plant community composition can have far-reaching effects on ecosystem properties, including plant diversity and productivity, the type and availability of wildlife forage and habitat, and soil erosion (Munson et al. 2011a). Integration of climate and plant community composition vital sign data is essential to provide park resource managers with tools to forecast climate change and its effect on ecosystems, which are goals of I&M protocols (e.g., Hubbard et al. 2012).

Although management decisions are often made at the park scale, climate change and its impact on ecosystems is occurring at regional and global scales (Breshears et al. 2005). The diversity of landforms across regions makes it difficult to use individual park data to assess the broad-scale effects of climate change or to extrapolate the results to other areas. An assessment of the response of plant cover and community composition to climate change would benefit greatly from the synthesis of data across multiple parks and I&M networks. Understanding climate–vegetation relationships across parks can help NPS managers address several concerns about the current and future condition of natural resources (Box 1). A forward-thinking strategy to prepare for the impacts of climate change is to assess whether the protocols used by I&M networks will be suitable to track long-term changes in vegetation cover and composition. To determine spatial and temporal changes that are ecologically meaningful and useful for land management, monitoring methods must provide highly precise estimates that are made at an appropriate spatial scale (Havstad and Herrick 2003). To maximize the efficiency and practicality of monitoring efforts, these methods must also be time-effective and easy to implement in the field. The goal of our USGS–NPS collaboration is to: (1) integrate historical park monitoring data across I&M networks in the southwestern US to assist managers in identifying plant species, functional types, and plant communities at risk from climate change, and (2) determine if long-term monitoring protocols currently being used by I&M networks will be able to track long-term changes in vegetation in the future. Our cross-site analyses focus on parks in the Sonoran and Chihuahuan Desert I&M networks, which are expected to warm faster than many parts of the country and are likely to experience decreases in precipitation, resulting in reduced soil moisture for plant growth in an already water-limited environment (Cook et al. 2004; Christensen et al. 2007).

Methods

Site descriptions. The Sonoran Desert I&M Network (SODN) consists of 10 national parks in Arizona and New Mexico. Climate at low elevations (< 1500 m) in parks across this network is characterized by low precipitation (< 500 mm) that occurs primarily in the winter

Box 1. Management concerns addressed by understanding climate–vegetation relationships

- Extirpation or declines of native or threatened and endangered species
- Loss of biodiversity
- Invasion of non-native species
- Changes in forage and habitat for wildlife
- Shifts in structure and function of ecosystems and the services they provide
- Changes in fire regime
- Reduction in the quality of the visitor experience
- Increased susceptibility to soil erosion
- Challenges to restoration

and summer months (bimodal precipitation regime), mild minimum temperatures in the winter (> 4°C) and very high maximum temperatures (> 40°C) in the summer (Davey et al. 2007a). SODN parks have plant communities that represent most of the Sonoran Desert ecoregion and are situated at the boundary between the southern limits of temperate species and northern limits of cold-sensitive subtropical species distributions (Shreve and Wiggins 1964). Mesquite (*Prosopis* spp.) savannas, Arizona upland–Sonoran desertscrub (composed of leguminous trees, shrubs, and cacti), and creosote bush (*Larrea tridentata*) shrublands are major plant communities represented at low elevation in parks of this region.

The Chihuahuan Desert I&M Network (CHDN) consists of seven national parks in New Mexico and west Texas. The Chihuahuan Desert also has low precipitation, but receives a greater proportion of summer precipitation from the North American Monsoon than the Sonoran Desert and generally has cooler temperatures owing to its higher elevation (Davey et al. 2007b). Chihuahuan Desert plant communities include perennial grasslands and shrublands dominated by creosote bush, tarbush (*Flourensia glandulosa*), and honey mesquite (*Prosopis glandulosa*). There is 52% similarity in genera between the Chihuahuan and Sonoran Desert floras, which creates considerable overlap in plant community composition (MacMahon and Wagner 1985).

Vegetation and climate measurements. We used repeat measurements of dominant plant species canopy cover from permanently marked plots at four sites in the Sonoran Desert and eight sites in the Chihuahuan Desert (Munson et al. 2012; Munson et al. 2013a), which is a common metric used in plant vital sign monitoring across I&M networks. The long-term vegetation monitoring sites include Saguaro National Park and Organ Pipe Cactus National Monument in the Sonoran Desert, Big Bend National Park in the Chihuahuan Desert, and several sites adjacent to parks that have plant communities similar to those found inside (Figure 1). The frequency of plant species cover measurements varied from an annual to decadal scale, depending on the site, and spanned from 1928 to 2012. Mean annual and seasonal temperature and precipitation measurements from long-term weather stations nearest to the vegetation monitoring sites were supplemented at some sites by measurements from

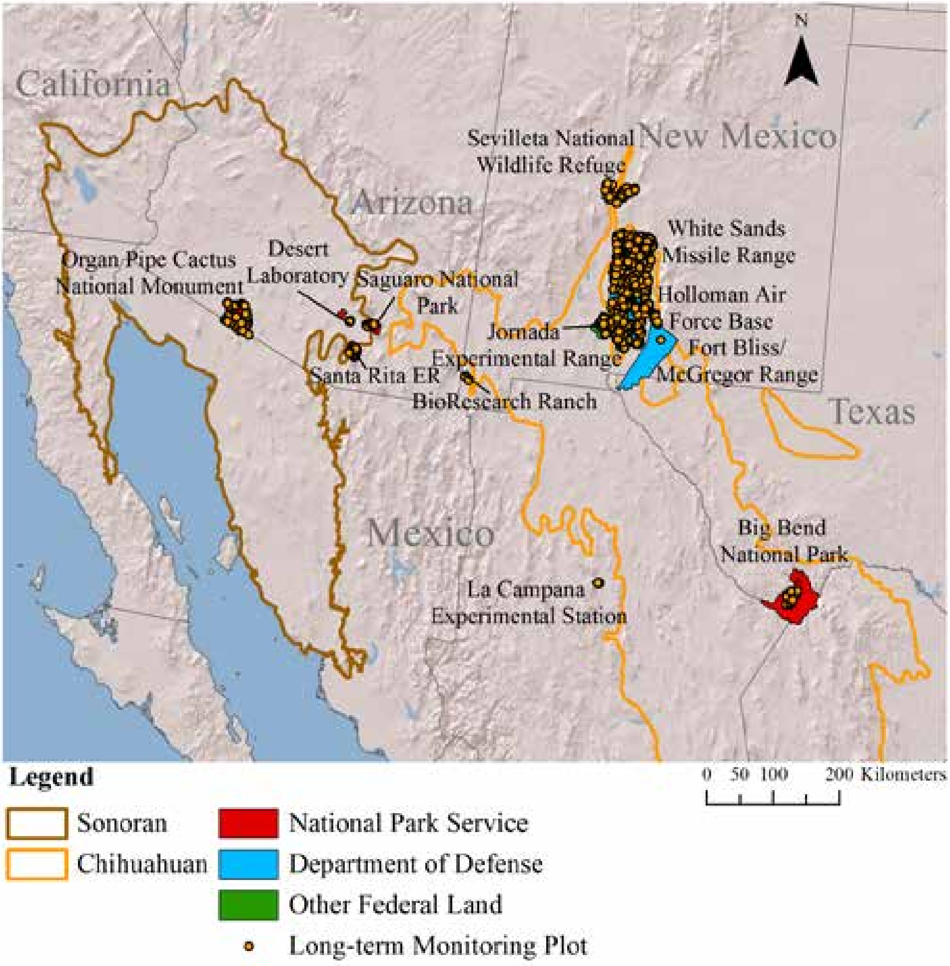

Figure 1. Map of long-term vegetation monitoring sites and plots in the Sonoran and Chihuahuan deserts.

rain gauge networks. We also calculated aridity and drought indices based on precipitation and temperature measurements.

Assessment of climate–plant relationships. To determine how plant species responded to past climate, we related increases or decreases in plant species cover between sampling events with the long-term record of climate (Munson 2013; Munson et al. 2013; Figures 2 and 3). We determined two management-relevant metrics from the climate–plant relationships: (1) the magnitude of a plant species' response (the slope of the climate–plant relationship), which can be defined by the capacity of a plant species to increase in abundance when water is available and decrease in abundance when not, and (2) the critical amount of water availability that causes a plant species to shift from increases to decreases in abundance (the x-intercept of the climate–plant relationship), which we define as a "climate pivot point." A

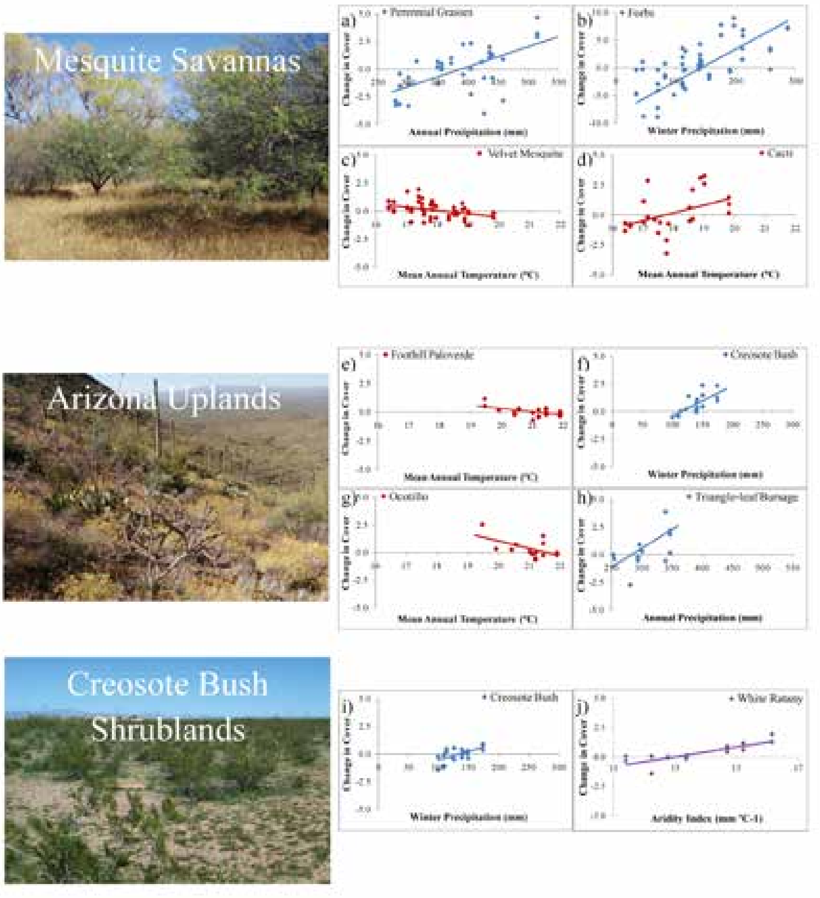

Figure 2. Change in cover of dominant plant species in relation to climate variables in the Sonoran Desert (red = temperature, blue = precipitation, purple = aridity index) for: (a) perennial grasses, (b) forbs, (c) velvet mesquite and (d) cacti in mesquite savannas; (e) foothill paloverde, (f) creosote bush, (g) ocotillo, and (h) triangle-leaf bursage, in Arizona uplands; (i) creosote bush and (j) white ratany in creosote bush shrublands. Points represent mean values of all plots sampled within a plant community at a site for each year and lines represent significant regressions.

climate pivot point is an important indicator of drought resistance, as plant species with a low precipitation pivot point or high temperature pivot point are able to maintain positive increases in abundance with low water input or high evaporative demand. Plant species that cross climate pivot points by losing cover have reduced capacity for growth and survival, but these changes are generally reversible as climatic conditions become more favorable. Extreme or sustained climatic conditions beyond a pivot point, which negatively affect the cover of a dominant species or collectively influence many plant species, may lead to the permanent alteration of the plant community and affect ecosystem function. For example, extreme drought

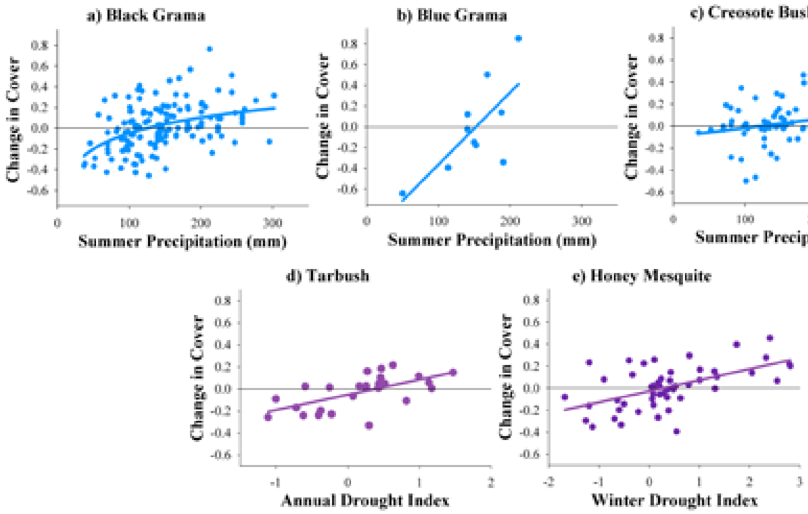

Figure 3. Change in cover of dominant plant species in relationship to climate variables in the Chihuahuan Desert (blue = precipitation, purple = drought index) for: (a) black grama, (b) blue grama, (c) creosote bush, (d) tarbush, and (e) honey mesquite. Points represent mean values of all plots sampled within a plant community at a site for each year and lines represent significant regressions. For the drought index, negative values indicate dry periods and positive values indicate wet periods.

and freezing temperatures in Big Bend National Park in 2011 that were well beyond the climate pivot points of creosote bush, a dominant shrub across North American warm deserts, resulted in widespread reduction in cover of the shrub and killed other plant species in the park (Figure 4).

Assessment of vegetation monitoring protocols. To assess whether protocols shared by the Sonoran and Chihuahuan Desert I&M networks are suitable to track long-term changes in vegetation driven by climate and other environmental factors, we compared how well they performed relative to a well-established and proven mapped census method used at the Desert Laboratory in Tucson, Arizona, since 1903. The Sonoran and Chihuahuan Desert I&M networks' terrestrial vegetation protocol (Hubbard et al. 2012) uses a line-point intercept (LPI) method, whereas the Desert Laboratory method is done by mapping canopy edges of individual plants and digitizing them in GIS. We compared plant species and soil cover values obtained from historically mapped plots at the Desert Laboratory with the I&M LPI method to assess how well the monitoring methods tracked changes in cover through time. Because perennial vegetation historically was not measured using the LPI method, we used a GIS-based LPI approach to track cover changes back in time, which consisted of projecting LPI sampling points onto the historical maps and recording the perennial plant species or soil intercepted by them (Munson et al. 2011b).

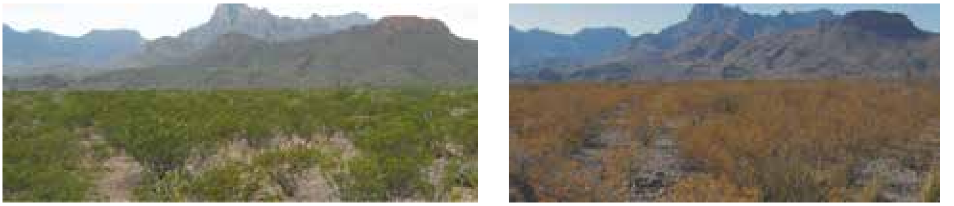

Figure 4. Repeat photos of creosote bush and other Chihuahuan Desert vegetation before (left) and after (right) extreme drought and freezing temperatures in 2011 beyond climate pivot points at Big Bend National Park. Photos courtesy of Natasja van Gestel.

Results and discussion

Sonoran Desert climate–plant relationships. Mean annual temperatures significantly increased in 6 of the 11 parks in the last 60 years, with the largest rates of increase occurring since the early 1970s. There was below-average precipitation across parks from the 1940s into the early 1960s, above-average precipitation from the mid-1970s until the late 1990s, and a return to below-average precipitation in the 2000s. Many plant species and functional types in communities across the Sonoran Desert responded to these patterns of temperature and precipitation changes (Munson et al. 2012; Munson and Wondrak Biel 2012).

Mesquite savanna. In the relatively mesic mesquite savanna communities, perennial grass cover decreased when annual precipitation dipped below a climate pivot point of 390 mm (Figure 2a), whereas forbs (non-grass herbaceous plants) decreased in cover below 142 mm of winter precipitation (Figure 2b). Perennial grasses and forbs showed large responses to precipitation, likely because they are fast-growing and shallow-rooted. The climate pivot points of perennial grasses and forbs may indicate water input thresholds that limit production and diversity in the Sonoran Desert. In response to increasing mean annual temperature (MAT) there was a decrease of velvet mesquite (*Prosopis velutina*) cover (Figure 2c), which is in contrast to its general expansion in the 20th century. Our results suggest that a temperature pivot point near 18°C may cause significant stress on velvet mesquite by increasing evapotranspiration rates, especially in years with low precipitation or in upland settings. Cacti cover increased with increasing temperature (Figure 2d), a trend that has been documented across the southwestern US (Turner et al. 2003). This trend of increasing temperature was associated with a decreased frequency of extreme freezes, reducing the risk of tissue damage and mortality for succulents that store water.

Arizona upland (Sonoran desertscrub). In the drier Arizona upland communities, the dominant leguminous tree, foothill paloverde (*Parkinsonia microphylla*), declined on hillslopes in response to increasing MAT (Figure 2e). Previous research (Bowers and Turner 2001) has documented high mortality of the largest trees under conditions of increased temperature and decreased water availability, suggesting that such periods likely have the greatest influence on older, senescing trees. The cover of creosote bush, significantly correlated to winter precipitation, began to decline with a drop below a climate pivot point of 110 mm annual precipitation (Figure 2f). Ocotillo (*Fouquieria splendens*), a semi-succulent shrub, decreased on south- and west-facing slopes in response to increasing MAT (Figure 2g). In these landscape positions, seedling recruitment is low and roots can be susceptible to direct heat damage and low water availability when temperatures are high (Nobel and Zutta 2005). The drought-deciduous triangle-leaf bursage (*Ambrosia deltoidea*), which serves as a nurse plant for many woody species in the Sonoran Desert (Bowers and Turner 2001), showed large fluctuations in cover in response to shifts in annual precipitation (Figure 2h). Cover for this facilitative species increased above a climate pivot point of 283 mm annual precipitation, which may indicate an important threshold for new recruitment in this region.

Creosote bush shrubland. In one of the driest Sonoran Desert plant communities, the co-dominant species creosote bush and its hemiparasite, white ratany (*Krameria grayi*), decreased with a decrease in winter precipitation and increased aridity, respectively (Figures 2i and 2j). A greater number of plots had declines in cover of creosote bush, and this evergreen shrub had a higher winter precipitation pivot point (135 mm) in communities where it was dominant than in Arizona uplands (see Figure 2f). The decline of creosote bush was only evident on old soil surfaces, which have restrictive layers, including petrocalcic horizons. These layers may limit the soil volume available to plant roots and restrict water infiltration, holding water at shallow depths where it is more susceptible to evaporation at high temperatures (McAuliffe 1994).

Chihuahuan Desert climate–plant relationships. The Chihuahuan Desert experienced increases in temperature and patterns of drought over the last several decades similar to those of the Sonoran Desert. Plant species across the Chihuahuan Desert varied in their sensitivities to different aspects of climate within the plant communities in which they were dominant (Munson et al. 2013a, 2013b).

Perennial grasslands. The cover of the perennial grass black grama (*Bouteloua gracilis*) decreased more in dry summers (< 125 ± 13 mm) than increased with wet summers (Figure 3a), whereas blue grama (*Bouteloua gracilis*) had a large positive response when summer precipitation was > 153 (±15) mm (Figure 3b). This higher climate pivot point indicates that blue grama may require more summer water input than black grama to increase in cover, in part because it is dominant in grasslands that receive more precipitation. Unlike grasses, woody vegetation performance was best explained by winter precipitation in grasslands (not shown). Cooler temperatures in the winter months create less evaporative demand, which allows precipitation to sink deeper into the soil profile where many woody plants have roots (Gibbens and Lenz 2001). The different responses by perennial grasses and shrubs to precipitation seasonality demonstrate the importance of the timing of rainfall events in influencing the balance of herbaceous and woody vegetation in the Chihuahuan Desert, although fire and grazing are also important.

Creosote bush, tarbush, and mesquite shrublands. Shrub responses to climate in shrublands varied according to the dominant species. The change in cover of creosote bush in shrublands was weakly explained by summer precipitation (Figure 3c), in contrast to its response to winter precipitation in the Sonoran Desert (Figures 2f and 2i). However, summer precipitation comprises a larger proportion of the annual total in the Chihuahuan Desert and the evergreen shrub has been shown to be physiologically active to water input during the warmest time of the year (Reynolds et al. 1999). The change in cover of tarbush was most related to the annual drought index (Figure 3d), and cover decreased below an index of 0.39 (±0.18). The change in cover of honey mesquite was strongly linked to the winter drought index (Figure 3e), and decreased shrub cover occurred below an index of 0.28 (±0.22). Both these drought pivot points are considered near-normal conditions, with most decreases in cover occurring during dry conditions indicated by a negative drought index. The growth of honey mesquite is likely most influenced by the deep-penetrating winter water supply because its roots can extend over 5 m deep (Gibbens and Lenz 2001). Like creosote bush, mesquite has largely expanded over much of the southwestern US, including areas that were formerly grasslands (Buffington and Herbel 1965).

Assessment of vegetation monitoring protocols. There is enormous potential for the monitoring protocols developed by the I&M networks to benefit from the knowledge gained from previous monitoring efforts. The Sonoran and Chihuhuan Desert I&M networks' LPI method was completed in ~3 hours for each 10-ha plot instead of the 60 hours per plot necessary to conduct the mapped census. By comparing I&M LPI methods to historically mapped plots from the Desert Laboratory in GIS, we found that estimated cover using the two methods was not significantly different ($P > 0.05$ from chi-square test) for dominant species and bare ground through time (Munson et al. 2011b, 2011c). Furthermore, we found that changes in the cover of dominant perennial plant species, total vegetation, and soil from 1928 to 2010, were related to distinct wet (1928–1940, mid 1970s–late 1990s) and dry (1940s–early 1960s, early 2000s–2012) periods (Figure 5). These results suggest that I&M vegetation monitoring protocols may be able to detect changes in plant species cover in response to climate change with considerably less time spent on each plot, freeing up resources to measure additional plots across parks.

