Fall 2013 • Volume 30 • Number 2 • www.nature.nps.gov/ParkScience

PARK Science

Integrating Research and Resource Management in the National Parks

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
Office of Education and Outreach

DESIGNING PARKS FOR HUMAN HEALTH BENEFITS

A series of articles examines the importance of free play in national parks and opportunities to implement the Healthy Parks Healthy People initiative

ALSO IN THIS ISSUE

- Archeology in park management
- Cryptic plant invasions: The case of cattails
- Effects of roadside automobile pollution at Grand Canyon
- Revisiting the "Monte Video" inscription at Grand Canyon

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Volume 30 • Number 2 • Fall 2013
www.nature.nps.gov/ParkScience
ISSN 0735–9462

Published by
U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Office of Education and Outreach
Lakewood, Colorado

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Sample style for article citation
Marburger, J., and S. Travis. 2013. Cattail hybridization in national parks: An example of cryptic plant invasions. Park Science 30(2):58–68.

Printed on recycled paper.

From the Editor

Parks and people: Past, present, and future

In our search for personal growth and a better understanding of American heritage, national parks facilitate transformative experiences. They blend aspects of inspiration, discovery, challenge, recreation, and education as we seek to define and celebrate ourselves and our national identity. The parks are there for us to experience, learn from, and enjoy.

Another important role for national parks is emerging. Increasingly parks are being recognized as places with great potential to enhance public health, especially at a time when stress, poor nutritional choices, and a lack of physical activity are contributing to widespread health problems. Concern for public health is galvanizing a movement among scholars, health professionals, business and nonprofit leaders, and park managers to work together in order to engage the public to a greater degree in discovering the healthful benefits of national (and all) parks.

In this issue of *Park Science* we highlight this idea in a brief series of articles that explores the science behind these perceptions and the implications for resource management. Several national parks have begun to develop and market their health values for exercise, free play, and nutrition. The articles also discuss the compatibility of these goals with the need for natural and cultural resource stewardship.

We also feature a section on recent archeological research in national parks. The authors describe the evolution and application of archeological techniques, particularly the integration of various data sets, that are increasing our knowledge of past park inhabitants.

Centuries from now a historian or archeologist studying a national park will find a photograph, letter, or notated brochure. Along with other information, the relic will paint a picture of 21st-century people who loved their national parks and how the parks helped fulfill a variety of societal needs. The story of people and their parks is continuous and science is a tool that helps us to write the next chapter.

—Jeff Selleck, Editor

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

Articles are field-oriented accounts of applied research and resource management presented in nontechnical language. The editor and board or subject-matter experts review content for clarity, completeness, usefulness, scientific and technical soundness, and relevance to NPS policy.

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

Park Science is published online at http://www.nature.nps.gov/ParkScience (ISSN 1090-9966). The Web site provides guidelines for article submission, an editorial style guide, an archive and key word searching of all articles, and subscription management.

Though subscriptions are offered free of charge, voluntary donations help defray production costs. A typical donation is $15 per year. Checks should be made payable to the National Park Service and sent to the editorial office address.

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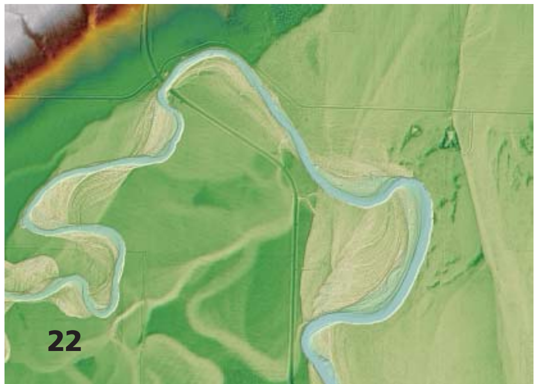

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DEPARTMENTS

ON THE COVER

Students from Jose de Diego Community Academy in Chicago enjoy free-play activities on the April 2013 opening day of the new Nature Play Zone at Indiana Dunes National Lakeshore. Read more about this program in our article on page 48.

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FEATURE

IN FOCUS: ARCHEOLOGY IN PARK MANAGEMENT

Archeology integrates new and existing data to understand how humans interacted with their environment, in both the recent and distant past. These articles provide examples of research into human-environment interactions and provide insights on how resulting information can assist park managers across programs.

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UPCOMING ISSUES

Winter 2013–2014
Theme issue: Biodiversity science in the national parks. May 2014 release. In production

Summer 2014
Seasonal issue. September release.
Contributor's deadline: 1 June

Fall 2014
Seasonal issue. December release.
Contributor's deadline: 15 September

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In This Issue

NATIONAL PARKS AND OTHER PROTECTED AREAS DISCUSSED IN THIS ISSUE

Abbreviations

Mem	Memorial
NHP	National Historical Park
NHS	National Historic Site
NL	National Lakeshore
NM	National Monument
N Mem	National Memorial
NP	National Park
NRA	National Recreation Area
NS	National Seashore
NSR	National Scenic Riverway(s)
NWR	National Wildlife Refuge

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Feature

COURTESY OF GRAND CANYON NATIONAL PARK MUSEUM COLLECTION

The "Monte Video" inscription at Grand Canyon National Park: Why it's likely from the Bass tourist era

By Jonathan Upchurch*

"SHERLOCK HOLMES WOULD have loved this!" Grand Canyon National Park anthropologist Robert C. Euler was reading from a letter dated 4 February 1982 written by his professional colleague, B. L. Fontana. Euler had shared information with Fontana about a mysterious sandstone inscription in the canyon that reads "MONTE VIDEO." After supplementing his own investigation with the additional information from colleagues like Fontana, Euler concluded that MONTE VIDEO was late 19th century or early 20th century in origin. Other key findings of Euler's (1980) site survey:

- The inscription is located near a canyon tourist destination operated by William Wallace Bass from 1885 to 1923.
- "The incised lettering . . . appears to be late 19th century in style."
- "In a crack in the sandstone adjoining the inscription was a rusted corned beef can" with a "soldered bottom . . . manufactured between 1875 and 1920."
- Language experts concluded that "monte video" is Latin for "I see the mountains from this place."[1]

Prior to Euler's site investigation, the only formal documentation of an inscription at the MONTE VIDEO site was a 1975 photograph by Gene Wendt (fig. 1). In the 38 years since then, it is likely that only a small handful of Grand Canyon backcountry users have been to the inscription's remote location. During the past few years the inscription has received more exposure as its origin has become a topic of scholarly debate. Geologist Ray Kenny proposed, in an article published in *Park Science* in 2010, the hypothesis that the inscription was made in 1540 by Spanish explorers (Kenny 2010). This article presents the case that the inscription was likely created between 1885 and 1918 and also critiques the Spanish-origin hypothesis.

Abstract

The MONTE VIDEO rock inscription at Grand Canyon was likely created between 1885 and 1920 when there was substantial human activity in the immediate area. This conclusion is supported by previous archeological site investigation and recent study of human history that demonstrates that this area was frequently visited during the Bass tourist era. A photographic comparison of the inscription in 1975 and 2011 reveals substantial deterioration in 36 years and casts doubt on the possibility of the inscription originating in the 16th century. An interpretation of Spanish accounts of the Coronado expedition questions whether the inscription site is likely a location the Spanish would have visited.

Key words

Colorado River, Coronado, engraving, Grand Canyon, human history, inscription, Spanish exploration

Tourism operations

William Wallace Bass arrived to live on the South Rim of Grand Canyon in 1884 and began advertising for the tourist trade a year later (Maurer 1983, p. 1). By 1891 Bass had completed the South Bass Trail from the rim to the Colorado River and had developed improvements for tourist camps at Bass Camp (on the South Rim at the trailhead; fig. 2) and in the canyon. The first of these facilities in the canyon was located at Mystic Spring on the Esplanade. The Esplanade is a large, relatively flat topographic feature within the canyon about one-third of the way from the rim to

1 Personal correspondence of Paul H. Ezell; Professor Emeritus, Department of Anthropology, San Diego State University, forwarding the opinion of Sister Catherine Louise La Coste, a Latin scholar at the Diocese of San Diego, as to the language and translation of the inscription; 28 January 1982. Ezell also provided his opinion that "video" is Latin and means "I see."

Figure 1 (left). The MONTE VIDEO inscription as photographed in November 1975, by Gene Wendt.

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Figure 2. Desmond tourist party at Bass Camp, George Wharton James at far left and William Wallace Bass third from right.

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Figure 3. The Grand Canyon of Arizona, in camp along the Mystic Spring Trail. Maine lumbermen camp on the Esplanade. Frederick H. Maude photograph, 1898.

the river. The Esplanade does not exist in the eastern one-third of the canyon.

From 1885 to 1923, 3,000 to 5,000 tourists visited Bass Camp on the South Rim (Murbarger 1958, pp. 5–9; Madsen 1980, p. 55). Anderson (1998, pp. 44–45) describes that "early visitors to the rim who spent one and sometimes two days in uncomfortable buckboards or stagecoaches were not about to glance into the scenic abyss then turn for home. They often stayed a week and sometimes lingered for a month or more to justify the round-trip effort." Most visitors ventured into the canyon (fig. 3), and documentary accounts of trips to the Esplanade emphasize the popularity of Mystic Spring as a destination (Martin 1982, pp. 5–14; Madsen 1980, pp. 32,34; James 1901, pp. 147–159):

> With a water supply at Mystic Spring, tourists could stay [t]here overnight enjoying day trips exploring and marveling at the magnificent views.... Comfortable overnight conditions were found at Mystic Spring, and unless someone had a specific reason, few people desired to go farther, even after Bass improved the section of the trail continuing below the Supai Plateau [the Esplanade] to the river. (Madsen 1980, p. 25)

> For a time, it [Mystic Spring] became the center of all activities on the plateau [the Esplanade]. (Madsen 1980, p. 27)

> Referring to conditions after 1905, "Although trips to Mystic Spring were not as frequent, it remained a favorite day trip for visitors staying at Bass Camp." (Madsen 1980, p. 55)

> Ada Bass diary entry: "Numerous trips were made to this spring by tourists traveling on horse or mule back. They spent the night at Mystic Spring, returning the next day to the Rim Camp." (Garrison 1952)

The popularity of Mystic Spring is important for addressing questions about the origin of the MONTE VIDEO inscription because its location is not far from the spring and the South Bass Trail.

Mystic Spring was also popular with noted landscape photographers, and the presence of visitors near the inscription is underscored by their work. Frederick H. Maude took a photo in about 1896 at a location only 800 feet from MONTE VIDEO.[2] Henry Peabody published photos in 1902 (Peabody 1901) taken from the Mystic Spring Trail; one photo was captured only 1 mile (1.6 km) away from the inscription. Madsen (1980, p. 23) reports that "Maude returned often to spend long

2 The source of this photo, and the photo itself, are not disclosed here in order to conceal the exact location of the inscription.

periods of time at the Canyon taking and developing photographs." Photographers G. L. Rose, Henry Peabody (Madsen 1980, p. 23), James Putnam, and C. C. Valentine (Garrison 1952) are all known to have used Bass's darkroom at Bass Camp.

With large numbers of visitors venturing into nearby parts of the canyon from Bass Camp, there were ample opportunities for many people between 1885 and 1920 to have made the MONTE VIDEO inscription. Bass worked hard to attract customers, and he thoroughly knew the Esplanade area around South Bass Trail. If the MONTE VIDEO inscription had existed before the tourist era, Bass certainly would have seen it, understood its significance, and exploited the opportunity to advertise and market it as a tourist attraction.

A new hypothesis

While Robert Euler concluded in 1980 that the MONTE VIDEO inscription was created around 1900, a new hypothesis was advanced in 2010 by geologist Ray Kenny, who postulates that the engraving was made in 1540 by members of the Cárdenas expedition. Coronado had sent the Cárdenas party in search of a large river reported by Native Americans and they became the first Europeans to see the Grand Canyon. The idea that the Spanish carved "MONTE VIDEO" in 1540 is very romantic and tantalizing; however, the following discussion raises several questions that cast doubt on the Spanish hypothesis.

The Spanish account

Most information that is known about the 1540 Spanish expedition to Grand Canyon comes from an account written by Pedro de Castañeda in 1560.[3] Though he was one of the common soldiers on the Coronado expedition (Bartlett 1940, p. 41; Winship 1969, p. v), de Castañeda is not believed to have been one of the 13 men on the Cárdenas trip to Grand Canyon (Bartlett 1940, p. 41). Additionally, his account was not written until about 20 years after the expedition took place (Bartlett 1940, p. 41; Winship 1969, p. xxx). Therefore, it is likely that de Castañeda simply recorded what he had heard from one or more of the Cárdenas expedition participants about 20 years earlier (Bartlett 1940, p. 41).

Admittedly, the description of the Cárdenas expedition is very sketchy. In addition, two different translations of de Castañeda's account from Spanish to English have rendered the story differently. For example, the 1922 version translated by historian George Parker Winship (1969) includes the passage "they came to the banks of the river. It seemed to be more than three or four leagues in an air line across to the other bank of the stream which flowed between them." In this translation "bank" apparently refers to the rim of the canyon. The version printed in (Winship) 1896 reads, "they came to the banks of the river, which seemed to be more than three or four leagues *above* the stream which flowed between them [emphasis added]." Any historical interpretation of de Castañeda's account needs to understand and acknowledge the limitations of the original source documents and the translations. Similarly, readers of the interpretations are better able to judge the historical interpretations if they understand the limitations.

Likely location for a Spanish descent?

A good question to ask in order to help determine the route of the attempted Spanish descent to the Colorado River is, "From where on the rim did the Spanish view the Canyon?" The traditional belief of historians is that Cárdenas likely observed the canyon between Desert View and Moran Point, though supporting evidence is weak. As Ray Kenny points out, there is a considerable length of the South Rim that is "full of low twisted pines" (de Castañeda's words). Low twisted pines (likely referring to juniper) exist on the South Rim today from Desert View to 50 or more miles (80 km) to the west. By this clue there are many different places from which the Spanish could have viewed the canyon.

Another clue is that de Castañeda suggests that the explorers were very interested in the river. Coronado sent scouts under the leadership of Don Pedro de Tovar to one of the seven villages of Cíbola (at or near the present-day Orabi, Arizona), and de Tovar "obtained information about a large river" in the arid lands to the west (Winship 1969, p. 35). Upon learning this news Coronado then "dispatched Don Garcia Lopez de Cárdenas with about 12 companions to go see this river. . . . After they had gone twenty days they came to the banks of the river. . . . [Cárdenas's men] spent three days on this bank [the rim of the Canyon] looking for a passage down to the river" (Winship 1969, p. 35).

As a source of water, the river was clearly of great interest to the expedition. As a general route of navigation or exploration the river also would have been of interest to the explorers. Every river eventually leads to an ocean, and this was a fairly large river. In addition, Coronado's explorers knew that two ships led by Don Pedro de Alarcón had been sent north in the Gulf of California to resupply Coronado (Winship 1896, pp. 385–386). The river could be a pathway to the expedition's resupply (Lavender 1984, p. 42).

Although de Castañeda's party had no direct communication with Alarcón, the actual situation is intriguing. Winship (1896) reports that Alarcón discovered the mouth of the Colorado River and made two trips upstream on the river. His second trip began on 14 September 1540 and he travelled 85 leagues (roughly 250 miles or

3 In addition to Castañeda's account, a second account is given in *The Journey of Coronado* by Winship entitled "Translation of the Relacion del Suceso: Account of What Happened on the Journey which Francisco Vasquez Made to Discover Cibola."

Figure 4. View of Grand Canyon from South Bass Trailhead on 24 April 2011. Note that the Colorado River is not visible from this location.

402 km) upstream. This would have been about as far as Lake Havasu City (Winship 1896, pp. 403–408). Thus, Alarcón was up the Colorado River within days of the date that Cárdenas was exploring along the rim of the Grand Canyon.

Thus with major interest in reaching the river, it makes sense that the Spanish would have sought locations on the rim from which the river could be seen to plan their descent. It is also sensible that they would have wanted to keep the river in sight during descent. Does the route leading from the South Rim to the MONTE VIDEO inscription support these ideas? No. The most easily traversable route from the rim to the MONTE VIDEO inscription would have generally followed today's South Bass Trail for initial descent. However, the river is not visible from the rim at this location (fig. 4). In fact, there are several miles of rim in this vicinity from which the river is not visible. In spending three days on the South Rim looking for a passage to the river, the Spanish probably would have gone to a location where the river was more visible from the rim. Furthermore, in descending from the South Bass trailhead and walking to the location of MONTE VIDEO, there is no location from which the river is visible until shortly before arriving at the inscription. Even from the inscription site itself, there is only one very short section of the Colorado River—perhaps a few hundred feet long—that is visible. Thus, it is unlikely that the Spanish explorers would have gone to the location of the inscription, because their goal was to reach the river.

If the Spanish were focused on the river, and the river could not be seen during nearly all of the trek from the rim to the inscription site, but the river was visible from that site, why would they carve words that mean "I see the mountains from this place?" Would it not be much more logical that they would carve "I see the river"? A second account of the Cárdenas expedition states that "this river comes from the northeast and turns toward the south-southwest at the place where they found it" (Winship 1969, p. 203). In the portion of the canyon where MONTE VIDEO is located the river comes from the southeast, not the northeast.

Probability?

We know that three Spaniards (Captain Melgosa, Juan Galeras, and their unnamed companion) descended into Grand Canyon in 1540 from a location on the South Rim that was "full of low twisted pines," and that around 50 miles (80 km) of rim meet this description. We also know that from 1885 to 1923, 3,000 to 5,000 tourists visited Bass Camp on the South Rim. Most of these visitors ventured into the canyon where Bass had developed the trail and other facilities for tourists. What is the probability that three Spaniards in 1540 happened to go to this particular place in a 50-mile-long stretch of the South Rim? Compare this with the probability that 1,000 or more tourists were likely within a few miles of the inscription site from 1885 to 1923.

Enough time?

Would the Spanish explorers have had enough time to carve the MONTE VIDEO inscription? The size of the inscription (35 × 4 inches [89 × 10 cm]), the depth of the engraving (as much as ¼ inch [6 mm]), and the feature's quality suggest that several hours, or more likely multiple days, would have been required to create it. As Ray Kenny (2010, p. 61) wrote, "the inscriber(s) took great care and pride in making the inscription. . . . Engraving serifs takes patience, time, and attention to detail." Did the Spanish have time to do this? Today, a hiker in good shape requires at least four hours to make the round-trip from the rim to the MONTE VIDEO site. But that hiker would be taking advantage of a constructed trail and would know what route to follow. In 1540 there was no constructed trail. Although there was a Native American route, it was not as easily traversed as Bass's constructed South Bass Trail (Anderson 1991, pp. 1, 6, 32). The Spanish were also likely doing their own route finding. The round-trip would therefore have taken much longer. The Spanish account says "[the three Spaniards] returned [to the rim] about 4 o'clock in the afternoon" (Winship 1969, p. 36). Even if they had started their descent at dawn, it is very unlikely they would have had enough time to do an engraving of this caliber. It is also worth contemplating that if their superiors had directed them to find a way to the river, would they have stopped and spent hours making an engraving?

Figures 5A and 5B: Comparison of the inscription in November 1975 (left) and on 22 May 2011. Note the major exfoliation between *N* and *T* below the letters.

Figures 6A and 6B: Comparison of the inscription in November 1975 (left) and on 22 May 2011. Note the major exfoliation in the top center of letter *D*.

Figures 7A and 7B: Comparison of the inscription in November 1975 (top) and on 22 May 2011. The more recent image shows 14 locations that experienced noticeable exfoliation of the rock or other weathering deterioration over 36 years.

Age and deterioration rate

The MONTE VIDEO inscription is carved in sandstone, a rock type of medium hardness. The rock surface in which the engraving appears is slightly inclined from horizontal. There are no nearby cliffs or overhangs. As a result, the inscription is fully exposed to the elements. It is subject to freezing and thawing of water that collects on the engraved surfaces. Kenny (2010, p. 62) states that "the inscription does exhibit some degree of enhanced weathering" and he refers in particular to the "DEO" in "VIDEO." Is the weathering the result of 471 years of exposure or possibly that of just 110 years?

Photographs of the inscription taken in 1975, 1980, 2000, 2010, and 2011 are deposited in the Grand Canyon National Park archeological site file and the Grand Canyon Museum Collection. The November 1975 photo taken by Gene Wendt is a good, detailed close-up (fig. 1).

On a May 2011 visit to the MONTE VIDEO inscription site, I made a side-by-side comparison of the 1975 photo with the current condition of the engraving. That comparison revealed 14 places that have experienced noticeable exfoliation of the rock or other weathering deterioration in a period of just 36 years. The largest affected area is about 2 × 3 inches (5 × 8 cm) located below the letters *N* and *T* (figs. 5A and 5B).

Another large weathered area is the upper interior portion of the letter *D* (figs. 6A and 6B). A part of this area, the size of a quarter, appeared to be a very recent exfoliation. The individual sand crystals in this fracture were sharp and angular, whereas crystals in the remainder of the inscription surface (including the other areas of exfoliation since 1975) were rounded, probably because of continuing exposure to the elements and blowing sand.

The inscription clearly has experienced a significant level of deterioration in the 36 years from 1975 to 2011 (figs. 7A and 7B). If a similar rate of deterioration had occurred over a period of 471 years, would this engraving be in as good condition as it is today? The intuitive answer is probably no. From this evidence the inscription is much more likely to be one century instead of five centuries old.

Opinion of Coronado expedition experts

Richard Flint and Shirley Cushing Flint, research associate professors at the University of New Mexico, are regarded as the foremost authorities on the Coronado expedition. In personal correspondence dated 31 October 2012 to both me and Ray Kenny, the Flints offered the following observations:

- Although the Coronado expedition lasted three years and covered thousands of miles, only two documented inscriptions are known that were created by that expedition. Both of these were inscribed in wood. Coronado's folks simply were not in the habit of creating inscriptions.

- There is no other 16th-century use of the phrase "monte video" or the single word "montevideo" in either Spain or the New World.

- Many Spanish colonial inscriptions were made at El Morro in New Mexico, beginning with one by Juan de Oñate in 1604. These reflect the cursive handwriting styles of the day, not rectilinear printing styles like those in the MONTE VIDEO inscription. Even most of Spanish printed matter of the 1530s and 1540s was not rectilinear, but rather of a decidedly gothic appearance. So the Grand Canyon inscription is not consistent with Spanish practice of that time.

- "For these [the above] reasons we can imagine no scenario in which 'MONTE VIDEO' would have been inscribed on a rock face in the Grand Canyon by Spaniards of the 1540s."

Conclusion

For several reasons I find it unlikely that MONTE VIDEO is Spanish in origin:

- This location is unlikely for the Spanish to have chosen to descend to the river because the river is not visible from the point on the rim that provides access to the inscription. Moreover, the river is never visible during descent until just before arrival at the inscription site.

- The number of people who were known to have been in the vicinity of the inscription was far greater during the Bass tourist era.

- The inscription is exquisitely carved and the Spanish would not have had time to do so.

- Weathering over the last 36 years suggests that the inscription would not be in as good condition if it were 471 years old.

The preponderance of the evidence supports the conclusion that MONTE VIDEO was carved during the Bass tourist era.

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PS

In Focus: Archeology in Park Management

Deep-time perspectives and understanding change on public lands

By Dawn Bringelson

THE NATIONAL PARK SERVICE was formed under the Organic Act in 1916 with a mandate to protect and conserve the special resources of the National Park System for public enjoyment, now and into the future. Cultural resources in this system are subject to multiple other laws, including the National Historic Preservation Act (1966, last amended in 2006), which requires the federal government to take inventory of its historical properties (all kinds) and to take into consideration impacts on those properties when planning all management-related undertakings. In response to these legislative mandates, the National Park Service has collected information on archeological resources (i.e., evidence of past human activities in the form of artifacts and features across park lands) for decades and applies knowledge derived from these data to the management of these and other park resources.

The Midwest Archeological Center (MWAC) in Lincoln, Nebraska, was formed from a Smithsonian River Basin Survey office in 1969 to assist the National Park Service with collection of archeological information. It serves as a center of expertise for the NPS Midwest Region and is a repository of artifact collections, archives, and digital data that have been collected over the past 44 years. With access to these and an increasing variety of new data as technology develops, the center integrates layers of old and new information to increase our understanding of the human past. The following set of articles highlights a series of current research projects at the center, illustrating this integration and its power to address human-environmental interaction over the last 10,000–12,000 years (i.e., Holocene epoch).

The Midwest Archeological Center has worked with Indiana Dunes National Lakeshore, as described in the first article, on dozens of archeological inventories, ranging from landscape- to house lot–scale projects across the park. Although most of these data were collected in previous decades, their synthesis with the use of modern geographic information systems (GIS) provides a means to evaluate how this sample represents the history of human occupation of the dunes area, as well as to address ways in which environmental factors influenced human behavior (and vice versa) throughout the Holocene.

Understanding the interaction of human activities with climate change is a research priority emphasized by the National Park Service in Secretarial Order 3289 (NPS 2010) and is the subject of our second article. Archeology makes particular contributions to this research by its ability to access the deep history of human-landscape interactions, tying in with (and adding to) paleoenvironmental data needed to better understand the long history of climate change. Case studies at Apostle Islands National Lakeshore (Wisconsin) and Ozark National Scenic Riverways (Missouri) illustrate ways in which archeological studies in national parks can advance efforts to better understand and ultimately respond to current climatic shifts.

Archeology also provides information regarding past use of the landscape by indigenous groups, and is especially important to those affected by colonial and industrial practices that resulted in sparse historical records and incomplete oral histories. Studies at Voyageurs National Park (Minnesota) and Knife River Indian Villages National Historic Site (North Dakota), the next articles in the series, demonstrate ways in which archeology integrates new and old technology to more fully document the history of human interaction and land use in these places, with great implications for natural resource management and indigenous stakeholder communities. Finally, work at Wind Cave National Park (South Dakota) exemplifies how a traditional archeological project can contribute to understanding the interaction of humans and other species over thousands of years.

Multiple data sets, collected over much of the last century, can be used in novel ways to address these and other topics of interest to resource managers and researchers. New field, archival, and digital projects, often conducted to fulfill requirements of the National Historic Preservation Act, are constantly providing additional data and analyses to refine research. At the same time, research contributes to collective knowledge of the deep history of humans' interaction with natural resources, climate change, and other pertinent questions. The relationship among archeological fieldwork, old and new research techniques, and developing useful information is critical to managers in addressing the mandates of the National Park Service and fulfilling its founding principles.

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Predicting the past with GIS at Indiana Dunes National Lakeshore

By Amanda Renner

Abstract

The National Park Service's Midwest Archeological Center is the repository for cultural resource site and survey location data collected for nearly five decades at more than 50 parks in the Midwest Region. As more and better data are accumulated, focus is now shifting toward integrating these large data sets to address "big picture" issues facing park resource managers. To that end, an ongoing multiyear archeological inventory at Indiana Dunes National Lakeshore included the creation of a GIS-based archeological site predictive model. The model integrates data collected from small compliance projects to large parkwide inventories, and identifies patterns in the environmental characteristics of site locations. This article outlines the protocol used to integrate multiple data sets and addresses questions regarding prehistoric land use as well as the nature of previous sampling, providing a point from which to continue scientific inquiry.

Key words

archeology, Geographic Information Systems (GIS), Great Lakes, Indiana Dunes National Lakeshore, predictive modeling

INDIANA DUNES NATIONAL LAKEshore was established in 1966 "in order to preserve for the educational, inspirational, and recreational use of the public . . . the Indiana dunes and other areas of scenic, scientific, and historic interest and recreational value" (16 U.S.C. 4604). Located along the southern shoreline of Lake Michigan, this 15-mile-long (24 km) park preserves roughly 15,000 acres (6,070 ha) of sand dunes, oak savannas, swamps, bogs, marshes, and forests (fig. 1). This tightly packed set of ecosystems harbors biological diversity that is among the highest per unit area in the National Park System, and is associated with a series of dunes that began to form as glaciers started receding from the area nearly 14,000 years ago, according to the Indiana Dunes National Lakeshore Web site (NPS 2013). Glacial retreat, in addition to wind and water action, resulted in spatially distinct dune systems, dating to the late Pleistocene, mid-Holocene, and recent past. The national lakeshore is notable for these chronologically distinct systems, and the study of ecology is even linked to this place because of the opportunity to observe the correlation of plant communities with landform age.

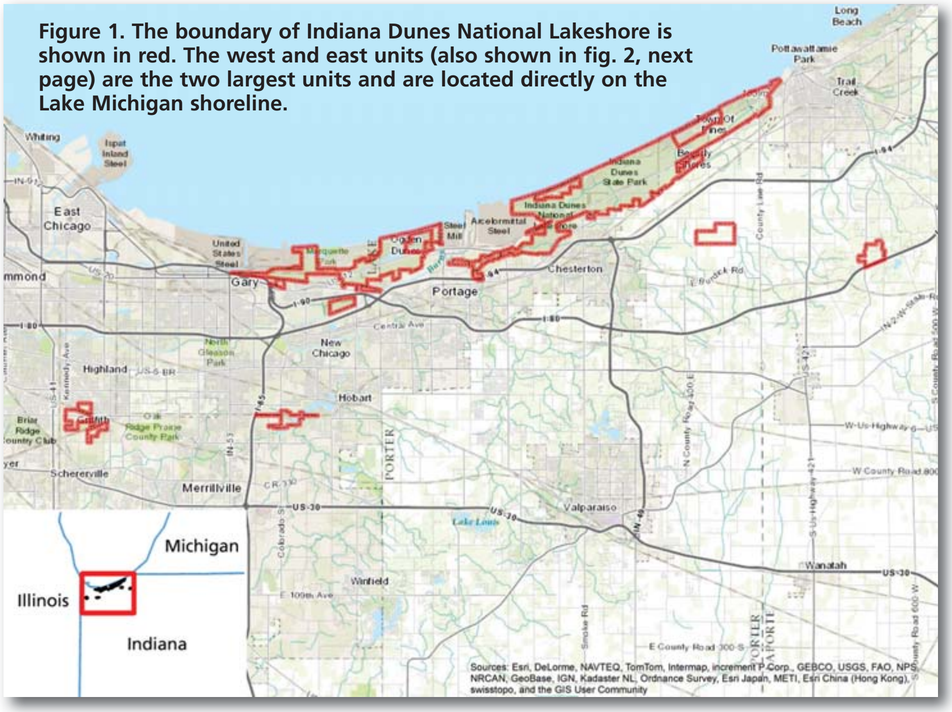

Figure 1. The boundary of Indiana Dunes National Lakeshore is shown in red. The west and east units (also shown in fig. 2, next page) are the two largest units and are located directly on the Lake Michigan shoreline.

The Midwest Archeological Center has fostered a relationship with Indiana Dunes National Lakeshore spanning four decades. Nearly 70 archeological projects have been conducted in that time, resulting in the inventory of some 1,000 acres (405 ha), or 7% of the park. Around 239 archeological sites have been recorded in the park (NPS 2012, Archeological Sites Management Information System), extending archeological evidence of human use of the southern Lake Michigan shoreline to the Late Paleo-Indian period approximately 10,000–8,500 years ago (Bringelson and Sturdevant 2007). While some of this information was acquired as part of research-oriented work representing large-tract sampling, most of it was gathered during small-scale projects for legal compliance purposes. In accordance with Section 106 of the National Historic Preservation Act of 1966, federal agencies must determine if their actions are likely to have an effect on historical properties, in this instance an archeological site. For example, shovel-testing of expiring lease properties is a simple method used to determine the presence of archeological sites, and is conducted as part of park planning. Regardless of the quantity of archeological work conducted here, the sample is limited in size and scope. This makes it difficult to draw conclusions about human land use along the lakeshore during the Holocene. Questions also linger regarding the apparent lack of occupation of certain areas within the park before the arrival of Europeans.

Answers sought

The Midwest Archeological Center is taking advantage of this large yet diffuse data set as part of a multiyear archeological inventory of the park. We have incorporated data from past projects with environmental data sets acquired from county, state, and federal government sources in order to create a GIS-based archeological site location predictive model. We obtained measurements for slope, elevation, and distance to water for archeological site and nonsite locations. We then conducted a Multivariate Logistic Regression (MLR) analysis to detect patterns in the environmental characteristics of prehistoric site locations and thus identify landforms with potential for past human use. Preliminary results indicated that archeological sites correlated with the sand dune and ridge formations, as researchers had previously assumed. During the 2012 field season, we inventoried and tested high-probability areas identified by the model and have confirmed seven new archeological sites.

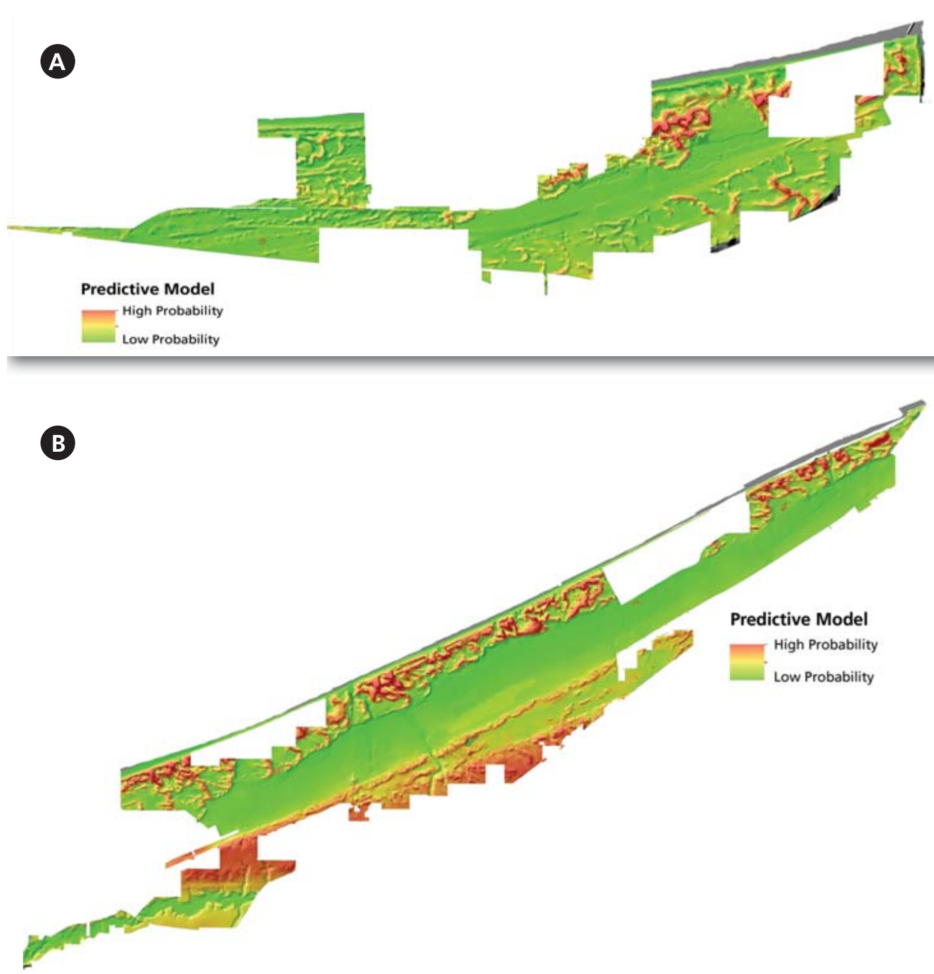

Figure 2. Archeological site predictive surface raster, Indiana Dunes National Lakeshore. Raster A (top) shows areas of high probability for archeological site locations (red), which are associated mainly with recent dune formations along the shoreline, and low-probability (green) lowland areas in the western unit. Raster B (bottom) shows areas of high probability for archeological site locations (red) associated with recent and older dune systems dating back to the late Pleistocene further inland and low-probability (green) lowland areas in the eastern unit.

The science of modeling

Archeological site location modeling typically compares the environmental characteristics of site and nonsite locations to predict where other sites are likely to be located in areas that have not been surveyed (Kvamme 1985, 1990, 1992). Typical environmental variables found to influence site location selection include proximity to water, slope, aspect, elevation, soil type, and vegetation type. We selected four variables to create the Indiana Dunes model: elevation, slope, soil type, and proximity to water other than the lake. Using GIS we measured each variable at archeological site and nonsite locations within the project area. Slope and elevation data were obtained from a 5-meter-resolution Digital Elevation Model created from contours derived from elevation data acquired by NPS staff from county and state sources. Distance to the nearest water source was obtained from the U.S. Environmental Protection Agency National Hydrography Data Set and from the USDA Geospatial Data Gateway (USGS 2012). Soils data were acquired from the Natural Resource Conservation Survey Soil Data Mart (NRCS 2012).

We conducted a Multivariate Logistic Regression (MLR) analysis to determine how the combination of variables influenced prehistoric site selection in the area. We found three of the variables to have a significant influence on site location: elevation, slope, and soil type. The model correctly predicted 74% of nonsite locations and 62% of site locations. After performing this analysis, we used the resulting formula (next page) to create archeologi-

Typical environmental variables found to influence site location selection include proximity to water, slope, aspect, elevation, soil type, and vegetation type.

cal site predictive surface raster images as shown in figs. 2A and 2B.

The end result of the MLR analysis is a *Z* "score" representing the logarithmic odds of a positive response for the dependent variable, in this case archeological site presence:

$$Z = B_0 + B_{1X1} + B_{2X2} + B_{3X3} + B_{4X4}$$

In the formula, B_0 is the "constant" or value of *Z* when the independent variables are zero. B_1, B_2, and B_3 are the "regression coefficients" of the independent variables x1, x2, and x3, respectively.

We used the regression coefficient for each variable to weight each corresponding raster data layer in the GIS. This is accomplished using the raster calculator via the "Spatial Analyst" tool in ArcGIS 10.1. For example, using the raster calculator tool we multiplied each cell value in the slope data layer by the regression coefficient for slope, and we repeated this process for each variable. The layers were then added together with the value of the constant (B_0) to create a GIS raster data layer representing the *Z* score for each location on the landscape. In this layer each cell value is the *Z* score for that location. We then converted this "score" to a probability using the following equation:

$$1 / (1 + \text{exponent}^{(-\text{score})})$$

(Pampel 2000). This converts the *Z* score to a probability on a scale of 0–1, which in turn creates the predictive surface raster layer with cell values that represent the probability that the location will have an archeological site. Cell values range from 0 (low probability) to 1 (high probability).

Conclusion

The predictive surface raster model helped guide our selection of archeological inventory areas for the 2012 field season. For 2013 we also relied on the model but first fed results of the 2012 season back into it to help refine its predictive abilities. We will continue to follow this pattern as more data are collected. We are hopeful that this approach will expand our understanding of the archeological record at Indiana Dunes, including how well the current sample of sites represents the total record. Additionally, with the development of this method archeologists are better able to support planners, resource managers, and interpreters at the park. Ultimately, these methods will lead to further knowledge of the ways people used wetlands, dune ridges, and other key aspects of the Indiana Dunes ecosystem over time.

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Archeological contributions to climate change studies: Past, present, and future

The Current River valley has been home to humans for most of the last 12,000 years. Dynamic environmental change during that time period has affected the preservation of archeological sites.

By Erin C. Dempsey and Dawn Bringelson

ARCHEOLOGISTS HAVE A distinct role to play in climate change research, especially in the context of how humans respond to situations of dynamic climate. Archeology pursues information about past human activity as it is reflected in the deposits people left behind and seeks data from a longer history (or deeper past) than other cultural disciplines, such as history or sociology.

Archeologists are also interested in learning about changes in human activities through time and often posit climate change as an explanation for why these changes occurred. In order to test such explanations, archeologists rely upon (and often collect) paleoenvironmental data, which are critical to the study of human behavior within the context of a dynamic physical environment. By collecting these types of data, archeologists are well positioned to ask and answer questions concerning human-landscape interactions, particularly during periods of climate change.

Landscape change and archeology at Apostle Islands National Lakeshore

The National Park Service has sponsored archeological surveys at Apostle Islands National Lakeshore (Wisconsin) for inventory and management purposes since the mid-1970s. The cumulative data set represents only a fraction of the total land at the national lakeshore, but each new project adds to our knowledge about prehistoric human use of this archipelago at the southern shore of Lake Superior.

In general, this information indicates that people used certain settings on the islands repeatedly, likely in short-term and perhaps seasonally specific ways. Based on historical documents and oral histories, archeologists presume that people exploited nearshore resources such as fisheries, blueberries, and wild rice. Until recently, information on dates of occupation was rare at the national lakeshore, but radiocarbon, thermoluminesence, and typological dating indicate that humans occupied this area at least as early as the middle Holocene (around 5,000 years ago) and continued to do so at various points up to the recent past.

Questions now turn to how changes in the physical environment through time influenced people's use of the landscape. Combining archeological site distributions with paleoclimatic information such as lake level shifts helps us envision ways in which humans adapted to these changes. For example, several sets of archeological deposits situated at the intersection of alluvial sands and overlying eolian or wind-

Abstract
Archeological research is positioned to provide useful information on human-landscape interactions during periods of dynamic climate. Several recent investigations across the mid-continent highlight the connection between climate change and archeology, informing us about various aspects of human behavior throughout the last 12,000 years of the late Pleistocene and Holocene. Deep geomorphic testing of river terrace sediments and soils at Ozark National Scenic Riverways provides landscape evolution and paleoenvironmental data, and allows for the identification of landforms people may have occupied at various times. Archeological and environmental data at Apostle Islands National Lakeshore offer insights on changes in land uses through time and ways in which they correlate with environmental shifts. Archeology is a critical component of multidisciplinary studies that seek to understand past human responses to climate change.

Key words
alluvial geomorphology, Apostle Islands National Lakeshore, archeology, climate change, Current River, lake levels, Lake Superior, optically stimulated luminescence, Ozark National Scenic Riverways, Ozark Plateau, paleoclimate, stable carbon isotopes, thermoluminescence

NPS MWAC/DAWN BRINGELSON

Figure 1. Staff of the Midwest Archeological Center, Apostle Islands National Lakeshore, and a Student Conservation Association intern investigate an archeological site dated using luminescence to approximately 4,500 years ago.

blown deposits have been dated to the Late Archaic period, approximately 4,500 years ago (fig. 1). Vertical and horizontal distribution of these materials suggests beach-front land use at that time of higher lake levels (also called the Nippissing transgression) and later (more rare) occupations in these locations during the last millennium.

Ongoing research questions revolve around understanding human occupation during the "quiet" time of the late-middle Holocene: are there other sites yet undiscovered on the archipelago, did people move farther inland, did they occupy areas now inundated by Lake Superior? Each new data point refines our understanding of how humans responded to environmental change over thousands of years, providing insights for modern decision makers. One other consideration brings this full circle: the sandy benches created during the Nippissing transgression, within which key sites are found, are also among those predicted to be most vulnerable to lake level fluctuation in coming years (see Pendleton et al 2007). Thus, current climate change may be the largest hindrance to understanding humans' response to such change in the past.

Geoarcheological investigations at Ozark National Scenic Riverways

Integrating archeological and paleoclimate data sets helps archeologists understand how environmental change has formed and altered the record of the human past. Site formation processes alter the preservation potential of archeological resources from various time periods. Issues such as where sediments have been deposited and removed through time, stream channel movement (Saucier 1987), and vegetation regime change (Delcourt and Delcourt 1984) are important components of finding and interpreting the archeological record. These data are also critical for natural resource specialists studying how dynamic climate changes environments.

Through time, the Ozark Plateau region has been a highly dynamic environment with deeply incised, narrow, and bedrock-lined river valleys and, in some places, karstic features (Sauer 1968). Such dynamism interferes with traditional pattern identification in the archeological record; it affects a variety of factors such as flood frequency and magnitude, terrace formation, and preservation of alluvial fills (Saucier 1987, 1996). Therefore, in addition to asking questions such as "what places did people occupy at different times?" and "what did they do there?" we can ask questions such as "how has climate change affected where these archeological sites may be preserved?" and "how did a changing environment affect human-landscape interactions?" This "ground-up" approach to understanding the archeological record and human behavior requires obtaining knowledge of late Quaternary landscape evolution.

The current study, funded by both the National Park Service and the ODYSSEY Archeological Research Fund (Kansas Geological Survey, University of Kansas), synthesized archeological, environmental, geomorphological, and chronological data to make inferences about geological preservation of archeological resources in the Current River valley at Ozark National Scenic Riverways (Missouri; see photo, facing page). Environmental data were obtained through stable carbon isotopes ($\delta^{13}C$) on soil organic matter. Optically stimulated luminescence (OSL) dating

ROLFE MANDEL, KANSAS GEOLOGICAL SURVEY

Figure 2. National Park Service staff collect a soil core from the alluvial fan at the Chubb Hollow locality using a hydraulic coring rig.

Combining archeological site distributions with paleoclimatic information such as lake level shifts helps us envision ways in which humans adapted to [physical environmental] changes.

helped establish the chronology of soils and sediments. Eight localities within the park, representing a variety of alluvial landforms (first, second, and third terraces, as well as one alluvial fan) were sampled using hydraulic coring (fig. 2). Correlating the OSL ages and soil-stratigraphic data, including particle size distribution data, indicates that buried soils (formerly stable surfaces) of various ages are preserved in the alluvial fills at Ozark National Scenic Riverways. The $\delta^{13}C$ data demonstrate that the late Pleistocene and Holocene environment of the last 12,000 years was dominated by forest plant species. Plant resource availability certainly affected how and when people occupied the Ozark Plateau; perhaps as the Prairie Peninsula (a tallgrass prairie biome) spread eastward during the middle Holocene, people exploited forest resources that were continually established on the Ozark Plateau.

The geoarcheological work under way at Ozark National Scenic Riverways also provides insight into the preservation of cultural resources through time by presenting a predictive geomorphic model for cultural deposits in alluvial landforms. This work lays the foundation for more specific archeological, geological, and paleoenvironmental investigations in the future and leaves room for using these data to make predictions for the preservation of archeological resources in the face of modern climate change. Additionally, it facilitates our understanding of geomorphological processes in the Current River valley and their effects on the archeological record and lays the groundwork for helping us understand human use of dynamic environments.

Conclusions and further study

Archeologists often collect data that contribute to climate change–driven research questions and climate databases. While these data are primarily useful for archeology, they can be made available to cultural and natural resource specialists within the National Park Service, as well as to researchers from sister agencies and cooperating research institutions. Combining archeological and environmental data is critical for fully understanding human-landscape interactions in the past, which may serve as a proxy for developing human response to modern climate change.

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Ojibwe cultural landscapes of Voyageurs National Park, Minnesota

By Andrew LaBounty

Abstract
Appreciation and preservation of Ojibwe cultural resources are a major focus of Voyageurs National Park, Minnesota. Stereo pairs of 1927 International Joint Commission aerial photography were compared to archeological site locations recorded over the last 30 years to identify more than 250 historical features. These features reveal otherwise isolated archeological sites as a system of contemporaneous and interrelated occupations. Through the identification of structural features and vegetation differences, Ojibwe archeological sites are newly associated with one another by trails, piers, portages, and other landscape features. By combining and overlaying these data in a GIS along with modern imagery, historical Ojibwe occupation can be better understood and interpreted by park staff as a complex and persistent cultural landscape spanning the lakes of Voyageurs National Park. The results of this research are therefore a combination of archeological and nonarcheological data sets, repurposed and recombined to the benefit of the park as a whole.

Key words
cultural landscape, geographic information system (GIS), homesteading, International Joint Commission, logging, Midwest Archeological Center, Ojibwe, photographic analysis, stereoscope, Voyageurs National Park

FOR SEEING THE BIG PICTURE, so to speak, archeologists turn to aerial imagery. For examining cultural landscapes over a large area, such as at Voyageurs National Park in Minnesota, *historical* aerial imagery supplies an incredible wealth of information. Although Voyageurs was not established as a national park until 1975, the earliest aerial photographs were taken in 1927 as a result of a flight conducted by the International Joint Commission (IJC) to manage the waterways between Canada and the United States (Bullard and Scovil 1930). Under conditions of high water and intensive logging (see Lynott et al. 1986), the IJC inadvertently captured not only the status of the waterways, but also aerial images containing more than 250 cultural features related to Ojibwe land use. Using a stereoscope in combination with modern GIS techniques, it is now possible to investigate and record the cultural landscape of nearly 200 years of historical occupation by the Bois Forte band of Ojibwe as it appears in these early photographs.

Stereoscopes have been in use since 1838, often as a recreational device. These units mimic binocular vision by feeding a separate image to each eye through mirrors and lenses. When used to view one scene at two slightly different angles, a stereoscope allows the brain to see a 2-D image in three dimensions. In this case, an airplane took a series of pictures as it flew over the international boundary in 1927, with no thought to later viewing them in 3-D. Each successive picture is therefore at a slightly different point of view, but two adjacent pictures still contain the same features, so overlapping features can be seen in three dimensions with the stereoscope. Our research took advantage of this phenomenon to gauge tree height in 1927 and to differentiate bare earth from thick stands of vegetation in these black-and-white photos. The simulated three-dimensional view also made it possible to distinguish pit features, buildings, and other Ojibwe cultural features from natural variations in topography.

Digital, georeferenced copies of the 1927 aerial photos were simultaneously created by the Minnesota Department of Natural Resources and overlaid with archeological site locations provided and maintained by the Midwest Archeological Center in Lincoln, Nebraska. Using this combination of data, we selected salient pairs of aerial photographs for examination under the stereoscope, accurately recorded all observed cultural features in a GIS, and compared the observed historical features with previously identified archeological sites. We further based interpretations of observed features on Ojibwe oral histories and extensive research into historical Ojibwe land allotments (Richner 2002), resulting in a powerful way of viewing the historical landscape of Voyageurs National Park.

Results: Alligator Bay

Nearly the entire park area exhibits some form of cultural activity in 1927. Most of

By using a combination of old and new technologies, this research provides a glimpse into the past cultural landscapes of Ojibwe residents, enhancing preservation of the land with a deeper understanding of its meaning.