Conclusions and management implications

The results of our USGS–NPS collaboration highlight how dominant plant species and functional types responded to seasonal and annual change in climate across the Sonoran and Chihuahuan deserts. Plant species responses in the Sonoran Desert were driven by winter and annual precipitation coupled with high temperatures and associated aridity, whereas changes in cover of Chihuahuan Desert plant species were related to summer precipitation and drought indices. These impacts of climate on plant community composition serve as important indicators to natural resource managers of how vegetation may shift as climate in the region becomes increasingly arid, as projected. Importantly, losses of dominant plant species cover with warming and drying conditions indicates potential for land degradation and disruption of ecosystem processes, which may be marked by declines in productive capacity, diversity, and wildlife habitat. The climate pivot point that we utilized in our study is a useful metric derived from long-term monitoring data, which represents an important transition in how a species responds over a range of climatic conditions. The climate pivot point approach can be used to help natural resource managers understand historical vegetation dynamics and forecast future plant community composition under different climate regimes. Monitoring protocols shared by the Sonoran and Chihuahuan Deserts I&M networks are well-suited

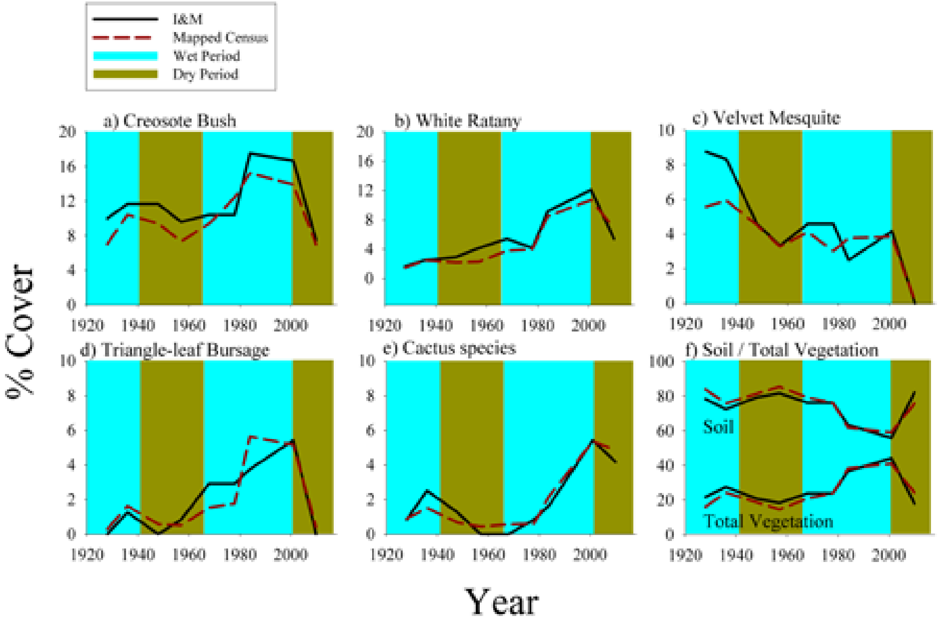

Figure 5. Comparison of line-point intercept from the I&M protocol and mapped census methods to estimate cover of dominant plant species, including: (a) creosote bush, (b) white ratany, (c) velvet mesquite, (d) triangle-leaf bursage, (e) cactus species, and (f) soil/total vegetation. P > 0.05 (not significant) for all chi-square tests. Blue panels indicate wetter and brown panels drier than average conditions.

to detect shifts in the cover of dominant plant species driven by climate and other factors. This collaboration between USGS and NPS demonstrates the importance of long-term monitoring data in assessing the impact of climate on plant community composition, which is essential for future conservation planning in national parks and adjacent lands.

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Interagency Collaboration on an Active Volcano: A Case Study at Hawai'i Volcanoes National Park

Jim Kauahikaua and Cindy Orlando

Introduction

Hawai'i Volcanoes National Park (HVNP) includes two active Hawai'i shield volcanoes: Mauna Loa, the largest active volcano on earth, which most recently erupted for three weeks in 1984, and Kīlauea, which has been erupting continuously for more than 31 years. Unlike the steep-sided volcanoes around the rim of the Pacific Ocean, all Hawai'ian volcanoes have gentle-sloped flanks that result from copious eruptions of fluid lavas with infrequent interludes of explosive activity. Each of the Hawai'ian volcanoes erupts from its summit area—Kīlauea and Mauna Loa both have summit calderas (large subsided craters)—and from one or more rift zones (a sequence of vents aligned radially away from the summit).

Because Kīlauea and Mauna Loa are included within the national park, there is a natural intersection of missions for the National Park Service (NPS) and the US Geological Survey (USGS). HVNP staff and the USGS Hawai'ian Volcano Observatory (HVO) scientists have worked closely together to monitor and forecast multiple eruptions from each of these volcanoes since HVNP's founding in 1916.

The US Geological Survey's Hawai'ian Volcano Observatory

HVO was founded in 1912 by Massachusetts Institute of Technology professor Thomas A. Jaggar, Jr., to study the Kīlauea volcano. After being managed by academic institutions and various federal agencies (including NPS), HVO was permanently transferred to USGS in 1947.

HVO's current mission is to provide timely and accurate warnings of volcanic and earthquake activity. To achieve that goal, the observatory operates a large network of monitoring instruments and researches volcanic and earthquake processes to better understand the workings of both phenomena.

Hawai'i Volcanoes National Park

HVNP was established on August 1, 1916. Today the park protects and manages approx-

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Figure 1. Kamoamoa fissure erupting on March 6, 2011, just west of the Pu'u 'Ō'ō vent. USGS photo.

imately 135,000 ha (333,000 acres) of public land that includes some of the most unique geological, biological, and cultural landscapes in the world, while educating and keeping safe 1.6 million visitors during their visits. Extending from sea level to the summit of Mauna Loa at 4,169 m (13, 677 ft) (the most voluminous volcano in the world measured from its base on the ocean floor), the volcanic topography also supports one of the most fascinating biological landscapes in the world, with diverse populations of plant and animal communities across seven ecological life zones. The park also plays a unique role in the history of human development on the Hawai'ian Islands and remains an important place for living cultures in Hawai'i. Just as the biological and geological features of the park have shaped the landscape, so too has the Native Hawai'ian culture.

Named as an international biosphere reserve in 1980 and a World Heritage site in 1987, the outstanding universal values by which these designations occur transcend national boundaries. In fact, HVNP is a model for other protected areas around the world for management of active volcanic sites.

Eruption responses within HVNP

Kīlauea's most recent and ongoing eruption started in early 1983 along the volcano's east rift zone about 19 km (12 mi) from its summit and near the eastern boundary of the national park. The eruption began with episodic lava fountains that quickly built a 255-m-(835-ft-) tall cinder-and-spatter cone later named "Pu'u 'Ō'ō." Since 1986, the eruption site has periodically moved from vents at Puʻu ʻŌʻō to vents downrift and uprift of the cone. Each shift in the eruption site has resulted in dramatic changes at Puʻu ʻŌʻō, changes in the lava flows that were active prior to and after the shift, and changes in the hazards posed to the public within and outside HVNP. As of 2014, the eruption has covered 127.2 sq km (49.1 sq mi) and added about 202.5 ha (500 acres) of new land along the southeast coast of Kīlauea. In early 2008, a second eruption started at a new location within the volcano's summit caldera and, for the first time in recorded history, Kīlauea was simultaneously erupting persistently from two locations. Every development in these two ongoing eruptions requires the focused attention of both agencies until public safety is achieved.

Kamoamoa eruption, March 5–9, 2011

The Kamoamoa fissure eruption in March 2011 is a good example of a short, but dramatic, eruptive event during the Kīlauea volcano's continuous east rift zone eruption and the joint work of NPS and USGS in monitoring and mitigating the hazards posed by volcanic activity.

From 2007 through early 2011, lava continuously erupted from a vent east of Puʻu ʻŌʻō flowed southeast to the coast, where it destroyed several homes in a nearby community. Interestingly, HVO instruments measured inflation (increased storage of magma below the surface) of Kīlauea's summit even as lava continued to erupt from the Puʻu ʻŌʻō vent.

HVO scientists also recorded an increasing number of earthquakes along the rift zone between the summit and Puʻu ʻŌʻō starting in late January 2011 and continuing into the first

Figure 2. Low lava fountains from the west Kamoamoa fissure fed a lava flow to the south on March 9, 2011. USGS photo.

few days of March 2011. On March 5, at 1:42 pm HST, Kīlauea's summit lava lake began to drop, indicating that magma pressure beneath the summit was rapidly decreasing. At 1:56 pm, HVO's automated data alarms were triggered and scientists began watching webcams positioned at the Puʻu ʻŌʻō vent to see what changes might happen. At 2:16 pm, the crater floor within Puʻu ʻŌʻō started to collapse dramatically. At that point, HVO contracted with a helicopter for aerial reconnaissance of the area and first-hand observation of the activity by HVO geologists.

After discussions among HVO scientists based on all available monitoring data, the HVO scientist-in-charge (SIC) began calling contacts on the emergency-manager call-down list, the first being HVNP dispatch for NPS personnel. At 2:49 pm, the SIC spoke with the HVNP duty ranger to explain what was happening and the possible future outcomes. A few minutes later, the HVO SIC had the same conversation with the director of the Hawaiʻi County Civil Defense agency. HVO then issued a public volcanic activity notice, raising the alert level code to its highest level ("WARNING") and instituted continuous personnel rotations at HVO to assure that staff was on duty to monitor the activity at all times.

At 5:15 pm, an HVO geologist who was inspecting, from a helicopter, the collapsing floor of Puʻu ʻŌʻō crater, witnessed the start of a fissure eruption west of the Puʻu ʻŌʻō cone. This outbreak of lava was relayed to HVNP rangers, who responded with evacuations of park visitors and closure of park areas near the eruption site. A small crew of HVO geologists was also dispatched to the site on foot to monitor the eruption overnight.

HVNP response to the eruption

No other place in Hawaiʻi, nor elsewhere in the world, has as dynamic a landscape and one so approachable during volcanic activity. As mentioned above, HVO operates within the park and is mandated to provide timely and accurate warnings of volcanic or seismic activity within the park boundary, as well as within the entire state. Additionally, HVNP relies on USGS science to inform park management decisions relative to visitation, closed areas, research and permitting, and access to wilderness. It is a unique partnership and relationship within the National Park Service. At HVNP, volcanic research is equal in importance to the conservation and public use aspects of the area. Working closely with USGS scientists in 2011, the park had a unique opportunity to showcase, in real time, the dynamic eruptive events as a part of its interpretive and educational programs.

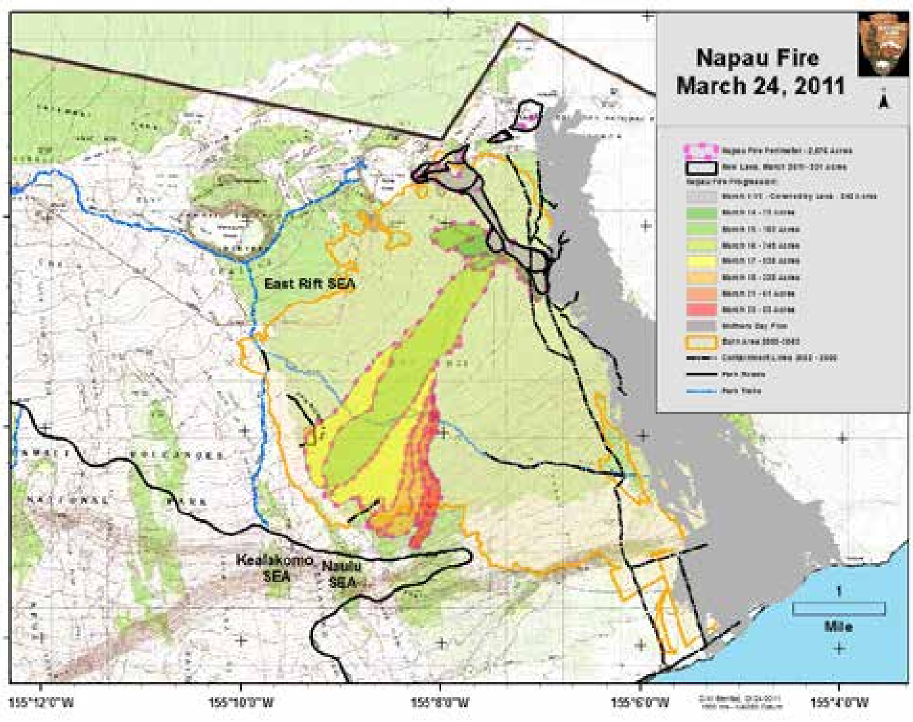
Providing real-time eruption information and education was a top priority for the park and of critical importance to this messaging effort was the collaboration that took place between NPS and USGS. Unlike previous eruptive events, HVNP interpretive staff went to the fissure eruption site to collect photos and videos that were posted on the NPS website and on computer monitors and exhibits in both park visitor centers, on the same day. This on-site coverage by interpretive staff, the first in park history, allowed the eruption to become real for park visitors, who otherwise would not have witnessed the event. HVNP did not have a social media plan during the 2011 event but West Hawaiʻi parks did a great job covering the Kamoamoa fissure eruption on the Pacific Island blog, an unofficial but popular site.

HVNP safety concerns

HVNP manages for all-risk. Incidents within incidents happen regularly, and this event was no exception. For example, when HVO notified HVNP of increased earthquake hazards and gas emissions (measured at almost 10 times normal rates) along Chain of Craters Road near Kealakomo, all NPS response personnel were directed to have respirators with them while in this area. HVO webcams also alerted HVNP to fire creeping into the park and, later on March 5, the expectation of a lava-ignited wildfire was realized, adding a layer of complexity to the eruptive response and messaging efforts. The resources at risk included the park's East Rift Special Ecological Area (SEA), which has been intensively managed to exclude invasive species and to protect and restore highly valued native plant and animal communities. Resource values include remnant native rainforest and mesic forest that contain some of the only known populations of threatened and endangered species such as the Hawai'ian jewel orchid, rare endemic lobeliads and mints, as well as rare endemic bird species such as the Hawai'ian hawk, honeycreeper, and Hawai'i's only endemic terrestrial mammal, the Hawai'ian hoary bat.

A major problem with the fire, located 11 km (7 mi) east of Kīlauea Visitor Center on Kīlauea volcano's east rift zone, was access, which required long hikes over deep earth cracks,

Figure 3. Map showing the western Kamoamoa lava flow (gray with black outlines) and the progression of the lava-induced fire (multiple colors, each with pink outlines; HVNP 2011).



fissures, and areas of high potential for exposure to volcanic gases. Helicopter access was also necessary. Trade winds pushed the fire to the southwest towards the SEA, and over a 13-day period it grew to over 2,000 acres. Early during the fire the volcanic activity paused, which allowed NPS to reopen Chain of Craters Road to the public. NPS also began to focus on exploring all suppression points, continuing to coordinate with USGS on eruption activity and air quality. Earlier NPS fire reconnaissance flights also sent GIS map files of the lava flow to HVO geologists. Access to the fire remained a problem as intensified trade winds and the radiant heat generated from the lava flow caused the fire to burn actively. By day two, the Chain of Craters Road was closed again, this time due to smoke impacts. Portions of fence lines also burned, causing numerous snags to fall across and significantly damage the fence. By day three of the fire, the lava flow had subsided, though the fire was not contained until April 5, 2011. The fire continued to be monitored by helicopter until April 21, 2011, to detect hot spots and verify that the fire was contained and extinguished (HVNP 2011).

In addition to minimizing loss or damage to natural and cultural resources, staff at both HVNP and HVO have safety in their mission. With fire, the management objective always focuses on the safety of firefighters and park personnel, visitors, and cooperators. During this already complex response, two other unforeseen issues compromised employee safety. Both required close corroboration between NPS and USGS and daily risk assessment exercises.

Media flight poses danger to scientists on the ground

Because the eruption started late on March 5, there was time overnight for word to spread about the new volcanic activity and, as the sun rose on the eruption's second day (March 6, 2011), a small fleet of helicopters bearing members of the media converged on the Kamoamoa fissure eruption. The fissure erupted through a thick blanket of tephra (cinders) produced during lava fountaining in the early 1980s. HVO had sent a small crew on foot to monitor the eruption during the first night, so when the helicopters converged on the eruption area, HVO scientists were already on the ground.

As in other US areas, the Federal Aviation Administration (FAA) regulates aircraft flight paths in Hawai'i that are used by a mixture of commercial airliners, air tour operators, media, USGS, and other agencies. Air tours are restricted to pre-approved paths at minimum altitudes of 500 to 1500 ft above ground level (agl). Media flights, used by independent videographers and photographers, as well as news media, have no such restrictions and are allowed to fly at any altitude as long as they do not land and do not endanger people on the ground. The exception is when a temporary flight restriction (TFR) is in effect. In that instance, approval for access must be granted by the land manager.

On the morning of March 6, 2011, one particular media flight with an independent videographer onboard was flying low and just upwind of the erupting fissure. With the videographer focused on shooting footage of the spectacular sight and the pilot focused on steering clear of the eruption, neither noticed the two HVO scientists who were standing in a field of cinder observing the lava fountaining. The helicopter was flying so low that the rotor wash (downward airflow from the spinning helicopter rotor blades) blew cinder into the scientists' eyes, thereby endangering their safety on the ground.

The incident was reported to FAA, including video footage (provided by the videographer) in which the two scientists can be clearly seen. According to the report, the pilot was not looking for people on the ground and inadvertently flew low over the scientists while trying to position the videographer for dramatic footage. Along with reporting the incident, HVNP officially requested a TFR to keep all aircraft, other than those used by HVO and HVNP to perform their official duties, out of an area within a 5.6-km (3.5-mi) radius of the vent and 1,220 m (4,000 ft) agl. FAA immediately instituted this restriction and there were no additional such incidents during the Kamoamoa eruption. On March 7, the TFR was reduced to a 2.4 km (1.5 mi) radius and 460 m (1,500 ft) agl.

Another safety issue centered on air tour congestion while HVO and HVNP monitored the eruptive and fire activity, both on the ground and in the air. The film captured by the previously mentioned videographer aired nationally and internationally on major television networks. Because the area was closed to visitors on the ground for safety reasons, the only way this short-lived eruption could be personally witnessed was by air tour. Thus, airspace and radio communication around the lava flow and wildfire became a concern for the park. The park and regional aviation manager met with FAA and the Hawai'i Helicopter Tour Operators Association to discuss the aviation operations and related concerns. An aviation safety communiqué (SAFECOM) was also issued.

Once these measures were put in place, operations supporting eruption monitoring and science, park interpretation and safety, and fire containment proceeded without interference.

The science of the Kamoamoa eruption

Throughout the eruption, HVO scientists made on-site measurements and documented as much of the eruptive behavior as possible. This documentation included a webcam set up by HVO to record details of lava fountains along the western fissure. These images were shared with the public via HVO's webcam webpage and were accessed several million times during the eruption. For months afterward, the fissure itself was studied because it was constructed from lava spatter ejected by low fountains. Understanding the processes that built the Kamoamoa spatter ramparts allow HVO scientists to approximate the conditions of unwitnessed fissure eruptions through their remaining spatter deposits. Three-dimensional representations of the spatter ramparts built along the Kamoamoa fissure were made to document the result of this eruption and lava samples were acquired during the course of the eruption to determine if magma feeding the fissure was changing. In addition, geophysical data, including radar satellite coverage, were interpreted to understand why the eruption occurred.

The results will help forecast the next change in the ongoing eruption of Kīlauea and will improve the information provided to land and emergency managers. According to the eruption studies, the Kamoamoa eruption resulted from overpressure of the volcano's magmatic system (Lundgren et al. 2013). More magma was being injected into the subsurface plumbing than was being erupted at the surface. The overpressure caused an increase in the number of earthquakes recorded between the summit and Pu'u 'Ō'ō prior to the outbreak. The lava that was erupted contained traces of older un-erupted lava that had been stored below the ground surface. As the magma rose to be erupted, it mixed with magma from storage areas on the way to the surface.

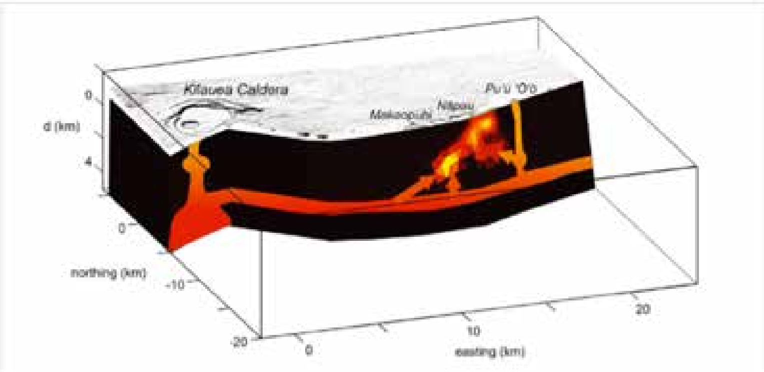


Figure 4. The geophysical model of the subsurface magma plumbing and its connection between the summit (Kīlauea Caldera) an the Kamoamoa fissure eruption between Nāpau Crater and Pu‘u ‘Ō‘ō (orange arrows; Lundgren et al. 2013).

The Kamoamoa eruption was the first of three such events in 2011. The sequence was the same for each event: the crater of Pu‘u ‘Ō‘ō filled with lava slowly and then collapsed quickly while lava issued from its crater or flank. The lava flow from an event in August continued for several days and also induced a fire, while the lava flow from an event in September continued for several months in the opposite direction and outside HVNP. The lessons learned by HVO and HVNP during the Kamoamoa eruption helped minimize the negative effects of these two later 2011 eruptions.

Conclusion

The Kamoamoa eruption started on March 5, 2011, and was over by March 9, after having erupted almost 3 million cubic m (almost 4 million cubic yds) of lava and several tens of thousands of tons of sulfur dioxide gas. Lava returned to the long-lived vent at Pu‘u ‘Ō‘ō two weeks later and Kīlauea volcano’s ongoing east rift zone eruption resumed. HVNP wrapped up the lava-induced fire response by April 21, 2011. HVO continues to monitor volcanic activity on Kīlauea.