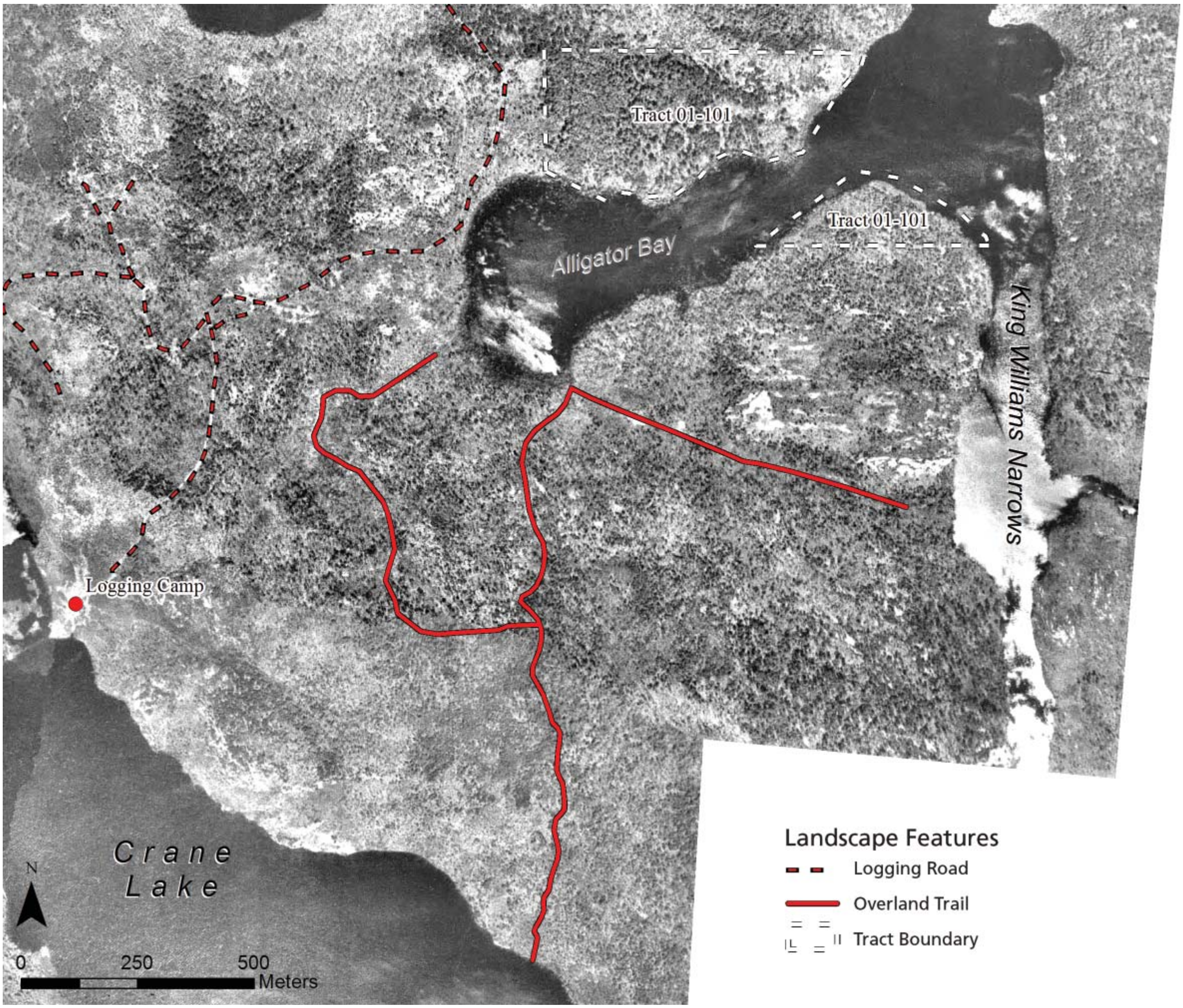

Figure 1. Alligator Bay, 1927. Notable cultural features are highlighted in red and include uncut pine stands in tract 01-101 and an overland winter trail from Crane Lake to Alligator Bay and King Williams Narrows.

the results from this preliminary investigation can be associated with Ojibwe activity specifically, but of those, only one will be presented here to illustrate the results of the research.

Prior to this investigation, notable features at Alligator Bay—named for the amphibious logging vessel rather than the animal—included several archeological sites and the remains of a major Virginia and Rainy Lake Logging Company camp. The 1927 manifestation of these is remarkable, and several additional features are revealed in the historical imagery (fig. 1).

Tract 01-101 within Voyageurs National Park is currently held in trust by the Bureau of Indian Affairs (BIA), meaning the land is owned by the BIA on behalf of the historical Ojibwe owners in perpetuity, but is managed by the National Park Service because it falls within the boundaries of the national park. Based on archeological and historical research, the land appears to have been a historical Ojibwe dwelling established under the Homestead Act of 1862 (Richner 2002, p. 76). Its proximity to the King Williams Narrows suggests that the land may have been claimed by a family member of Joe King Williams Bego, an Ojibwe man for whom the strait is named. In claiming such an allotment, Ojibwe families subjected themselves to the requirements of homesteading and gave up their claim to reservation land and the associated annuities, choosing instead to claim ownership and development rights on a particular parcel of land (Richner 2002). On this particular tract, virgin pine is obvious in the simulated 3-D stereo view, terminating precisely at the tract boundaries that are still in effect today. A nearby, deeply cut logging road (not highlighted) attests to the volume of wood removed from nearby tracts, and bare earth can be seen extending south and west from tract 01-101. Combined with tract 01-101's current BIA trust status, these features suggest that it was protected from clear-cutting through private ownership, providing further visual evidence in support of the archeology that the land was an off-reservation allotment to a native Ojibwe family as of 1927. In addition, the aerial photographs demonstrate a contrast between Ojibwe and some European land management practices, and provide explanations for why the vegetation on tract 01-101 remains so different from the rest of the park today.

To the south of tract 01-101 is a set of overland trails that appear to follow drainages and skirt high ground. Although archeological sites are known in the vicinity of the trail, there was nothing to link these sites interpretively. Given the clear evidence of traffic between the northern and southern shores, however, it now seems that previously disparate archeological sites may indeed be part of a community or network of habitation sites. Moreover, it is known that King Williams Narrows does not freeze completely in the winter because of its rapid flow, and is therefore unsafe as a winter walking trail. It is therefore likely that the trail seen in the 1927 aerial photos is the traditional winter passage between Crane Lake and Alligator Bay. On an even larger scale, this winter trail may be part of the Mukooda Portage, which provided, even until recently, access to the Lac la Croix First Nations to the east (National Park Service, Voyageurs National Park, Mary Graves, Chief of Resources, e-mail dated 12 June 2013).

Implications for management

Alligator Bay is a small area with relatively few visible cultural features dating to 1927. Elsewhere throughout the park, this research identified trails, structures, culturally managed vegetation (e.g., logging or lack thereof), and docks. At many locations, past logging activities still exert a dominating influence over the landscape, as evidenced in historical clear-cutting and abandoned road and rail networks. At other places, thick stands of pine suggest (and physically obscure) Ojibwe ownership and land use. In still other areas, extensive logging reveals the bare-earth expression of a long history of Ojibwe use through standing structures, mounds, trails, and portages.

The 1927 cultural landscape of Voyageurs National Park is more evident today as a result of this research and demonstrates a variety of Ojibwe cultural connections, including water travel, family lands, social connections, and vegetation management. These findings directly apply to resource management and the way the park interprets the culturally modified spaces between archeological sites. As another example, the trees at Alligator Bay were known to be virgin timber. We now understand how and when they were protected from logging, lending historical and cultural value to an otherwise natural resource. For natural resource management itself, there is evidence of fire throughout the park, contributing to the establishment of a fire history and the relative ages and burn frequency of old growth at Voyageurs.

These results also inform future research by combining old and new data to represent otherwise unidentified features in a practical, manageable way. We combined stereoscopic photo analysis with GIS-based documentation, which proved to be an effective way to derive information from even poor-quality aerial photographs. This made it a simple (if time-consuming) process given the tools and the resource, and allows for the addition and recombination of additional information through GIS technologies. Most importantly, however, by using a combination of old and new technologies, this research provides a glimpse into the past cultural landscapes of Ojibwe residents, enhancing preservation of the land with a deeper understanding of its meaning.

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Use of high-resolution airborne laser scanning for the analysis of archeological and natural landscapes on the northern Great Plains

By Jay T. Sturdevant, Stephen K. Wilson, and Jeff Bragg

Abstract

In 2012, an interdisciplinary team from the Midwest Archeological Center, the Northern Great Plains Inventory and Monitoring Network, and Knife River Indian Villages National Historic Site initiated a research project to produce a high-resolution laser scan of the landscape along the Knife River at its confluence with the Missouri River. Airborne laser scanning (ALS) is an airborne-based light-emitting sensor that produces a high-resolution three-dimensional model of the ground surface, vegetation, and other landscape features. Applied to archeological sites, this technique can reveal archeological features such as earthen lodge depressions, walled enclosures, trails, and linear earthen mounds. Natural features are also evident in the three-dimensional landscape models and include former river channels of the Knife River, eroded banks, vegetation, and infrastructure such as roads, buildings, and bridges. The three-dimensional landscape models provide detailed information on the location and extent of archeological resources, assist with the investigation of complex village landscapes, and enable the consideration of impacts from natural processes on archeological site preservation.

Key words

airborne laser scanning, alluvial geomorphology, archeological landscapes, archeology, Hidatsa, Knife River, Knife River Indian Villages National Historic Site, Missouri River

PEOPLE ARE CONTINUALLY MODIfying natural landscapes in ways that meet the needs of individuals and communities. Understanding how humans live within the natural environment and how we modify landscapes provides useful insight into human behavior and cultural practices. Archeological landscapes harbor details about past cultural practices at spatial scales that change over time and reveal community structures and patterning. The advancement of airborne technologies is creating new opportunities to explore archeological landscapes in ways not possible a decade ago (Chase et al. 2011; Crutchley and Crow 2009; Doneus and Briese 2011; Shaw and Corns 2011). The challenge for archeologists and other researchers is to produce data sets with sufficient resolution to identify and analyze individual archeological features such as earthen lodges, palisade walls, and earthen mounds. Earlier maps and aerial imagery have been effective at detailing topography, locating archeological sites, and illustrating archeological features. Current laser scanning technologies offer the potential to produce landscape models with incredibly detailed illustrations of archeological sites that can be used in geographic information systems, thereby harnessing the power of modern computing to generate new insights into past human interactions with natural landscapes. This multidisciplinary research project has produced a high-resolution three-dimensional data set that allows for detailed analysis of landscape features that clearly illustrate the archeological landscapes along the Knife River in North Dakota.

Hidatsa villages and communities

Knife River Indian Villages National Historic Site (NHS) preserves the ancestral home of the Hidatsa people. These villages exemplify the Missouri River cultural lifeways when people lived in compact earthen lodge villages, grew crops, negotiated trade, and hunted buffalo (fig. 1). Connections to the earth and the natural landscape are ever present and form meaningful foundations of Missouri River cultural systems. The earthen lodges are considered a living representation of Hidatsa culture and incorporated traditions central to the daily lives of village occupants. Representing the 16th to 19th centuries, the archeological landscapes at Knife River reflect a time of significant change for the Hidatsa people. Contact with Europeans and Americans introduced diseases that irrevocably altered Hidatsa communities even as many of their cultural traditions proved incredibly resistant to outside influence. Warfare with other Native American tribes also had profound impacts on the Hidatsa communities: defense against hostile raids is evident in the palisade walls that surround the villages. How did the Hidatsa people cope with the unprecedented forces of cultural contact, warfare, and multiple disease epidemics? Understanding how these pressures influenced the construction and accumulation of Hidatsa village landscapes provides insight into how these communities adapted to the pressures of a rapidly changing world. In order to investigate changes in village landscapes, archeologists need broad-scale data sets that complement the past archeological excavations within the villages.

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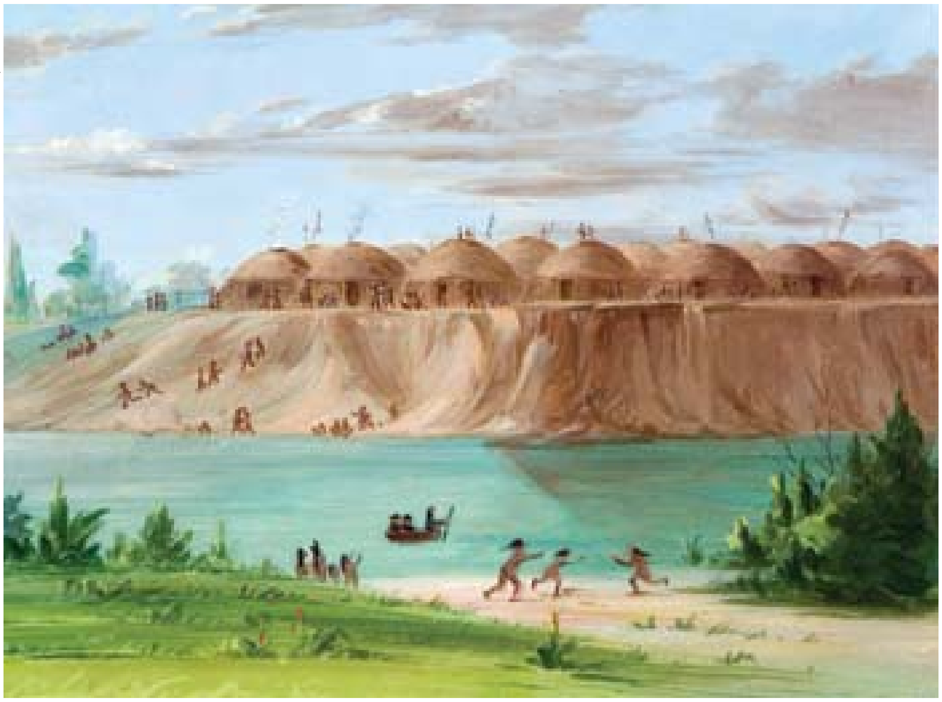

Figure 1. Renowned western artist George Catlin painted this scene of daily life at a Hidatsa village on the Knife River in 1832.

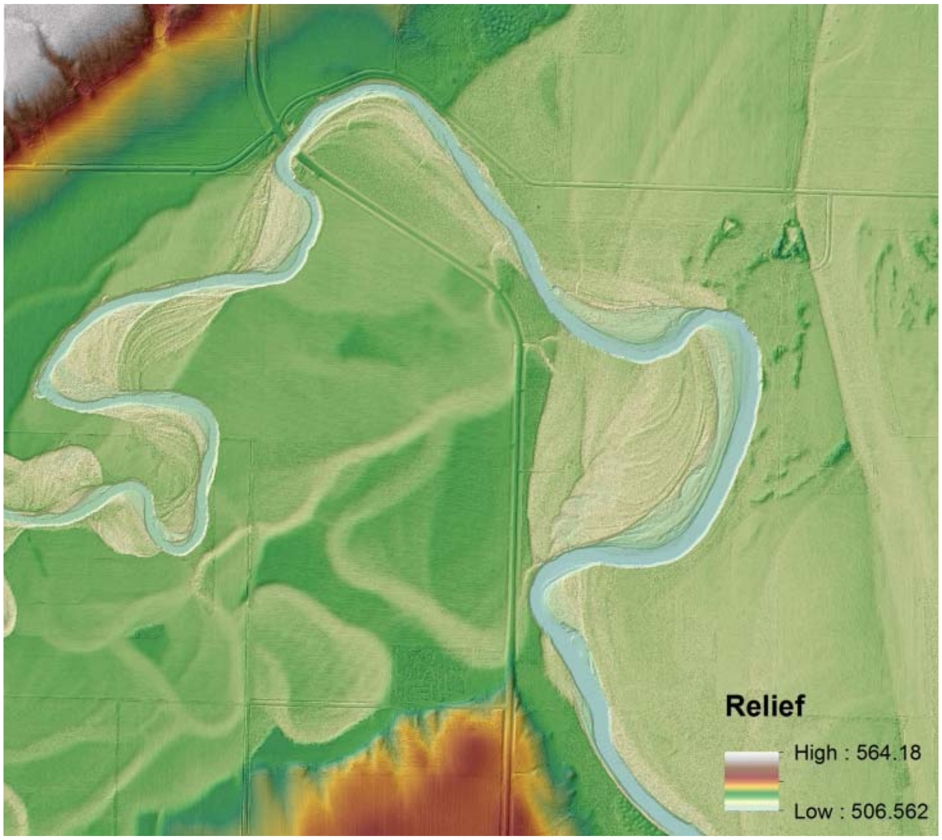

Figure 2. The digital terrain model was generated from the airborne laser scan of the Knife River area and shows the current river and old channel scars left behind during the river's migration within the confines of upland areas.

Illumination of landscapes

In 2012, an interdisciplinary team from the Midwest Archeological Center, the Northern Great Plains Inventory and Monitoring Network, and Knife River Indian Villages NHS initiated a research project to produce a high-resolution laser scan of the landscape along the Knife River at its confluence with the Missouri River. Airborne laser scanning (ALS) is an airborne-based sensor that emits laser light, detects variations in the timing and strength of its reflection, and is processed into high-resolution three-dimensional models of the ground surface, vegetation, and other landscape features (fig. 2). The aerial survey at Knife River covered more than 5,300 acres (2,145 ha) and produced a six-points-per-meter (1.8 points per foot) point cloud coverage and a digital terrain model with a fine-grained vertical resolution of 25 cm (10 in) RMS (root-mean-square) error. The term *point cloud* describes the effect of covering the ground and aboveground features (vegetation, buildings, bridges, archeological features) with laser-emitted pulses that create clusters of data points from objects or surfaces that reflect the laser light (fig. 3, next page). These data reveal village features such as earthen lodge depressions, palisade wall enclosures, trails, and linear earthen mounds. Natural features are also evident in the data and include former channels of the Knife River, erosional banks, and vegetation. Local infrastructure such as roads, buildings, and bridges is also reflected in the data.

When combined with other data sets, the ALS findings provide researchers and managers with access to landscape models that show how natural and cultural resources are closely linked at Knife River Indian Villages. Understanding local conditions is a key component to the long-term preservation of archeological resources. This research will enable more effective management when park resources are subjected to changes in river flow or

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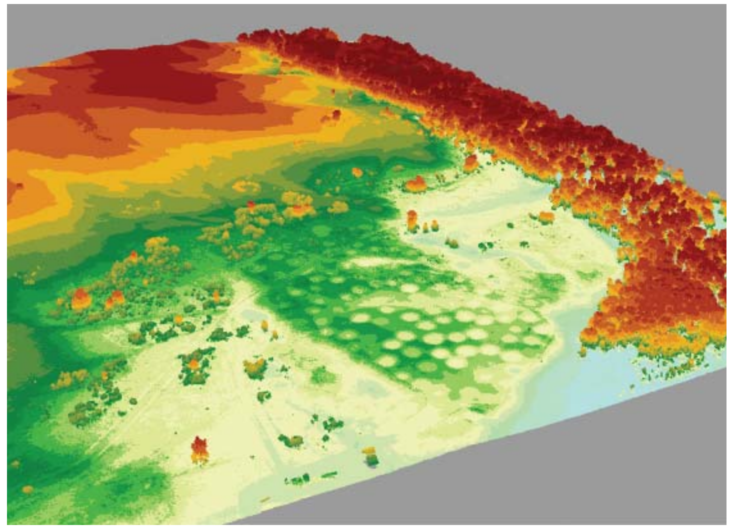

Figure 3. (Above right) Three-dimensional point cloud data overlay the terrain model for the Big Hidatsa Village area (left) and can be compared easily with the modern-day aerial image (above left). The point cloud gives definition to aboveground features while the terrain model defines the ground surface and landforms. The aerial photo shows earthen lodge depressions, trails, and areas that are interpreted for the public.

climate. Landscape models derived from airborne laser scanning complement other GIS data sources such as soils data, aerial photographs, topographic maps, and historical maps. Their combination with previous information is effective for evaluating floodplain dynamics and associated elevation characteristics at archeological sites.

Contact with Europeans and Americans introduced diseases that irrevocably altered Hidatsa communities even as many of their cultural traditions proved incredibly resistant to outside influence.

Understanding changes to archeological landscapes

Changes to Knife River village dynamics are revealed in the ALS data, particularly in village population size and site fortifications. These changes resulted from multiple waves of smallpox and disease epidemics that affected the villages in the 18th and 19th centuries (Trimble 1986, 1993). A local relief model of Big Hidatsa Village shows the contraction of the village and construction of a new fortification wall that occurred after the smallpox epidemics of the late 18th century (fig. 4). The reduction of village populations and corresponding smaller villages and fortification enclosures has also been observed at the Double Ditch Village just downstream on the Missouri River (Kvamme 2003; Kvamme and Ahler 2007). At Double Ditch, researchers have used multiple remote sensing techniques to identify contracting fortifications and village sizes that also correlate with the effects of disease and warfare. The contraction of villages on the upper Missouri River demonstrates the dramatic impacts that disease and warfare had on the Hidatsa people and how they used cultural traditions and practices to overcome severe hardships during the era of westward expansion.

The intersection of Hidatsa cultural traditions, active river processes, and European contact defines the human experience at Knife River. Moreover, the Hidatsa villages at Knife River are critical for understanding the human experience in North America. Understanding past human modifications to the natural landscapes is indispensable for effective management and preservation of these places for future generations. The recent use of nondestructive technologies to produce high-resolution landscape models has enhanced our understanding of this complex cultural setting. More generally this method provides information for multidisciplinary research and site conservation that can address questions for which traditional archeological excavation techniques are poorly suited or not feasible. Employing advanced digital technologies to investigate the past places Knife River Indian Villages at the forefront of the ongoing dialogue relating to tradition and change.

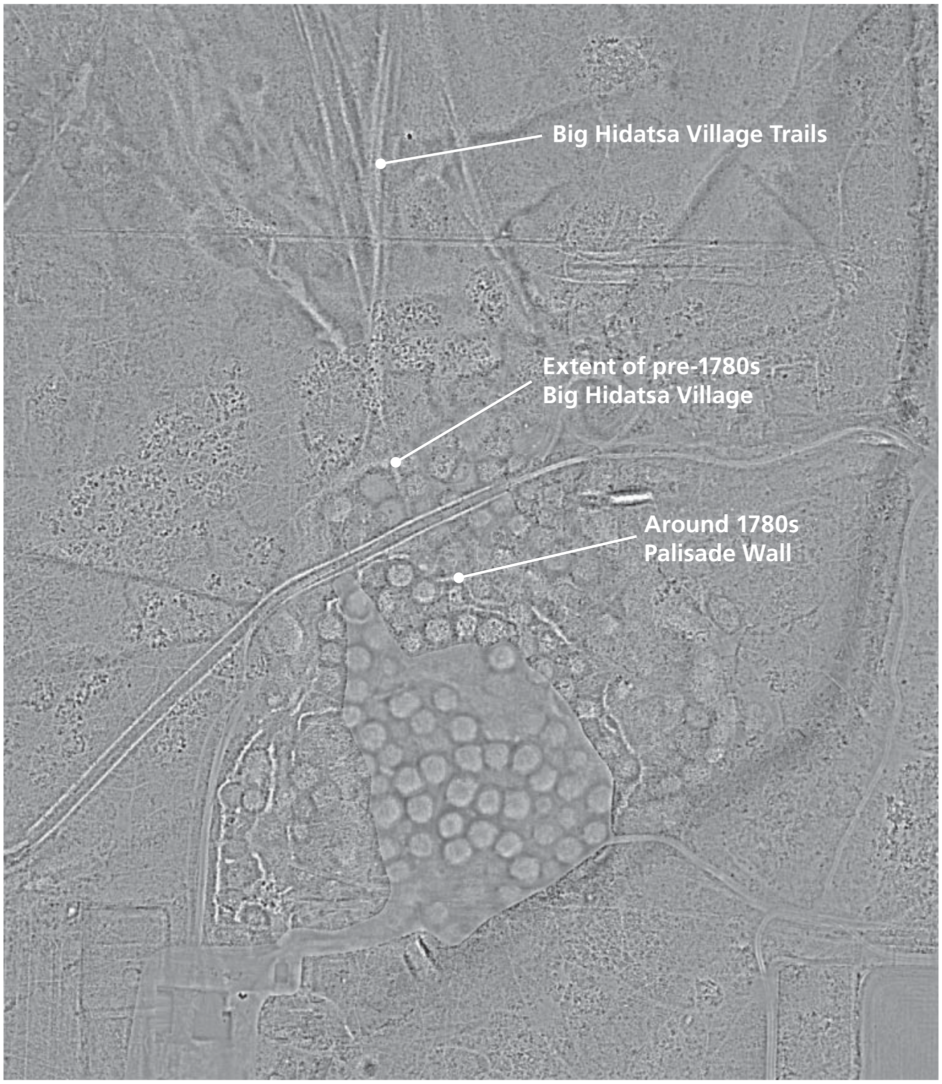

Figure 4. This ground surface model was generated from the airborne laser scan and illustrates archeological features associated with the Big Hidatsa Village and the changing dynamics of village life.

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Native American culture and prehistoric bison hunting in the Black Hills

By Anne M. Wolley Vawser and Timothy Schilling

LOCATED IN THE BLACK HILLS OF southwestern South Dakota, Wind Cave National Park has been home to large herds of bison since legislation passed in 1912 established the Wind Cave National Game Preserve. The National Park Service manages the herd at the park to ensure genetic diversity and herd health through a program that is a model for bison management (NPS 2006). Despite the success of this program, little is known about the history of Native American bison-hunting techniques and management practices in what is today the national park. Hence, when the Park Service acquired a 5,556-acre (2,248 ha) tract of land in 2011 that contained what many believed to be an ancient bison jump, park staff sought the help of archeologists from the Midwest Archeological Center to investigate. In 2012 scientists spent three weeks evaluating remains found at this site through survey, mapping, excavation, and geophysical prospection (figs. 1A and 1B). Additional analysis of recovered artifacts continued in the lab to confirm tool type, manufacture, use, and faunal analysis of the bison bone.

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Figure 1A. Archeological technician Stephen Damm collects geophysical data with a dual magnetometer at the top of the bluff near the drive line. This modern technology allows a view into the ground without excavation and helped identify additional drive line features at the site.