For future responses by HVO and HVNP personnel, a TFR request will be made immediately to extend for the duration of the entire eruption and fire incident. Otherwise, this incident was typical of joint HVO and HVNP responses to an eruption with the national park.

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USGS Geologic Mapping and Karst Research in Ozark National Scenic Riverways, Missouri, USA

David J. Weary and Victoria M. Grant

Introduction

Ozark National Scenic Riverways (ONSR), a unit of the national park system, was created in 1964 to protect 134 miles of the Current River and its major tributary, the Jacks Fork, that are located in south-central Missouri (Figure 1). The park includes numerous large karst springs, including Big Spring, which is the largest spring in the national park system by flow volume. The National Park Service (NPS) administers a narrow, nearly continuous corridor of land adjacent to the two rivers. Base flow for the rivers is chiefly supplied by groundwater that has traveled through the karst landscape from as far as 38 miles away (Imes and Frederick 2002). The watershed is vulnerable to pollution, but the area remains largely rural with few industries. The springs and rivers provide habitat for numerous aquatic species as well as recreational resources for floaters, fishermen, and campers. ONSR is a major cave park with hundreds of known caves and diverse in-cave resources.

The geology of ONSR comprises a Mesoproterozoic (~1.4 giga-annum) basement of intrusive and extrusive igneous rocks discomformably overlain by relatively flat-lying Cambrian and Lower Ordovician (~500– to 470–mega-annum) sedimentary rocks, on which various surficial and residual sedimentary units are superposed. The basement rocks, chiefly granite and rhyolite, are exposed as erosional remnant hills in an uplifted area near the central part of the park area (Figure 2). The Paleozoic sedimentary rocks are chiefly dolomite that contain interlayerings of quartz sandstone and chert. The bedrock is cut by chiefly vertical strike-slip faults of the Ouachita Orogeny to the south. The entire exposed Paleozoic section is pervasively karstified.

Geologic issues at ONSR

The US Geological Survey (USGS) conducted geologic mapping in ONSR area for two

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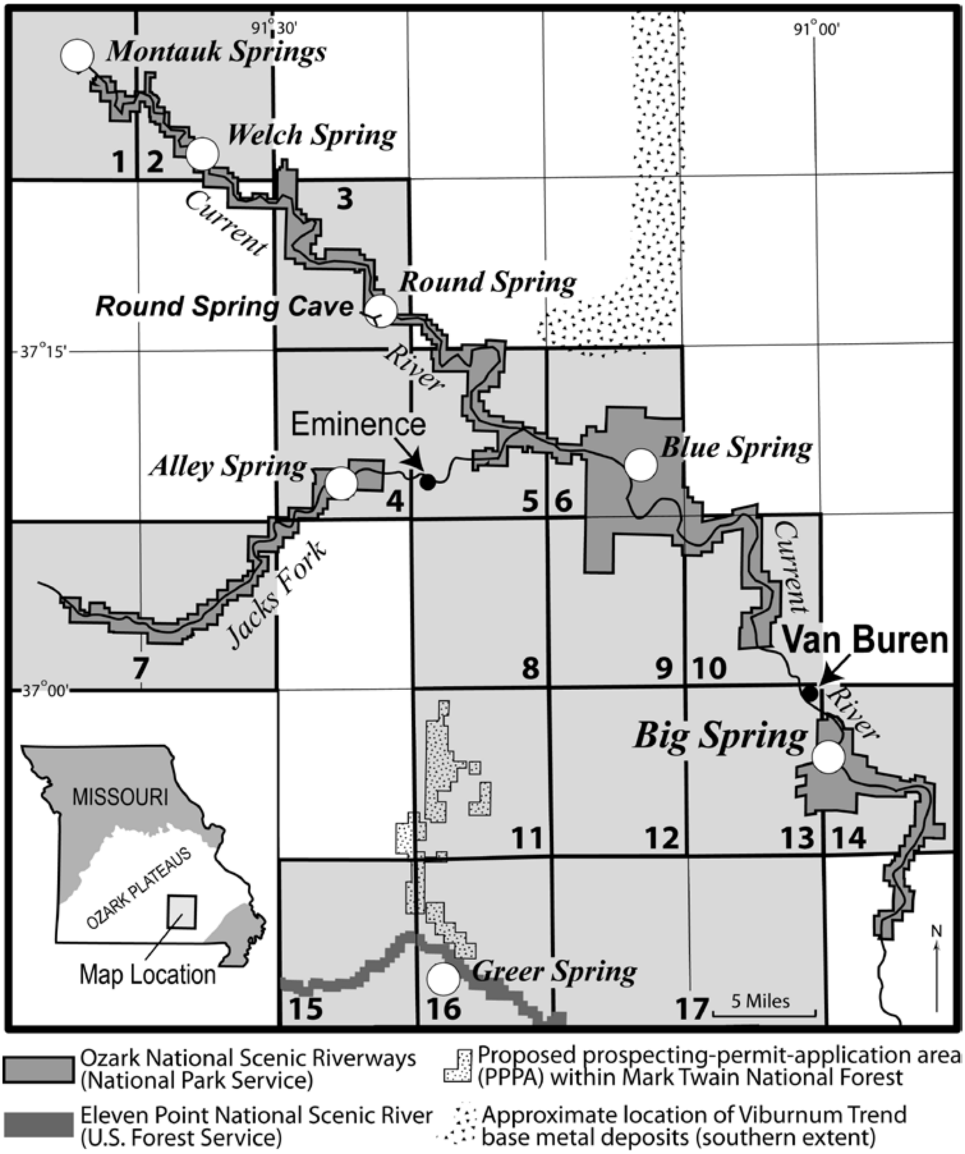


Figure 1. Map showing the location of Ozark National Scenic Riverways (ONSR) and geologic maps (gray rectangles) published by USGS from 1998 to 2013. Numbers on rectangles correspond to entries on Table 1. See reference section for full citations. The ONSR headquarters is located in the town of Van Buren. Base metal (lead–zinc) deposits occur in the subsurface of the Viburnum Trend and in parts of the previously proposed prospecting–permit application area of Mark Twain National Forest.

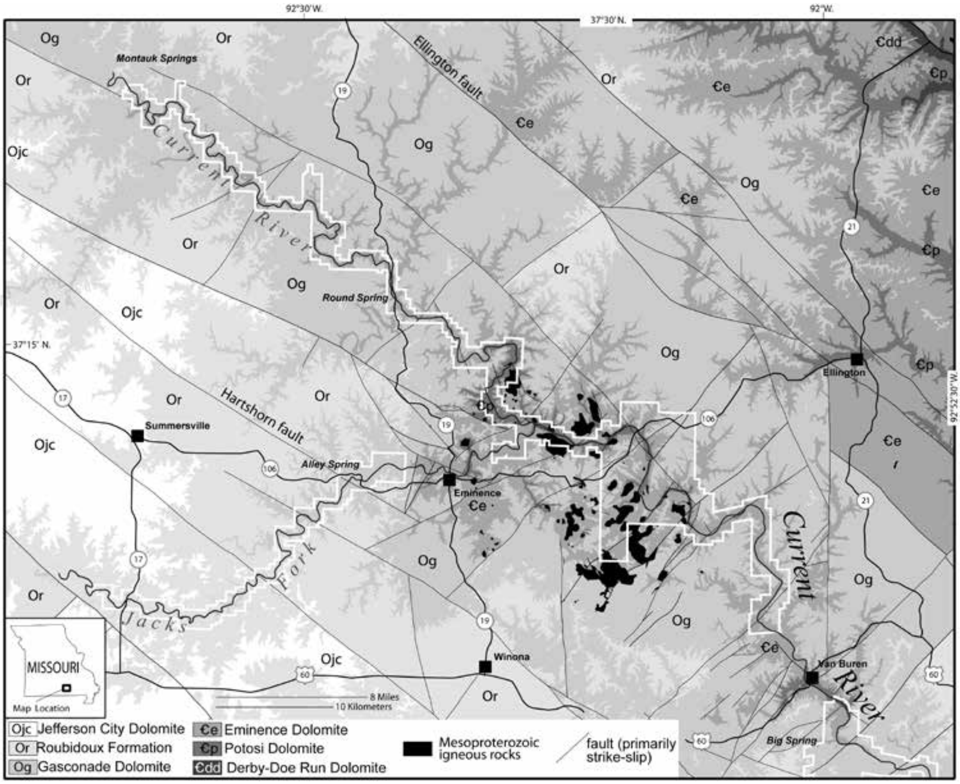


Figure 2. Generalized geologic map of ONSR park area. The ONSR boundaries are indicated by the white lines. Note that the park extends an additional 7.2 miles beyond the south border of this map. Map modified from Lowell et al. (2010).

primary reasons. First, to provide mapping to an NPS-mandated geologic inventory of the park; and second, to provide a detailed regional geohydrologic framework in support of ongoing multidisciplinary studies in an effort to determine the potential for migration of groundwater contaminants into ONSR from a proposed subsurface base-metal exploration site located on US Forest Service land near the park (Figure 1).

USGS mapping in ONSR

Geologic mapping is a valuable investment in earth science research, as it is multidisciplinary, exploratory, and results in expanded research insights years after the initial ground traverses are made. The bedrock geology of an area comprises the basal part of the earth's "critical zone" and knowledge of it is integral to all other ground-based natural science studies. The critical zone is defined as "the external terrestrial layer extending from the limits of vegetation down to and including the zone of groundwater. This zone sustains most terrestrial life on the planet" (Brantley et al. 2006). Prior to USGS mapping, the only geologic map data available for ONSR was a 1:62,500-scale map covering part of the park area by Josiah Bridge (1930), and reconnaissance maps by the Missouri Department of Natural Resources, Division of Geology and Land Survey. None of the previous mapping was in digital form.

USGS, in partnership with NPS and other federal and state agencies, conducted geologic mapping in the vicinity of ONSR from 1996 to 2013. Detailed geologic maps by USGS were completed in nineteen 7.5-minute quadrangles (See Figure 1 and Table 1).

A seamless 1:24,000-scale digital compilation map, planned for publication in 2014, will complete geologic coverage of ONSR, thereby enabling NPS to achieve its inventory goal under the geologic resource evaluation initiative. All of these maps are GIS-based and the data are available via the Internet. A 1:100,000-scale geologic map for the combined area of the West Plains and Spring Valley, Missouri (1:100,000 sheets, and adjacent areas) is in preparation and will be released for publication in 2014. This area, approximately 4,300 mi2 (11,116 km2), encompasses most of the drainage basins for the Current River, the Jacks Fork, and the Eleven Point River to the south of ONSR.

USGS geologic research in ONSR

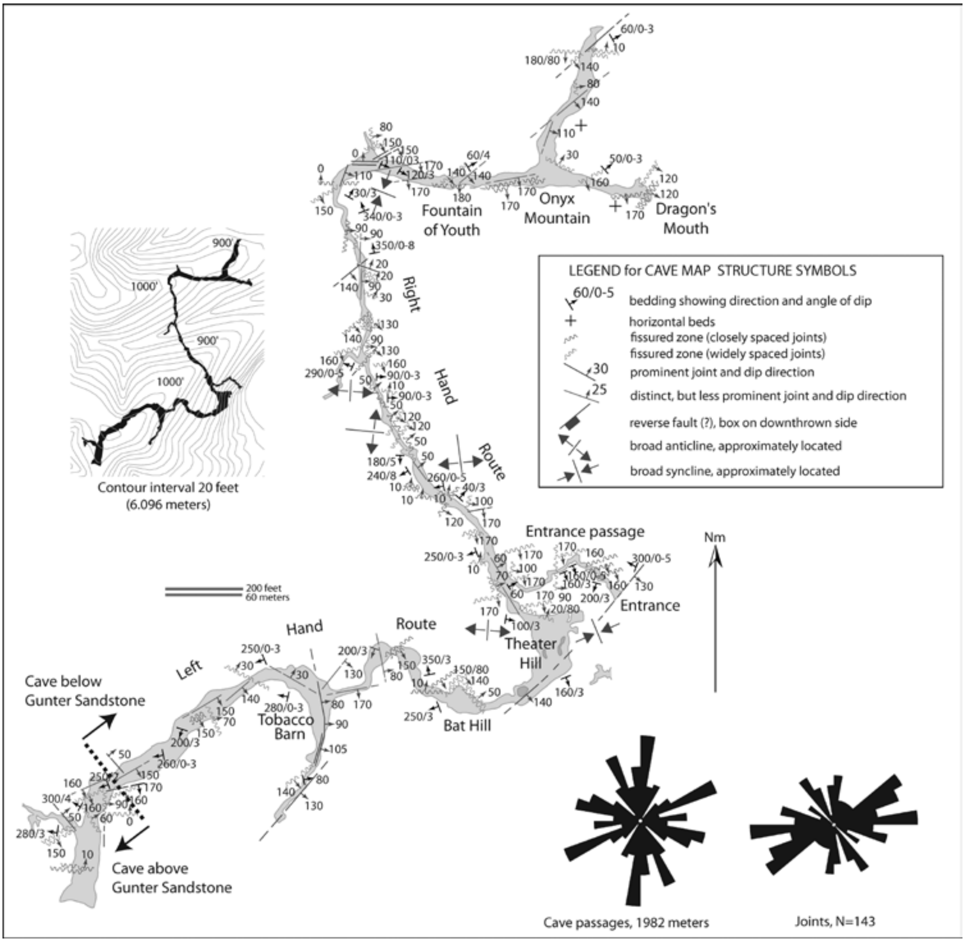
In addition to completing geologic maps of park areas, USGS scientists have produced numerous reports and made many presentations on various geologic and cave research

Table 1. List of quadrangle maps completed in ONSR and vicinity by USGS. See reference section for full citations. Numbers correspond to quadrangle locations in Figure 1.

Figure 1 number	Quadrangle(s)	Author(s)	Year of publication or status
1	Montauk	Weary	In production, estimated 2014
2	Cedargrove	Weary	2008a
3	Round Spring	Orndorff and Weary	2009
4	Alley Spring	Weary and Orndorff	2012
5	Eminence	Orndorff et al.	1999
6	Powder Mill Ferry	McDowell et al.	2000
7	Jam Up Cave and Pine Crest	Weary et al.	2013
8	Winona	Orndorff and Harrison	2001
9	Stegall Mountain	Harrison et al.	2002
10	Van Buren North	Weary and Weems	2004
11	Low Wassie	Weems	2002
12	Fremont	Orndorff	2003
13	Van Buren South	Weary and Schindler	2004
14	Big Spring	Weary and McDowell	2006
15	Piedmont Hollow	Weary	2008b
16	Greer	McDowell	1998
17	Wilderness and Handy	Harrison and McDowell	2003

topics. One of the prime research topics was to characterize karst features in ONSR and interpret their importance to both the present and past geohydrologic framework of the area. Locations of sinkholes, caves, and springs, some previously unknown, were recorded during the course of the geologic mapping. Cave locations have not been published following the rules and guidance of the Federal Cave Resources Protection Act, but other karst features are included in the GIS data published with each quadrangle map. From 1996 through 1999, various aspects of cave geology were studied by USGS in cooperation with Stanka Sebela of the Slovenian Karst Research Institute. Sebela is an expert on the role of small-scale geologic structures (faults, fractures, bedding orientation, etc.) as controls on cave passage formation. See Figure 3 for an example from this research.

Figure 3. Map of structural features mapped in Round Spring Cave, ONSR (from Sebela et al. 1999). Rose diagrams show orientations of cave passage segments and orientations of joints measured in the cave.

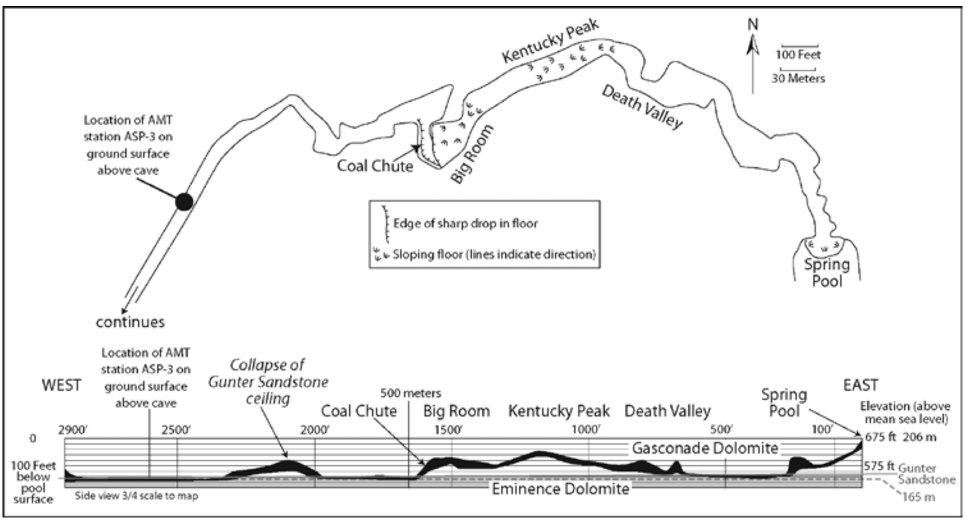


Seventy-nine caves in or near ONSR were studied to understand the geologic controls on the development of groundwater conduits along the southeastern margin of the Ozark Plateaus. Geologic mapping of 19 of these caves provides information on the stratigraphy, cave passage orientation and morphology, and fracture attributes (Sebela et al. 1999; Orndorff et al. 2006). Most of the cave base maps were obtained from the Missouri Speleological Survey. A few of the caves were mapped by USGS scientists in cooperation with personnel from the Cave Research Foundation (CRF), particularly Bob Osburn of St. Louis, Missouri.

USGS cooperation with the Ozark Cave Diving Alliance (OCDA) facilitated NPS permitting the OCDA to dive and map the underwater cave feeding Alley Spring, the third largest spring in ONSR (Figure 4). Geologic observations made by the divers verified assumptions about the stratigraphic control of the geometry of the conduit. Video recordings of the dives have been a valuable outreach tool for the park.

Knowledge of the geometry of the Alley Spring conduit (cave) led to a successful proposal for a FY2009 USGS geology venture capital fund award titled "Three-dimensional geophysical prospecting for a major spring conduit in the Ozark karst system using audio-magnetotelluric (AMT) soundings and ground penetrating radar: A proof of concept study." AMT field data collected over a 2-week period in the vicinity of Alley Spring were processed and analyzed by Herbert A. Pierce of USGS. Use of ground-penetrating radar is inappropriate for the geologic setting and was not attempted. The results of the study were integrated with

Figure 4. Map and profile of Alley Spring Cave, simplified from a map produced by the Ozark Cave Diving Alliance (2005). Geologic interpretation by D. Weary (USGS), based on surface geologic mapping, observations by OCDA divers, video footage, and analogy to geologic control seen in air-filled caves in the region. Discussions of this figure may be found in Weary and Pierce (2009) and Lowell et al. (2010).



the detailed geologic information, acquired through mapping, and the synthesis reported in Weary and Pierce (2009) and discussed in detail in Lowell et al. (2010).

Early in the project, USGS mappers utilized conodont biostratigraphy as a tool to aid in verification and correlation of stratigraphic units in ONSR. Conodonts are nearly microscopic phosphatic parts of the oral apparatus of extinct primitive chordates that lived during a period about 500–200 million years ago. Conodonts were ubiquitous in warm and temperate seas during the Paleozoic through early Mesozoic and are one the most useful fossils for biostratigraphic research in sedimentary rocks of this age.

Rock samples for conodont analysis were collected, as needed, under annual sampling permits issued by NPS. USGS geologists were highly cognizant of the need to make as little impact as possible on park resources, so samples were kept as small as practical and collected from inconspicuous locations. These samples also contributed data to ongoing studies on the stratigraphic history of Lower Paleozoic strata in the Ozarks region. Two research topics of particular interest are: (1) the nature of the unconformable contact between the Eminence Dolomite and the overlying Gasconade Dolomite, which corresponds to the Cambrian–Ordovician boundary, and (2) the age of the Gasconade Dolomite to Roubidoux Formation transition interval (Repetski et al. 1998, 2000a, 2000b; Miller et al., in press). Macrofossil abundance is sparse, and when present they are commonly poorly preserved due to the pervasive recrystallization of the rocks in ONSR; therefore they were not specifically studied by USGS.

Uses for USGS data in ONSR

Beginning in 1996, USGS geologic data were being used by Missouri Department of Conservation (MDC) as the foundation of the ecological classification system within the park watershed. An ecological classification system is a physical and biological framework that allows managers to identify, map, and describe land characteristics at scales suitable for natural resources planning and management. Geologic data are one of the important layers used in producing these maps and USGS cooperated closely with MDC and others by providing timely geologic map data as particular areas were being mapped. These products are used for vegetative community mapping, modeling, and management; invasive species control; and species management and protection, among other uses.

Geologic education and outreach

Since 1996, USGS geologists have been *ad hoc* consultants for ONSR in support of multidisciplinary studies, proposals, land management issues, and geologic educational outreach. USGS geologists have been asked to review or comment on various geologic interpretive displays produced for the park. On two occasions USGS karst experts accompanied groups of seasonal cave guides assigned to Round Spring Cave to discuss and educate them on the various aspects of the geology and speleology of the cave. This knowledge is used to enhance the information provided by NPS guides in public tours of the cave. USGS geologists also have led formal field trips in the project area in conjunction with professional geological society conferences (e.g., Lowell et al. 2010).

Direct and indirect support for USGS mapping activities

The majority of the funding for geological mapping and research in ONSR came from the USGS National Cooperative Geologic Mapping Program (NCGMP), with additional funding provided by the NPS Geologic Resources Division (GRD). Other significant contributions included Congressional line-item funds via the US Forest Service to support studies related to potential base metal mining in the area. ONSR has also contributed valuable field support to USGS researchers via vehicle loans, vehicle parking, subsidized lodging, and canoe shuttles for river work. Federal investment in this project leveraged additional geologic mapping in ONSR by the Missouri Geological Survey. ONSR natural resource specialists have also coordinated informal information exchange between USGS geologists and other scientists working in the park.

Comments on and recommendations for USGS and NPS collaboration

Over the duration of the approximately 16-year mapping project, it became apparent to USGS that there was value in involving several different mappers. Each geologist possessed a particular set of knowledge and interests beyond his or her core competencies as mappers. This diversity enriched and compounded the scope of geologic inquiry and interpretation.

Cooperation between USGS geologists and ONSR staff has been an ongoing success because of the consistent funding support between similarly aligned programs within each bureau. The presence of a NCGMP-supported project in the park area encouraged interdisciplinary networking that leveraged other research activities. Communication and coordination between NPS and USGS personnel has been successful due to the enthusiasm and personal commitments by the individuals involved to the research.

After the GRD geologic inventory is completed, and NCGMP-sponsored activity has moved elsewhere, it would be valuable to have a mechanism in place to encourage and support continued USGS research and outreach in the national parks. This would encourage topical research and USGS geologists could author or contribute to interpretive materials and publications for parks they have worked in. Both agencies have invested time, money, and significant parts of the careers of their staff in park geologic research. Formal ongoing relationships between USGS researchers and the parks would facilitate extended use of the geologic expertise gained and encourage delivery of better outreach and education products to the American public.

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- Others: Raymond Ethington, Geological Sciences Department, University of Missouri, Columbia; James Loch, Earth Science Department, University of Central Missouri, Warrensburg; Gary Lowell, Earth & Environmental Sciences, University of Texas–Arlington; Bob Osburn, Cave Research Foundation, and Department of Earth and Planetary Sciences, Washington University, St. Louis, Missouri; Stanka Sebela, Karst Research Institute, Postojna, Slovenia.

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Mercury in the National Parks

Colleen Flanagan Pritz, Collin Eagles-Smith, and David Krabbenhoft

Unpredictable.

Or is it?

One thing is certain: Even for trained researchers, predicting mercury's behavior in the environment is challenging. Fundamentally it is one of 98 naturally occurring elements, with natural sources, such as volcanoes, and concentrated ore deposits, such as cinnabar. Yet there are also human-caused sources, such as emissions from both coal-burning power plants and mining operations for gold and silver. There are elemental forms, inorganic or organic forms, reactive and unreactive species. Mercury is emitted, then deposited, then re-emitted—thus earning its mercurial reputation. Most importantly, however, it is ultimately transferred into food chains through processes fueled by tiny microscopic creatures: bacteria.

Mercury is ephemeral, but enduring and pervasive. It poses serious risks to environmental and human health. So, can we predict exactly where? What areas are most at risk?

Mercury is a highly toxic pollutant that has been both extensively utilized and widely distributed across the globe by humankind's activities. Because of its ubiquity and considerable toxicity, the US Geological Survey (USGS) has conducted several decades of research to unravel mercury's complex and seemingly mysterious behavior. One product of this work has been the collection of an unprecedented amount of information to better understand the story of mercury in the national parks, and other areas.

Once mercury enters an aquatic or terrestrial food web, trouble begins to brew. Mercury can harm all forms of life; it is one of very few elements for which there is no known biochemical or biophysical need. In wildlife, high mercury concentrations can result in altered behavior and reduced foraging efficiency, reproductive success, and even survival. Exposure to high levels of mercury in humans may cause damage to the brain, kidneys, and the developing fetus. Pregnant women and young children are particularly sensitive to mercury exposure.

Mercury contamination is evident everywhere. More than 16 million lake acres and 1 million river miles are under fish consumption advisories due to mercury in the United States, and 81% of all fish consumption advisories issued by the US Environmental Protection Agency are because of mercury contamination (USEPA 2013).

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Mercury contamination can be a substantial water quality issue for national parks in even the most remote, relatively pristine locations far removed from point-source emissions, because many of the landscape characteristics of aquatic ecosystems in protected lands—abundant wetlands, full forest canopies, and naturally fluctuating water levels—are associated with the production of the most toxic and bioaccumulative form of mercury: methylmercury. Undeveloped landscapes with dense wetlands and forests generally yield highly favorable settings for converting inorganic mercury, which is relatively unavailable for biological uptake, to methylmercury. Wetlands are commonly home to anaerobic sediments, which in turn serve as ideal landscape settings to host sulfate-reducing bacteria, commonly implicated as the primary methylating agent in the environment. Tall and dense forested canopies act as air filters, collecting and concentrating mercury from the air onto foliage, which later drops to the ground in rain, snow, or litterfall. Mercury then collects in the soil and eventually moves into streams and lakes. Drying and rewetting cycles resulting from seasonal fluctuations of the hydrocycle also promote mercury methylation.

The importance of the methylation process on how mercury manifests itself as a serious environmental concern cannot be overstated. In fact, were it not for mercury's relatively uncommon susceptibility to become methylated, it would certainly be of little or no consequence to living organisms except under the most extreme of contamination conditions.

Further, many national park ecosystems are largely intact. With this, there are complex food webs and long food chains that also promote high concentrations of mercury at top levels. Predatory fish, which commonly include those sought after for sport and human consumption, are more likely to have elevated mercury concentrations due to biomagnification within the food web. Older fish are particularly at risk given the increased susceptibility for contaminant bioaccumulation over their longer life spans. Other factors that may further exacerbate mercury accumulation and heighten ecosystem sensitivity, specifically in high-elevation and high-latitude areas, include the shorter growing season and slower growth of aquatic species.

A major concern about mercury in national parks is the fact that much of the mercury found in these remote areas is largely the result of air pollution from outside the parks. Although there are natural sources of mercury such as volcanoes and mercury-enriched geogenic deposits, much of the mercury that affects parks comes from burning fossil fuels, like coal, in power plants. Waste incinerators, industrial boilers, cement manufacturing, and mining operations are other human-related mercury emission sources. Once emitted to the air, mercury can travel great distances before it returns to the earth with rain, snow, dust, and fog, or via passive uptake by photosynthetically active plants. Upon conversion to methylmercury, a transformation that easily occurs in the ideal environmental conditions provided by many national parks, mercury both bioaccumulates (builds up) and biomagnifies (increases in concentration with each successive step up the food chain) in organisms (Figure 1). Organisms that live at the top of food chain (e.g., bald eagles, common loons, bears, lake trout, humans, etc.) are most at risk for exposure to high levels of mercury through fish consumption.

Mercury threatens the very resources that the National Park Service (NPS) is mandated to protect. The NPS Organic Act (16 USC 1 [1997]) directs the agency to promote and reg-

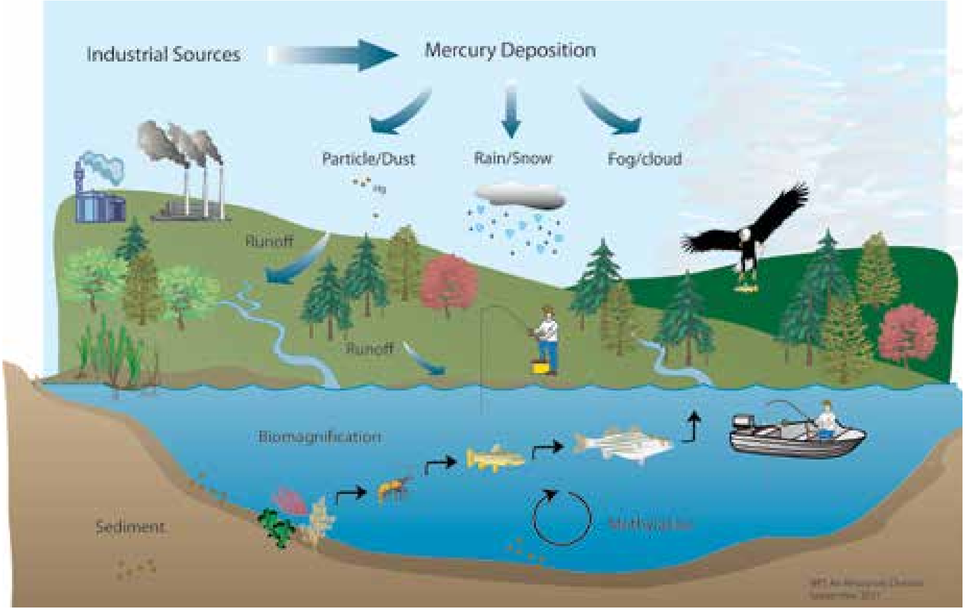

Figure 1. Sources and paths of mercury in the environment.

ulate the use of the national parks, whose "purpose is to conserve the scenery and the natural and historic objects and the wild life therein, and to provide for the enjoyment of the same … as will leave them unimpaired for the enjoyment of future generations." Additionally, under the Clean Air Act (42 USC 7470 [2]), NPS is mandated to "preserve, protect and enhance the air quality in national parks … and other areas of special national or regional natural, recreational, scenic or historic value."

NPS and USGS are mutually interested in studies concerning the effects of mercury, as well as other air pollutants, on natural resources. These studies tie into National Park Service goals to lead America in preserving and restoring treasured resources, demonstrate environmental leadership, offer superior recreational experiences, foster exceptional learning opportunities that connect people to parks, and be managed with excellence. The focus of USGS research on mercury in the national parks centers on ecosystem and human health risk, both predicted and actual. The projects highlighted herein specifically outline work contributed by the USGS Mercury Research Lab (MRL) and USGS Forest and Rangeland Ecosystem Science Center (FRESC), in collaboration with the NPS Air Resources Division (ARD), across parks, regions, and networks (Figure 2).

Where we have been

Everglades National Park (FL): Investigating the mercury cycle. Due to an increased public concern for wildlife and human health resulting from mercury toxicity in the Florida Everglades, USGS MRL initiated the Aquatic Cycling of Mercury in the Everglades (ACME) project in 1995. The overall objective of the ACME project was to conduct intensive, pro-

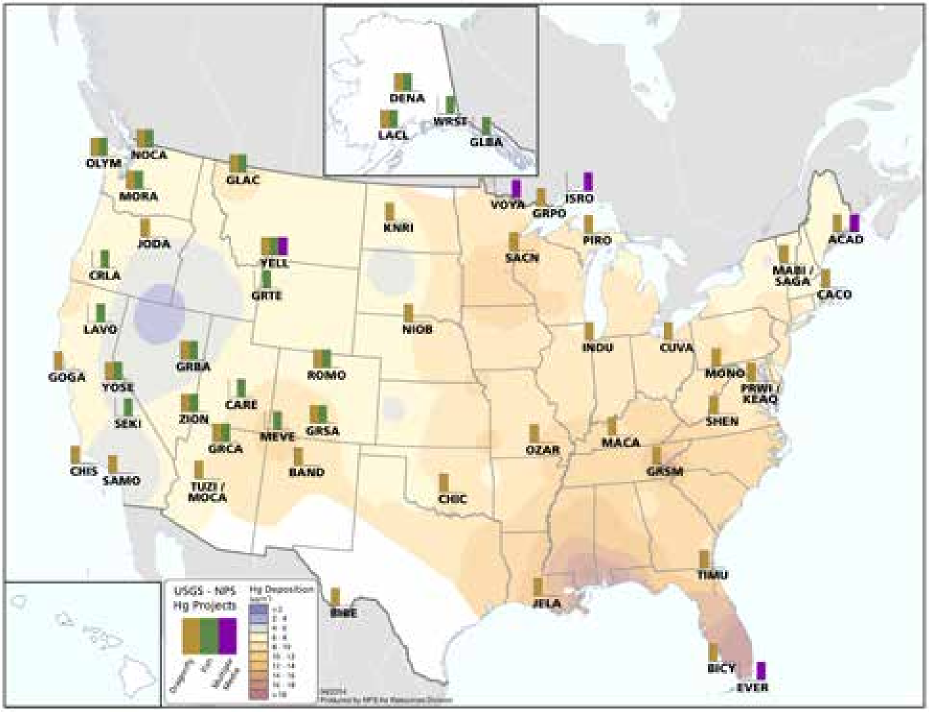

Figure 2. Recent USGS–NPS collaborative studies on mercury in the national parks: fish (2008–2012), dragonfly larvae (2011–2015), and multiple media (1995–present; intensive research on mercury dynamics and distribution at hotspot parks). The background layer illustrates 2012 mercury wet deposition estimates. Data from National Atmospheric Program Mercury Deposition Network; http://nadp.sws.uiuc.edu/mdn/.

cess-oriented research that focuses on the primary mercury sources, cycling pathways, and bioaccumulation in the Everglades, and to provide an anticipatory understanding of how the ecosystem restoration program may affect mercury in the future. ACME made several key contributions toward improving understanding of the mercury cycle in the Everglades, including basic information on the relationship between methylmercury production and biogeochemical variables, such as nutrients, sulfate, sulfide, and dissolved organic matter (Krabbenhoft et al. 2000). Key findings included: (1) sulfate loading to the Everglades increases microbial sulfate reduction in soils and ultimately enhances methylmercury production and bioaccumulation in some parts of the Everglades ecosystem; and (2) the large gradients in sulfur, methylmercury and dissolved organic matter across the Greater Everglades Ecosystem are driven in part by agricultural drainage and water management practices. Dvonch et al. (1995) attributed elevated mercury concentrations in several Everglades rain event samples to local sources. At Everglades National Park, elevated concentrations of mercury in invertebrates, frogs, fish, wading birds, pythons, alligators, and Florida panthers have been documented; some at levels known to cause neurologic and reproductive impairment (NPS 2011a).

Yellowstone National Park (MT/WY): Studying the source, pathways, and fate of mercury. Yellowstone National Park is saturated with spectacular geothermal features. These geysers and hot springs also happen to be natural sources of mercury. Given that, many scientists speculated that the park might be one of the largest natural mercury emission sources on the planet. USGS scientists tested that assumption and set up the Mobile Atmospheric Mercury Laboratory to assess the relative importance of sources from within and outside Yellowstone National Park (Hall et al. 2006). Results indicate that Yellowstone is not as large a source of mercury to the atmosphere as was once thought. In fact, scientists found that wildfires burning near or in the park released appreciably more mercury to the atmosphere than the park's geothermal sources. USGS also studied the dynamics in the park's thermal features, using the ratio of naturally occurring mercury isotopes present in the geothermal waters to trace or identify sources of mercury to the environment. Although mercury occurs naturally in hot springs, its most toxic form, methylmercury, appears to be entering the food chain largely by accumulating in slimy microbial mats (King et al. 2006; Boyd et al. 2009; Sherman et al. 2009). The results of these studies have increased our understanding of the origins, transport, and fate of mercury from Yellowstone's geothermal areas. In addition, new insights have been gained on the relative contributions of natural versus human mercury sources and local versus regional mercury sources.

Where we are now

NPS Inventory & Monitoring networks: Predicting mercury risk. To reiterate: the toxicological risk of mercury contamination is strongly tied to factors that facilitate the conversion of inorganic mercury to the more toxic and bioavailable form, methylmercury. Methylmercury production is driven by multiple biogeochemical factors such as organic carbon availability and quality, redox fluctuations, inorganic mercury speciation and adsorption, and sulfur chemistry (Figure 3). These factors influence both the activity of mercury-methylating microbial groups, as well as the availability of inorganic mercury. However, these factors and their relative importance can vary in time and across the landscape, making predictions of risk difficult. Understanding how these local drivers influence mercury cycling across ecosystem types is a critical component to developing robust predictions of potential mercury impacts to aquatic ecosystems in national parks and other sensitive areas.

USGS research summarized in Lubick (2009) and Wentz et al. (2014) showed that mercury deposition, primarily atmospheric deposition from industrial emissions, is just one factor that influences the levels of bioavailable methylmercury. However, "variations in ecosystem properties that govern methylmercury production in an ecosystem are probably much more important [in determining which ecosystems have fish with high methylmercury] than the variation of mercury deposition across the country" (Lubick 2009, citing M.E. Brigham). That said, while variability in ecological conditions tend to drive spatial trends in methylmercury abundance, swings in deposition drive the majority of temporal methylmercury variability.

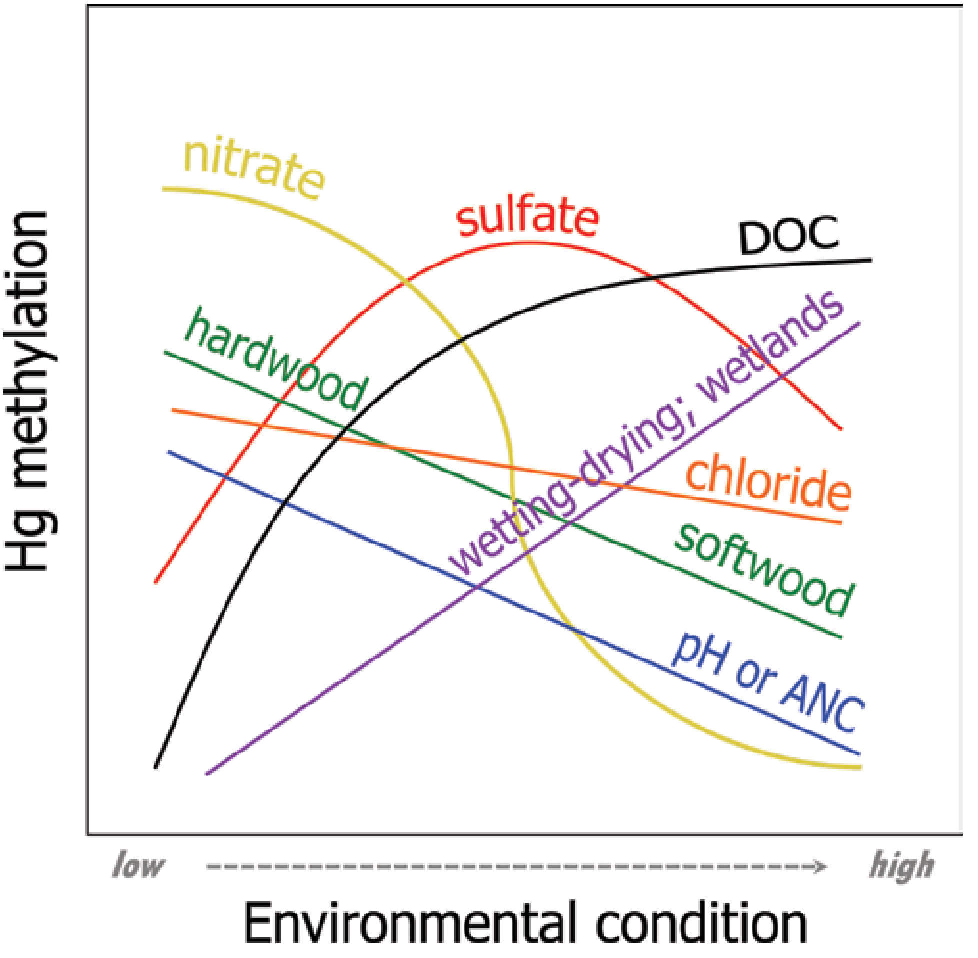

Figure 3. Emerging relationships between mercury (Hg) methylation and environmental conditions or gradients. Water chemistry and site characteristics measured in USGS studies in national parks allow for testing of these responses. Figure adapted by Eagles-Smith et al. 2013.

Wetland abundance within a watershed, carbon levels within soils, dissolved organic carbon (DOC) in surface waters, suspended sediment concentrations in streams, and streamflow have all been shown to be key factors in determining the levels of methylmercury in waters, and mercury concentrations in aquatic fauna, within a given watershed (Brigham et al. 2009; Chasar et al. 2009; Marvin-DiPasquale et al. 2009).

Although our understanding of mercury cycling and distribution is well understood at national parks such as Everglades and Yellowstone, these sites are the exceptions, not the rule. Comparatively few parks nationwide have received substantial study of mercury cycling and ecosystem risk. In order to assess potential risk of mercury contamination at other national parks, USGS MRL is working in collaboration with NPS ARD to refine a sensitivity model for predicting methylmercury concentrations in surface waters of the 270 parks in the Inventory & Monitoring networks. Based upon common water chemistry data (i.e., DOC, sulfate, pH) and landcover criteria (wetland coverage), the model predicts aqueous methylmercury concentrations and identifies park units that are likely to have conditions most conducive to methylmercury production (Krabbenhoft et al. 2011).

An associated NPS-mapping-specific application for national parks is currently under development. The tool will allow users to select a particular park, drill down to the mega-watershed level (HUCs; hydrologic unit codes) within each park, and assess the predictive variables and the estimated methylmercury concentration. For each respective layer, the parameters were classified by quintiles, relative to all other NPS units included in the model: the top two upper quintiles (4th and 5th) represent the highest risk, the middle two quintiles (2nd and 3rd) represent moderate risk, and the lower quintile (1st) the lowest risk. For example, watersheds that contain the highest percentage of wetland land cover (the 5th quintile) fall into the high-risk category.

The methylmercury risk mapper provides direction for *in situ* studies of biota in national parks, providing resource managers with insight on potential hotspots, or areas at particular risk for elevated mercury levels. The interactive tool was made publicly available in the summer of 2014.

Western national parks: Assessing fish and ecosystem health. Fish tissue from freshwater environments represents an important component for evaluating mercury cycling, bioaccumulation, and ecological risk, including the potential risk to humans consuming fish. Fish are the fulcrum on which the story of mercury pivots. The public identifies with fish; people eat them. Fish provide recreational enjoyment through sport fishing; they also offer spiritual and cultural benefits, particularly for tribes who depend on them to sustain life. The dietary benefits of consuming fish include improved cardiac health from increased omega-3 fatty acid consumption or potential reduced intake of unhealthy fats due to food substitutions. The risk of elevated mercury in fish is not only a concern for people who eat fish, but for land managers who manage other fish-eating organisms, such as birds and mammals, and the fish themselves.

While previous studies identified regional patterns in mercury deposition (Krabbenhoft et al. 2002) and elevated mercury concentrations in some fish from remote, high-elevation water bodies in a few western national parks (Schwindt et al. 2008), there was a lack of a systematic characterization and assessment of mercury risk across remote areas of the West. In addition, for many years there was an assumption among researchers that generally drier western US areas experience less mercury loading due to lower rainfall amounts. However, more recent information has revealed that eastern versus western atmospheric loading differences are largely minimized by a better appreciation for the importance of mercury loading from dry deposition (e.g., dust), and thus there is a better appreciation for more mutually susceptibility along longitudinal gradients.

Given the significant role that atmospheric mercury deposition plays in these areas, USGS FRESC worked in collaboration with NPS ARD to study mercury in freshwater fish across 21 western national parks, from Alaska to Arizona. Between 2008 and 2012, NPS resource managers collected more than 1,400 individual fish from 86 lakes and rivers extending over a distance of 4,000 km. USGS scientists measured mercury concentrations in fish muscle tissue. Sixteen fish species were sampled, with a focus on commonly consumed sport fish found across the study area such as brook, rainbow, cutthroat, and lake trout. Smaller prey fish consumed by birds and wildlife were also sampled. The primary objectives included: (1) comparing fish mercury concentrations between parks and among sites within parks, (2) determining at what spatial scale variation in fish mercury concentrations is attributed, and (3) evaluating fish mercury concentrations in parks with respect to a range of wildlife and human health benchmarks (Eagles-Smith et al. 2014).