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Figure 1B. In this overview of the Sanson site (looking northeast) the buffalo jump is marked by the black line at the top of the bluff and the bone bed excavation area at the base. The village area occupied the terrace where the vehicles are seen south of the jump. The nearby creek (indicated by the line of trees) is now dry but supplied both bison and Native Americans with water at the time of the site's use.

Background

Paleoindian people began to appear on the Great Plains 10,000 to 12,000 years ago. Initially they hunted a variety of large mammals, but shifted to bison after prey such as the mammoth became extinct. Hunting involved a range of techniques, from small groups taking individual bison on the open plains to large-scale, communal events. Trapping entailed herding a group of bison to natural landscape features or constructed enclosures where the animals could be killed. "Jumps" involved the strategic stampeding of bison toward

Abstract
Wind Cave National Park has played a pivotal role in restoring bison to the Great Plains as well as preserving their once extensive grassland habitats. The Midwest Archeological Center is contributing to the park's knowledge about the history of bison through research at a park archeological site that includes remnants of an occupation by Native Americans whose culture was centered on plains bison. Archeological evidence recovered at the site suggests that while these people practiced communal hunting by driving bison off a nearby cliff, they apparently did not regularly kill more bison than the group could use as no large bone bed was discovered below the bluff. The site was also occupied multiple times over hundreds of years suggesting sustained bison populations through time.

Key words
archeology, bison ecology, Black Hills, Plains Indian culture, Wind Cave National Park

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Figure 2. An excavation trench at the base of the cliff resulted in discovery of a narrow band of soil where all of the artifacts and bison bone were discovered. In this photo archeologist Tim Schilling collects soil samples for further analysis in the lab.

lines of people, brush, or other features, which in turn directed the animals over a cliff. These techniques often resulted in the killing of more animals than could be used, as evidenced by the large bone beds that usually remain at trap and jump locations. Trapping and jumping were practiced from the end of the last ice age until native peoples acquired horses (Kornfeld et al. 2010) in the 17th or early 18th century. In the late 19th century, Euroamerican contact was disastrous for both Native Americans and bison. Native lands were divided, hunting territories were confiscated, and Euroamerican hunting practices devastated bison herds and nearly brought about the extinction of this symbol of the Great Plains.

The archeological site

The Sanson site is a roughly 30-acre archeological site including a bison jump and village that is located along an intermittent creek in the tract of land recently added to Wind Cave National Park (fig. 1b). Here a rock wall rises nearly 15 meters (49 ft) above the valley floor just above the creek. Archeological excavation has revealed the scattered remains of an undetermined number of bison. While we recovered 84 bone fragments, analysis by a zooarcheologist identified five fragments, mostly vertebrae, as bison (fig. 2). Based on the size and stratigraphic association of the remaining 79 fragments, all but two (identified as commensal species: plains pocket gopher and eastern cottontail) are probably also bison. Isotopic analysis and radiocarbon dating suggest the remains represent at least two individual bison that lived in the late 13th or early 14th century. Above the cliff are linear stone anomalies that we interpret as "drive lines" (fig. 3). These alignments mark the location where obstacles such as brush or stakes would have been placed or where people waving hides or other items would have stood to drive the bison toward the cliff. This same line of stones also includes rock cairns that are often interpreted as ceremonial features. Additional visible elements are stone circles (tipi rings), cooking and food processing features (anvil stones and hearths), and artifacts associated with bison hunting and processing (fig. 4, page 29). Large stone tools such as choppers were used for initial processing of bison, and finer tools such as bifaces and scrapers were used to further process meat and hides.

Findings

The 2012 investigations led us to conclude that the Sanson site has a long history of use. An early McKean-style projectile point found at the site provides the earliest date, of about 4,000 years ago. Radiocarbon analysis of charcoal from two fire pits at the site returned dates of 1,200 and 920 years ago (Agenbroad 1989). Finally, radio-

Figure 3. In this view looking west from the top of the cliff a row of stones indicates one of the drive lines. The edge of the cliff is marked by the arrows. Note how the downhill approach to the cliff makes it appear as if the prairie simply continues and hides the cliff edge from the charging bison.

The Native Americans who hunted and lived at the Sanson site practiced smaller, sustainable hunts for up to 4,000 years before Euroamericans nearly drove the bison to extinction.

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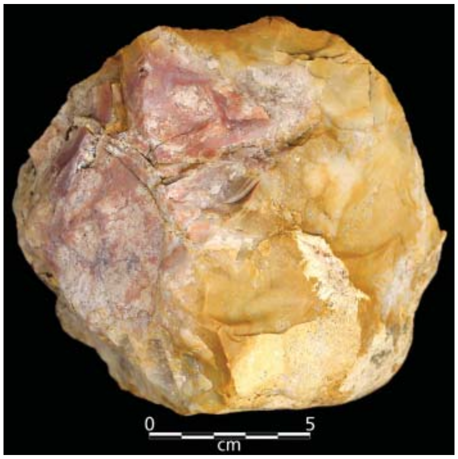

Figure 4. This large chopping tool is made of chert and would have been used for the initial dismemberment of bison, such as separating large pieces from the body, to transport to the village for additional processing.

carbon dating of bison bone from the site indicates the most recent occupation at the site was about 700 years ago. The area was used for several purposes: as a bison jump and processing location, a stone source for tool production, a habitation site, and the locale of individual or group ceremonies.

In addition to its multicomponent nature, the Sanson site is atypical for a bison jump site where archeological investigations commonly document the remains of hundreds of animals (Frison 2004). Although the "killing floor" at Sanson has likely been affected by changes in the stream channel, the geomorphic setting of the jump site, the spatially restricted nature of the remains, and multiple size classes of bone fragments (from > 10 cm to < 1 mm) indicate that flooding or stream migration would not have been sufficient to completely remove a large bone bed. Rather, it appears that the bone bed never contained the remains of more than a few individual animals.

The archeological remains suggest that communal bison hunting was just one part of a complex culture of these Plains Native Americans whose methods of bison hunting may have changed over time. Here, bison jumping appears to have been a well-planned and highly managed activity. Hunters likely targeted only a few animals at a time and drove them off the jump, ensuring death in small-scale, efficient hunts. We conclude that the Native Americans who hunted and lived at the Sanson site practiced smaller, sustainable hunts for up to 4,000 years before Euroamericans nearly drove the bison to extinction. Whether or not this type of hunting helped sustain bison populations that led to long and prosperous use of the area by native peoples remains a topic for further study. However, our research provides biologists and modern national park and grassland managers with information that more fully tells the story of Native American Plains life in the vicinity of Wind Cave National Park.

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Designing Parks for Human Health Benefits

Park health resources: Benefits, values, and implications

By Jennifer M. Thomsen, Robert B. Powell, and Diana Allen

Abstract

Society is faced with a range of mental and physical health issues. The Healthy Parks Healthy People movement seeks to increase society's recognition of parks and protected areas as places for the promotion of physical and mental health and social well-being. The diversity of park areas within the National Park System makes it impossible to have a single prescribed plan for managing park resources as health resources. However, there are some common themes that can be applied to all national park settings to maximize health promotion and benefits, which include (1) designing programs and infrastructure for multiple outcomes, (2) managing food and beverage services to deliver healthy food and activities, and (3) forming diverse short- and long-term partnerships. This article offers case studies from diverse park settings to illustrate how managers have applied the strategies to help achieve the goals of Healthy Parks Healthy People and the "Call to Action" initiatives.

Key words

health benefits, health resources, management strategies

OBESITY, CARDIOVASCULAR DISEASES, DIABETES, and mental illness have reached alarming proportions among children and adults in the United States. For example, approximately 36% of adults are considered obese, 10% have diabetes, and 25% suffer from some form of mental illness (CDC 2013). These chronic diseases reduce quality of life and cause early mortality (Hyde 2011). To combat these public health challenges, many health professionals promote developing additional recreational programs and infrastructure, such as parks, to increase physical activity (WHO 2008; NPC 2011) and as a form of preventive medicine (Frumkin and Louv 2007). Generally these parks are part of local communities' infrastructure, but all parks and public lands, no matter their location, potentially could serve as part of a unified system of health resources for the public.

One effort to enhance and promote the use of parks as health resources is the Healthy Parks Healthy People (HPHP) program, which promotes proactive and healthy activities as part of the public health and medical care delivery systems worldwide. In the United States, the Healthy Parks Healthy People movement also works to increase society's recognition of parks and protected areas (including state, local, and regional park systems) as places for the promotion of physical and mental health and social well-being. Aligned with these HPHP tenets, NPS director Jonathan Jarvis in the "Call to Action" emphasized the need to "expand the health community's use of parks as a healing tool and increase citizens' recognition of the value of parks to improve health and well-being and encourage park visitors to make healthy lifestyle choices" (NPS 2012). To address these needs, the National Park Service established the Health and Wellness Executive Steering Committee in 2010 to initiate steps for HPHP's integration in the United States and "for park lands to take their rightful place in creating a healthy and civil society" (NPS Health and Wellness Executive Steering Committee 2011, p. 8). The committee's objectives were twofold: (1) explore the role of the National Park Service in promoting the health and well-being of the nation, and (2) develop a strategy to support health promotion. To advance their role in enhancing public health, the National Park Service hosted the HPHP U.S. summit in 2011, developed a strategic action plan, will host the Second International HPHP Congress, and will contribute to the Sixth World Parks Congress with a health and wellness component.

The NPS "Call to Action" and the HPHP U.S. movement illuminate the important role that national parks play in enhancing human health by offering recreational opportunities and by promoting healthier lifestyle choices. For nearly 100 years, society has assumed that national parks have contributed to human health and well-being by protecting these places that inspire physical activity and promote mental health (Wexler 2004). However, members in the health community are increasingly calling on parks to provide more tangible ways of increasing healthy activities and behaviors (Frumkin 2001; St Leger 2003). So what strategies can NPS managers use to maximize visitors' health benefits? This article seeks to answer this question and to provide a set of case studies and examples that illustrate how the National Park System can inspire the American public to enjoy resources of the national parks and derive health benefits.

Table 1. Physical and mental health benefits associated with parks and green space

Health Benefits	Research
Physical • Reductions in cardiovascular disease and diabetes • Reduced obesity • Reduced heart rate, muscle tension, blood pressure • Positive influences on immunity and cardiovascular function	Pretty et al. 2005; Lee 2011; Lee and Maheswaran 2010; Maller et al. 2002
Mental • Improvements in cognitive functioning • Improved mood and self-esteem • Reduced depression, anxiety, and stress • Increased attention levels	Barton and Pretty 2010; Pretty et al. 2005; Thompson Coon et al. 2011; Fletcher et al. 1996; Taylor et al. 1985

The link between parks and human health

Research generally supports the notion that parks, green space, and natural landscapes support physical and mental health (Godbey 2009; Lee and Maheswaran 2010; Maller et al. 2009; Bowler et al. 2010; Richardson and Parker 2011; Sallis et al. 2012; Frumkin 2001; Frumkin and Louv 2007; Abraham et al. 2010; St Leger 2003). The unique characteristics of many national park units make them ideal settings for promoting diverse outdoor recreational opportunities (Sallis et al. 2012). These activities, such as walking and bicycling, can deliver a range of physical and mental health benefits, as illustrated in table 1.

Though the literature supports the role that parks may play in supporting healthy outcomes, there is little research that specifically confirms that visitors to national parks receive health benefits (Maller et al. 2009). Though many national park visitors do participate in healthy activities while in parks, many may not. For example, national park experiences are often physically passive or are driving experiences (Hallo and Manning 2009) and in general most park visits result in sedentary instead of active behaviors (Mowen 2010; Cohen et al. 2007). So how can national park managers increase visitor participation in healthy activities that produce health benefits within their units?

Managing park resources as health resources

Parks, operating within a broader landscape, provide diverse resources for promoting healthy behaviors and lifestyles. *Park health resources* can be defined as programs, facilities, and environments (natural and cultural) that when used by visitors can provide demonstrable and often distinctive physical, mental, and social health benefits. For example, a visit to a park can provide opportunities for physical activity through hiking, promote nutrition through purchase of healthy foods, encourage mental health and wellness through contact with nature, and further social well-being by providing educational opportunities and social interactions.

The 401 park areas managed by the National Park Service include 124 historical parks or sites, 79 national monuments, 59 national parks, 25 battlefields or military parks, 18 preserves, 18 recreation areas, 10 seashores, four parkways, four lakeshores, and two reserves. The diversity of these park areas makes it impossible to have a single prescribed plan for managing park resources as health resources. However, there are some common questions and themes that can be applied to all national park settings to maximize health promotion and benefits, which include (1) designing programs and infrastructure for multiple outcomes, (2) managing food and beverage services to deliver healthy food and activities, and (3) forming diverse short- and long-term partnerships. Many of the following case studies were submitted to the "Call to Action Success Stories" and are directly linked to specific action items (NPS 2013).

Designing programs for multiple outcomes

Developing programs and facilities that promote the delivery of multiple outcomes is possible with thoughtful planning and efficient use of resources. By viewing park resources as potential health resources, managers can adapt existing programs to enhance physical, mental, and social health outcomes. Not all programs need to be changed dramatically, but instead managers need to evaluate what potential health outcomes may be achieved in tandem with other desired outcomes. Some examples to illustrate how national parks can reevaluate existing programs to maximize health outcomes follow:

Zion National Park, located in Utah, implemented a mandatory shuttle system for visitor transportation during busy tourist seasons. Visitors must leave their vehicle in a remote lot and use the shuttle system to view and interact with the park's resources (fig. 1). The shuttle system has expanded visitor access, improved the visitor experience, and reduced negative impacts on park resources (NPS 2008). It is also thought that the shuttle system promotes increased walking opportunities, improved air quality, and a quieter soundscape, all of which support positive health and mental outcomes. Managers at Zion (and elsewhere) could promote these health outcomes and enhance visitor opportunities through increased signage pertaining to walking opportunities and communication of its potential health benefits.

Great Smoky Mountains National Park, located in Tennessee and North Carolina, recently enhanced a trail that connects the Cherokee Nation and town to Oconoluftee Visitor Center. The interpretive trail was codeveloped in cooperation with the Cherokee Nation and incorporated signage that interpreted Cherokee legends and language. The trail extends over 2 miles (3.2 km) and has enhanced connectivity between the park and the local community. Local people now hike the trail on a regular basis, contributing to improved relations with park neighbors and promotion of physical activity.

Educational and interpretive programs offer another area for managers to achieve multiple outcomes. The National Park Service offers a variety of programs for visitors and students that can be effective venues for park staff to promote healthy choices for visitors within and outside the park. By providing active interpretive programs, parks may increase physical activity levels while also meeting educational goals (fig. 2). Some examples that illustrate how park units have designed educational and interpretive programs for multiple outcomes are as follows:

Minute Man National Historical Park, located in Massachusetts, has implemented the multiple outcomes approach through the development of a 5.5-mile (8.9 km) multiple-use pedestrian and bike trail that connects two historical sites. Guided ranger talks along the trail are a way for the park to promote physical activity, expose visitors to natural and cultural resources, and provide education to visitors in a safe and scenic venue (NPS 2009).

Timucuan Ecological and Historic Preserve, located in Florida, is an example of how cultural and historical parks have the opportunity to highlight connections between their site and past and present cultures through interactive visitor experiences. Timucuan and the National Park Foundation provided transportation costs for students to visit the park so that they may learn about history while also promoting healthier lifestyles. Students were able to compare their own physical activity through the use of pedometers to the physical activity of the 16th-century Timucua people. Additionally, students learned about the Timucua diet and food options and made the connection to healthier food options for today.

North Cascades National Park, located in Washington, and the Wounded Warrior Project designed a program for wounded service members and veterans to improve physical and mental health. Over several days, the veterans hiked, canoed, and camped with the guidance of park rangers and volunteers. Through this therapeutic and specialized program, the group of service members and veterans overcame physical and mental obstacles while completing the challenging hikes and canoe trip and received many physical, mental, and social benefits.

Managing food and beverage services

Another opportunity for the National Park Service to improve public health outcomes is through the active management of food offerings in vending machines, stores, and restaurants within national parks. In 2011, the Centers for Disease Control and the National Park Service conducted a study of 47 parks in 33 states using adapted nutrition environment measures surveys (NEMS) to assess restaurants, snack shops, and vending machines for access, pricing, and promotion of healthful as opposed to less healthful foods and beverages (Wong et al. 2011). The preliminary results revealed that only 26% of beverage vending machine choices consisted of healthful drinks (including water), and only 19% of restaurants offered more than one entrée on the menu labeled as healthy.

Some of the recommendations of the 2011 National Prevention Council's National Prevention Strategy for improving health on which the National Park Service can focus its efforts are (1) increasing access to affordable and healthy foods, (2) implementing organizational nutritional standards and policies, (3) improving nutritional quality of the food supply, and (4) helping people recognize and make healthy food and beverage choices (NPC 2011). These efforts can be achieved in multiple ways by focusing on internal efforts with park staff and volunteers and on external efforts through concessionaire management. Some examples that illustrate how diverse park units have provided healthier food options include:

Wolf Trap National Park for the Performing Arts provides an example of park staff and volunteers taking the initiative to grow fresh produce that is used inside and outside of the park. Garden plots were established and maintained for the production of numerous herbs, fruits, and vegetables, which are used by concessionaires in food preparation for visitors (fig. 3). Any extra produce is donated to the local food bank. The garden also acts as an educational resource. The gardens are located along popular

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Figure 1 (left). A shuttle bus service at Zion National Park has contributed to reductions in crowding and adverse environmental impacts while creating a quieter landscape and more positive visitor experience.

Figure 2 (above). A ranger leads a bike tour at the National Mall that integrates physical activity into an educational program for visitors.

NPS PHOTO

Figure 3. A garden at Wolf Trap National Park for the Performing Arts demonstrates how to grow and integrate local foods into park concessions for visitors.

NPS PHOTO

Figure 4. The Get Outdoors Under the Gateway Arch event illustrates how local partnerships can create events that can contribute to the physical, mental, and social health of a community.

pathways where interpreters regularly discuss the art and science of gardening and how visitors can start their own gardens.

Mount Rushmore National Memorial, located in South Dakota, illustrates a concessionaire's efforts to showcase the region's culture and history through the use of local produce, while also providing healthy food options. Carvers Café, operated by Xanterra, offers on its menu Lakota popcorn from the harvest of the Lower Brule Sioux Tribe and locally raised bison, antelope, elk, and venison. Carver's Café chefs also use produce from a local garden. Signage and displays explain to visitors where the food originated and other sustainable food options. Last, Xanterra has developed a composting operation, which diverts about 30,000 pounds (13,607 kg) of waste each year (Mills 2011).

Forming partnerships

Short- and long-term partnerships offer an opportunity for national parks to expand healthy opportunities for visitors inside and beyond park boundaries. One of the main pillars of the HPHP Strategic Action Plan is to build partnerships and leverage resources (NPS 2011). Partnerships can help support the National Park Service as it takes a more proactive role in contributing to human health and well-being. Short- and long-term partnerships with local businesses and area attractions can be used to create local events and ongoing opportunities that promote health. Following are several examples to illustrate how diverse national park areas have formed short- and long-term partnerships to provide healthier visits and options for park visitors:

Table 2. Information sources and strategies for managers to support park health resources

Source	Focus	Site URL
Healthy Parks Healthy People Central	International research, innovations, and programs of the HPHP initiative	http://www.hphpcentral.com/
Healthy Parks Healthy People U.S. Strategic Action Plan	The specific role of the United States and the National Park Service in the HPHP initiative	http://www.nps.gov/public_health/hp/hphp/press/1012-955-WASO.pdf
NPS Healthy Parks Healthy People Science Plan	The research and science needs linking the health of NPS areas to human health	http://www.nps.gov/public_health/hp/hphp.htm
Centers for Disease Control and Prevention: Division of Nutrition, Physical Activity, and Obesity	Guidelines, strategies, statistics addressing nutrition, physical activity, and obesity	http://www.cdc.gov/nccdphp/dnpao/
National Environmental Education Foundation's Children and Nature Initiative	Specific focus on interaction of children and adolescents and nature, and provides resources and publications	http://neefusa.org/health/children_nature.htm
Richard Louv's Children and Nature Network	Research, publications, recent news, and ways to get youth engaged with the natural world	http://www.childrenandnature.org
Active Living by Design	Strategies for creating healthier communities that support physical activity and nutrition by working with local, state, and national partners	http://www.activelivingbydesign.org/
Let's Move	Initiative led by Michelle Obama to increase physical activity and nutrition for youth throughout the nation	http://www.letsmove.gov/
Leadership for Healthy Communities	A guide for local and state leaders to create healthier communities, including an action strategies toolkit	http://www.leadershipforhealthycommunities.org/
Active Living Research	Translates research to advocates, decision makers, and practitioners with the goal of creating healthier communities	http://www.activelivingresearch.com
Guide to Community Preventive Services	Resources on a variety of topics to proactively address health issues in communities	http://www.thecommunityguide.org/index.html
National Recreation and Park Association (NRPA)	Strategies and resources found in six issues briefs and other publications for how NRPA has played an active role in creating healthy communities	http://www.nrpa.org/Grants-and-Partners/Recreation-and-Health/Healthy-Communities/
American Medical Association Public Health Resources	Medical-related resources and solutions to promote healthy lifestyles and reduce health disparities among diverse populations	http://www.ama-assn.org/ama/pub/physician-resources/public-health.page?
Food for the Parks	Case studies of sustainable food and roles of concessions in NPS efforts for healthier park visits	http://www.concessions.nps.gov/docs/concessioner%20tools/food-for-the-parks-report.pdf
NPS Pathways to Healthy Living	Strategies and examples of how the Rivers, Trails, and Conservation Assistance program has contributed to human and ecological health	http://www.nps.gov/ncrc/portals/health/healthprojects.htm
National Prevention Strategy: America's Plan for Better Health and Wellness	A comprehensive strategic plan developed by the National Prevention, Health Promotion, and Public Health Council	http://www.surgeongeneral.gov/initiatives/prevention/strategy/report.pdf
2008–2013 Action Plan for the global strategy for the prevention and control of noncommunicable diseases	Global strategies formulated by the World Health Organization to reduce cardiovascular disease, diabetes, cancers, and respiratory diseases by addressing specific risk factors	http://whqlibdoc.who.int/publications/2009/9789241597418_eng.pdf

Cuyahoga Valley National Park, located in Ohio, developed long-term partnerships to create healthier options for park visitors while also preserving the park's resources. The Countryside Initiative is a partnership among the national park, the Countryside Conservancy, and local farmers to connect local culture, resource conservation, and food production with the public. Partnerships with 11 local farmers produce locally grown fruits, vegetables, eggs, poultry, goats (for meat), and wine. Park staff also implemented educational programs focused on the farming operations, and the park wants to expand current efforts and form additional partnerships (Mills 2011).

Gulf Islands National Seashore, located in Mississippi and Florida, hosted a Healthy Parks Healthy People event, that highlights the use of short-term partnerships to promote health and well-being. Gulf Islands formed partnerships with health care and wellness providers, outdoor recreation providers, and environmental education professionals from the southeastern United States. During the event, visitors could take advantage of free health care screenings or participate in a blood drive. Partners also provided outdoor recreational activities such as bird walks, bike rides, and use of kayaks in addition to numerous types of exercise classes.

Jefferson National Expansion Memorial, located in Missouri, formed partnerships with the St. Louis Sports Commission, USA Gymnastics, VISA Championships, Girl Scouts, and the World Bird Sanctuary to host thousands of people at the Get Outdoors Under the Gateway Arch. The event promoted healthy activities and lifestyles by offering wildlife, fishing, gardening, bicycling, and other exercise programs in nearby green space and provided information on healthy lifestyles and foods for children and adults (fig. 4, page 33). Based on the event's success, the national park and its partners are planning a second event.

Pinnacles National Park, located in California, formed a partnership to provide programming inside and outside park boundaries. The park partnered with Central Coast YMCA for the Let's Move Outside program in the neighboring cities. As part of this program, park rangers visit surrounding local communities to engage low-income and at-risk youth from a nonprofit housing development in enjoyable physical activities. The park then invites youth and their families to come to the park to participate in guided moonlit hikes, which are offered in multiple languages.

Promoting healthier parks for healthier people

The NPS "Call to Action" goals and the HPHP U.S. movement illuminate the important role that national parks may play in enhancing human health by offering recreational opportunities and through the promotion of healthier lifestyle choices. The examples discussed in this article and the additional sources in table 2 offer managers a starting point for enhancing their resources and programs and designing future health initiatives that support park and human health in their respective parks. Through the use of multiple-outcome program design, food and beverage service management, and partnership formation, national parks can enhance health outcomes for visitors and NPS staff alike. The National Park Service has a special opportunity to act as a global role model for parks, protected areas, and public lands everywhere by managing the resources of the National Park System for healthy outcomes.

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CASE STUDY

Development of a Healthy Parks Healthy People strategic action plan for Hot Springs National Park

By Dorothy L. Schmalz, Jeffrey C. Hallo, Sarah F. Griffin, Michael Kusch, Mardi Arce

THE WORLD HEALTH ORGANIZATION HAS ESTIMATED that worldwide 1.9 million deaths annually are the result of physical inactivity, the equivalent of approximately 1 in 25 deaths (as cited in Barton and Pretty 2010, p. 3947). Yet, due to modern society's dependence on technology, mechanized transportation, and involvement in primarily sedentary occupations, levels of physical activity and mental health status continue to plummet. On a more local level, Arkansas is experiencing similar health concerns related to inactivity. According to the Centers for Disease Control and Prevention, 30% of Arkansas citizens are obese (CDC 2012). Furthermore, 30% of Arkansas adults (aged 20 years and over) reported no leisure-time physical activity (CDC 2012).