Findings indicate that mercury levels varied greatly, both from park to park and among sites within each park (Figure 4). Although fish mercury concentrations were elevated in some sites, the majority of fish across the region had concentrations that were below most benchmarks associated with impaired health of fish, wildlife, and humans. In most parks, mercury concentrations in fish were moderate to low in comparison with similar fish species from other locations in the western states. Mercury concentrations were below the US Environmental Protection Agency's (USEPA's) fish tissue criterion for safe human consumption in 96% of the sport fish sampled. There were, however, particular areas identified that had elevated fish mercury concentrations, including levels that exceed human consumption and/or wildlife health benchmarks. The average concentration of mercury in sport fish from Lake Clark and Wrangell–St. Elias (AK) national parks exceeded USEPA's human health criterion. Mercury levels in individual fish at Lassen Volcanic (CA), Mount Rainier (WA), Rocky Mountain (CO), Yellowstone (WY), and Yosemite (CA) national parks also exceeded the human health criterion (Eagles-Smith et al. 2014).

Mercury concentrations in individual fish also exceeded the most conservative fish toxicity benchmark at Capitol Reef (UT), Lake Clark (AK), Lassen Volcanic (CA), Mount Rainier (WA), Rocky Mountain (CO), Wrangell–St. Elias (AK), Yosemite (CA), and Zion (UT) national parks, and levels in some fish exceeded the most sensitive health threshold for fish-eating birds at all parks except Crater Lake (OR), Denali (AK), Grand Teton (WY), Great Basin (NV), Great Sand Dunes (CO), Mesa Verde (CO), and Sequoia–Kings Canyon (CA) national parks. Other national parks in this study were Glacier (MT), Glacier Bay (AK), Grand Canyon (AZ), North Cascades (WA), Olympic (WA), and Yellowstone (WY) (Eagles-Smith et al. 2014).

Where we are going: Evaluating mercury risk using dragonfly larvae

Given the complexities associated with local drivers of mercury cycling and the development of robust predictions of potential impacts to aquatic ecosystems in national parks, the application of biosentinel organisms has emerged as an important monitoring and research tool. Biosentinels can provide a better-integrated indicator of mercury variation among locations than water, and are more appropriate proxies for human and wildlife risk (Knights et al. 2005; Simonin et al. 2008; Sackett et al. 2009). Biosentinels are similar to the "canary in the coal mine," a surrogate for environmental health, that can be used to detect the potential risk

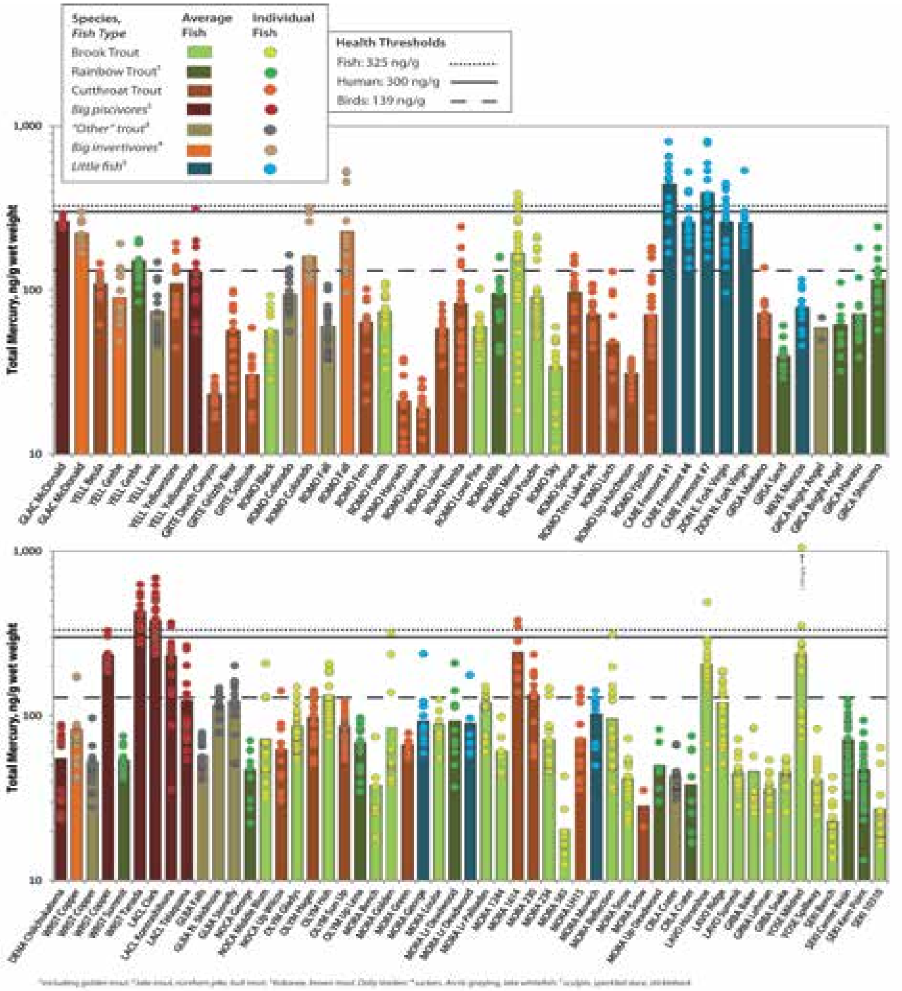

Figure 4. Total mercury in average fish muscle tissue (bars) and individual fish (circles), by species in wet weight (ww), compared with health benchmarks established for fish toxicity (325 ng/g ww), highly sensitive fish-eating birds (139 ng/g ww), and human consumers (300 ng/g ww; USEPA criterion). Data are plotted on a log10 scale. Figure from NPS 2014.

to humans and wildlife by providing advance warning of a danger. Effective biosentinels of ecosystem risk for mercury are widespread and ubiquitous, relatively easy to sample, linked to key energetic processes within ecosystems, ecologically well studied, and responsive to localized changes in methylmercury availability and cycling.

Dragonfly larvae (*Odonata: Anisoptera*) are aquatic macroinvertebrates that meet those criteria, and are being collected in at least 50 parks across the nation over five years (2011–2015) for analysis of mercury. USGS FRESC and MRL recently teamed up with NPS ARD, University of Maine, participating parks, citizen scientists, and other partners to build upon a successful pilot effort to evaluate and establish dragonfly larvae as robust biosentinels of aquatic mercury contamination in NPS units across the country (Flanagan et al. 2012; Wiener et al. 2013). This project is the first of its kind to validate a common and abundant biosentinel in national parks across the US, sample freshwaters in parks in a single coordinated study to determine mercury risk, and engage citizen scientists in the process.

Dragonfly larvae are shedding light on the risk of mercury contamination throughout the national park system. While fish are perhaps the most commonly used indicators because they occur across a wide geography and provide strong linkages to human and wildlife health, dragonfly larvae are relatively easier to collect, and represent the risk to mercury in fishless ecosystems like shallow ponds, ephemeral pools, and marshes—some of the most productive and ecologically important aquatic habitats. Preliminary results from the pilot study in dragonfly larvae indicate that mercury concentrations are greater at parks in the eastern US than those in the western US, and site differences within parks reveal that dragonfly larvae can reveal fine-scale differences in mercury risk. Related research shows that mercury in dragonfly larvae was correlated with both methylmercury in water and mercury in fish in the same water bodies (Haro et al. 2013), confirming their utility as an effective indicator of ecosystem risk.

Twenty-two national parks have participated in the project to date, from Denali (AK) and Big Cypress (FL), to Acadia (ME) and Golden Gate (CA), collecting over 700 dragonfly larvae at 50-plus sampling sites. Close to 300 citizen scientists, including students, Youth Conservation Corps members, and bioblitz participants have thus far contributed approximately 1,700 hours of volunteer time. Up to an additional 28 parks will participate in 2014–2015. Public engagement in this project directly implements the NPS Call to Action Items #7, "Next Generation Stewards," and #16, "Live and Learn," by enlightening a new generation of citizen scientists about the connection of all living things and the influence humans have upon natural systems, and how environmentally responsible decisions can protect our parks and the planet (NPS 2011b).

This project links chemical and habitat parameters with food web bioaccumulation and ecological risk. The main objectives are to: (1) use an established citizen scientist program network to collect samples for assessing variation in mercury and methylmercury in freshwaters and biosentinels across US national parks, and (2) determine how temporal variation, site characteristics, water chemistry, and biological drivers affect freshwater and biosentinel mercury accumulation. Habitat variables, developmental stages, and genus/species-specific traits of dragonfly larvae will also be considered.

Furthermore, this project contributes to the refinement and expansion of the methylmercury prediction model and mapper (Krabbenhoft et al. 2011) by providing both water chemistry predictor data (e.g., DOC, sulfate, pH) and measured total and methylmercury in surface waters for each participating park, and new data for previously unmodeled parks. This biosentinel project also provides the opportunity to compare predicted methylmercury vulnerability from the geospatial model to observed mercury in a single taxon—the dragonfly—across all participating parks. Validation data such as these, which confirm relative mercury burdens in biota, are sparse, and rarely are the same biota sampled across multiple parks or regions in a standardized way.

Where does that leave us?

NPS safeguards nearly 400 highly valued places for the protection of unique natural and cultural resources and scenic beauty. Research and monitoring efforts across the 84 million acres represented by national parks include assessments of mercury in insects, amphibians, fish, birds, water, sediment, snow, air, vegetation, and wildlife.

Variation in site-specific mercury concentrations within individual parks suggests that more intensive sampling in some parks will be required to effectively characterize mercury contamination at these locations. Future targeted research and monitoring across park habitats would help identify patterns of mercury distribution across the landscape and ultimately facilitate informed management decisions aimed at reducing the ecological risk posed by mercury contamination in sensitive ecosystems protected by NPS. Other investigations on source attribution and actual effects on park resources will further our understanding of this complex issue.

Continued coordination with other entities will build awareness of the issue of mercury contamination in the national parks. For instance, NPS and USGS FRESC are working together on developing a mercury benchmark to assess the condition for park planning processes. NPS is also working with state officials on potential fish consumption advisories, as is the NPS Office of Public Health to communicate advisories. Results are also related to USEPA efforts, including nationwide monitoring programs.

Further, the data collected herein serves as a baseline by which responses to anticipated future decreases in mercury emissions under USEPA's mercury and air toxics standards (MATS) can be assessed for effectiveness in removing mercury from food webs. The MATS final rule requires an approximate 90% reduction in mercury emissions from 1,400 of the largest coal- and oil-fired utilities by 2015. There are also implications for the international arena and global mercury treaties, and the myriad aspects of global change, which will affect the behavior and distribution of mercury worldwide (Krabbenhoft and Sunderland 2013).

Mercury is lively, complicated, and mercurial. It challenges the very mission of the national parks to leave wildlife unimpaired for future generations. Thanks to the working partnership between USGS and NPS, society is gaining a better understanding of the risk to national parks. Ultimately, NPS would like to see less contaminants in park ecosystems, especially those such as mercury where concentrations exceed thresholds for potential negative health effects on wildlife, and in some cases, people.

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Connecting the Dots: A Collaborative USGS–NPS Effort to Expand the Utility of Monitoring Data

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Introduction

The Natural Resource Challenge (National Park Service 1999) was a call to action. It constituted a mandate for monitoring based on the twin premises that (1) natural resources in national parks require active management and stewardship if we are to protect them from gradual degradation, and (2) we cannot protect what we do not understand. The intent of the challenge was embodied in its original description:

> We must expand existing inventory programs and develop efficient ways to monitor the vital signs of natural systems. We must enlist others in the scientific community to help, and also facilitate their inquiry. Managers must have and apply this information to preserve our natural resources.

In this article, we report on ongoing collaborative work between the National Park Service (NPS) and the US Geological Survey (USGS) that seeks to add to our scientific understanding of the ecological processes operating behind vital signs monitoring data. The ultimate goal of this work is to provide insights that can facilitate an understanding of the systems and identify potential opportunities for active stewardship by NPS managers (Bennetts et al. 2007; Mitchell et al. 2014). The bulk of the work thus far has involved Acadia and Rocky Mountain national parks, but there are plans for extending the work to additional parks.

Our story starts with work designed to consider ways of assessing the status and condition of natural resources and the potential for historical or ongoing influences of human activities. In the 1990s, the concept of "biotic integrity" began to take hold as an aspiration for developing quantitative indices describing how closely the conditions at a site resemble those found at pristine, unimpacted sites. Quantitative methods for developing indices of biotic integrity (IBIs) and elaborations of that idea (e.g., ecological integrity) have received considerable attention and application of these methods to natural resources has become widespread (Karr 1991; Barbour et al. 1999; Stoddard et al. 2008). Despite widespread use,

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many questions remain about how metrics are combined to form effective indices and about how to interpret both.

Scientists and natural resource specialists within NPS and USGS have joined forces to critique the current analysis methods, with the collaboration involving the Rocky Mountain and Northeast Temperate NPS Inventory and Monitoring (I&M) networks, along with others, and USGS scientists from the National Wetlands Research Center and Patuxent Wildlife Research Center. Funding that initiated the project was from a joint-partnership fund managed by the USGS Ecosystems Program for National Park Monitoring research and the work was focused at Acadia National Park and Rocky Mountain National Park. Here we present synopses of two major issues addressed by the group.

Problem 1: Developing an interpretive framework for assembling multimetric indices

Multimetric indices such as the IBI are constructed by combining measures of biological characteristics that correlate with human alterations of ecosystems into a single integrative measure. Combining measures into a single index seems like a simple matter, but the process is complicated by (1) the fact that both human activities and natural system characteristics can covary across environmental gradients, (2) the necessity to choose from many available metrics to create an effective index, and (3) the fact that one has to decide how to mathematically assemble the final index.

The issue of natural gradients (e.g., variations in elevation) is particularly problematic. Historic human use in parklands typically varied along such environmental gradients. For example, there have been fewer historical uses and there are now usually far fewer visitors at high elevations. Natural ecosystems also change along these gradients (high-elevation wetlands are naturally much different from those at low elevation) and thus false or spurious correlations between human disturbance and ecosystem condition can occur. Because of these complications, we are left to disentangle effects of natural gradients from those of human effects. While this problem is well understood, we feel that traditional solutions, which rely on "statistical control," not only obscure the logic behind adjustment procedures, they also risk biasing estimated effects. Scientists wish to make adjustments based on scientific interpretations of a situation, not on a purely automatic process with questionable assumptions. So, we decided on a different approach.

In our work, we decided to apply graphical analysis and causal modeling to tackle these problems (Schoolmaster et al. 2013). These somewhat advanced methods pose hypotheses about *why* variables are correlated, and use causal diagrams for analyses. Figure 1 shows a set of hypothetical scenarios we evaluated. In this example, there is a common suite of variables included, but the causal relations between them are different in each case. Standard methods of adjusting for the effects of the natural gradients treat all these situations as if they are the same, but we showed that such an approach leads to serious mistakes. We went on to provide a documented process for preparing indices that is appropriate for different situations (Schoolmaster et al. 2012a). Most importantly, by showing the presumed causal connections visually in a graph, the approach permits investigators and managers to consider *how* the coupled human–natural system works, while guiding the process of quantifying conditions.

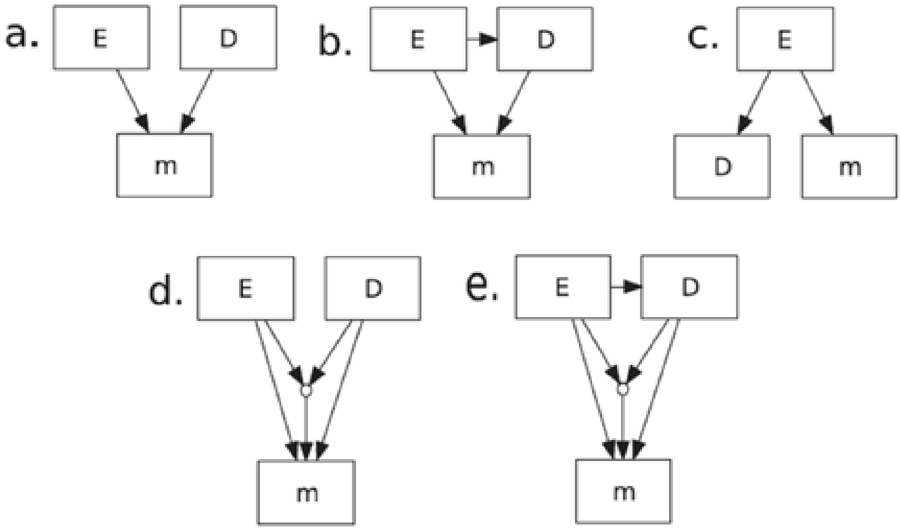


Figure 1. Range of scenarios used to consider how different causal situations would influence automatic approaches to statistical control in index of biotic integrity (IBI) construction (from Schoolmaster et al. 2013). "E" represents an environmental factor, "D" a human disturbance factor, and "m" a biological metric.

Building on these ideas, we re-evaluated the fundamental principles behind indices generally (Schoolmaster et al. 2012a). Here we again used causal graphical diagrams to lay out the problem, going on to develop a protocol for index assembly when the goal is to build an index in the most efficient and effective manner (Schoolmaster et al. 2012b).

Problem 2: Figuring out the pathways whereby human activities connect to biological conditions

The process of building an index for assessing biotic integrity involves combining many pieces of information into a single, integrative index. When calibrated against a quantified range of human disturbance, such indices become reflective descriptions that can be used to diagnose altered conditions in the landscape (Figure 2).

In addition to meeting the primary objective of assessing and tracking conditions (bioassessment), the data collected along the way can serve an additional, important purpose: providing insights into how human activities may have altered biotic conditions, and therefore, perhaps, what park managers might do about changes that are undesired. Describing our work on this second problem requires us to get a bit more specific about the systems being examined.

Acadia National Park is one of the most visited NPS units in the eastern US. Among its many outstanding features is a large collection of wetland communities scattered across its terrain. Prior collaborative studies of 37 nonforested wetlands involving NPS, USGS, and

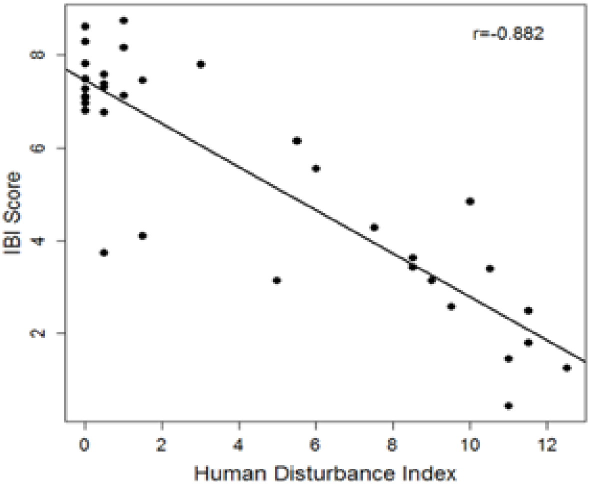


Figure 2. Bioassessment results for Acadia National Park wetlands (Schoolmaster et al. 2012a), expressed as a plot of scores for the IBI against estimates of the human disturbance index (HDI). The practical goal of the structural equation model (SEM) example presented in this paper is to elucidate the causal connections between human activities (disturbances) and the biotic responses identified in the IBI analysis.

university partners (Little et al. 2010) had described many of the ecological relationships between wetland types and environmental conditions. Measured were (a) landscape conditions for each wetland, (b) water pH and conductivity, (c) hydrologic fluctuations, and (d) plant community characteristics. Building on that, we added additional data describing the degree and types of human activities around the studied wetlands, permitting us to develop an IBI for the system (Figure 2). Then we went about the business of posing and evaluating hypotheses about how human activities might impact natural conditions in the wetlands. We tackled the problem using a methodology known as structural equation modeling. This method is built around the idea of causal networks, and specifically how hypotheses about cause–effect connections in systems can be evaluated against data. The details of our study and of the methods used are given in Grace et al. 2012; here we describe generally what was examined and found in that analysis.

Of all the activities in our study, the business of proposing and evaluating hypotheses about how wetlands might be impacted by human activities required the most teamwork. Here, both researchers and park natural resource managers had plenty of ideas. Figure 3 shows the major ways that humans typically impact wetlands: through alterations to nutrient inputs and changes in hydrology. Following a consideration of the measured variables and using our knowledge about the system, we constructed an initial causal network model for evaluation (Figure 4).

Lots of thinking and discussion went into constructing the initial hypothesis/model. First, as shown in the top part of Figure 4, the model considered how the different measures of human activities fit together. Patterned after prior work developing IBIs for wetlands (Mack 2001), an evaluative system appropriate for quantifying human activities in the local area was developed and information on human activities were aggregated into measures of (a) intensity of land use, (b) the degree to which hydrology had been altered, (c) how close to the edge of a wetland human activities had occurred (also known as “buffer intrusion”), and

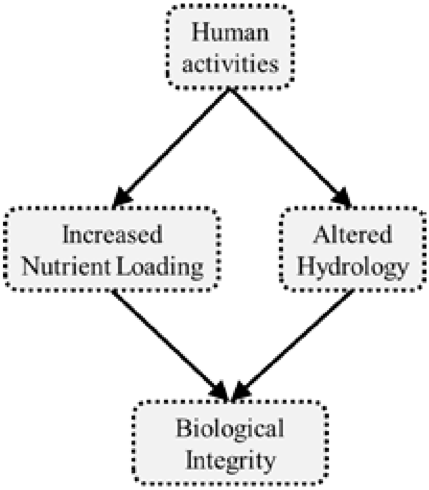
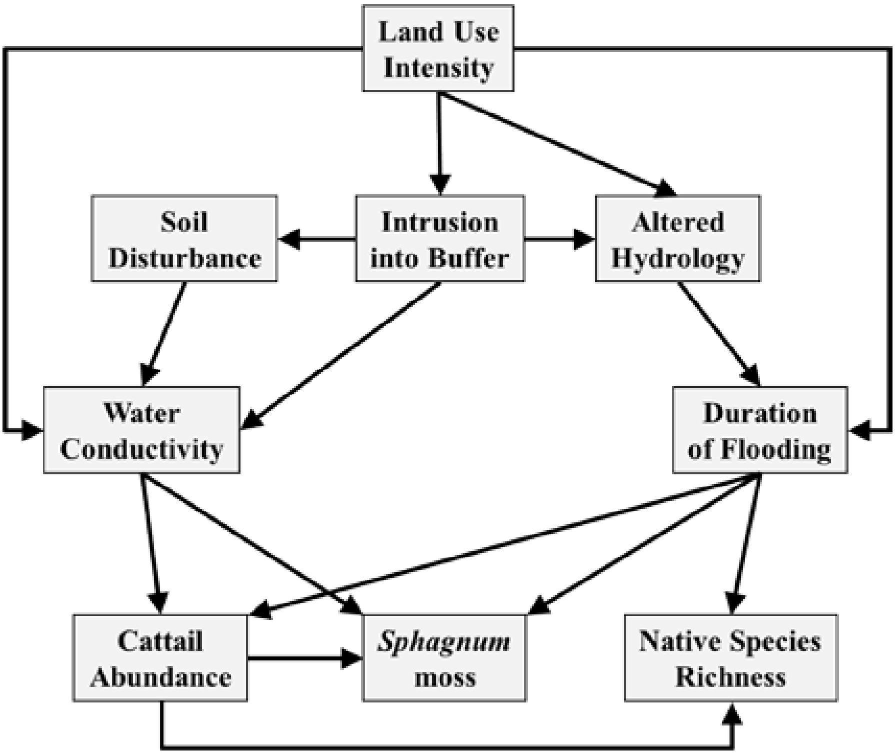


Figure 3 (left)**.** Conceptual model representing general *a priori* expectations for how human activities most commonly affect wetland communities.

Figure 4 (below)**.** Initial SEM representing a complex hypothesis developed for how biological conditions in wetlands (at bottom of diagram) might connect with human activities in the landscape (at the top of the diagram). From Grace et al. 2012.



(d) where there was obvious soil disturbance adjacent to or in the wetland. A logical set of hypothetical relations between elements of the model was developed.

The bottom of the model in Figure 4 includes three major system attributes selected to represent wetland condition or characteristics apparently sensitive to human alterations of the habitat. Such characteristics were revealed in the process of screening a long list of possible metrics against an overall index of human disturbance (constructed from the above-mentioned measures of human activities). First, we saw a prominent negative relationship between human disturbance and native species diversity (specifically, species richness). Second, *Sphagnum* moss, an indicator of higher-quality bog habitats, was also lower where human activities were greatest. Third, cattails (*Typha* taxa) were observed to dominate in heavily disturbed areas, a common phenomenon in wetlands worldwide (Newman et al. 1996). While other wetland features were also found to vary with human disturbance, modeling is partly about simplification, and we felt the three characteristics included in the model were the most interpretable and most meaningful to management.

The final thing we considered when developing the initial model was whether any measured variables might capture the environmental changes linking human activities to the biotic responses (these are often referred to as mediator variables). Measurements of water conductivity and pH showed clear relationships to human activities. While nutrient inputs into the wetlands were not measured directly, we felt that water conductivity, which is strongly influenced by total mineral solutes in the water, might serve as an indicator of nutrient loading (Biggs 1995). Finally, data from water level recorders allowed us to calculate a number of summary measures of water level and its fluctuation. Most importantly, the number of days each year when the soil was flooded at the monitoring site was most clearly related to wetland condition. The general hypothesis represented by our model was that human influences on water conductivity and duration of flooding could explain the major effects of land use intensity on wetland characteristics (Figure 4).

In structural equation modeling, the evaluation of the initial hypothesis with actual data is a matter of seeing "if things add up." If a model accurately reflects important properties of a system then the raw correlations between system properties (as represented by the variables in the model) will all add up to those implied by the model. For example, we would expect the observed correlation between land use intensity and native plant richness would equal the sum of all path strengths connecting the two variables. Proceeding from this basic premise, an evaluation of alternative models was conducted.

Once the initial model was evaluated with data, some of the ideas incorporated in the model had to be revised. Perhaps most importantly, the analyses showed that some additional connections beyond those initially suspected needed to be included (Figure 5). It seems that land use intensity is negatively associated with native plant richness (shown as a direct arrow from land use intensity and plant richness in the model) for some reason beyond those captured by the mediator variables in the model. We must be careful to rule out influences of land use planning before concluding there is some additional influence of actual land use on native plant richness, but both possibilities remain for future consideration. Also unanticipated were small, but detectable, impacts on *Sphagnum* from hydrologic alterations and soil disturbance, which were added to the model, again for future investigation.

Perhaps as important as the links that had to be added to the model are those whose impacts were undetectable in the data (Figure 5 versus Figure 4). Surprisingly, the intrusion of human construction activities into the immediate buffer around a wetland is not required for

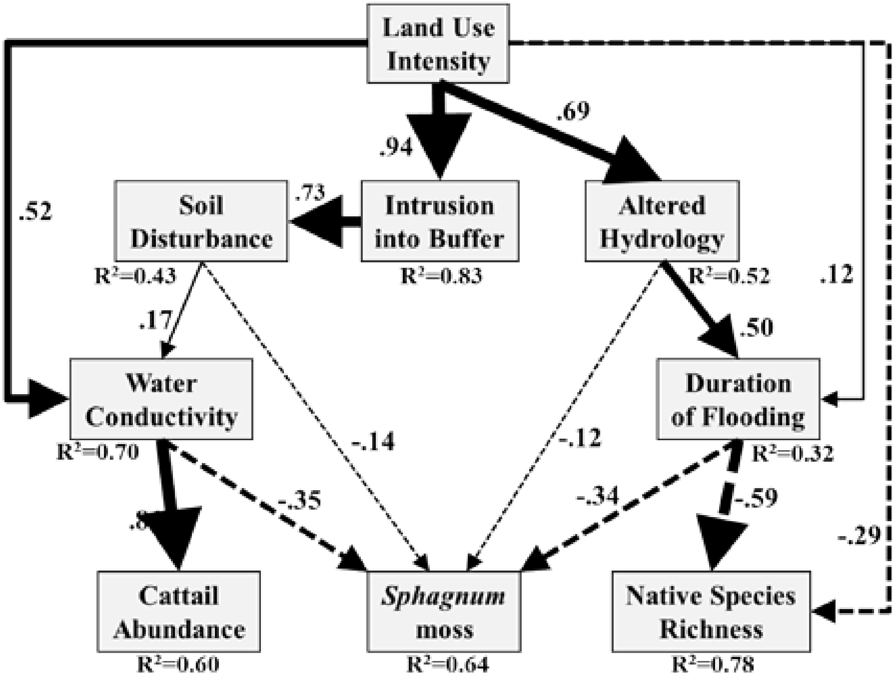


Figure 5. Representation of SEM results (from Grace et al. 2012). Solid lines represent predicted positive effects while dashed lines represent negative effects. Widths of lines are proportional to predicted sensitivities. Variance explained for each response variable is given as R-squares. Coefficients presented are standardized values.

hydrologic alterations to be important. Our revised view is that damming of outflows, either purposely or in concert with roadways, works in combination with the natural topography to stabilize water levels in many of the wetlands. Also, buffer intrusion does not seem to automatically enhance nutrient runoff and elevated water conductivities as expected. Results reveal the direct path in the model from land use intensity to conductivity was quite strong, suggesting nutrient inputs to wetlands primarily involve established routes for water movement. Expected but not detected was an influence of flooding duration on cattails, as has been found in other locations (Grace 1989). Finally, once joint influences were considered, we did not detect direct impacts of cattails on *Sphagnum* or native species diversity. It is believed that this lack of relationship occurred because cattail abundances have not yet reached critical levels (and hopefully will not).

Overall, the results from Acadia (especially focusing on the thickest arrows that show the strongest relationships in Figure 5) provide a general confirmation of the idea that human influences on biotic conditions are through nutrient inputs and altered hydrology, though with some additional processes operating as described in the preceding paragraph. Aside from providing a concrete and quantified representation of the coupled human–natural system, details of the model results suggest some opportunities to prevent further degradation, as explored in Grace et al. 2012. For example, we can ask how blocking any particular path in the model might influence this particular suite of wetlands (those sampled). It must be noted that modeling enterprises such as the one demonstrated here depend on assumptions that require further evaluation. Nonetheless, it is notable that nearly all the data necessary for this analysis were already collected in the previous studies through the natural intuitions of the scientists and natural resource personnel involved.

A joint effort—Using modeling to motivate monitoring

High-quality monitoring efforts such as the NPS Vital Signs program are challenging to develop and expensive to maintain. Sustaining year-after-year measurement protocols depends on the long-term value of the effort being sufficiently appreciated to maintain support for the effort. We believe that the example described above represents a proof of concept that additional analyses can produce insights from monitoring data that are intuitive, useful, and may aid management decisions. At Rocky Mountain National Park, where similar wetland bioassessment modeling was developed (Schweiger et al., in press), the initial effort to develop IBIs is being extended to include structural equation modeling studies of how human and natural disturbance agents may be affecting ecosystem conditions. At Acadia National Park, the wetland focus has been replaced by an effort to develop general models for forest health, with the ultimate intention of extending this effort to additional parks in the eastern forest biome. The partnership between NPS and USGS in this endeavor results in a combination of talents, skills, and knowledge that generates an important synergism with many potential benefits. It is our hope that the modeling effort will help maintain awareness of the many values of the monitoring effort, which is ultimately vital to management.

Acknowledgments

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The US Geological Survey–National Park Service Water Quality Partnership

Alan C. Ellsworth, Mark Nilles, and Gary Rosenlieb

The National Park Service (NPS) and the US Geological Survey (USGS) work together to administer and operate a water quality-focused partnership program. This program was started as part of the Clean Water Action Plan, a 1998 presidential initiative to commemorate the 25th anniversary of the Clean Water Act through plans and actions to further restore and protect America's waters. Under the partnership, water quality projects are developed jointly by USGS and NPS personnel to support a broad range of policy and management needs related to high-priority issues in national parks.

The National Park Service manages highly valued aquatic systems across the country, including portions of the Great Lakes, ocean and coastal zones, historic canals, reservoirs, large rivers, high-elevation lakes and streams, geysers, springs, and wetlands. The water quality partnership program has proven tremendously successful in supporting USGS-led studies, resulting in nearly 160 completed projects that support efforts to conserve and improve the nation's water resources. Some of the ongoing projects are highlighted in the NPS Call to Action item "Crystal Clear," which celebrates national park water resource initiatives to provide clean water into the next century of park management (www.nature.nps.gov/water/crystalclear/).

Partnership projects range from one-year technical assistance activities that provide consultation with USGS scientists to three-year intensive projects involving hypothesis-driven data collection, assessment, and publication in peer-reviewed reports. These partnership projects are developed in response to an annual request for proposals that is released to national parks through their regional offices and USGS science centers. To date, 197 partnership projects have been undertaken in over 120 national park units. The current program bibliography (http://water.usgs.gov/nps_partnership/pubs.php) includes over 135 publications.

Project selection is highly competitive, funding only 8 new projects each year out of the approximately 75 short pre-proposals that are initially submitted for the annual call. At each

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stage in the evaluation and selection process, proposals are reviewed by teams composed of experienced professionals in equal numbers from USGS and NPS to ensure that the process reflects a true and equal partnership. Recent projects have addressed issues such as identifying and quantifying impacts of historical mining operations to help prioritize cleanup efforts, evaluating nutrient inputs related to reservoir level management, identifying recreational use effects, and providing state-of-the-art research on the presence of endocrine-disrupting compounds and their impacts on fish and other organisms within park units. In the following four common project themes for partnership work, a completed project is highlighted along with the key information gained by these collaborative studies between USGS and NPS.

Historic land use and reclamation

Many NPS-managed lands have experienced impacts from land use activities including mining, logging, road construction, and water diversion projects. Evaluating current water quality conditions related to past development and gauging the effectiveness of environmental remediation projects has been an important component of the partnership program. A recently completed assessment of mining reclamation at Kantishna Hills in Denali National Park and Preserve in Alaska provides an example of treatment efficacy research (Brabets and Ourso 2013).

The Kantishna Hills is an area of low-elevation mountains in the northwestern part of Denali National Park and Preserve. The Kantishna Hills are drained by clearwater streams derived from rain, snowmelt, and subsurface aquifers that support several species of fish. Past mining practices that began in 1903 and continued until 1985 generated acid mine drainage and excessive sediment loads that negatively affected water quality and aquatic habitat. Currently the effects of mining are visible on more than 1,500 acres of land covering 12 watersheds in the Kantishna Hills area. Due in part to a short growing season, recovery through natural processes is limited and several reclamation projects have been implemented on multiple streams in the Kantishna Hills region in an effort to improve degraded water quality. Projects consisted of (1) removing hazardous materials, contaminated soils, and abandoned equipment, and (2) reconstructing floodplain and stream channel structures to stabilize stream banks from erosion and revegetating sites. A cooperative study between USGS and NPS was undertaken during the years 2008–2011 in order to assess the water quality of the Kantishna Hills' streams and determine whether reclamation efforts have proven effective.

In 2008 and 2009, 104 macroinvertebrate taxa and 164 algae taxa were identified from samples collected at seven different locations encompassing six different streams. Eighty-six percent of the macroinvertebrates were insects and most of the algae consisted of diatoms. An assessment of stream quality using biological indices (National Community Index) indicates Rock Creek (a reference site) and Caribou Creek (a reclaimed mining stream) exhibited the best overall stream conditions. Slate Creek and Friday Creek, two small streams that were abandoned after extensive mining without reclamation efforts, exhibited the worst stream conditions. This study establishes improvements to water quality and the necessity of site reclamation following intensive mining within this sensitive environment.

Figure 1. Tim Brabets, USGS Alaska Water Science Center, and Larissa Yocum, Denali National Park and Preserve, processing a water sample. Photo by Dan Long, USGS.

Nutrient loading impacts

Nutrient loading of aquatic systems in parks from land use development outside the park's boundaries can be a major resource management challenge. Excessive nutrient enrichment can lead to eutrophication and losses of biological diversity and habitat value. Streams and lakes located within national parks can be affected by increased nutrient inputs from sources that include septic systems, agricultural production, atmospheric deposition, and municipal wastewater.

An NPS–USGS partnership study was initiated to examine nutrient loading to Kabetogama Lake in Voyageurs National Park, Minnesota. The southwest shore of Kabetogama Lake

Figure 2. Most of the sampling sites in the Denali National Park study were very remote and required helicopter service to access. Photo by Tim Brabets, USGS.

is not part of the park and therefore is open for development. The numerous homes, cabins, and resorts along the roughly 19 kilometers of shoreline are a potential source of nutrients. Residential and commercial areas on Ash River, which flows into Kabetogama Lake, also are a source of nutrients. As a result, additional development on Kabetogama Lake may cause additional eutrophication, thereby threatening the lake's water quality, ecology, and recreational value. Dam operations at Kabetogama Lake were modified in 2000 to restore more natural water dynamics and improve water quality. In particular, new rule curves were expected to lower phosphorus loading by lessening the effects of drying and rewetting of sediments from fluctuating water levels, reducing nutrient inputs resulting from littoral vegetation, and reducing nutrient concentrations because of increased volume. Nutrient enrichment has led to excessive algal growth in the lake. Microcystin-LR, a cyanotoxin, was detected with concentrations as high as 3.94 micrograms per liter (μg/L) in 2006.

The USGS and NPS partnership project evaluated nutrient, algae, and nuisance bloom data in relation to changes in water level management of Kabetogama Lake through extensive water quality sampling in 2008 and 2009 (Christensen, et al. 2011). The project found that chlorophyll *a* concentrations have decreased, whereas total phosphorus (TP) concentrations have not changed substantially since the beginning of water level manipulations. The study found that the Lost Bay area of the lake is one of several that may be contributing to internal loading of TP from lake sediments. Internal loading of TP is a concern because increased TP may cause excessive algal growth, including that of potentially toxic cyanobacteria. Using these analyses, park managers are able to show the benefits of lake level manipulation as well as better understand the source of total phosphorous inputs.

Visitor use impacts

Wilderness areas in the US receive substantial use by day hikers, backpackers, and pack animals (stock), with recreational visitor-use days having increased sixfold from 1965 to 1994, when the number of visitors approached 17 million/year. NPS and others are concerned that visitor activities in high-use areas of wilderness may be affecting natural resources, including

Figure 3. Kabetogama Lake, Voyageurs National Park, under typical conditions. Photo by Victoria Christensen, USGS.

Figure 4. A wilderness lake sampled in the Sequoia and Kings Canyon National Park investigation on visitor use and water quality. Photo By David Clow, USGS.

water quality. The influence of pack animals and backpackers on water quality in wilderness lakes and streams was evaluated in Sequoia and Kings Canyon National Parks (Clow et al. 2013) and a similar study was begun in Yosemite National Park in 2013. The studies included a synoptic survey of water quality in park wilderness areas, paired water quality sampling in areas with differing types of visitor use, and intensive monitoring using in-stream sensors to examine temporal variations in water quality. Sites are characterized based on minimal use, use by backpackers only, and mixed backpacker and stock use.

Results indicate that water downstream of mixed-use areas had higher concentrations of some constituents examined (including particulate phosphorus and *E. coli*), while backpacker only locations were minimally influenced by use when compared to upstream values. Overall, results from this study indicated water quality in the backcountry streams examined was generally good, except during rain events when pollutants are washed into adjacent waterways. Visitor use appears to have a small, but statistically significant influence on streamwater quality. Additional USGS–NPS partnership studies in other parks are currently underway to better understand the relationships between specific visitor use activities and water quality impacts.

Contaminants of emerging concern

Pharmaceutical compounds and personal care product residuals have been identified as contaminants of emerging concern that can bioaccumulate and adversely affect physiological processes in fish and other sensitive aquatic biota. USGS and NPS conducted a reconnaissance study at Lake Mead National Recreation Area, Nevada, to investigate the occurrence of pharmaceutical compounds in water samples collected from the lake and from Las Vegas Wash, which receives treated wastewater from the Las Vegas metropolitan area and flows into the lake (Boyd and Furlong 2002). The most frequently detected compounds in water samples from Las Vegas Wash included caffeine, carbamazepine (used to treat epilepsy), cotinine (a metabolite of nicotine), and a metabolite of the antianginal drug nifedipine. Less frequently detected compounds included several antibiotics, acetaminophen, and codeine, among others.

Fewer compounds were detected in samples collected from Lake Mead than from Las Vegas Wash. Caffeine was detected in all samples collected from Lake Mead. Other compounds detected in samples collected from Lake Mead were acetaminophen, carbamazepine, cotinine, 1,7-dimethylxanthine (a caffeine metabolite), and sulfamethoxazole (an antibiotic). Additional research related to this effort has been synthesized in a report on science and management of Lakes Mead and Mohave (Rosen et al. 2012). Documentation of emerging contaminants has helped NPS develop a productive partnership with the city of Las Vegas and the Southern Nevada Water Authority, which are working to reduce the occurrence of these compounds.

Conclusion

The water quality partnership program funds USGS-led scientific studies that would be otherwise limited or unavailable at the park level. Identification of research and investigation needs by NPS resource managers and a rigorous proposal and study plan review process ensures that priority NPS water quality issues are addressed by USGS scientists. The water quality partnership program exemplifies the ability of federal agencies to work together in order to efficiently and effectively manage the nation's valuable resources.

Since 1998, the water quality partnership program has enabled the NPS to make informed management decisions based on USGS-supported data analyses and interpretations. The partnership promotes the interaction of park staff with USGS scientists and creates long-standing relationships for continued science-based resource management. This program continues to produce high-quality, cost-effective products that are used to make defensible decisions regarding water resource protection so that this critical resource can be enjoyed by current and future generations.

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Synthesis of Thirty Years of Surface Water Quality and Aquatic Biota Data in Shenandoah National Park: Collaboration between the US Geological Survey and the National Park Service

Karen C. Rice, John D. Jastram, John E.B. Wofford, and James P. Schaberl

The eastern United States has been the recipient of acidic atmospheric deposition (hereinafter, "acid rain") for many decades. Deleterious effects of acid rain on natural resources have been well documented for surface water (e.g., Likens et al. 1996; Stoddard et al. 2001), soils (Bailey et al. 2005), forest health (Long et al. 2009), and habitat suitability for stream biota (Baker et al. 1993). Shenandoah National Park (SNP) is located in northern and central Virginia and consists of a long, narrow strip of land straddling the Blue Ridge Mountains (Figure 1). The park's elevated topography and location downwind of the Ohio River valley, where many acidic emissions to the atmosphere are generated (NSTC 2005), have made it a target for acid rain. Characterizing the link between air quality and water quality as related to acid rain, contaminants, soil conditions, and forest health is a high priority for research and monitoring in SNP. The US Geological Survey (USGS) and SNP have had a long history of collaboration on documenting acid rain effects on the park's natural resources, starting in 1985 and continuing to the present (Lynch and Dise 1985; Rice et al. 2001, 2004, 2005, 2007; Deviney et al. 2006, 2012; Jastram et al. 2013).

Acidification is both a chronic and an acute stressor that triggered the need for water quality monitoring and research in the late 1970s. Shenandoah National Park natural resource managers showed abundant foresight by implementing an aquatic biota monitoring program well before the park became a National Park Service prototype inventory and monitoring park in the early 1990s (Davis et al. 1995). As a result of these early and continued monitoring efforts, a combined record of over three decades of data on water quality and biota in SNP cold-water riverine systems exists.