While much of the responsibility for personal health lies with the individual to take advantage of opportunities, communities and public agencies have the responsibility of providing accessible venues and environments that encourage recreation and physical activity. Research strongly supports that exposure to the natural environment and involvement in the out-of-doors supports physical and mental health, including (1) decreased stress, (2) reduced crime rates, (3) improved social supports, (4) restoration and renewal for those experiencing psychological exhaustion, and (5) improved ability to maintain mental focus (Barton et al. 2009; Coon et al. 2011; Pretty et al. 2007).

While parks offer phenomenal opportunities for users to experience natural beauty and time for peaceful pause, tranquility, and quiet self-reflection, parks also hold potential for serving as an advocate and avenue for elevating participation in physical, energy-expending activity (Cohen et al. 2007). To fulfill this potential, park leaders must consider what aspects of a park promote or deter visitors' use of an area for active recreation and exercise. Researchers also acknowledge that in addition to individual benefits, it is important to consider the outcomes that an interrelationship among parks, natural settings, and personal and public health could have on national initiatives, such as decreased health care costs and economic growth.

Abstract

Hot Springs National Park is in a special position for the Healthy Parks Healthy People (HPHP) initiative based on its rich history as an early national reserve intended to conserve geothermal springwater for the purposes of public health, wellness, and enjoyment. Nearly two centuries after its first protection, Hot Springs National Park has the potential to serve as a keystone in the HPHP movement and to act as a catalyst for change in the role of national parks as venues not only for recreation and conservation, but also for health and well-being. We proposed a comprehensive project to develop an HPHP strategic action plan for Hot Springs National Park to incorporate and implement HPHP principles. The project consisted of three phases: (1) a review of literature on HPHP topics as they relate to assets available within the park, (2) an HPHP strategic planning workshop, and (3) development of an HPHP strategic plan for the park. We reached conclusions by incorporating a mixed-methods approach, using secondary data from the literature review and primary data from workshop participants. Workshop attendees identified a number of short- and long-term goals for Hot Springs National Park that will achieve the guiding principles of the HPHP initiative, enhance the health and wellness of park visitors and the surrounding community, while also keeping cultural and environmental impacts to a minimum.

Key words

community, health, planning workshop, visitors

Healthy Parks Healthy People

In 2011, NPS director John Jarvis initiated a five-year action plan for Healthy Parks Healthy People (HPHP). The intent of the movement is to consider how the national parks can play an influential role in reversing the current trend of poor health among U.S. citizens (NPS Health and Wellness Executive Steering Committee 2011). The mission of the National Park Service to preserve resources and to provide for the public's recreational enjoyment of those resources makes the National Park Service a vital player in efforts to improve the health and well-being of the U.S. citizenry. Several national-level strategic planning meetings involving representatives from the National Park Service, the

National Park Conservation Association, and community and university partners have been held to further define and identify the goals of the HPHP movement. From these meetings a vision and seven guiding principles have been established (table 1). The initiative is designed to build and foster existing relationships among national, state, and local parks, as well as business and health care leaders, foundations, and advocacy programs as a means of better communicating and facilitating the role parks play in public health.

Table 1. Seven guiding principles of the Healthy Parks Healthy People initiative

We promote health and well-being as an interrelated system linking human health to natural landscapes and all species.
We seek expertise and resources from a wide range of partners in the public and private sectors.
Our aim includes activities that contribute to physical, mental, and spiritual health and social well-being.
Our work takes place both within and beyond park boundaries.
We encourage uses that promote the health of all species while avoiding those that impair resources.
We seek to provide equitable access to open spaces and natural places.
Our commitment to improving public health will be mirrored in internal programs for our workforce.

Hot Springs National Park

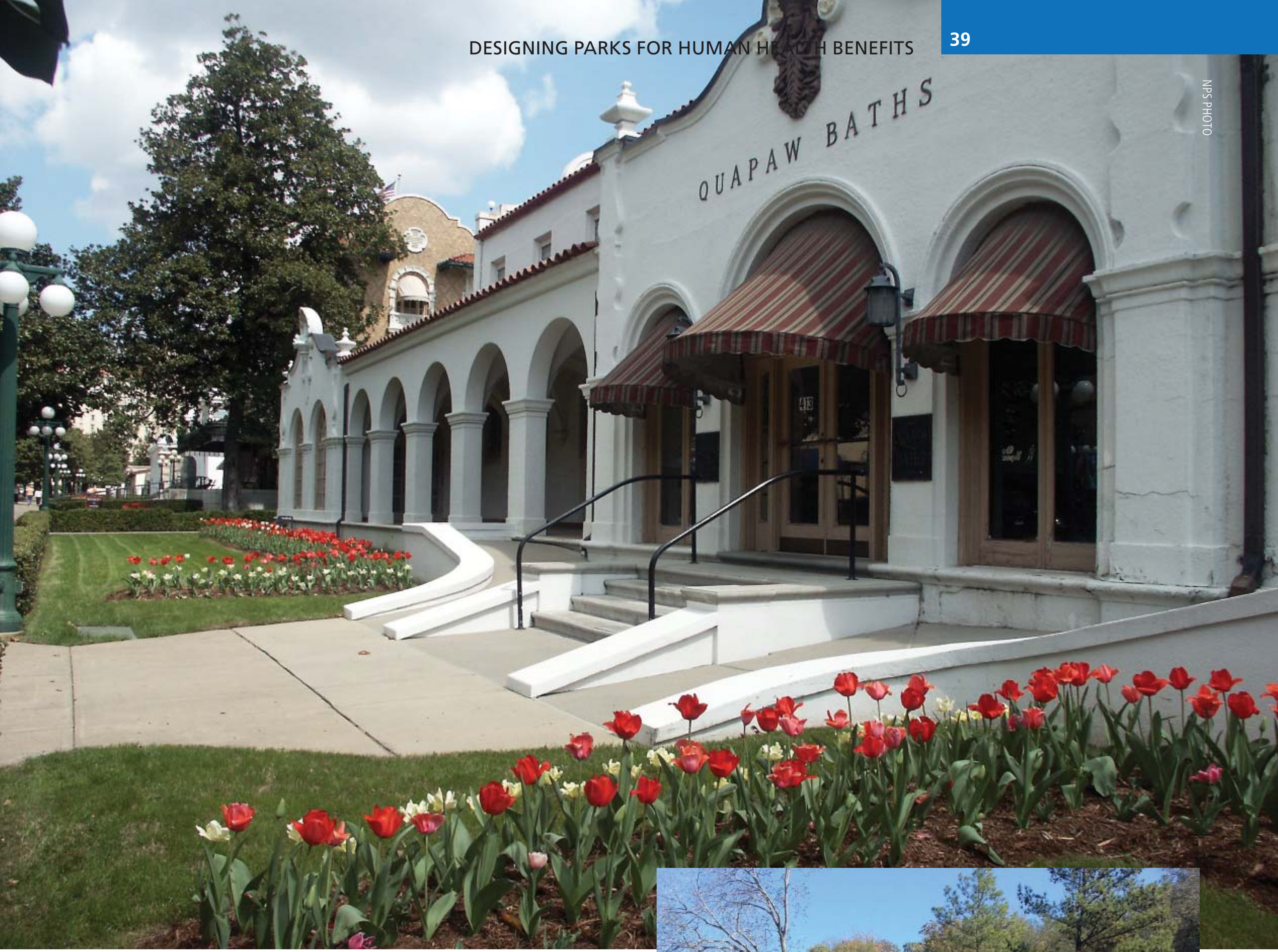
With the purchase of the Louisiana Territory in 1803, the land region now recognized as Hot Springs National Park, Arkansas, became part of United States territory. News of the springs spurred the Dunbar-Hunter expedition in 1804 and 1805 to investigate the thermal springwater. Immediately the uniqueness of and need to safeguard the natural springs were recognized. The federal government established a reserve to protect the natural springs and surrounding landscape in 1832. This makes Hot Springs National Park the oldest protected site in the National Park System.

In the late 1870s, the region began to evolve from a rugged countryside to a more developed, urbanized area in which roads, large buildings, lavish spas, and park landscapes designed and built by the Department of the Interior thrived. By the turn of the 19th century, the natural springs had been enclosed by protective structures, and the thermal waters distributed to bathhouses for health and mental restoration. A "Bathhouse Row" evolved over many years and at one time consisted of more than 20 bathhouses, providing public health and wellness services to the community through the 1950s (fig. 1). At their peak, the bathhouses provided therapeutic pools, gymnasiums, gardens, billiard rooms, massage therapy, hydrotherapy, and mercury-based therapies to the public. Today, nine bathhouses still stand in Hot Springs National Park and provide a variety of services to the local community and park visitors.

In 2012, a park foundation statement was created that builds on the original intent of Hot Springs National Park: "The purpose of Hot Springs National Park is to protect the unique geothermal spring water and associated lands for public health, wellness, and enjoyment" (NPS 2008, p. 8). Because the legislative purpose of Hot Springs National Park is closely linked with health, the park already offered numerous health-oriented programs: (1) the "Let's Move Outside" campaign encourages hiking and walking on the extensive trail system in the park, (2) the Junior Ranger Program provides youth an opportunity to learn about the history of the park and the purposeful uses of the hot springs water and land area for health, (3) the Junior Trail Ranger Program in partnership with the "Let's Move Outside" initiative encourages children to get involved in physical activity and exercise outdoors, and (4) two bathhouses along Bathhouse Row provide therapeutic pools, massage, and hydrotherapy. Hot Springs National Park's rich history as an early national reserve to preserve geothermal springwater for the purposes of public health, wellness, and enjoyment and its mission for health and wellness puts it in a special position in support of the HPHP movement.

Project overview

The purpose of this project was to develop an HPHP strategic action plan for Hot Springs National Park. Toward this end, Clemson University faculty and graduate students collaborated with staff and administration at the park to identify key stakeholders to participate in a strategic planning workshop. A three-day workshop was held in October 2012 in the town of Hot Springs. The workshop was planned and implemented by Clemson University researchers and Hot Springs National Park staff in close coordination. We generated a list of potential workshop attendees that included state and national experts in public health, fitness-wellness, and parks and recreation. We also invited local and regional experts in these subject areas, stakeholders from both the for-profit and nonprofit sectors, and several Hot Springs National Park staff to participate. The workshop was attended by approximately 25 people representing a diversity of interests, subject areas, and affiliations. We encouraged attendees to focus on three primary questions during the workshop: (1) how is Hot Springs National Park's mission of public health, wellness, and enjoyment outlined in the 2012 foundation statement interpreted by local residents and out-of-town visitors?, (2) how does Hot Springs National Park successfully accomplish this mission?, and



NPS PHOTO

Figure 1 (above). Established in 1832 as a federal reserve dedicated to protecting geothermal springwaters and associated lands for public health, wellness, and enjoyment, Hot Springs National Park in Arkansas is an ideal focal area for the Healthy Parks Healthy People initiative.

Figure 2 (right). Participants of the October 2012 workshop stroll the park promenade and learn about the park's historical features and contemplate the potential for enhanced public engagement for health and well-being.

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(3) how is success measured? Workshop-based answers to the last two questions are the focus of this article.

The workshop included an introduction to and discussion of goals; a tour of Hot Springs National Park (including health and wellness resources) (fig. 2); presentations by subject-matter experts on relevant aspects of public health, recreation/leisure, parks in general, and Hot Springs National Park history; individual and group brainstorming sessions; topical breakout sessions; and sessions in which we evaluated and synthesized workshop outcomes (interim and final). Of particular note, Dr. Brent Bauer, director of the Mayo Clinic's Complementary and Integrative Medicine Program, presented a practicing clinician's perspective on integrating health, wellness, and Hot Springs National Park–related resources (e.g., spa experiences, mind-body activities; fig. 3). The workshop was led by a professional facilitator from Clemson University who was trained and experienced in conducting group strategic planning processes. The Clemson University project team helped to further focus the workshop efforts toward the goal of gathering information to inform an HPHP strategic action plan.

The workshop agenda was intentionally designed to lead workshop participants in gathering information (via experiences and talks), brainstorming and evaluating those ideas, and finally building a shared agreement among the attendees on recommended actions, related constraints, and measures of success. The facilitator and project team took notes on flipcharts, and these were organized and posted throughout the room. This process helped record the workshop results while creating opportunities for participants to review, use, and validate the workshop outcomes.

MICHAEL KUSCH

Figure 3. Dr. Brent Bauer, director of the Mayo Clinic's Complementary and Integrative Medicine Program, speaks to participants of the HPHP strategic planning workshop at Hot Springs National Park in October 2012.

Workshop outcomes and project proposals

Most of the interactive portions of the workshop were focused on brainstorming and evaluating ways in which Hot Springs National Park could better integrate public health, wellness, and enjoyment. In table 2 we present key themes that emerged for any actions to be taken as part of a future plan.

Workshop participants generated a large number of specific ideas for programming, facilities, events, partnerships, and activities that could help to further incorporate health and wellness at Hot Springs National Park. These ideas were explored and discussed, including promoting biking by allowing access, holding biking events, dedicating bike lanes, and providing storage racks; working with hospitals, physicians, and health providers to write "park prescriptions for health"; a rehabilitation center that takes advantage of the thermal waters; encouraging youth to participate in physical activities and play in the park (e.g., sports

Table 2. Key themes for HPHP actions taken as part of a future plan

Theme	Description
Fun	Efforts should focus primarily on creating enjoyment that has the secondary benefit of being healthy and promoting wellness, and where possible provides opportunities for socialization.
Informed	Actions should be guided by the collection of reliable, empirical information on what visitors want, visitor characteristics, visitor activities (including locations of use), and their attitudes toward potential changes. This should be done prior to taking any substantial action so that good decisions are made and baseline data are available.
Intergenerational	Ideas should be developed that appeal to all ages, and where possible have visitors of multiple generations interacting regularly. Also, at least some actions should place particular emphasis on better connecting younger adults and families with children to the park.
Collaborative	Actions should leverage and facilitate success by working with partners (e.g., friends groups, local educational institutions, state and local governmental entities, health providers, hospitals, businesses, and nonprofit groups) and with current local or national initiatives.
Marketed and promoted	As part of any action, the National Park Service should actively engage participants and the local community through free media, involving students, comarketing, sponsorships, creating a guide for health professionals, and linking with community events.
Achievable and demonstrable	Actions, at least those in the short term, should be those that can be most certainly accomplished and that produce immediate, tangible, and impactful results. This suggests the need for a demonstration project that would build on momentum of existing efforts, require minimal investments, not overburden NPS staff, produce multiple benefits, and be innovative or unique.

Hot Springs National Park is now poised to serve as a keystone in the HPHP movement and to act as a catalyst for change in the role of national parks as venues not only for recreation and preservation, but also for health and well-being.

Table 3. Ideas for implementing an HPHP program

Model and promote health and wellness within the park's staff

Example: Worksite Wellness Program—This program would allow Hot Springs National Park staff to model and promote health and wellness through example. Such a program could include changing practices to ensure time for physically active work during each employee's workday, extending policies granting law enforcement ranger opportunities for on-duty exercise to all employees, and providing employee incentives for participation in health and wellness programs. Current but informal successes with employee health and wellness (e.g., employees' weight loss through lunchtime walks and peer-supported dieting) could be used as a starting basis for this program.

Engage local partners and serve the local community in promoting health and wellness

Within park boundaries

Example: Whittington Park (a traditional outdoor park area within Hot Springs National Park boundaries) Activation—This idea is focused on creating more demand for health and wellness-related–use of Whittington Park by residents and visitors. This would include promoting the use of the space by appropriate private businesses (e.g., yoga and fitness instructors) and creating structural draws to the park, such as a fitness course, walking path, children's play area, or measured running/biking loop.

Outside park boundaries

Example: A Health Event—this idea would take advantage of the draw that festivals and events have in engaging a large number of people. The event could be focused directly on health and wellness, such as a competitive sports event (e.g., running events/races); a noncompetitive physical activity gathering (e.g., a yoga festival); or a fair that would allow people to interact with health providers, try healthy foods and drinks, and exercise in unusual ways (e.g., Indian club-swinging). Health and wellness could also be subtly incorporated into events (some currently happening) focused on arts, theater, or foods/drinks.

Engage state, regional, and national partners and serve these geographic levels in promoting health and wellness

Example: Million Hearts and Smoking Cessation Programs—Workshop participants identified specific opportunities for Hot Springs National Park to become engaged with state and national health initiatives. This included participation in the Million Hearts Campaign and working with established state and national programs for smoking cessation (particularly those related to a workplace).

Actively promote health and wellness among Hot Springs National Park visitors

Example: Geocaching—This idea would develop, formalize, and market the activity of geocaching in the park. Virtual caches (a specific location that needs to be found using a geographic positioning system [GPS], with a logbook to be signed once found) would be placed in areas of the park (likely in undeveloped parts) that would necessitate physical activity to reach. A series of caches could be developed into a "trail" and stamps could be used at caches (in lieu of a logbook) that would tie into the existing NPS Passport to Your National Parks® Program. This would be a low-cost, achievable that could be facilitated by linking to local and state geocaching organizations.

Example: QR Codes—Similar to the geocaching trail idea, a series of locations (likely in developed areas) could be marked with QR codes (a two-dimensional bar code readable by smartphones that transmit information) to form a trail that requires physical activity to complete and could provide information on health and wellness. Completion of this trail could be a requirement for the junior ranger program, tied to a visitor incentive (e.g., a token gift or discount), or be integrated into the existing NPS Passport to Your National Parks® Program. Also, this trail could be a theme-based children's exhibit, perhaps focused on water-life-health connections, that includes an interactive water fountain, bike trail, or walking path.

Reconceptualize Hot Springs National Park as a park dedicated to and founded on the promotion of health and wellness

Example: A Tobacco-Free Park—This idea would encourage smoking cessation and a tobacco-free lifestyle. The substantial precedent for prohibiting tobacco at some public facilities (e.g., hospitals, schools) would be extended, by policy or directive, to Hot Springs National Park. Such a program could be initially applied to employees, limited to certain areas (e.g., Bathhouse Row and facilities), promoted through the media, and could include designating areas for smoking that required some physical activity to reach. The ultimate goal of this would be to make Hot Springs National Park tobacco-free for both employees and visitors.

Provide a laboratory for innovation, advancement, and applied research related to the connections among health, wellness, parks, recreation, and nature

Example: An HPHP Science and Learning Center—Some parks, such as Acadia and Denali National Parks, have established formal science and learning centers to facilitate research related to park resources. A similar center, the first of its kind, could be established at Hot Springs National Park to facilitate research related to HPHP initiatives in the park. This center could host researchers and health providers, sponsor HPHP conferences/meetings, facilitate interdisciplinary research, and provide a library of HPHP research publications and reports.

Develop techniques and best practices for the measurement and monitoring of outcomes related to the HPHP actions at Hot Springs National Park

Example: Apply established processes—Well-established and tested processes for monitoring the obtainment of objectives and evaluating program effectiveness should be applied to any HPHP initiative at Hot Springs National Park.

tournaments, hiking or walking trips, treasure/scavenger hunts, activities specific to the talents and interests of park employees and community members, active games like “olly olly oxen free”) by partnering with the local recreation organizations, youth clubs, community groups, and schools; an HPHP research center, in coordination with universities, that focuses on the connections between health (e.g., obesity prevention) and nature; and a Health Advocate–in–Residence program similar to the existing Artist-in Residence Program in the National Park System.

Many of these ideas have merit and potential for success and should be considered for implementation. However, only the ideas embraced by an overwhelming majority of workshop participants were explored in detail. These mutually agreed-upon ideas fell into seven categories as presented in table 3.

Meeting participants identified numerous local and state partners that could assist Hot Springs National Park with taking action on these ideas and developing them further. Also, Hot Springs National Park could partner in local and state health efforts by coordinating and hosting a health and wellness fair to launch the “new” programs in the park and community. The park could use the event to develop relationships with potential partners in the community (and beyond) by means of exhibitions, demonstrations, programs, and sponsorships. Other suggestions were that the park could make special use permits and space (both indoor and outdoor) available to appropriate health and wellness providers, and it could partner with concessioners and local restaurants to offer and market healthy eating choices.

Meeting participants also discussed how to define and measure the success of HPHP efforts at Hot Springs National Park. The first step is for the park staff to develop SMART (Specific, Measureable, Attainable, Relevant, and Time-specific) goals and objectives through subsequent internal planning meetings. These goals and objectives will be the foundation for programming success in Hot Springs National Park’s efforts to enhance the health and well-being of visitors and the community. As a team we caution against using only health status indicators and health behavior rates as measures of success, as there are too many ecological influences that are out of a park’s control. Second, program administrators should use process evaluation to help ensure that programs are developed collaboratively, promote Hot Springs National Park as a healthy park, and are designed and delivered with fidelity to the guiding principles and themes (tables 2 and 3). An evaluation framework such as RE-AIM (Klesges et al. 2005; Dzewaltowski et al. 2004), described on the Web site http://www.re-aim.org/index.html, can be used for this, and emphasizes assessing reach, effectiveness, adoption, implementation, and maintenance. Third, the NPS’s Visitor Experience and Resource Protection (VERP) framework was recommended (in combination with the evaluation framework above) as a mechanism for determining and monitoring the outcomes of Hot Springs National Park’s HPHP actions. The VERP process helps establish effectiveness measures for each goal/objective (termed indicators) and measures of success (termed standards).

Recommendations and implications

As a team our primary recommendation was to implement the actions developed and vetted through the HPHP strategic planning workshop (table 3, previous page). In 2013, Hot Springs National Park staff took an important and substantial step by developing—based on the workshop outcomes described above—a strategic action plan that defines the objectives and goals for implementing the HPHP initiative at their park. This plan also provides a detailed description and prioritized list of HPHP actions that will be undertaken in the park and a schedule for their implementation. Hot Springs National Park is now poised to serve as a keystone in the HPHP movement and to act as a catalyst for change in the role of national parks as venues not only for recreation and preservation, but also for health and well-being.

Some caution is warranted, however, for no work or progress is ever made without a meaningful and often substantial investment of resources, particularly effort and money. Lack of commitment of required resources to a plan often results in inaction. Securing adequate program funding and leadership support at the regional and national levels is a necessary first step to implementing the recommended actions. This includes programmatic support and monies to conduct a visitor HPHP needs assessment (including baseline data collection), implement low-cost and near-term HPHP actions, complete a substantial HPHP demonstration project, and dedicate staff to the HPHP efforts.

The information-gathering approach employed in this project is applicable to all parks interested in starting an HPHP program. Although what has been outlined in this article is specific to Hot Springs National Park and the idiosyncrasies of the surrounding community, the approach is replicable. As with any planning process, interested parks are advised to first identify and establish the reasons for and why they are pursuing the plan. Getting parties on board at all levels within the agency, and cementing understanding and buy-in from the agency itself, are the first step toward success. Second, soliciting input from key stakeholders and from a variety of fields (as was done here) can contribute to success. Third, park staff should then assess their specific goals and the actions they would take to implement an HPHP program at their park.

Conclusions

As suggested by Director Jarvis, the time has come for national parks to embrace and encourage healthy behaviors and lifestyles, and to become an active player in efforts to address the current health crisis in the United States. Hot Springs National Park, with its charge to preserve and protect healing thermal waters from natural springs, is an ideal fit for the HPHP initiative, and it is in a unique position to be an important keystone in the adoption of the HPHP movement in parks nationwide.

It seems clear that the time for action to promote health and wellness in national parks is now. Our nation's needs to do so are both compelling and critical. Equally apparent is that Hot Springs National Park offers the perfect context for implementing such actions and serving as a leader and model for the HPHP initiative in the National Park System. The next steps in doing this are to secure the necessary resources and to take action.

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Managing vegetation for children: Enhancing free-play opportunities through direct management

By Thomas Marlow, Mike DeBacker, and Craig Young

Abstract

This article explores the potential benefits for children afforded by free play in natural areas and develops a strategy to enhance natural areas for this purpose. Children obtain benefits from contact with natural areas that loosely fall into three categories: behavior, health, and environmental sensitivity. Research reveals that the primary vector for these positive outcomes is free play outdoors. Enhancing free play therefore forms the basis of an implementation strategy, which relies on a multistep approach. First, areas suitable for free play are identified by the presence of three environmental factors identified in the literature: refuge, diversity, and accessibility. From here, projects may be developed with the goal of simple and cost-effective vegetation management. We present several ideas and examples of what projects of this type could look like. Overall, this article offers a simple and cost-effective means to designing cultural and natural landscapes to encourage free play in national parks.

Key words

behavior, Call to Action, children, environmental sensitivity, free play, health, vegetation management

RECONNECTING OUR NATION'S YOUTH WITH NATURE has become a central theme in the National Park Service (NPS) (NPS 2011, 2012). This focus is an understandable response to societal changes that are limiting time spent in natural areas and increasing problems among youth, including poor health, emotional issues, and a loss of environmental knowledge and sensitivity. With this in mind, we explored opportunities for vegetation managers to contribute directly to this growing emphasis within the Service. Our backgrounds in ecology, conservation, and environmental ethics prompt our interest in the topic, and our perspective is shaped by direct experience working with national parks in the Midwest Region through involvement in planning and interpretive activities connected with our work in the NPS Inventory and Monitoring Program.

When considering how to connect children with parks, we see free play as a promising goal for vegetation managers. Free play affords children time to roam around, collect things, make up stories, climb, crawl, throw, and invent games without prompting. The importance of this as a transformative experience that inspires and educates children can be found throughout the literature on environmental education. Richard Louv's influential book *Last Child in the Woods* can be seen as a manifesto for free play (2008). Louv contends that lack of contact with green spaces during childhood is a root cause of many problems seen in children and society as a whole. He dubbed this condition "nature deficit disorder" and prescribed free play outdoors as a remedy. Elements of free play already permeate NPS programs such as bioblitz, Junior Ranger, and Parks as Classrooms. We reviewed the research to ensure empirical connections and to help develop vegetation management strategies to promote free play.

Benefits of free play

We found in this review that positive outcomes resulting from free play can be grouped loosely into three categories: (1) behavior, (2) health, and (3) environmental sensitivity. Studies reveal that natural areas like the national parks help restore our ability as humans to focus, thus making them potentially helpful in managing attention deficit disorder (ADD and ADHD) (Faber et al. 2001). Research examining the physical health benefits of play in natural areas is likewise promising.

Free play is linked to developmental benefits such as increased motor skills in young children while also increasing activity levels in children and adolescents (Fjørtoft 2001; Klesges et al. 1990; Sallis et al. 1993; Cleland et al. 2008; McCurdy et al. 2010). Although this may be an intuitive conclusion, it is nonetheless a vital outcome in an age when childhood obesity rates continue to rise, putting a whole generation at risk of related health problems.

Finally, the role that nature plays in developing awareness and sensitivity to environmental problems should not be undervalued.

We feel that free play is a very open-ended goal that, if based on the design principles we have derived from the empirical research, can be confidently promoted at little cost.

Contact with nature is one of the most significant life influences that emerge in studies and is therefore important in developing environmentally connected citizens (Chawla 1998, 1999).

We acknowledge that some of these benefits require significant time and frequency in the outdoors. The National Park Service's urban parks, national recreation areas, and easily accessible community parks, as designed, provide the opportunity for frequent visits that may extend throughout childhood (please see the brief case study on free play at Indiana Dunes on page 48). It is to this group of parks that this research is most applicable and the recommendations particularly relevant. (For a more complete review of the research linking outdoor play with benefits for children, please refer to Marlow et al. 2013.)

Strategies

Our literature review prompted us to look for ways to manage actively for free-play potential in natural and cultural landscapes. We envision these projects to be unobtrusive, simple, and suited to the particular park. We are not advocating for construction of playgrounds, but rather subtle manipulations of areas identified as particularly well suited for free-play activities. This requirement, that preexisting outdoor spaces have attributes conducive to free play, helps avoid and minimize conflict with other priority uses for these areas. Additionally, because little infrastructure is required, these projects are highly scalable and can be adjusted to the needs of individual parks.

Teams of subject-matter experts in the fields of natural and cultural resources, education, interpretation, and facility management are necessary for such projects. As such, this kind of work affords significant opportunities for interdivisional collaboration through these multidisciplinary teams. In some cases, ongoing management activities may already create unrecognized opportunities for free play and thus allow for free-play projects to become integrated cost-effectively. For example, a project reducing basal density in a forest to its historical precedent may increase the free-play potential of an area by making it more accessible to children. Overall, we feel that free play is a very open-ended goal that, if based on the design principles we have derived from the empirical research, can be confidently promoted at little cost.

Design elements

In order to apply this research to vegetation management, we developed a simple series of questions (fig. 1, next page). After assessing site safety for issues such as the presence of poisonous plant or animal species, the most difficult question to address is whether or not an area is suitable for free play. As a practical starting point, three elements should be considered when planning and designing free-play opportunities in cultural and natural landscapes: (1) refuge, (2) diversity, and (3) accessibility. Each principle is based in part on the research and observations of education professionals.

"Refuge" is a recurring theme in the literature on child play behavior. Studies, as well as anecdotal evidence, demonstrate that children prefer enclosed spaces during free-play time (Kirkby 1989; Nabhan and Trimble 1994). During free play, children seek out areas that are small, enclosed, and protected. MaryAnn Kirkby argued that young children seek refuge as places to play because of a larger developmental bias for areas that are scaled to them and offer safety and security (1989). This is reflected in children's preferences for spaces with multiple "escape" routes and the ability to see out of the area without being able to be seen.

Diversity also factors in as an environmental preference for children (Kahn 1997). Increasing the level of diversity can be thought of as increasing the possible experiences for a child in an area. This requires having rocks of different sizes, trees to climb, crawling spaces, water, dirt, topographical diversity, and animals. Much of this is inherent in nature and outdoor environments, thus making these areas ideal settings for free play; however, where possible, assessing and enhancing diversity may be pursued. Furthermore, qualitative characteristics should be considered as well. For example, a feeling of mystery has been associated with preference in natural scenes and lends itself to drawing in children, exciting their imagination, and fueling their creativity (Kaplan and Kaplan 1995).

Accessibility is a final, important, and multidimensional characteristic affecting free play in children. On one level, making sure there are plenty of entrance points for kids to begin engaging with the space is all that is needed. Kahn (1997) noted that the diversity and complexity of the intended play space should not come at the

Figure 1. Evaluating free-play potential

1. **Is the area in question suitable for free play?**
   There are no set rules for determining the potential for free play, but the following criteria are based on research and should be weighted accordingly. Discretion should, however, be used in the final judgment.

   I. Accessibility

   - Accessible via trail or road
     - Trail hikes must be considered easy enough for children to complete
   - Legibility—one can reasonably hope to enter an area and find one's way out (Kaplan and Kaplan 1995)
     - clear entry and exit points
     - distinct landmarks for easy navigation
     - coherence—the scene make sense overall

   II. Diversity

   - Integration between vegetation and open spaces (Mårtensson 2009)
   - Topographical diversity and physical challenges
     - uneven ground
     - objects for climbing
     - low spaces for crawling
   - Elements for manipulation. Including but not limited to
     - edible plants
     - collectible items
   - Mystery—the attribute about which one could acquire more information by venturing deeper into the area and changing one's vantage point (Kaplan and Kaplan 1995)
     - Area is marked by any of but not limited to the following attributes:
       – winding narrow trail
       – meandering streams
       – drastic changes in lighting that draws viewers in
       – partially obstructed views
       – enclosures and refuge

   III. Refuge criteria

   - Presence of at least one proper enclosure (refuge spaces) with some of the following attributes (Kirkby 1989)
     - Ceiling effect (canopy, roof) is present in some enclosures
     - Sub-spaces or a high degree of complexity
     - Visual connections to surrounding environment
     - Multiple access points and "escape" opportunities
   - Two or more refuge spaces
   - Varied scale of enclosures (Kirkby 1989)
     - small-scale spaces (two to four children)
     - large, loosely joined enclosures allowing more movement and group activity

2. **If the area is suitable for free play: Are there ongoing park uses or plans for the area in question?**

3. **If yes: Do these uses prevent any adjustments to vegetation management or other changes?**
   As long as an area is suitable for free play (Question 1) and has management plans already in place (Question 2) that do not prevent further modification and management changes (Question 3), then it may be considered as a viable site for the introduction of management for free play.

expense of a child's ability to enter that space, maintain orientation, and eventually find a way out. Accessibility is also important in designing individual spaces within the whole. Kirkby included this in her design principles, saying "Multiple point access to enclosed spaces accommodates individual style, allows 'escape' opportunities, and lends itself to a greater variety of use" (p. 11). She even noted the differences in the size of the entry point, saying that children seemed "attracted to spaces that were scaled to them" (p. 11).

After the team has established the suitability of an area, follow-up questions should be addressed to clarify whether further action is appropriate. Managing particular park areas for children has from the beginning been considered a secondary goal and as such should not supplant existing management goals. We do not want, for example, sensitive natural areas to be opened up to free play. We believe, however, that with a pragmatic, open-minded, and careful approach to these projects, the integrity of a park's natural resources can be preserved. Policy of the National Park Service supports this by defining *appropriate use* to include the promotion of health and fitness and by encouraging visitor activities that are "inspirational, educational, or healthful" (NPS 2006, section 8). These goals are also prominent in the direction set forth for managing national parks in the recent report "Revisiting Leopold: Resource stewardship in the national parks" (NPS 2012) and in the NPS initiative "A Call to Action Plan" (NPS 2011). (For those interested in a more complete discussion and guidance on designing free-play spaces please refer to Marlow et al. 2013.)

From here, many options for simple modifications are available that can be incorporated into existing management plans. For example, in an open field, mowing could have major impacts on the ability of the area to offer refuge and accessibility. For example, mowing to create connected networks of paths could make an area more welcoming while these same paths could offer refuge if carefully designed. Conversely, allowing vegetation to grow higher could offer significantly more opportunities for refuge during free play. Mowing is an easy option as any mowed trails can be widened or narrowed depending on the intended purpose. Narrow networks of trails offer refuge and intrigue for the creative young mind while widening trails could provide the opportunity for diverse play activities. Forested areas require slightly more involvement from managers.

Finally, while free play in its purest form is a spontaneous act by children, in order for the maximum number of children to reap the benefits that free play in the national parks can offer, some prompting and encouragement using more traditional educational curricula must occur. For example, a volunteer entomologist located at a central landmark and equipped with a handful of butterfly nets could offer children the opportunity to collect insects on their own while the volunteer aids in identification. Ornithologists could do the same with binoculars. Historians and geographers could facilitate mapping of areas of interest. Also, the important role of social interaction during free play to create transformative experiences should be taken into account when designing these programs.

Conclusion

Designing cultural and natural landscapes to encourage free play in national parks offers a simple way for managers to respond to several goals set out in the "Call to Action." The planning approach and design principles outlined provide important criteria for implementing these designs for real-world applications. As many of the applications derived from these recommendations will be novel, managers should monitor the effectiveness of the projects. Surveys and other measures could be helpful in the continual modification of projects for children. In this way, management of the vegetation in these landscapes may lead to a number of positive physiological, psychological, and developmental outcomes for children.

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The Nature Play Zone at Indiana Dunes National Lakeshore: A case study

By Kim Swift

IT IS A GORGEOUS JUNE DAY AT INDIANA Dunes National Lakeshore, and I am watching several families enjoying the park (photos on following pages and cover). One group is standing around a young oak tree looking up at two young girls scurrying up the branches like a couple of squirrels. Their mom turns to me and says, "I didn't even know they knew how to climb a tree." Another group is playing in the sand, hiding rocks, digging up others, and exclaiming with joy as if they just found gold. A third group is building a small fort, laying an intricate pattern of sticks and driftwood around a larger trunk they have inserted into the ground. The older sibling is helping the younger one in a rare display of cooperation, according to their dad. In another park location, these would all be ticketable offenses, and I would be going out to chide the parents and wrangle the kids back onto a trail or to a picnic area. However, these are just the sort of park interactions we are seeking at our new Nature Play Zone, so I just smile and watch.

We have been witnessing and facilitating this kind of behavior in kids since we started testing the play area in April 2012, and we could not have asked for a better response. It all started with Richard Louv's 2008 book, *Last Child in the Woods*. Several of us on staff read his book, including our park superintendent, Constantine Dillon, who approached the interpretive staff and suggested we initiate an unstructured play area similar to what Louv describes. First, we visited other nature centers to see their play areas. We found some excellent examples and were inspired by the range of options, from the highly developed Hamill Family Play Zoo at Brookfield Zoo to the Wild Place at Lyman Woods, which is just a roped-off section of meadow and woods behind the nature center.

Site criteria and description

We started by looking for a good spot at the national lakeshore. We wanted an area where staff could interact with participants regularly, so it had to be near a staffed site with parking. We needed a place that was already developed or disturbed. We did not want to open up a new area of the park, and it could not be in endangered species habitat. We manage for both the federally protected Karner blue butterfly and the federally threatened Pitcher's thistle. So we had to do some vegetation sampling at any potential site to be sure these plants were not present. Luckily, as we were doing a park cleanup near the Paul H. Douglas Center for Environmental Education, the park's primary education facility, we stumbled upon a site that met all three criteria: near parking and a staffed site, no sensitive species, and previously disturbed, as it was a railroad junction about 50 years ago.

It was really pretty easy after that. We worked with a high school group to sample the vegetation of the area and identify what was growing there. We cleaned up the site, removing trash, glass, and debris. We did the necessary archeological compliance work and put the project onto the Planning, Environment, and Public Comment Web site for feedback. The area previously had been cleared for archeology when the parking lot was first constructed. We removed invasive species such as oriental bittersweet, black locust, and tree of heaven, again with the help of volunteers and student groups.

Nature play looks different than traditional playground play. It is inquiry-oriented, with kids asking questions and finding answers on their own or with the help of adults or other kids.

NPS PHOTO COLLECTION/KATRINA GEORGE

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Children work together to create a shelter using tarps and logs (upper right) at the Nature Play Zone at Indiana Dunes National Lakeshore. These children attended the park's opening event in April 2013. Building with driftwood (above) and climbing are two popular activities in the Nature Play Zone.

Interpretive Ranger Julie Larsen leads a group of Gary, Indiana students into the Nature Play Zone during their visit to Indiana Dunes National Lakeshore last spring. The park provides simple tools and buckets to aid children in their free nature exploration.

NPS PHOTO COLLECTION/KATRINA GEORGE

Two Gary, Indiana, students enjoy digging in the sand at the Nature Play Zone during their spring visit to Indiana Dunes National Lakeshore.

Once the compliance process was complete and we received a green light, we set up a pilot program. The first big obstacle popped up in early spring in the shape of three leaves—poison ivy, very serious poison ivy. At first, we thought we could just leave it and post signs, identifying the plant species for visitors. We realized, as the full spring growth erupted, that the area was thick with the itchy, native plant. So we worked with resource management to use low-grade herbicide to remove larger patches of it. We did leave a small patch and have signs showing folks what it looks like.

The vegetation at our Nature Play Zone is primarily dune grasses, grapevines, small oaks, and cottonwood trees, with some interesting native species coming in at different times of the year. Prickly pear cactus is one of the favorites of the kids. Even though it has some safety issues, we have decided to leave it and allow children to learn "the hard way" how to explore it. Unlike poison ivy, there is an immediate cause-and-effect reaction to touching cactus. We have not had any complaints, and visitors seem excited to find it nestled among the grasses. Horsetail is another fun plant that grows profusely in the play area and can be manipulated and made into a play item for the kids without damaging the plant seriously. We created a plant scavenger hunt for children to try to find as many of the common plants as they can in the area, which adds an educational element to their visit.

Lessons learned from the pilot program

That first summer of testing provided excellent feedback for our team. We set up an unobtrusive observation form for staff to use when they brought families to the area. We learned which activities children preferred and which areas of the play zone were their favorites. We also watched the adults and how they interacted with the students, and we quickly learned that the way adults react directly correlates with how students behave in the area. When the adults are relaxed and get involved, even in a small way, the children respond positively. If children sense the adults are not comfortable and are going to get upset if they get dirty, then they react differently, quarreling with one another, resorting to traditional playground behavior, and being less willing to experiment. Exploring and experimenting are the behaviors we want to see at this new space. When kids are given that freedom, their imaginations kick into gear and the magic of nature happens. Time seems to slow down here, and they forget about electronic devices and TV shows and just play.

Nature play looks different than traditional playground play. It is inquiry-oriented, with kids asking questions and finding answers on their own or with the help of adults or other kids. They build elaborate nests, forts, and designs. They cooperate with each other and try new things all because the boundaries and spare parts are loose and can be manipulated. They explore and search for the six-lined racerunner lizards that dart between the rocks. They dance with the wildflowers and just sit by themselves making castles with rocks. It feels so good to watch this kind of play, especially in our area, a middle-class neighborhood of Gary, Indiana, where these types of play areas are nonexistent and even playgrounds are few and far between. It is accessible to thousands of local residents who can walk, ride bikes, or take public buses to the play area, which is part of the Douglas Center for Environmental Education and open for indoor nature activities.

Several adults who brought children to the first pilot programs at the play area suggested that a shade structure be erected since the area is open to the sun and elements. Fortunately, the National Park Service provided the funding for this through its Healthy Parks Healthy People initiative. We contracted for an innovative shade shelter and used green paving materials to make a pavilion and walkway that are accessible for strollers and wheelchairs.

In addition to the structure at the play area, the park initiated a Nature in My Neighborhood campaign to coincide with the opening of the Nature Play Zone. In the hopes of inspiring and cultivating nature play at home, we are providing free nature backpack kits to the first 1,000 families who visit the Nature Play Zone this spring and summer. The backpacks provide tools such as binoculars, journals, and a field guide for children to continue nature exploration on their own. Additional funding for this program came from the park's partner, the Dunes National Park Association, who helped us kick off the opening in April 2013.

Positive response

Since that grand opening, the play area has hosted more than 1,000 children. The response has been overwhelmingly positive from the public and the park staff who facilitate play. Based on this initial success and research on the benefits of nature play, we believe the benefits of unstructured nature play in a national park are far-reaching and can be achieved with minimal disturbance. However, while anecdotal evidence is positive to date, we must also continue to evaluate use of the site by observing children at play, monitoring vegetation, and looking for signs of increased impacts on other areas that might be resulting from the freedoms allowed in the play zone. We have posted an orientation panel at the play area, explaining that this site has different rules than other areas of the park, but we all know signs are limited in their effectiveness. In addition to these direct effects of the play zone, we would like to work with researchers to measure more long-term, qualitative effects of exposure to this type of play in nature and how the smiles and laughter we see so prevalently might translate into creating future stewards of our national parks.

—***Kim Swift*** *(kimberly_swift@nps.gov) is Education Programs manager at Indiana Dunes National Lakeshore, Indiana.*

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Research Reports

Cars and canyons: Understanding roadside impacts of automobile pollution in Grand Canyon National Park

By Julie A. Kenkel, Thomas Sisk, Kevin Hultine, Steven Sesnie, Matthew Bowker, and Nancy Collins Johnson

JULIE KENKEL

A sunset view of Grand Canyon near the main park visitor center.

EACH YEAR MILLIONS OF VISITORS FROM AROUND the world come to Grand Canyon National Park, in Arizona to witness awe-inspiring views and to observe over 60 million years of Earth's history preserved in the strata displayed in the canyon walls. Some days, visitors are disappointed to find these canyon views veiled by haze, reducing visibility to a fraction of the canyon's legendary vistas (NPS 2013). Disappointed visitors understandably ask what causes this haze and how air pollution affects the Grand Canyon. How can clean air and breathtaking views be restored at Grand Canyon?

Atmospheric haze is composed of a mixture of chemicals, including nitrogen oxides (NOx), ozone (O_3), peroxyacetyl nitrate (PAN), and sulphate (SO_4^{2-}) (Jimoda et al. 2011). Two of these components, O_3 and NOx, not only compromise Grand Canyon views, but also damage plant tissues and have impacts on ecosystem processes (Fenn et al. 2003; Bobbink et al. 2003), with potentially wide-ranging effects. Under certain weather conditions, urban air pollution and haze from Las Vegas, Phoenix, and Los Angeles, plus industrial pollution from power plants and copper smelters, accumulate in the canyon (Macias et al. 1981; Eatough et al. 1997; Eatough et al. 2001). In addition to visitors, automobiles bring air pollution to the park in the form of exhaust that may also reduce air quality at Grand Canyon. Every year, approximately one million automobiles pass through the south entrance of Grand Canyon National Park; nearly 200,000 pass through the east entrance at Desert View (NPS 2013; fig. 1).

Even though 78% of the atmosphere is composed of N_2 gas, this form of N is unavailable for plant use. Consequently plant growth in natural ecosystems is often limited by a shortage of N. Plants acquire some organic forms of N along with ammonia (NH_3^+) and nitrate (NO_3^-) from the soil. The process of transforming N_2 gas into plant-available NH_3^+ or NO_3^- requires a lot of energy, and occurs naturally through nitrogen-fixing microbes and lightning, or through industrial processes related to fertilizer production, and fossil fuel combustion for transportation and the production of electricity.

Since the industrial and agricultural revolutions, human activities have doubled the amount of bioavailable N on the planet, overloading some ecosystems (Vitousek et al. 1997). Even low levels of persistent NOx pollution may cause the buildup of excess N, which can result in the ecological equivalent of "too much of a good thing." Critical loads are defined as the amount of pollutants below which there are no adverse ecological effects (Fisher et al. 2007; Burns et al. 2008). Nitrogen inputs that surpass critical loads create undesirable effects on natural communities and ecosystems,

Abstract

Nitrogen oxides (NOx) in air pollution contribute to haze that diminishes the views at Grand Canyon National Park. NOx pollution negatively impacts vegetation and ecological communities, but these effects are not well understood. Some sources of this pollution, like regional airborne emissions from urban areas and coal-fired power plants, are beyond the direct jurisdiction of the National Park Service (NPS). However, NOx emitted from vehicular exhaust is one source of pollution that the park can potentially manage as it strives to provide alternative transportation options for the public. We sampled atmospheric NOx and foliar $\delta^{15}N$ signatures (the ratio of nitrogen isotopes ^{15}N to ^{14}N can be used to identify emission sources) along a traffic gradient at the south rim of the national park to assess the extent to which vehicles on park roads may be adding nitrogen (N) to transportation corridors. Atmospheric NOx was found to be elevated within a few meters of the roadside and at the south entrance where automobile traffic was the greatest. We also found that foliar nitrogen isotope signatures along the roadside gradient matched known signatures from vehicular emissions, indicating that cars and other vehicles are primary sources of nitrogen in the ecosystem near roadways. Haze-reducing legislation has recently been enacted to reduce emissions from regional coal-fired power plants, but the National Park Service can further reduce park pollution by encouraging nonmotorized recreation and greater public use of alternative transportation options.

Key words

automobile, Grand Canyon National Park, nitrogen, NOx, pollution

NPS PHOTO

NPS PHOTO

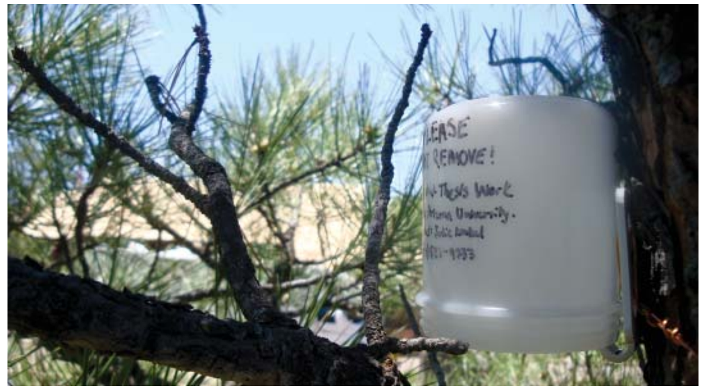
Figure 1. Automobile traffic idles at the south entrance (top) and Desert View (bottom) entrances to Grand Canyon National Park.

including changes in soil fertility that disrupt native plants and their consumers (Galloway et al. 2003; Aber et al. 1989; Weiss 1999).

Automobile emissions in our national parks may damage sensitive roadside vegetation, such as conifers, and favor a few dominant species, including invasive grasses (Trahan and Peterson 2007; Angold 1997). For example, in Rocky Mountain National Park, Colorado, N inputs from highways and long-range transport from urban and agricultural centers contribute to plant community shifts and establishment and spread of invasive grasses (Bowman 2000; Bowman et al. 2012). Similarly, roadside N enrichment in Grand Canyon National Park may provide too much N to organisms accustomed to otherwise N-limited plant communities, changing nutrient cycling processes and altering plant community composition. Currently we do not know the effects of N enrichment on Grand Canyon ecosystems; however, we do know that increasing population and industrialization in the region continue to challenge park staff's ability to mitigate the effects of air pollution originating both in and outside of park jurisdiction. How can clean air be restored in the Grand Canyon? The first step is to determine the amount and sources of N pollution, the next step is to find out how much N is too much (critical loads), and the final step is to develop strategies to reduce these inputs. Our research is focused on the first step. To address this, we explored potential indicators of N enrichment and the origins of pollution in Grand Canyon National Park.

The relative abundance of the stable isotope ^{15}N can be used to quantify inputs of atmospheric N and its incorporation into plant tissues. Isotopes are variants of elements that differ in the number of neutrons in their nucleus, with ^{15}N having one more neutron than the more common isotope ^{14}N. Stable isotope analysis offers a way to trace pollution in the environment to its source since the ratio of N isotopes differs in predictable ways. Isotope ratios are expressed using δ (delta) notation in parts per thousand (‰). $\delta^{15}N = [(R_{sample}/R_{standard}) - 1]$ times 1000, where R is the molar ratio of the heavier to the lighter isotope ($^{15}N/^{14}N$) for the standard or sample (Evans and Ehleringer 1993). The additional neutron makes ^{15}N heavier and this slightly changes its physical and chemical behavior. Differences in $\delta^{15}N$ ratios of exhaust from

Since the industrial and agricultural revolutions, human activities have doubled the amount of bioavailable N on the planet, overloading some ecosystems.



JULIE KENKEL

Figure 2. We detected roadside NOx in automobile exhaust using Ogawa passive air samplers, installed 2 m high in pinyon pine trees at the roadside and 30 m from the road. Atmospheric NOx was measured at the south entrance and Desert View entrance.

power plants, vehicular emissions, and natural sources can help identify the origin of N pollution (Elliott et al. 2007). $\delta^{15}N$ ratios in NOx from automobiles with catalytic converters generally range from +3.4 to +5.7‰, compared to background atmospheric $\delta^{15}N$ signatures (Ammann et al. 1999; Pearson et al. 2000) of around 0.003‰. Plant tissue $\delta^{15}N$ signatures have been found to be 10% higher (more positive) in highly trafficked roads than in remote areas (Pearson et al. 2000). Based on these findings, we hypothesized that trees close to roadsides and high traffic areas in Grand Canyon National Park should have higher $\delta^{15}N$ ratios than trees that are farther from automobile emissions.