Water resource data-collection efforts in SNP have been conducted by many different groups to satisfy a wide range of objectives. The majority of the data, however, were collected

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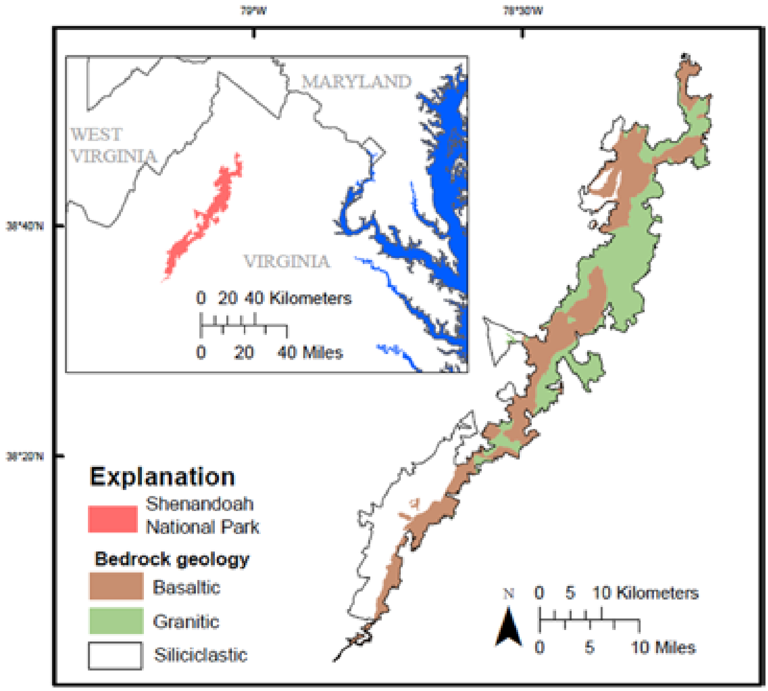

Figure 1. Map showing location of Shenandoah National Park in Virginia and simplified geology of the park.

as part of three efforts: (1) the Shenandoah Watershed Study (SWAS), a partnership led by the University of Virginia (http://people.virginia.edu/~swas/POST/scripts/overview.php), has monitored water quality in SNP since 1979; (2) SNP's Vital Signs Program (Olson et al. 2010), formerly known as the Long Term Ecological Monitoring Program, with independent efforts in fish monitoring (starting in 1982) and macroinvertebrates (starting in 1986); and (3) the Springs and Headwater Streams Study, conducted from 2007 to 2010 (Snyder et al. 2013), which identified the physical, chemical, and biological characteristics of headwater streams and small springs in SNP. Although the objectives of these efforts differed, the common element that unites the three is SNP water resources; therefore, some of the same water quality parameters were collected for each effort. For example, all three efforts measured water temperature, pH, and specific conductance for each sample, in addition to the collection of other data specific to the effort's objectives.

Inconsistent overlap among the three data-collection efforts described above resulted in spatially and temporally disparate data. Combination of disparate datasets containing common characteristics can result in a unified database that often supports broad and powerful data analyses. Starting in 2010, USGS and SNP undertook a study to combine the three datasets into a comprehensive water resources database. The objective of the study was to integrate, analyze, and interpret the data in the three datasets in order to provide SNP natural resource managers with information about current water resource monitoring gaps, trends in conditions, adequacy of the monitoring programs, and relations between aquatic fauna and streamwater chemistry.

The combined database, created in the NPSTORET framework, contains nearly 1.3 million measurements of stream habitat characteristics, approximately 442,000 measurements of water quality characteristics, and over 438,000 measurements of biological taxa, including fish and aquatic macroinvertebrates. The data were collected across 673 sites over a period of more than 30 years. After compilation, the database was used to support evaluations of spatial patterns and temporal trends in the available data, and characterization of those data to better understand interrelations among water quality, aquatic macroinvertebrates, fish, and the landscape. Highlights of the results are reported here, and full results of the study can be found in Jastram et al. (2013).

The geology of SNP is easily simplified into three major bedrock types, which include basaltic, granitic, and siliciclastic (Figure 1). Each bedrock type represents about one-third of the area within the park. Streams with watersheds underlain by these bedrock types differ in their ability to neutralize acidic inputs, as measured by the acid-neutralizing capacity (ANC) of the water. This strong geologic control on streamwater chemistry was noted long ago for the Blue Ridge Mountains of Maryland (Bricker and Rice 1989) and within SNP in particular (Cosby et al. 2006; Deviney et al. 2006; Rice et al. 2007). Because geology serves as a master variable with regard to streamwater chemistry, many of the results of the study can be summarized on the basis of the three bedrock types. Results of the assessment can be reported as both status and trend. Status of a particular metric generally reflects a spatial pattern on the landscape, here defined largely by geology, whereas trend reflects change in a metric over time. The results summarized here (Table 1) on the basis of bedrock type are broad generalizations and many details have been omitted; for such details, the reader is referred to Jastram et al. (2013).

Assessment of the status of the basaltic watersheds, which are the best buffered against acid rain, indicates relatively good measures of water quality as well as healthy communities of macroinvertebrates. These watershed types also have moderately high measures of fish species richness (most fish species found in the park are native) and brook trout abundance. Similarly, the granitic watersheds, which are intermediate between basaltic and siliciclastic in their ability to neutralize acidic inputs, also have relatively good water quality, the highest aquatic macroinvertebrate metrics, and intermediate measures of fish species richness and brook trout abundance. In contrast, the siliciclastic watersheds, which have the lowest ability to buffer against acid rain, have the lowest streamwater quality, the lowest measures of healthy community of aquatic macroinvertebrates, the lowest fish species richness, and relatively low measures of brook trout abundance. It is important to note that these quality designations are relative to comparisons within the park boundary; therefore, a designation of "degraded" for within-park resources may actually reflect "high quality" when compared with streams located outside of SNP.

Trends in ecosystem measures of health across the park were mixed. Air quality within the region generally has been improving since the Clean Air Act, passed in 1970, and the

Measure of stream condition	Basaltic	Granitic	Siliciclastic
Streamwater quality (ANC and sulfate)[1]	High	Intermediate	Low
20-year trend in streamwater quality (ANC and sulfate)[1]	Improving	Mixture of Improving and Degrading	Degrading
AM metrics	Intermediate	High	Low
20-year trend in AM metrics	Degrading	Degrading	Degrading
Fish mean species richness	Intermediate	Intermediate	Low
14-year trend in fish species richness	Improving	Improving	No trend
Mean abundance of adult (age 1+) brook trout	Intermediate	Intermediate	Low
14-year trend in adult (age 1+) brook trout	Mixture of Improving and Degrading	Improving	Improving

[1]Streamwater quality was summarized by combining ANC and sulfate concentrations and trends. High/increasing ANC and low/decreasing sulfate indicate high ranking and/or improving trends; low/decreasing ANC and high/increasing sulfate indicate low ranking and/or degrading trends.

Table 1. Summary of status quality ranking and trend results of the ecosystem health assessment by Jastram et al. (2013) on the basis of bedrock type. The 20-year and 14-year trends mentioned in the table both ended in 2009. AM = aquatic macroinvertebrate; ANC = acid-neutralizing capacity.

Clean Air Act Amendments, passed in 1990, went into effect, causing a decrease in acid rain (Burns et al. 2011). As such, one might expect that water quality trends, and associated trends in aquatic ecosystem health, would respond accordingly across the park. Most often, however, an ecosystem's recovery path is not a simple reversal of the degradation path. Basaltic watersheds had improving streamwater quality, with associated improvement in fish species richness as well as improvements in some macroinvertebrate metrics, though the overall pattern indicated degrading conditions in macroinvertebrate communities in these watersheds. Trends in brook trout abundance in basaltic watersheds were mixed and largely site dependent. Streams draining granitic watersheds showed improving or degrading streamwater quality, overall degrading trends in macroinvertebrate health despite stability in some metrics, improvement in fish species richness, and predominantly improving trends in brook trout abundance. The siliciclastic watersheds showed continued degrading trends in streamwater quality, continued declines in already degraded macroinvertebrate communities, stable trends in fish species richness, and surprisingly, improving trends in brook trout abundance. In general, the trend data reflect a pattern whereby the ecological health of streams currently degraded by acid rain are continuing to degrade, whereas streams more resilient to the effects of acid rain are either stable or are showing improvements in water quality and aquatic ecosystem health.

Additional analyses of the combined data indicated that some changes to aquatic ecosystems were occurring parkwide and were independent of underlying geology. For example, an unexpected result of the analysis of the combined data was the finding that temperatures in numerous SNP streams are increasing and seem to be related to increases in air temperature. One stream, White Oak Run, with a 30-year record of temperature data, had a small but statistically significant increase in annual mean, median, and maximum water temperature for the period ending in 2009. Most sites had shorter periods of data collection, but many sites with water temperature data collected for more than 10 years showed increasing trends in annual mean, median, and maximum water temperature values. Many macroinvertebrate metrics that showed changes parkwide (i.e., independent of geology) indicated a parkwide decline in ecosystem condition, and the data suggest that this might be a result of increasing water temperatures. Although brook trout population growth was generally stable parkwide, it is possible that additional increases in water temperature will cause thresholds to be crossed that would negatively affect cold-water fish communities.

SNP is one of a very few national park units that has such an extensive and long-term set of environmental data. These data span over 30 years and cover almost 40% of the park's history. Long-term monitoring programs can be difficult to implement because their value must be recognized up-front and on a recurring basis, even when the data may not appear to be tremendously useful over short time frames. The successful collaboration between USGS and NPS resulted in an unprecedented ability to interpret this wealth of data, answering questions about status and spatial and temporal trends in streamwater quality, aquatic macroinvertebrate assemblages, fish species distributions and richness, and their interactions with environmental factors. In addition, the collaboration resulted in the creation of a master database for aquatic data collected in the park. As the database is kept current with new information, it will facilitate other broad analyses and similar synthesis and trends work in the future. Most notably, the collaboration and resulting analysis highlight the importance of long-term environmental monitoring, particularly in a national park, where natural resources are mandated to remain unimpaired for current and future generations.

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Collaborative Socioeconomic Tool Development to Address Management and Planning Needs

Leslie Richardson, Chris Huber, Cathy Thomas, Liz Donovan, and Lynne Koontz

Introduction

Public lands and resources managed by the National Park Service (NPS) and other land management agencies provide a wide range of social and economic benefits to both nearby local communities and society as a whole, ranging from job creation, to access to unique recreational opportunities, to subsistence and tribal uses of the land. Over the years, there has been an increased need to identify and analyze the socioeconomic effects of the public's use of NPS lands and resources, and the wide range of NPS land management decisions. This need stems from laws such as the National Environmental Policy Act (NEPA), increased litigation and appeals on NPS management decisions, as well as an overall need to demonstrate how parks benefit communities and the American public. To address these needs, the US Geological Survey (USGS) and NPS have an ongoing partnership to collaboratively develop socioeconomic tools to support planning needs and resource management. This article discusses two such tools. The first, Assessing Socioeconomic Planning Needs (ASPN), was developed to help NPS planners and managers identify key social and economic issues that can arise as a result of land management actions. The second tool, the Visitor Spending Effects (VSE) model, provides a specific example of a type of analysis that may be recommended by ASPN. The remainder of this article discusses the development, main features, and plans for future versions and applications of both ASPN and the VSE.

Tool #1: Assessing Socioeconomic Planning Needs

Evaluating the overall social and economic effects of land management actions continues to be an essential component of the decision-making process, and the consideration of these effects is discussed in several agency planning documents (for instance, US Forest Service 1985; Machlis 1996; Bureau of Land Management 2005). However, there is a lack of a consistent framework both within and across agencies regarding how to comprehensively identify social and economic impacts, and many planners, managers, and field staff lack exposure to the

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variety of social and economic methods that can be used to analyze them. Further, agencies often have limited planning budgets and time frames to conduct such analyses, requiring a prioritization of the most pressing issues. To help build capacity for socioeconomic analyses and expand on training and education for planners across agencies, social scientists at the USGS partnered with NPS, the US Forest Service (USFS), the Bureau of Land Management (BLM), the US Fish and Wildlife Service (USFWS), and USGS information technology specialists to develop ASPN. A web-based decision-support tool, ASPN provides a consistent framework that assists land management agencies in the identification and prioritization of pertinent social and economic issues to address in their planning processes, and provides guidance on appropriate social and economic methods to address their identified issues, tailored to best meet the needs of the specific plan or project.

The development of ASPN first required the identification of a comprehensive set of social and economic impacts to various stakeholder groups that could result from the wide range of management actions taken by NPS and other land management agencies. These were identified through reviewing agency social and economic regulations, training materials, Environmental Impact Statement documents, as well as through a comprehensive review of the available social and economic analysis documents and guidance used in the US and internationally (for instance, Clark et al. 1998; US Department of the Interior 2001a, 2001b; Bright et al. 2003; Millennium Ecosystem Assessment 2003; Bureau of Land Management 2004; Audit Commission 2005; The World Bank 2005; Erikstad et al. 2008; Allen et al. 2009). The set of possible impacts was reviewed and refined by a group of economic and social science experts comprising agency personnel, university researchers, and others with expertise in these disciplines. Next, a comprehensive review of economic and social analysis methods was conducted, based on both the applicability to land management planning as well as scientific integrity. Initial reviews by the group of experts helped refine the methods, pair them with different intensity levels of analysis, and calculate the time and cost of methods based on their experience in contracting out similar analyses or conducting the analyses themselves. Additional reviews by outside experts were conducted to further ensure the scientific integrity of the suggested methods and accuracy of time and cost estimates. USGS scientists then worked closely with USGS information technology specialists to finalize the web component and add additional features to the tool, including a mapping component, various sources of demographic and economic data, and links to online social and economic planning references. The tool was pilot-tested with agency planners and additional feedback from these field tests was incorporated into the program.

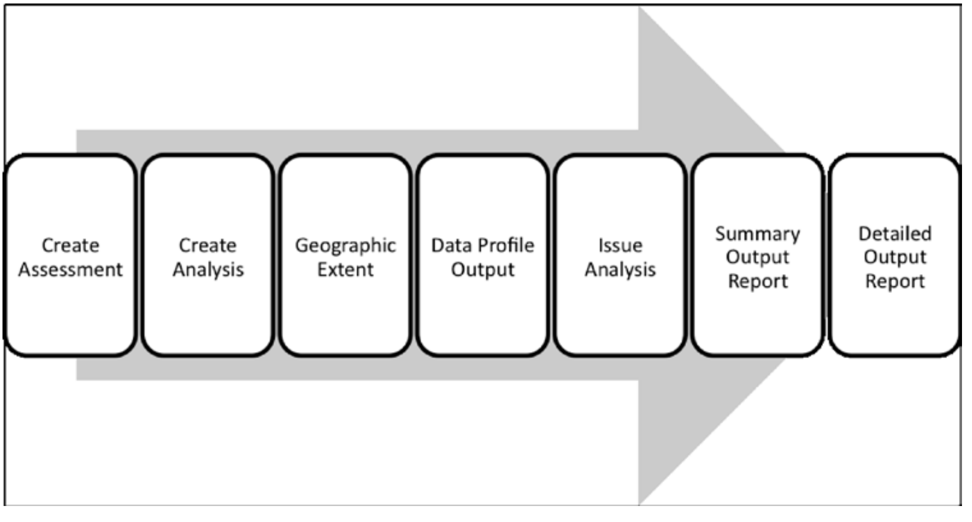
The result of this highly collaborative and iterative process is a web-based tool that assists agencies in identifying and prioritizing social and economic planning issues, and provides guidance on appropriate social and economic methods to address their identified issues. ASPN is designed to provide a consistent framework for natural resource managers and planners to begin to evaluate the socioeconomic effects of management actions on public lands. Its development was driven by NPS and other agency partners, resulting in a product that reflects the needs of all partners. Specifically, ASPN is designed to:

1. Provide demographic and economic data reports for the counties and states within an agency's specified planning area;
2. Help decision-makers identify stakeholder groups that may be impacted by a specific land management action;
3. Help decision-makers identify and prioritize the social and economic issues that may need to be addressed given a specific land management action; and
4. Highlight the range of applicable social and economic methods and analyses that are available to address these issues.

ASPN steps. The specific steps of ASPN are illustrated in Figure 1. Once users log into the program, they are prompted to create an *assessment,* which is made up of one or more *analyses* that start the user through the series of the program. These are flexible and determined by the user, but could represent one alternative in the planning process, various stages of the planning process (pre-scoping, post-scoping, etc.), or one specific action. For instance, an NPS planner may be interested in identifying and prioritizing the social and economic issues associated with the development of new campgrounds in Rocky Mountain National Park.

The user is then asked to specify the physical land unit that the management action is occurring on, for example, Rocky Mountain National Park. ASPN contains geospatial land unit data for NPS, USFS, BLM, and USFWS. A map illustrates the specified land unit in red (Figure 2). The user is then asked to select a *geographic extent* of interest, which entails one of three choices: counties that intersect the federal land unit's borders (shown in yellow in Figure 2), counties that intersect a buffer area 60 miles beyond the federal land unit's borders (shown in gray in Figure 2), or counties that intersect a buffer area 120 miles beyond the federal land unit's borders (shown in orange in Figure 2). This decision drives the results

Figure 1. Series of steps in the ASPN tool.



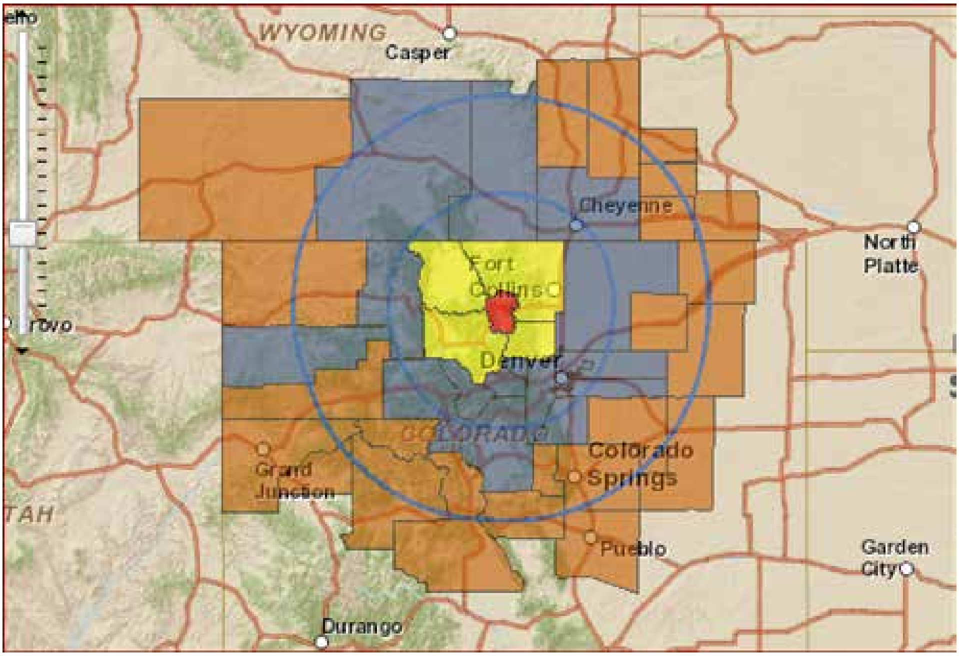


Figure 2. ASPN geographic extent map, using Rocky Mountain National Park as an example.

of the first page of output, referred to as the *data profile*, which produces demographic and economic data reports for each of the counties and states included in the specified geographic extent.

The user is then asked to identify whether six distinct stakeholder groups could be directly or indirectly affected by the management action of interest. These include: community/community residents, interest-based groups/place-based groups/general public, visitors, commercial users, traditional/subsistence users, and tribes.

Definitions of each stakeholder group, including an explanation of why they might be important to consider, is provided. The user is then presented with a series of questions associated with each group, which prompts them to think through and identify the full range of possible economic and social effects of the management action. There are a total of sixty-two questions across the six stakeholder groups, many of which contain several follow-up questions. Each question is associated with a particular issue category, such as access and resource use, demographics, the local economy, infrastructure, health, tribal uses, and values and perceptions. For each of these questions, the user is prompted to identify the level of intensity, categorized as "low," "medium," or "high." Suggested guidance for each intensity level is provided. For instance, a high-intensity issue may be one that is contentious on a local, regional, or national level; highly visible; or involves a significant change in management actions that may impose concentrated impacts on a single entity or stakeholder group. Although some guidance is offered, the selection of intensity level is still somewhat subjective on the part of the user. This process of identifying impacted stakeholder groups and walking through a series of questions for each in order to identify the full spectrum of potential social and economic impacts is referred to as the *issue analysis* in ASPN. Agency planners and managers can use this list of questions to communicate to other members of a planning team or other agency partners how the social and economic issues associated with the management action were identified.

Next, the user is presented with a *summary output report*, consisting of a series of summary output tables aimed at helping the user prioritize the social and economic issues that may need to be addressed given a particular management action. ASPN also produces a *detailed output report*, which provides a set of recommended economic and social methods to address each individual question identified as being important in the issue analysis. For each method, definitions, benefits, and limitations are provided, along with cost and time estimates. The level of intensity of each issue serves to connect that issue to an appropriate method of analysis. For instance, a low-intensity issue may be adequately addressed with a literature review or method based on the use of existing data, whereas a high-intensity issue is more likely to require primary data collection through surveys, focus groups, etc. This is the type of information provided in ASPN's detailed output report.

Use of ASPN within NPS. The APSN website was launched in April 2014 and is available to all NPS personnel and contractors. The NPS Social Science Branch will be initiating a series of ASPN presentations and webinars to inform and provide assistance to all potential NPS users. It is anticipated that ASPN will provide a valuable starting point for a broad range of NPS users, including decision-makers, on-the-ground managers, and planners. However, it is important to note that while ASPN is meant to inform NPS managers and planners about the social and economic effects of a management action, it is not designed to replace the need for consultation with both internal and external experts in these fields. Additionally, there are specific legal requirements that must be met throughout the decision making process to ensure compliance with NEPA; ASPN does not serve as a replacement for these legal obligations. In most cases, the user will need to consult with social science or economic experts in the NPS Social Science Branch prior to or during the ASPN analysis and afterward to complete the recommended methods of evaluation.

Following the release of the first version in April 2014, it is anticipated that future versions will be developed, which will extend ASPN's functionality and incorporate feature improvements identified in ongoing usability testing with NPS personnel. For instance, several users have expressed interest in incorporating the ability for users to identify a custom set of counties or upload their own shape files in ASPN's geographic extent. This is especially useful when evaluating the potential social and economic effects associated with a new land unit. Additional features of interest include various project management components that could help the user identify a realistic work plan for the social and economic analyses, given time and budget constraints. Regardless of the specific features added to future versions of ASPN, it is clear that the collaborative nature involved in their development will be essential to ensuring that the tool continues to serve the evolving needs of NPS.