Research methods

We studied N inputs at different times and places in the park near (0 m) and farther away (30 m) from roadsides. We measured two indicators of N enrichment, atmospheric NOx using Ogawa air samplers (Ogawa Inc., Pompano Beach, Florida, USA; fig. 2) and $\delta^{15}N$ in needles of pinyon pine (*Pinus edulis* Engelmanii) trees near the roadside (fig. 3). We installed Ogawa passive air samplers at the south entrance and Desert View entrance. We attached the air samplers 2 m (6.6 ft) above ground level in pinyon pine trees located 0–30 m (98.4 ft) from either side of the road. We deployed two additional samplers at the south entrance to gain a finer-scale measurement of NOx concentrations at the most highly trafficked area (NPS 2013). We collected the samplers at two-week intervals, six times throughout a 12-month period (May 2011–March 2012). At collection, samplers were sealed in airtight containers and shipped to the laboratory where they were analyzed for nitrogen oxide and nitrogen dioxide concentrations using colorimetry and diazo-coupling reactions (Research Triangle Institute, North Carolina). The length of time that Ogawa samplers are exposed to air is factored into calculations of the concentration of NOx in parts per billion (ppb). Exposure times were fairly similar across sample sites and collection dates, and any variance in exposure time is accounted for by the analysis protocol (Ogawa Inc., Pompano Beach, Florida, USA).

We evaluated the $\delta^{15}N$ signature of pinyon pine needles from samples taken at 10 sites along the south rim drive of Grand Canyon National Park (fig. 4). We collected annual needle whorls from 2009 to 2011 at chest height, on the south aspect of the tree at distances of 0, 15, and 30 m (0, 49.3, 98.4 ft) from the roadside. A total of 240 samples were collected, dried, ground, and analyzed for $\delta^{15}N$ signatures using mass spectroscopy (Colorado Plateau Stable Isotope Lab, Northern Arizona University). We used the multivariate analysis of variance (MANOVA) for repeated measures to determine whether or not location in the park and distance from roads account for the variance observed in NOx concentration and foliar $\delta^{15}N$ signatures. All statistical analyses were performed using JMP 10 software (JMP 10. 2012).

Results

Across all sample dates the concentration of NOx detected by the samplers was significantly higher at the south entrance than at Desert View (fig. 5). Furthermore, at the south entrance, roadside (0 m) NOx concentrations were 52% higher than those at sites 30 m (98.4 ft) away from the road. Across all 10 sites, foliar $\delta^{15}N$ was on average about 1 part per thousand higher (less negative) at the roadside than at 15 m or 30 m (49.3, 98.4 ft) away from the road (fig. 6).

INSETS LEFT TO RIGHT: NPS, NPS/MICHAEL QUINN, NPS/NEAL HERBERT

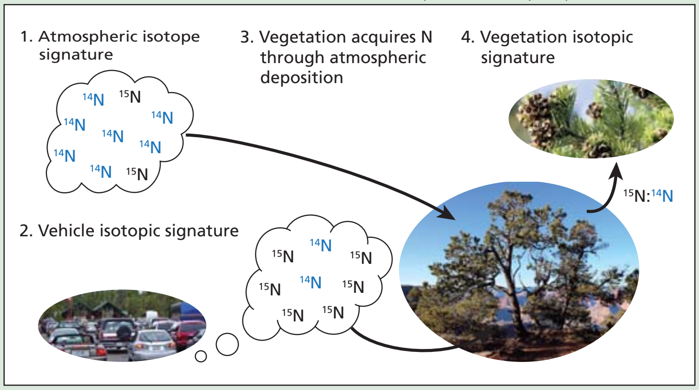


Figure 3. $\delta^{15}N$ signatures are useful in tracking human sources of N in plant tissue and air. (1) In an unpolluted environment, the isotopic signature of N is dominated by ^{14}N, and is very close to 0.00 parts per thousand (‰). (2) Automobile exhaust is relatively enriched in ^{15}N and displays a higher $\delta^{15}N$ when compared to the background atmospheric $\delta^{15}N$. (3) Vegetation acquires N via atmospheric deposition onto foliage and also through the soil, which may be influenced by vehicular sources. (4) The isotopic signature of samples of vegetative tissue can be analyzed. A stronger influence of vehicular N sources would produce greater enrichment of ^{15}N.

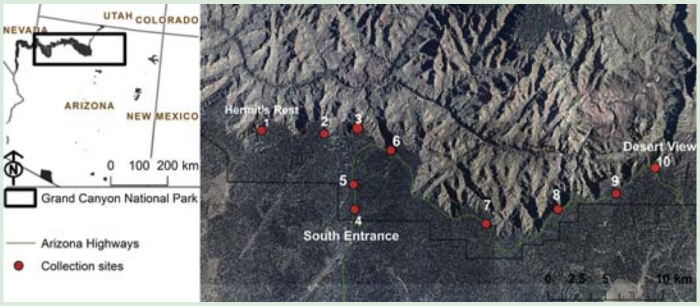
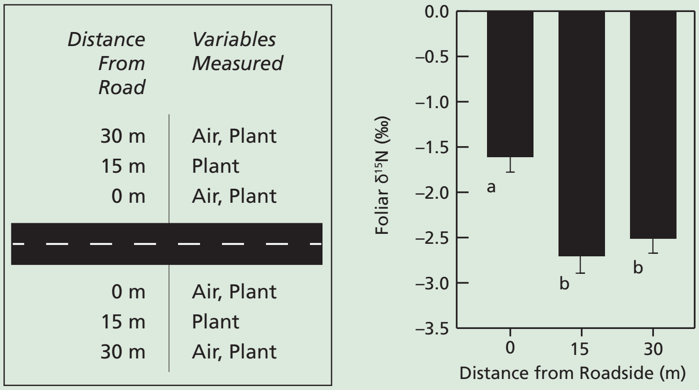


Figure 4. (Above) We measured roadside sites along the south rim drive of Grand Canyon National Park (May 2011–March 2012). (Below at left) Atmospheric NOx samples were measured at the south entrance and Desert View entrance at 0 and 30 m from the roadside; foliar samples were collected across all 10 sites along the south rim drive at 0, 15, and 30 m from the roadside.



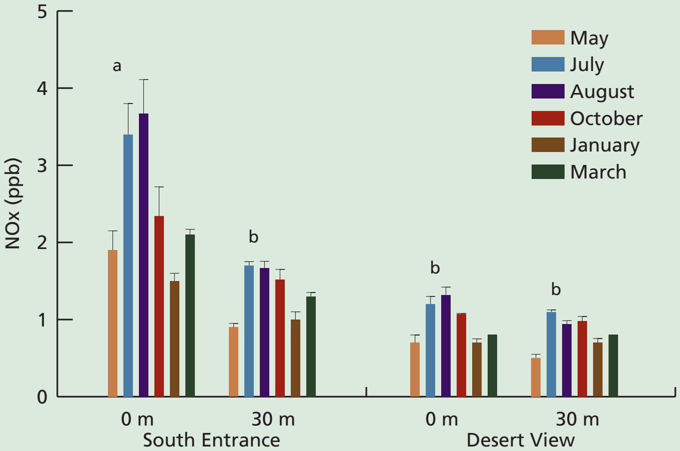


Figure 5. (Left) Ogawa passive samplers measured atmospheric NOx (ppb) along roadsides at the south entrance (0 m, n = 4; 30 m, n = 2) and at Desert View entrance (0 m, n = 2; 30 m, n = 2) sites in Grand Canyon National Park. (Right) Samples were collected for six two-week periods in May, July, August, October 2011, and January and March 2012. NOx collected at each of the sites were averaged by distance from the road (0 m and 30 m). Tukey test results denoting significant differences between NOx at each site are represented by *a* and *b*.

Figure 6. We measured pinyon pine $\delta^{15}N$ (‰) signatures from roadside environments along the south rim drive of Grand Canyon National Park (May 2011–January 2012). In the figure, bars represent means (n = 237) and lines represent standard errors. Different letters indicate that means are significantly different according to Tukey HSD test ($p < 0.05$).

Discussion

We discovered that air from highly trafficked areas in Grand Canyon National Park contained a higher concentration of NOx than air from areas with fewer automobiles. Although the long-range transport of pollutants from urban centers and power plants may contribute to atmospheric haze, automobile emissions affect local air quality and, over time, this chronic N fertilization is likely to affect ecological communities along adjacent roadways (Angold 1997; Fenn et al. 2003). Input of N from automobile exhaust is particularly high at the south entrance, where more than one million cars, with engines idling, line up each year for admittance to the park.

As hypothesized, we detected higher $\delta^{15}N$ ratios in pine needles collected near roadsides than in those collected 30 m (98.4 ft) away from the road. The observed plant $\delta^{15}N$ signatures were within the range expected from automobile emissions (Ammann et al. 1999; Saurer et al. 2004).

Although the NOx concentration we observed in air samples from Grand Canyon National Park is below the national air quality standards (EPA 2013), there is concern that these limits may not be low enough to protect ecological communities in semiarid ecosystems, which may be more vulnerable to human sources of N enrichment than wetter ecosystems (Burns et al. 2011; Fenn et al. 2003). Low-elevation, short-range N emissions from automobiles, especially in times of high vehicular traffic, may affect roadside ecological communities more than other, less direct sources of pollution (Forman et al. 2003). Over time, the gradual buildup of biologically available N can initiate a cascade of undesirable ecological responses (Galloway et al. 2003). Pollution from automobiles, urban areas, industry, and power plants all contributes to the larger issue of air quality in Grand Canyon National Park. The clean air and world-renowned views expected by park visitors can be restored to the canyon through policies that target haze-producing NOx emissions. The recent EPA mandate to install NOx pollution–reduction technologies at the Navajo Generating Station, a coal-fired power plant only 24 km (15 mi) northeast of the park, helped it to advance one important step toward better air quality (EPA 2013). Grand Canyon National Park is continuing to take strides toward cleaner air by targeting improvements in the air pollution source within its boundary: automobile emissions.

The National Park Service encourages people to visit their national parks and has adopted the motto "Experience Your America™". This goal increasingly involves alternative transportation options. Nonmotorized recreation and public transportation offer ways to accommodate increased park visitation without compromising the park's ability to protect natural resources. The shuttle bus system at Grand Canyon began in 1974 and continues to enhance the protection of park resources and improve the visitor experience. In 2008, the park increased its fleet of natural gas–run buses to 29 vehicles, reducing NOx emissions in the park by 176 tons/year (NPS 2013). The park's low-pollution vehicles also provide service from the gateway community of Tusayan into the park, and provide access to sensitive features of the park, like Hermit's Rest Road, which is closed to private vehicles for much of the year. Other national parks, including Acadia in Maine and Zion in Utah, have successfully adopted public transportation systems to limit traffic congestion, increase public access to the park, and conserve park natural resources. Continued development of public transportation alternatives allows visitors to enjoy their national parks and the natural resources within them. "Rerouting" the way we experience our national parks may safeguard fragile natural resources, preserve important ecosystem functions, and help to ensure their protection for "the enjoyment of future generations" (NPS Organic Act 1916).

Acknowledgments

Funding was provided by the NPS Air Resources Division, a Doris Duke Conservation Fellowship to the first author, and the National Science Foundation Undergraduate Research Mentoring Program (DBI-1041255). We appreciate help provided by Tamara Blett of the National Park Service, Judy Bischoff of the Colorado Plateau Cooperative Environmental Studies Unit, Michael Julian, Jeff Propster, members of the Lab of Landscape Ecology and Conservation Biology, the Soil Ecology Lab at Northern Arizona University, the Colorado Plateau Stable Isotope Lab, and the Research Triangle Institute. We acknowledge advice and support from fellow N deposition researchers.

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Figure 1. (Left) native broadleaf cattail, *T. latifolia*, and (right) nonnative narrowleaf cattail, *T. angustifolia*, in the field.

NPS/JOY MARBURGER

Cattail hybridization in national parks: An example of cryptic plant invasions

By Joy Marburger and Steve Travis

HYBRIDIZATION IS A GENETIC PROCESS IN WHICH individual organisms from two genetically distinct populations mate and produce offspring. It can occur between distinct populations of the same species or between two different species. Plant hybrids of different species in the same genus are called *interspecific* hybrids or crosses. Hybridization between two closely related species is actually a common occurrence in nature with regard to plants, but is also being greatly influenced by human activities (Allendorf et al. 2001). Hybrids can produce either sterile (not viable) or fertile (viable) seed. They can also exhibit "hybrid vigor" or heterosis, which results in more robust growth than exhibited by the parent species. This phenomenon determines the kind of effect that a hybrid will have on its own population and others with which it interacts. Hybrid zones occur where the ranges of two species meet; hybrids are continually produced in great numbers in these zones. Hybrid zones are useful as biological model systems for studying the mechanisms of speciation confirmed by DNA analysis.

The main harmful genetic effect of hybrids on native species is the loss of both genetic diversity and locally adapted populations, such as rare and threatened species (Rieseberg 1991; Ellstrand and Elam 1993). From a conservation perspective, hybrids can

Abstract

Hybridization of plants occurs when two species from the same or different genera mate and can successfully produce viable seeds. Hybridization of plants can increase genetic diversity, but it can also result in aggressive taxa that can displace native species and decrease wetland plant biodiversity. Here we identify two cattail species, *Typha latifolia* L. and *T. angustifolia* L., and hybrids of these two species referred to as *T.* x *glauca* Godr. using molecular markers called microsatellites, since morphological characteristics are not reliable indicators for identifying cattail taxa. The importance of cattail hybridization is that it has facilitated cattail spread in various wetlands of North America. From 2004 to 2012 we evaluated whether hybridization of cattails was occurring in seven Great Lakes national parks and two other national parks. We present results for Apostle Islands National Lakeshore, Cuyahoga Valley National Park, Indiana Dunes National Lakeshore, Pictured Rocks National Lakeshore, St. Croix National Scenic Riverway, Sleeping Bear Dunes National Lakeshore, and Voyageurs National Park. All parks except Pictured Rocks included hybrid taxa. The technique holds promise for cattail taxonomic identification for wetland managers. Cattail management methods are also described.

Key words

cattails, hybrids, microsatellites, *Typha* species

negatively affect biodiversity if they spread aggressively in a community. The spread of aggressive hybrid groups can reduce the growth of, or replace, native species (Vilà et al. 2000). The main anthropogenic factors promoting hybridization of species are increased species dispersal by humans, landscape fragmentation, and land disturbance. Enhanced cross-pollination of two species and increased range expansion of an exotic species into native ranges are the result primarily of human activity.

Certain differences in flowering times, pollination, and seed dispersal patterns differentiate parental species from hybrids (Vilà et al. 2000); however, the barriers to crossing can break down if life history traits overlap. For example, production of fertile hybrids can result when the pollen cells of one species can fertilize ovules (immature seeds) in the other species and the chromosomal barriers (such as pairing during meiosis) are overcome by similarity of the chromosomes or through polyploidy (multiple sets of paired chromosomes).

Introgressive hybridization (transfer of traits between species) can also increase genetic biodiversity of a taxon (Vilà et al. 2000) and can be the source of new adaptations. However, in many cases the genetic integrity of a common native species can be threatened. This is the case with the hybridization of the California cordgrass *Spartina foliosa* with the introduced *S. alterniflora* (Daehler and Strong 1997) in San Francisco salt marshes.

Hybridization of cattails and their recent expansion in national parks

Three species of cattails (*Typha* spp.) occur in the United States—*Typha latifolia* L. (broad-leaf cattail), *T. angustifolia* L. (narrow-leaf cattail), and *T. domingensis* Pers. (southern cattail)—and an interspecific hybrid taxon referred to as *T.* × *glauca* (fig. 1). The three species are primarily cross-pollinated by wind. The three distinct species have the same chromosome number (2N=30; Smith 2000), which may facilitate successful hybridization. They also reproduce by asexual cloning through rhizome growth. The taxonomic relationships of *Typha* spp. was extensively described in the 1960s–1980s by Galen Smith, who also conducted experimental crossing of the species (Smith 1967, 1986, 1987). Smith obtained fertile seeds from some of these experimental crosses. Others have described the expansion of whole *Typha* stands or discrete patches of hybrids within stands based on hydrological alterations (Wilcox et al. 1985; Wilcox 2011) without any reference to genetic structure. Unfortunately, such morphological and environmental analyses are hindered by the complex blending of characters that typically occurs in cases of continuous hybridization (e.g., Rieseberg and Ellstrand 1993).

North American expansion of cattails over the past 100 years (Grace and Harrison 1986; Galatowitsch et al. 1999) has been driven by a combination of environmental (e.g., Wilcox et al. 1985; Woo and Zedler 2002) and evolutionary forces (Travis et al. 2010; Ball and Freeland 2013). *Typha* × *glauca* is considered the most invasive North American *Typha* species (Smith 1987; Galatowitsch et al. 1999), although some consider *T. angustifolia* equally invasive (Tulbure et al. 2007). *Typha* × *glauca* is reportedly more effective at supplanting native vegetation (Galatowitsch et al. 1999; Woo and Zedler 2002; Boers et al. 2007) and inhibits germination of native species once established (Frieswyk and Zedler 2006). In addition, *T.* × *glauca* competitively dominates both *T. angustifolia* and *T. latifolia* (Waters and Shay 1992; Kuehn et al. 1999), with the latter generally considered the least aggressive of the three. In spite of a general recognition of *T.* × *glauca* as the most invasive cattail species, explicit tests of the role of hybridization in the rapid spread of cattails are lacking (Frieswyk and Zedler 2006).

Managers in the Great Lakes national parks have observed that cattail populations have been expanding in wetland habitats. In 2003, biologists at Indiana Dunes National Lakeshore (Indiana), St. Croix National Scenic Riverway (Wisconsin), and Voyageurs National Park (Minnesota) noted that there were no taxonomic plant keys that could accurately identify the cattails. The question was raised about how to identify and manage cattail populations in the national parks in order to reduce or prevent the negative impacts of hybrid and nonnative species expansion that reduce wetland plant biodiversity.

Evaluation of cattail populations in national parks

Microsatellite DNA analysis is a relatively new tool used to evaluate plant species and their evolutionary relationships. Microsatellite DNA refers to repeating sequences of 1–6 unique base pairs (base pairs = adenine [A] with thiamine [T] and cytosine [C] with guanine [G]). The number of repeats varies among species and between members of a species, which determines relationships and genetic diversity. The analysis includes several markers (DNA sequences), and each is copied using polymerase chain reaction (PCR) technology to improve their detection in a gene analyzer. Over time, as a plant or animal population interbreeds, the microsatellites will recombine during sexual reproduction and the population will maintain a variety of microsatellites that is characteristic of that population and distinct from other populations that do not interbreed. Thus pure parental types can be detected from their hybrid offspring.

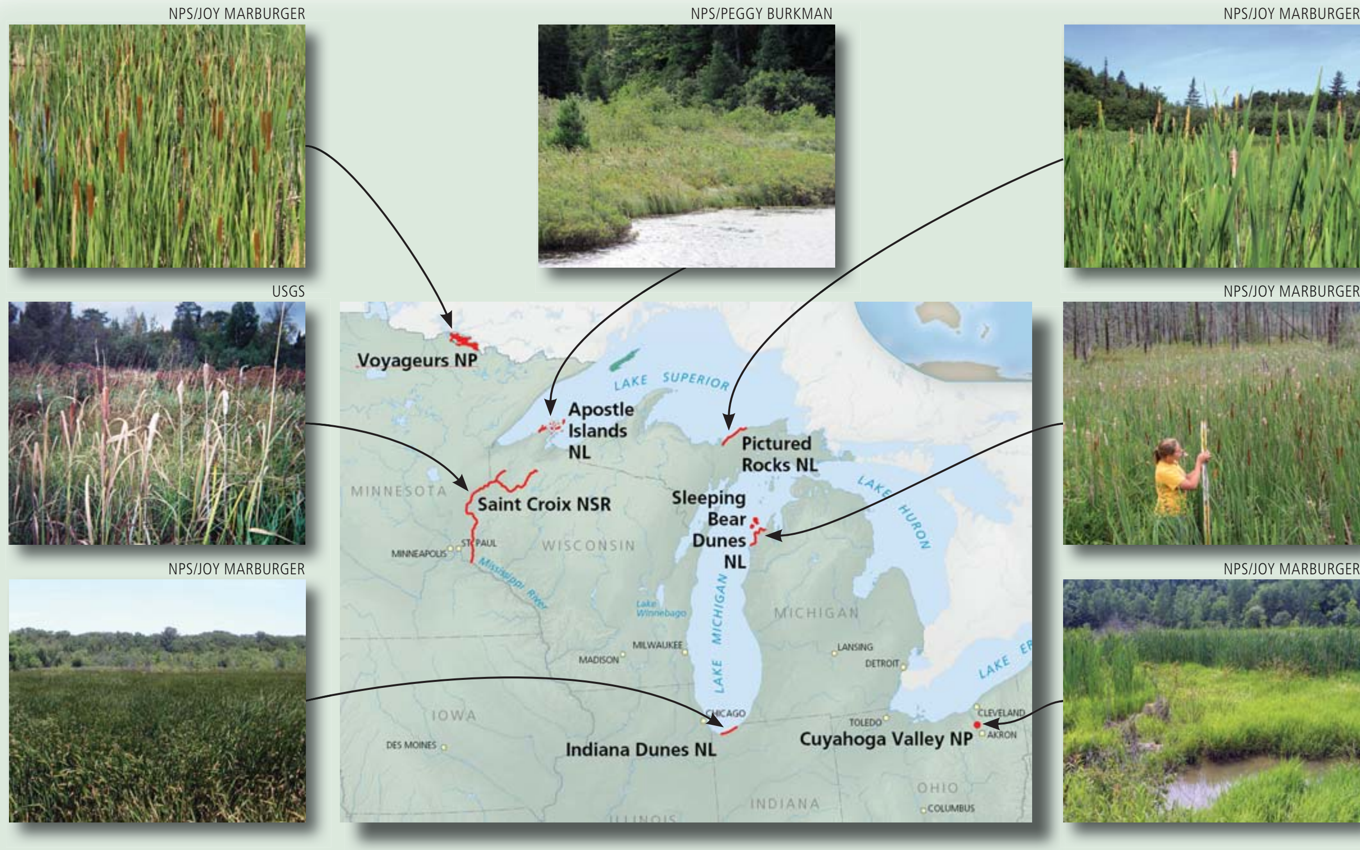


Figure 2. Locations of variable cattail populations in seven Great Lakes national parks.

From 2004 to 2012, park managers and the authors of this article surveyed nine national parks for morphological (form and structure) characteristics of cattails and to collect leaf material for microsatellite DNA marker analysis to determine the presence of *T. latifolia*, *T. angustifolia*, and hybrids. In 2004 we conducted surveys at Indiana Dunes National Lakeshore (Indiana Dunes), St. Croix National Scenic Riverway (St. Croix), and Voyageurs National Park (Voyageurs). From 2006 to 2010 we surveyed Cuyahoga Valley National Park (Cuyahoga Valley) in Ohio, Pictured Rocks National Lakeshore (Pictured Rocks) in Michigan, and Sleeping Bear Dunes National Lakeshore (Sleeping Bear Dunes) in Michigan. Point Reyes National Seashore (Point Reyes) in California and Everglades National Park (Everglades) in Florida were surveyed in 2011 as requested by park managers, and Apostle Islands National Lakeshore (Apostle Islands) in Wisconsin was added in 2012. In addition to the genetic surveys, we conducted a seed bank survey at Cuyahoga Valley, Pictured Rocks, and Sleeping Bear Dunes to determine if native wetland plant species were dormant in the seed bank. In this article we present molecular and seed bank results for these parks in the Great Lakes Inventory and Monitoring Network (fig. 2).

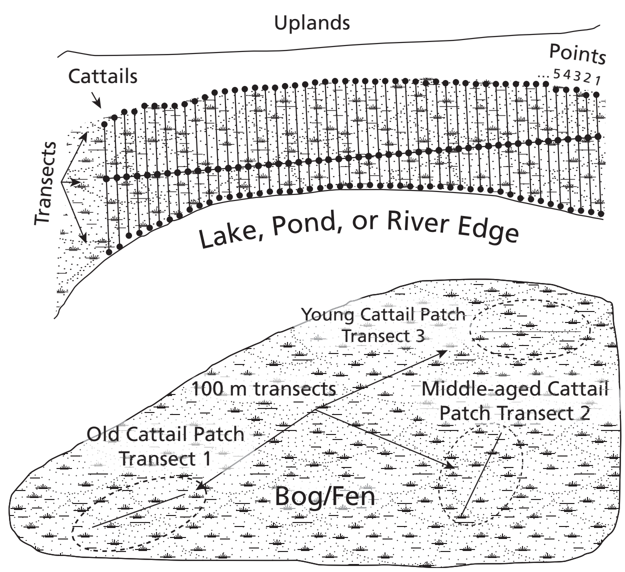


Figure 3. Cattail collection method was based on habitat classification as lake, pond, river (Apostle Islands, Cuyahoga Valley, Pictured Rocks, St. Croix, Sleeping Bear Dunes, Voyageurs), or bog/fen (Indiana Dunes). We sampled 25–50 plants per transect in all cases except for Pictured Rocks (14 plants per transect).