Tool #2: Visitor Spending Effects model

While the collaborative ASPN tool was developed to address the broad range of socioeconomic issues that NPS needs to consider, USGS and NPS are also collaborating on tools to address specific socioeconomic analyses. One example is the development of the VSE model, which specifically addresses the economic effects on local gateway communities of NPS visitor spending. Lands managed by NPS serve as recreational destinations for visitors from across the nation and around the world. On multi-day vacations or on day trips, visitors spend time and money in the gateway communities surrounding NPS sites, and these expenditures generate and support economic activity. NPS requires park-level estimates of the effects of visitor spending on local, state, and national economies as key indicators of how parks benefit communities and the American public through visitation. Quantifying these economic effects is essential for multiple planning, management, budget formulation, policy analysis, and public outreach needs, including:

- Informing policy questions and management scenarios that may affect a park's visitation;
- Highlighting returns on investments from federal budget appropriations, and framing the economic importance of park units to park managers, policy-makers, and local government officials; and
- Educating the public on the importance of park visitation, and the ramifications of changes to it due to policy or management decisions.

In 2013, NPS initiated a new collaborative partnership with economists at USGS to develop an improved modeling system to measure how NPS visitor spending cycles through local economies, generating business sales and supporting jobs and income. This resulted in the VSE model, which represents a major revision from previous analyses and establishes the framework for the NPS annual systemwide visitor spending effects report. Many of the hallmarks of the former Money Generation Model (MGM2) are preserved, but the new VSE model makes significant strides in the accuracy and transparency of the analysis. The first annual report using the new VSE model estimated the 2012 economic effects associated with visitor spending at 369 national park units that report visitation (Cullinane Thomas et al. 2014).

In developing the VSE framework, three key pieces of information were required to estimate the economic effects of NPS visitor spending: the number of visitors who visit each park, visitor spending patterns in local gateway regions, and regional economic multipliers that describe the ripple effects of visitor spending in local economies. Visitation source data were derived from a variety of efforts by the NPS Social Science Program. The NPS Visitor Use Statistics Office supplied the detailed 2012 park-level visitation data (Street 2013). Spending patterns were derived from survey data collected as part of the NPS Visitor Survey Project (VSP). Spending data for 56 parks surveyed between 2003 and 2012 were used to represent spending patterns at those parks. Non-surveyed parks were classified into four types: those that have both camping and lodging available within the park, those that have only camping available within the park, those with no overnight stays, and those with high day use (including national recreation areas, national seashores, and national lakeshores). Generic spending profiles for each of these were developed using data from the 56 surveyed parks. A number of parks were not well represented by the four types constructed using the VSP survey data. For these parks, profiles were constructed using the best available data. Spending and visitation information were then used in conjunction with IMPLAN input-output models to estimate the economic effects at four scales: local,[1] state, regional, and national.

Key findings from the 2012 VSE analysis include:

- In 2012, nearly 283 million national park visitors spent $14.7 billion in gateway communities.
- The ripple effect of visitor spending supported 243,000 jobs in the US economy, more than 200,000 of which are found in gateway communities.
- Visitor spending also provided a $26.75 billion benefit to the overall US economy, including an $18.2 billion benefit to local gateway communities.
- These effects represent a $10 return for every $1 America's taxpayers invest in the National Park Service.
- Most visitor spending supports jobs in restaurants (35%); hotels, motels, and bed-and-breakfasts (B&Bs) (27%); and other amusement and recreation industries (20%).

Continuous improvement and increased rigor for data inputs to the VSE model will be a significant focus for this USGS–NPS collaborative effort into the future. Notably, an effort is underway to establish an NPS socioeconomic monitoring program that will sample park units on a more representative basis. The primary goal of the program is to better understand and represent how visitors enjoy and value our national park system. Socioeconomic monitoring efforts will result in a gain in usable socioeconomic data that will be directly applicable to the VSE model, including additional data on visitor spending and on a variety of demographic and trip characteristics variables that are important inputs to the model.

Example of the NPS application of VSE results. The usefulness and flexibility of the VSE model as a USGS–NPS collaborative tool can be extended to a number of situations where the economic effects from changes to park visitation could evaluate various policy questions, management scenarios, and unexpected changes to park visitation due to factors outside the control of NPS. A recent example of using the VSE outside of its original, intended development is the NPS analysis of the changes in visitor spending as a result of the sixteen-day federal government shutdown during the period October 1–16, 2013 (Koontz and Meldrum 2014). The government shutdown had significant effects on NPS visitation levels, and resulted in forgone spending in gateway communities across the country. To estimate changes in visitor spending, Koontz and Meldrum (2014) compared the visitor spending averages from each park as they were calculated in the 2012 VSE report (Cullinane Thomas et al. 2014) with the three-year average of October visitation from the NPS Visitor Use Statistics Office.[2] This study found that with 7.88 million fewer visitors in October 2013 compared with average October visitation, gateway communities across the country lost a total of $414 million in visitor spending. Also estimated were the changes in visitor spending for the 14 parks that remained open during the federal government shutdown due to NPS agreements with the respective state governments to fund operations. These results showed that every dollar spent by state governments to maintain park operations resulted in an estimated $10 in visitor spending.

Conclusions

The collaborative USGS–NPS development of the ASPN and VSE tools provides the necessary framework to help answer a wide range of policy questions and evaluate various management scenarios that can have both social and economic impacts to communities, visitors, and the general public. ASPN was designed to improve guidance and training across federal land management agencies, based on their expressed need for more capacity in the realm of socioeconomics. It provides users with the ability to identify important social and economic issues as well as guidance on selecting appropriate economic and social methods to analyze identified issues.

Analyses using the VSE model serve as example applications of a type of analysis ASPN might recommend. In addition to the annual systemwide VSE reports that will be collaboratively conducted by USGS and NPS each year, the flexibility of the VSE model allows it to be extended to a number of situations where information about the economic effects of anticipated or real changes in park visitation can help inform policy and park management. For example, the model was modified to estimate changes in visitor spending due to the shutdown of the federal government that occurred in October 2013. In the future, the model can be further modified to evaluate other scenarios that may affect visitation to NPS-managed lands, such as natural and human-caused disasters. For instance, flooding in Colorado during 2013 resulted in the closing of major roads leading to Rocky Mountain National Park, which negatively impacted park visitation. Another example is a recent oil spill in Galveston Bay, Texas, that has the possibility of negatively impacting visitation to Padre Island National Seashore. For both of these scenarios, the VSE model could be used to estimate the economic effects of forgone spending on local, state, and national economies.

Overall, identifying and evaluating the social and economic effects of actions taken on public lands continues to represent an important component of the planning process. The collaboration between USGS and NPS continues to foster the development of tools to assist land managers and planners in addressing these important issues.

Endnotes

1. The local level includes the counties comprising the local gateway region around each park. The USGS used geographic information system (GIS) data to define the local gateway region for each park unit by spatially identifying all counties partially or completely contained within a 60-mile radius around each park boundary.
2. The Consumer Price Index inflation calculator (Bureau of Labor Statistics 2013) was used to adjust the 2012 spending estimates to 2013 dollars for the Koontz and Meldrum (2014) study.

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Park Break: Collaborative Opportunity Established for Graduate Students

Robin P. White, John Donahue, and Debbie O'Leary

Introduction

Among the many topics discussed during the 2007–2008 George Wright Society (GWS) board meetings was the subject of how to inspire graduate students seeking careers in science and natural resource management to consider the Department of Interior (DOI) in general, and the National Park Service (NPS) and the US Geological Survey (USGS) in particular, as good options for future employment. Board members participating in these discussions included Suzette Kimball, now acting director of USGS, and Gillian Bowser, now a research scientist with Colorado State University, who envisioned a program that would offer an alternative to the break from classes that universities typically offer students in early spring.

Since those initial discussions among the GWS board members, Park Break sessions have been held in eleven different NPS sites across the country. Each session has sponsored six to eight graduate students in various stages of their university programs for a week-long seminar focused on a specific theme relevant to the host park, such as conservation policy and climate change. Sessions have varied in format but all generally have been composed of a week of field and classroom activity with participation from local, state, and national experts.

History

The vision for Park Break was to offer graduate students an on-site experience in a national park where they would work with scientists and managers on real-life issues. The program would follow the DOI's Diversity and Inclusion Strategic Plan directives "to recruit and hire exceptional individuals from every background and every community" and encourage students of diverse backgrounds to apply (DOI Diversity & Inclusion Strategic Plan, March 2012, http://www.doi.gov/pmb/eeo/workforce-diversity.cfm).[1] Thus Park Break evolved as a unique cooperative venture pursued by GWS, NPS and USGS, presenting graduate students from all backgrounds with an unconventional opportunity for spring break activities in the form of a week-long, all-expenses-paid seminar in a national park. The students would be

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exposed to land and resource management issues of ongoing concern with the ultimate goal of encouraging them to pursue careers within DOI.

In 2008, the first year of the program, Park Break sessions were held in four national parks in the eastern United States: Acadia National Park (ME); Delaware Water Gap National Recreation Area (PA and NJ); Gateway National Recreation Area (NY); and Indiana Dunes National Lakeshore (IN) (Table 1). While no set program was followed by all four parks, each park identified a specific theme to focus on for the week tailored its particular management concerns. Topics ranged from science and policy questions to the examination of interactions between the parks and their surrounding communities. The timing of the session was up to each park, but an emphasis was placed on trying to synchronize with the week-long recess scheduled in March by many universities in the United States.

After the initial year of the program, three sessions were held in 2009, two in 2010, two in 2012 and two in 2014. USGS originally provided three years of funding for the program, with total funding per year ranging from $15,000 to $45,000 per year. Funds and in-kind services were provided by each of the parks sponsoring a Park Break session and from GWS for advertising, evaluating applications, and coordinating session planning. Additional partners contributed funds and in-kind services and included Colorado State University, Geological Society of America, Student Conservation Association, and Texas A&M University.

In 2012, in addition to USGS funding a science-oriented Park Break session, NPS sponsored a session focused on cultural resources at Boston African American National Historic Site, Boston National Historical Park, and Lowell National Historical Park (MA). A similar schedule was agreed to for 2014, where USGS funded a science-focused seminar in Saguaro National Park (AZ) while NPS funded a week focused on cultural resources at Keweenaw National Historical Park (MI).[2]

Park Break sessions have been held most regularly at one park, Delaware Water Gap National Recreation Area (DWGNRA) in 2008, 2009, 2010 and 2012. The theme of the pro-

Table 1. Park Break sessions, 2008–2014.

Site	Date	Theme
Acadia National Park (ME)	2008	Civic Engagement
Delaware Water Gap National Recreation Area (PA, NJ)	2008, 2009, 2010, 2012	Conservation Policy
Gateway National Recreation Area (NY)	2008	Global Climate Change
Indiana Dunes National Lakeshore (IN)	2008	Wildland–Urban Interface
Great Sand Dunes National Park and Preserve (CO)	2009, 2010	Climate Change and Sustainability
Fort Vancouver National Historic Site / Mount Rainier National Park / Olympic National Park (WA)	2009	Natural Hazards
Boston African American National Historic Site / Boston National Historical Park / Lowell National Historical Park (MA)	2012	Cultural Resources Management
Saguaro National Park (AZ)	2014	Hydrogeology
Keweenaw National Historical Park (MI)	2014	Archaeology and Cultural Resources Management

gram at DWGNRA has remained the same over the years, focusing on conservation policy, but the week's activities evolved with the goal of increasing both teamwork among the participating students and involvement with investigation of a real-life problem being faced by the park. A more detailed look at specific changes in the DWGNRA program is covered below.

Program development

In meeting one of the primary goals of Park Break—enabling graduate students to experience first-hand the challenges facing managers and scientists working in the host park—we have developed a set of general guidelines outlining typical events and activities to schedule for the week. By following these guidelines, our hope is that the students will be engaged in discussions with scientists, park managers, administrators, government representatives, naturalists, and other professionals, and will be exposed to the complexity of science and management issues from multiple perspectives. The Park Break program then becomes a unique experience, offering a week-long immersion in scientific and intellectual inquiry specifically related to land and resource management.

Assigned science project. A project relevant to current science and resource management issues affecting the park is assigned for the students to focus on during the week. Material is sent to students in advance of the session. Guidance is provided during the week on project objectives, methods, analysis, formal presentation, and final report.

Interactive sessions with park personnel. Interactions with personnel from the national park unit, including the superintendent, division chiefs, scientists and resource managers give the students multiple perspectives on day-to-day activities of DOI employees.

Coordination with local USGS science centers. Coordination with one or more nearby USGS science centers in discussing the assigned project as well as interaction with scientists currently working in the park exposes the students to specific research questions and ongoing fieldwork that provides information for management decisions.

Interactive presentations from local officials. Presentations by local nongovernmental organizations, elected officials, and personnel from other parks provide yet another perspective on issues facing the park, local politics, and current and historical conservation topics that are important to surrounding communities.

Final presentation. A presentation by the students on the last day of the session addressing the assigned project ensures that the students work as a team during the week, provide proposed solutions for discussion, and receive feedback from the session coordinators.

Final papers. A final report by the students based on the week-long work, to be submitted within a month after the session, helps the students reflect on their experience and can lead to a publication for the Park Break Perspectives series posted on the GWS website (http://www.georgewright.org/perspectives).

Case study: Delaware Water Gap National Recreation Area

DWGNRA is a 27,000-ha (67,000-ac) park established in 1978 along a section of the Delaware River in New Jersey and Pennsylvania. The park is unique in being close to major urban centers in New York and New Jersey but still providing a place with high waterfalls, hemlock ravines with rhododendrons, ridge tops with prickly pear cactus, the Middle Delaware river as a national scenic river, and wildlife populations of black bears, timber rattlesnakes, and bald eagles.

As one of the original parks selected to sponsor a Park Break session, and as the park which has now sponsored the most sessions in this program, DWGNRA staff viewed Park Break as an opportunity to prepare the next generation of professionals that would have responsibilities in park management and land stewardship. Author and DWGNRA Park Superintendent John Donahue recalls that "in the time it took Dr. Gillian Bowser and me to ride down an escalator at a George Wright Society Conference, we had agreed on the basic concept that would become the first Park Break at Delaware Water Gap."

In the first year of the program at DWGNRA, the sessions focused on local, national, and international conservation policy. Destry Jarvis, former special assistant to the director of NPS, highlighted the history of conservation in the United States, and was able to add the kind of personal, inside stories about important events and figures in the 19th- and 20th-century conservation movements that fascinate idealistic young people. Former assistant secretary of interior for fish, wildlife, and parks, Don Barry, highlighted important figures that had demonstrated the courage of their convictions at great personal sacrifice and were able to make a real difference through their efforts. Suzette Kimball, current acting director of USGS, provided her perspectives on the importance of science-based decisions in park management, and Bill Werkheiser, current acting deputy director of USGS, offered the students a comprehensive view of the science efforts within all of the agency's mission areas as well as a discussion on finding employment within DOI.

Nancy Shukaitis, a writer and former elected official, shared with the class how she first became involved in conservation because of her outrage with the plans to dam the Delaware River. Her tales of evolving from homemaker to Supreme Court litigant and stopping the proposed dam impressed upon the students the difference that one person can make in the development of a protected area. Panels also included local township planners and supervisors along with conservation district officials and environmental education experts sharing their experiences and approaches to issues facing the park and surrounding residential communities.

The fact that the meetings took place in Grey Towers National Historic Site, the ancestral home of US Forest Service founder Gifford Pinchot, added to the overwhelming sense of responsibility for stewardship that was conveyed in many of the discussions. Learning and engaging in discourse in the same rooms where Pinchot entertained intellectual and environmental giants of his time helped to make the experience all the more memorable.

As the program for Park Break at DWGNRA evolved, an on-site project was added to the week's activities. The first project centered on developing a proposal for establishing a national scenic byway for US Route 209, a highway running parallel to the Delaware River through the park. The second project involved the Pocono Environmental Education Center (PEEC), a nonprofit center within the park, in the design of new environmental education programs for park visitors. Each one of the DWGNRA Park Break sessions also has included interactions with USGS scientists currently conducting research projects within the park, which have ranged from vegetation mapping to studies monitoring eel populations in the Delaware River.

In looking broadly at the program since 2008, author and DWGNRA Park Break Coordinator Debbie O'Leary notes several important lessons learned that may be helpful to future parks involved in the program:

- Students have tended to respond best to presenters who engage the group in an interactive discussion as opposed to a lecture format.
- If presentations are given by invited speakers, it is important to make sure there is plenty of time for questions and answers. The students never run out of questions, so you can never have too much time for interactive discussion.
- Organizing a social get-together early in the week for the students, presenters, and local park employees provides an opportunity for the students to get to know each other and the people they will work with throughout the week.
- Since the Park Break session will be a first-time visit to the park for the majority of the participants, an early tour of some of the park's special features is a useful way to start the week. If the project involves field work, the students may be able to experience the park in ways not always available to other park visitors. If the majority of the project involves lab and classroom work, there should be time scheduled outside. We had a local naturalist lead a hike through one section of the park and USGS scientists led trips to their field sites, so the students were exposed to a representative portion of the park and its natural and cultural features.
- Inviting all of the speakers, panel members, local officials, and scientists to stay for lunch or dinner is another opportunity for the students to interact with professionals and engage in more personal or one-on-one exchanges.

The Park Break experience at DWGNRA was developed for students interested in spending their limited spring break from college classes to learn about the history of conservation in a unique setting. John Donahue sums up his experience with Park Break as one charged with enthusiasm: "Add a multitude of high-powered speakers, a project that talented graduate students complete in record time, stir in some case studies that include local, state and federal complexities, and you have a recipe that can stimulate graduate students not only in conservation policy—or other topics covered in Park Break sessions—but in potential careers in science and park management."

Program benefits and evaluation

Park Break participants are encouraged to collaborate with their fellow participants in writing professional papers and contributing to activities that build on their Park Break experience (see Monzon et al. 2011). As noted above, the Park Break Perspectives series was established by GWS as a web-based site dedicated to research papers and essays prepared by student participants. Papers have been developed on topics specific to projects investigated during the week as well as on topics of particular interest to an individual's graduate work but related to their Park Break experience.

Each Park Break participant receives a complimentary one-year membership to the GWS as well as preference for travel scholarships to the next GWS biennial conference. Park Break participants are encouraged to organize sessions at this conference as a way to become more involved with professionals at the meeting and to gain experience in participating in formalized panel discussions. During recent GWS conferences in Portland OR (2009), New Orleans LA (2011), and Denver CO (2013), Park Break sessions have been organized and moderated by former Park Break students.

Measuring success of a program such as Park Break is challenging since metrics may vary depending on the parks, students, and staff involved. In the past, students participating in Park Break sessions have been asked to provide feedback either verbally before they leave the session or in post-session questionnaires. In 2011, Park Break participants from Clemson University conducted a post-session survey, receiving responses from 23 students who attended Park Break sessions in different locations and years (Mora-Trejos et al. 2011). Topics covered in this survey ranged from motivations for participating in the program to satisfaction with preparatory materials, accommodations, and speaker selection. In responding to overall satisfaction with the Park Break experience, over 95% of the respondents were satisfied or very satisfied with their experience. Knowledge gained by participating in the program included different perspectives on natural and cultural resource management issues and greater understanding of how federal managers try to balance monetary, political, and social aspects of resource management concerns. The demographic analysis in their survey showed that at least 30% of Park Break participants were of African American, Native Hawaiian, Hispanic, or Asian heritage.

Some of the most encouraging feedback regarding the success of the program is in direct quotes we receive from past participants. We include two of these comments below.

> I think about our Park Break session often. It was one of the best organized meetings I've attended. I came to Park Break from a fairly narrow focus on the 'natural' in natural areas, and it was beneficial to meet with folks with broader interests (e.g. interpretation, history and archeology). It really opened my eyes to how complex decisions can become when all of the stakeholders are considered. The national scenic byway project was a great practical way to get our cohorts involved in making management decisions, and I still use quotes from John Donahue with my students (e.g. 'If your decisions aren't upsetting anyone, you're probably not making a difference').
>
> *— Heath Garris, Park Break participant, 2010*

> I was in the first Park Break session in 2008 and then was a mentor for 2009. I am in my second term as a botanist for Denali National Park. Park Break was a great introduction to upper-level positions in the NPS. Despite my five seasons working with the NPS, Park Break was the first time I was really allowed behind the closed doors of upper management, and recognized as a potential contributor to management in the future. It helped me view my role in the NPS a bit differently,

> and motivated me in my studies to stay true to my management interests and not get bogged down too much in the esoteric aspects of academia.
>
> *— Sarah Stehn, Park Break participant, 2008; Park Break mentor, 2009*

For 2014, we developed two surveys for Park Break students to complete regarding their experience with the program: one survey to fill out before the program and a second survey to fill out once the program is complete. The intent is not only to get feedback on the week's program but also to have some measure of knowledge gained from the experience.

Recent developments

For the 2014 Park Break session, a new process was initiated for selection of the host parks. In September of 2013, notice was provided to park units regarding availability of funds and a call for proposals. Each park interested in serving as a host was asked to fill out an online application posted on the GWS website that included a description of the proposed Park Break session, the topic for a special project focus, and the availability of on-site housing for up to eight students.

Two parks were selected as hosts, one with a science focus to be funded by USGS and one with a cultural resource focus to be funded by NPS. The science-focused session was held in Saguaro National Park and involved students in a project that examined the special hydrogeological resources of the park's desert environment. The cultural resources session was held in Keweenaw National Historical Park along the Lake Superior shoreline with a focus on archaeology and cultural resources management.

For 2015, we hope that we will be announcing another year of Park Break with sessions to be held in March or April of 2015. Protected area managers interested in the program should watch for a request for proposals announced by the George Wright Society.

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Endnotes

1. The term "diversity" is used broadly to refer to many demographic variables, including, but not limited to, race, religion, color, gender, national origin, disability, sexual orientation, age, education, geographic origin, and skill characteristics. America's diversity has given this country its unique strength, resilience and richness (from US Department of Interior's Compliance and Programs Division website: www.doi.gov/pmb/eeo/workforce-diversity.cfm (accessed March 17, 2014).
2. With the expansion of Park Break into the realm of cultural resources, the program now engages with historians, archaeologists, and other scholars and professionals outside the

realm of science. However, because the subject of this theme issue of *The George Wright Forum* is USGS–NPS collaboration, the remainder of this article will focus primarily on the scientific aspects of Park Break.

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