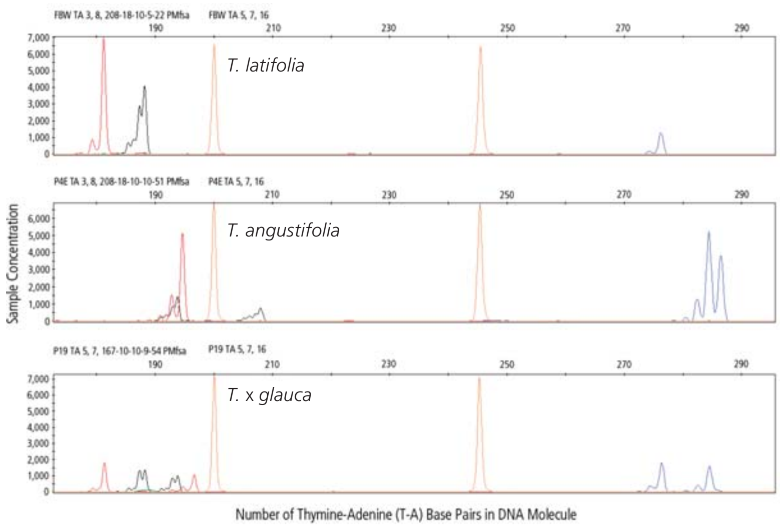


Figure 4. Standard DNA microsatellite graph showing detection of *Typha latifolia*, *T. angustifolia*, and hybrid *T. × glauca*. Note that the number of peaks for the hybrid includes peaks for both species with one peak of *T. angustifolia* absent. Orange peaks are size standards for DNA base pairs of thymine-adenine. The horizontal axis shows DNA fragment size.

Methods

Adult plant sampling

All sampling sites were located in areas where managers had a question about the identification of cattails. We marked the specific locations using a GPS unit with submeter accuracy. The methods differed somewhat at each site because of logistics, based on whether or not the wetland was near a lake or river or was contained in a bog/fen habitat (fig. 3). For seven Great Lakes parks (Apostle Islands, Cuyahoga Valley, Indiana Dunes, Pictured Rocks, St. Croix, Sleeping Bear Dunes, and Voyageurs) we surveyed one to three 100-meter (328 ft) transects at a particular location in the park. At Voyageurs additional sampling was conducted in isolated lakes. Plants were individually measured every 2 or 4 meters (6.6 or 13.1 ft) along each transect, and a leaf sample was collected from each plant for DNA analysis. We measured more than 1,200 plants, including those from isolated lakes in Voyageurs, and collected leaf samples at all sites for DNA analysis.

Data collection

Adult plants—morphology

We measured each plant collected along the transects in centimeters for plant height, leaf width at the widest point, female inflorescence length and width, and gap length (the length of these three features for plants in flower). We collected 15 centimeters (6 in) of a mature healthy leaf from each plant for genetic analysis. We cut leaf material with scissors and placed it in a sealed plastic bag labeled with park name, date, location, transect, and point. The leaves were kept inside a soft-sided lunch cooler with a frozen ice pack to prevent heat damage. After completing data and plant collections at a site, we shipped leaf materials via overnight carrier for molecular analysis. In the lab, the leaves were frozen at −80°C (−112°F) until genetic analysis could be conducted.

Genetic analysis to determine identity of plants

We used molecular techniques employing microsatellite DNA based on previously developed methods to identify each plant's relatedness via clones of the same plant, since cattails spread by underground rhizomes, and the plant's genetic parentage, whether or not it was hybrid, *T. latifolia*, or *T. angustifolia* (Tsyusko-Omeltchenko et al. 2003; Ball and Freeland 2013). The majority of plants were genotyped using six species-diagnostic DNA microsatellite loci based on techniques previously described (Travis et al. 2010; Travis et al. 2011; Tsyusko-Omeltchenko et al. 2003). Figure 4 shows typical results of microsatellites for *Typha* taxa.

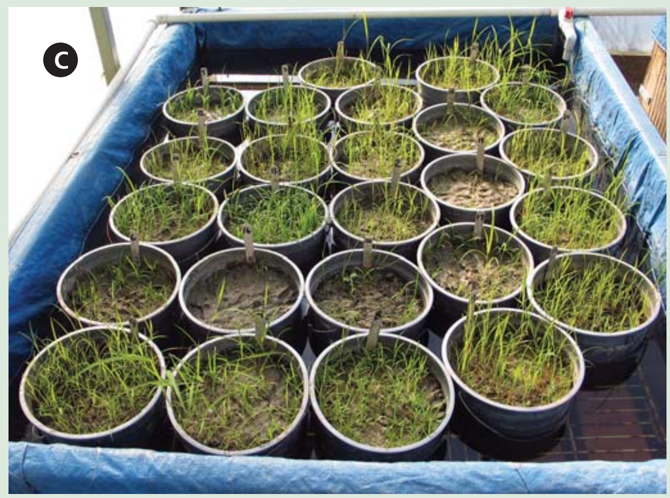
Seed bank samples

Seed bank samples were obtained at Cuyahoga Valley, Pictured Rocks, and Sleeping Bear Dunes to determine the proportion of cattail seeds in the soil where adult plants had been surveyed and to determine the biodiversity of native plants in the soil seed bank that could provide information relevant to management strategies. Soils were classified by type at each site for each park and sampled to determine the nature of plant biodiversity at the sites. Each soil core was about 10 cm (4 in) in diameter and 20 cm (8 in) in depth and was collected using a golf turf auger (see sidebar, next page). Soil samples were collected in sealed plastic bags along the middle transect every 4 meters (13 ft) at each site. Twenty-five sample cores were taken in Cuyahoga Valley and Sleeping Bear Dunes, and 14 were taken at Pictured Rocks. We used the auger because it causes less compression of soils and has the capacity to cut through highly fibrous material (recommended by D. Mason, botanist, Indiana Dunes National Lakeshore). Soils were stored in a portable cooler during transport and kept in a refrigerator at Indiana Dunes until prepared for the seed bank study on 11 June 2009.

The genetic nature of germinated cattail seedlings was also determined using the same techniques as for adult plants. We removed cattail seedlings and individuals from each bucket and placed them in plastic bags labeled with park, date, location, transect, and bucket number. We shipped them in an insulated cooler with a frozen ice pack by overnight mail to the principal investigator at the University of New England for genetic analysis. Plant

Soil seed bank analysis methods

We analyzed the seed bank at three parks (Cuyahoga Valley, Pictured Rocks, and Sleeping Bear Dunes) using the following methods adapted from van der Valk and Davis (1978) and Egan and Ungar (2000). (A) Soil was collected with a golf course soil auger. (B) Commercial plastic buckets measuring 25 cm in diameter × 25 cm in depth (10 × 10 in) were filled 75% with commercial sand. Four holes were drilled in each bucket about 2.5 cm (1 in) above the bottom. Each container was labeled with a permanent marker indicating the soil core sample and where it was taken along the transect. After removing debris (twigs, stones), we homogenized the soil sample and placed it on top of the sand. We washed the tools with well water between making sample additions to the buckets. (C) We then randomly placed the buckets with the seed bank soil samples in plastic-lined tanks (2 sq m or 22 sq ft) in a greenhouse at Indiana Dunes and maintained the samples with well water sufficient to saturate the soil, but with no standing water. We evaluated the samples for the number of seedlings and identified each to species as the plants matured.



NPS/JOY MARBURGER (3)

seedlings of all species in the seed bank were identified from both vegetative and flowering structures using standard plant taxonomic keys.

Results and discussion

Midwestern national parks

Morphological characteristics and water depth proved to be unreliable indicators for species identification in most populations. A number of natural and anthropogenic factors can cause morphological variation and hinder identification: (1) two genetically variable, outcrossing (cross-pollinating) cattail species produce various kinds of hybrids because of random mating; (2) proximity of a site to all seed sources; (3) site soil conditions; (4) hydroperiod (water depth and fluctuation); (5) land use characteristics such as proximity to roads and waterways, and (6) geographic location of a site. Human-related disturbance allows translocation of species, and habitat modifications accelerate rates of hybridization or transfer of genes to related species (Allendorf et al. 2001).

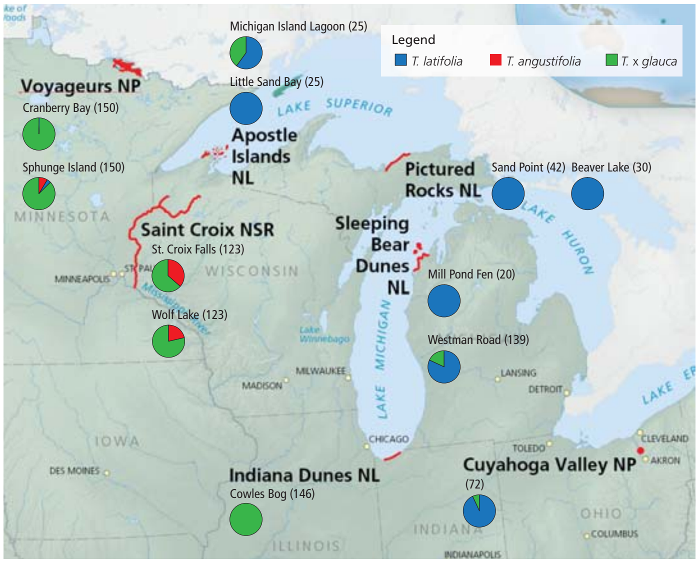


Figure 5. Based on eight nuclear and chloroplast microsatellite markers used in genetic analysis, all parks except Pictured Rocks showed some degree of cattail hybrids present. Pictured Rocks plants were identified as *Typha latifolia*. Numbers in parentheses represent the total stems genotyped at each study site.

The results of genetic analysis of adult and seed bank cattail populations in the seven Great Lakes national parks (fig. 5) provided important insight into the extent and amount of variation among the hybrids, particularly the variation found in the first set of three parks (Indiana Dunes, St. Croix, and Voyageurs). St. Croix and Voyageurs had backcrossed and advanced-generation hybrids in addition to first generation hybrids (F1); Indiana Dunes Cowles Bog had only F1 hybrids. Apostle Islands, Cuyahoga Valley, Sleeping Bear Dunes, Pictured Rocks, and Voyageurs had small populations of the native cattail species occupying small isolated lakes and ponds or island lagoons (Travis et al. 2010, 2011; unpublished data). *T. angustifolia*, the nonnative species, was found in St. Croix and Voyageurs. The results for Sleeping Bear Dunes showed the presence of *T. latifolia* (the native species) in both the adult and seed bank populations, with a few hybrids; one nonnative *T. angustifolia* was present in the seed bank. The populations at Cuyahoga Valley were re-analyzed with two additional microsatellite markers (total 8) and one chloroplast (photosynthetic structures in plant cells) DNA marker (Ball and Freeland 2013) that confirmed the presence of hybrids, although most of the plants were identified as *T. latifolia*. The results presented here reflect the genetic makeup of only the sampled populations, not all the cattail populations in a park. Random mating of species and hybrids could produce different genetic results for other populations. Using morphological and molecular markers, Snow et al. (2010) found a trend of morphological traits that suggested that hybrids and backcrossed generations favored nonnative *T. angustifolia*.

Because of the high cattail genetic variability among parks in the NPS Midwest Region, molecular identification techniques are currently the only reliable method to identify cattail taxa, although use of pollen morphology has been suggested as another identification method (Dugle and Copps 1972; Smith 1987).

Seed bank studies revealed the nature of plant biodiversity in each park site that was evaluated. The cattail taxa and seed bank response were unique to each site. Cattail seedlings were grouped as *Typha* spp. and seedlings from each park were randomly subsampled for genetic analysis. Seed bank results are summarized in fig. 6 (next page). Native wetland plant species, such as dicot herbs, grasses, sedges, and rushes, were represented in the soils of all the parks, but percentages varied widely. Number of cattail seedlings germinating from the seed bank also varied considerably, with the greatest number occurring in Cuyahoga Valley (59%), followed by Pictured Rocks (25%) and Sleeping Bear Dunes (3%).

Cuyahoga Valley National Park

Here, the most common species in the seed bank was cattail (*Typha* spp.), which comprised nearly 60% of all species observed. The most common wetland species other than cattail was rice cut-grass, *Leersia oryzoides*, which comprised about 33% of the seed bank.

Pictured Rocks National Lakeshore

In this park the most common species was *Symphyotrichum lanceolatum*, an aster, which comprised almost 58% of the seed bank. This was surprising since the aboveground plant population was dominated by sweet gale, *Myrica gale*. A rush, *Juncus acuminatus*, was fairly common, representing about 11% of the seed bank. Cattails (*Typha* spp.) comprised 25% of the seed bank.

Sleeping Bear Dunes National Lakeshore

The most common species were sedges, *Carex* sp., and rushes, *Juncus* sp., which comprised almost 81% of the total number of species and individuals. Late boneset (an aster), *Eupatorium serotinum*, was fairly common, representing about 9% of the seed bank. Only about 3% of the species in the seed bank were cattail seedlings. The fact that *Carex lurida* occurred in 57% of the seed bank recruits at Sleeping Bear Dunes indicated that some *Carex* species do persist in wetland soils until favorable conditions allow them to germinate (van der Valk and Davis 1978).

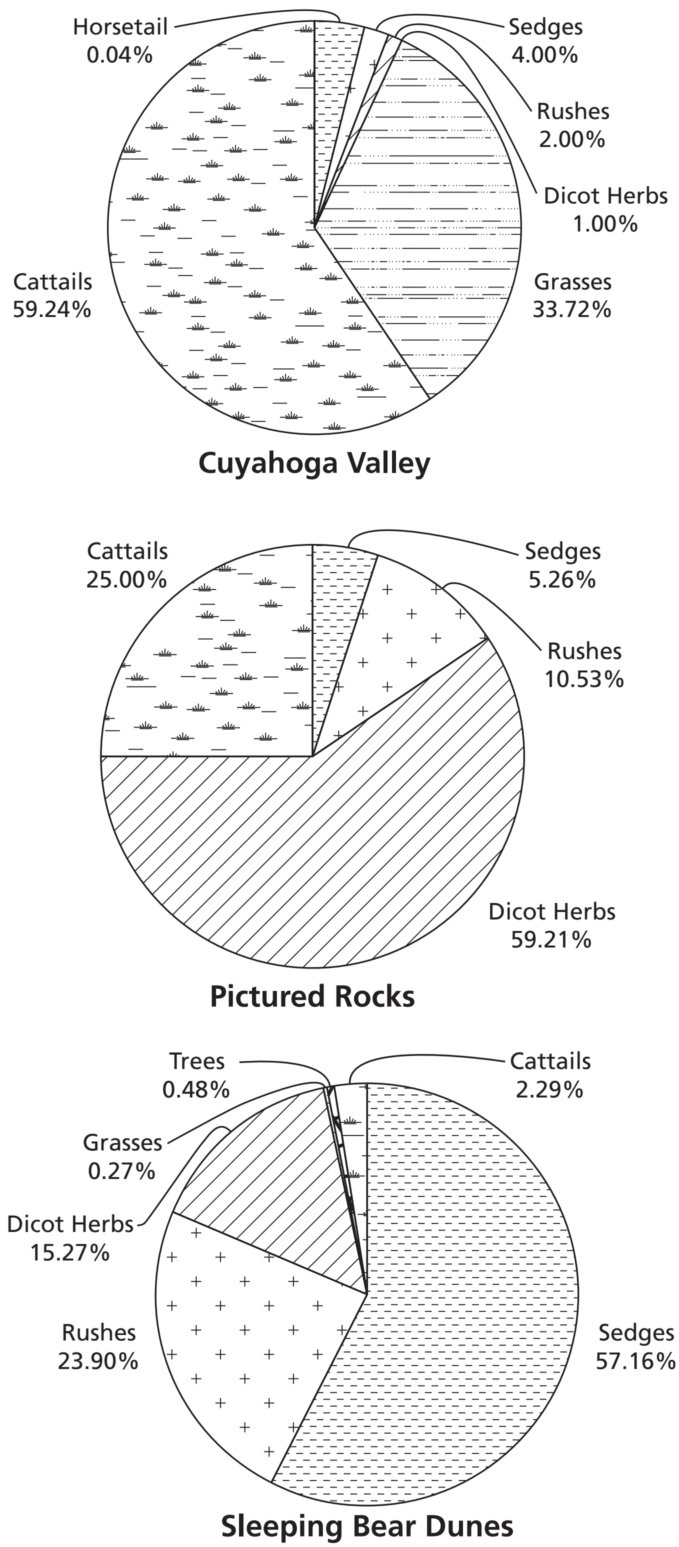


Figure 6. The pie charts show the percentages of plant species groups developing from the seed bank in three parks. The unique character of the seed bank at each park reflects the influence of environmental factors such as hydrology, proximity to source plants, and soil conditions.

Implications of restoring wetlands in national parks

Is native *Typha latifolia* being eliminated as a distinct species through hybridization and introgression of genes from the introduced *T. angustifolia*? The harmful effects of hybridization have led to the extinction of many populations of plant and animal species (Allendorf et al. 2001). In this case interspecific hybridization appears to be driven more by human-influenced than by natural evolutionary mechanisms. Landscape changes that result from urbanization and agricultural development have brought about wetland disturbances that promote plant invasions. The movement of plants across the landscape via human-made canals and waterways through the Laurentian Great Lakes states has promoted expansion of *T. angustifolia* westward from the North American coastline (Gallatowitsch et al. 1999). Hybridization of cattail species and clonal spread may thus be a considerable force in their expansion in wetlands of Great Lakes national parks (Travis et al. 2011).

More extensive investigations are needed of the occurrence and rate of hybridization at other locations within and outside of the national parks. Limitations of the previous studies include insufficient number of diagnostic markers to detect all the various hybrid types in a park and to detect parental differences. Since cattails are primarily a cross-pollinated genus, random mating within a population with both the native and nonnative species present can result in hybrids carrying any percentage of the nonnative genes. Can the native *T. latifolia* be "rescued" from introgressive genes from *T. angustifolia*? This approach may be possible where populations consist primarily of parental individuals and first-generation (F1) hybrids, as long as sufficient large numbers of diagnostic markers are examined to ensure that the species is pure (Allendorf et al. 2001). This is possibly the case for Voyageurs, where we identified cattail populations of native *T. latifolia* in isolated lakes. At Indiana Dunes, on the other hand, all the plants surveyed in Cowles Bog appeared to be primarily F1 hybrids and no native *T. latifolia* could be rescued. Before restoration of a site, cattail genotypes should be evaluated and the seed bank assessed to determine management strategies.

Research reveals that many sedge species (*Carex* spp.) do not persist in the seed bank over time under unfavorable germination conditions (van der Valk et al. 1999). In this pilot study of the seed bank in three parks, we detected *Carex* spp. only in Sleeping Bear Dunes. Other native forbs and grasses were evident, especially in the Sleeping Bear Dunes seed bank. This indicates that even in highly invaded sites, such as Indiana Dunes and Cuyahoga Valley, the seed bank can be a source of native plants once the cattails have been removed (discussed in next section). However, the array of native species varies widely and wetland managers often supplement the seed bank by planting both locally harvested seeds and container-grown plants, especially the sedges. Container-grown plants have better establishment success when transferred to field conditions. Planting of native material from nursery stock is also applied to enhance biodiversity.

Even with the presence of *Typha* taxa, the seed bank in the sampled sites reflected a diversity of native wetland plant species. Thus, removal of cattails, even those of questionable parentage, could result in a fairly diverse native wetland population. However, several cycles of cattail removal would likely be required, since seeds germinate at various time periods because of variation in seed dormancy and environmental conditions.

One of the critical questions that remains is to what degree the spread of *T.* × *glauca* or hybrids is dependent on human-related disturbance such as altered hydrology and elevated nutrient levels (Wilcox 2011; Woo and Zedler 2002), or whether or not hybrid vigor alone would be sufficient for the evolution of cattail invasiveness. A controlled, scaled-down approach to the elucidation of the relative roles of constant vs. variable water levels, high vs. low nutrient levels, and low vs. high levels of competition with native wetland taxa in the spread of *T. latifolia*, *T. angustifolia*, and *T.* × *glauca* and its respective backcrosses would greatly elucidate the roles of environment and genetics in cattail invasions.

Management of cattails in Great Lakes national parks

All *Typha* species can reproduce sexually by wind-dispersed seeds (achenes) and by growth of underground stems called rhizomes. The hybrids often have fertile seeds, but much of their aggressive spread is by clonal growth of rhizomes from the parent plant. Various methods have been used to control cattails in wetlands to preserve wildlife habitat and plant diversity. Controversy has surrounded the setting of appropriate conservation policies to deal with hybridization and introgression (Allendorf et al. 2001). Any policy that deals with hybrids must be flexible and must recognize that nearly every situation that involves hybridization is different enough that general rules are not likely to be effective. Each park with cattail populations could develop a vegetation management plan based on cost-benefit analysis of cattail removal.

The seed bank can be a source of native plants once the cattails have been removed. . . . Planting of native material from nursery stock is also applied to enhance biodiversity.

Management questions

1. Is there an acceptable proportion of mixtures of cattail taxa? Should a certain proportion of exotic and hybrid cattails be allowed to persist in wetlands managed by the National Park Service?

2. Can parental individuals of native *T. latifolia* be "rescued" from hybrid and exotic populations?

3. What management strategies are used to control cattail populations?

4. What is the trade-off between cost to remove large monotypic stands of cattails and cost of prevention of small hybrid populations from expanding?

Items 1, 2, and 4 require more applied research that can guide management decisions. To address the third question, several methods are currently in use to control cattails. The list in table 1, next page, provides a summary of these methods obtained from several sources (Buele 1979; Comes and Kelly 1989; USACE ERDC n.d.a; Wisconsin Department of Natural Resources 2013).

Summary and future research

The recent research on cattail hybridization in North America shows the pattern of a supposedly introduced species, *T. angustifolia*, spreading over the landscape (Galatowitsch 1999) and hybridizing with a native species, *T. latifolia*, resulting in hybrid swarms of mixed genotypes with morphological characteristics of both species or resembling one or the other species. The hybrids also exhibit more robust growth than both parental species, which reduces plant biodiversity (Farrer and Goldberg 2009; Snow et al. 2010; Travis et al. 2010, 2011; Tuchman et al. 2009; Woo and Zedler 2002). Although this body of work explores the nature of cattail populations from genetic and ecological perspectives, there are no models that predict the mechanisms and

Table 1. Cattail management methods

Method	Description
Animal grazing	Muskrats mostly on stems and rhizomes, and geese on young plants. This approach does not control cattail expansion because of the variable number and activity of the animals feeding on rhizomes and seedlings.
Hand pulling	This method works in very small sites on young plants with no extensive rhizomes. It also works for controlling seedling establishment in small areas newly invaded by cattails. It is labor-intensive and requires frequent visits to a site because the seedlings germinate at various times and begin producing rhizomes shortly after germination.
Mechanical-physical methods	
Crushing, cutting, shearing, disking	This works temporarily to create openings, but both native and nonnative species, including cattails, may become established in these openings. Rhizomes must be damaged to an extent that they do not regenerate, which is difficult since they are below the ground surface. Cutting or disking can create more propagules that can resprout during wetter conditions. This method is often combined with water-level management (drowning sprouts) and herbicide treatment.
Water-level management	Water-level management is highly effective where water-level control technology exists in a managed wetland, such as pumps, canals, and levees in a restoration site. Drawdown of water accompanied by herbicide treatment greatly reduces standing live material. Drawdown can occur naturally during the dry season when herbicides can be applied to large areas using an amphibious or all-terrain vehicle. Flooding cattail plants may also be effective if the entire plant is covered with water. In order for this to be effective, cattail stems must be cut or removed and flooded to at least 0.3 m (1 ft) above the cut stems for at least a few weeks to kill the plant.
Chemical control	National Park Service–approved herbicides (applied mid- to late-summer at plant maturity, but before seed dispersal) must be used according to product label and NPS guidelines for protected areas and sensitive organisms. Herbicides should not be stored in steel containers, since they may chemically react with the metal to produce explosive hydrogen gas.
Glyphosate	Glyphosate is a systemic herbicide that is transported through the plant and preferred for cattail treatment. It is approved for use by the National Park Service. It kills plants by interfering with photosynthesis, and therefore must be applied with great caution. A "sticking" agent is required in the formulation for application to cattails in aquatic environments to prevent water pollution. Formulations depend on the extent of cattail invasion. For single plants, a "glove of death" can be used to apply the herbicide. A manager wears an outer glove made of cloth, preferably cotton, that is saturated with herbicide, along with an inner glove of rubber or other impenetrable material to prevent skin contact. Herbicide is applied directly to the stems and leaves. For large populations, spraying (backpack, overland vehicle, air boat, helicopter, plane) is preferred, as it is effective, but there is risk of over spraying nontarget plants.
Diquat	Diquat is a contact herbicide that does not travel through the plant and is therefore not as effective as glyphosate. It also requires the addition of a "sticking" agent in aquatic environments to prevent water pollution. There are more restrictions for its use on public lands.
Prescribed burning	Use of prescribed fire to control cattails has mixed results. It burns off the top growth during a drawdown, but the rhizomes generally survive and can resprout, leading to recolonization of a site unless herbicides are applied to the aboveground stems. Under drier conditions, burning can cause subsurface peat fires that can result in extensive damage to soil structure and cause soil subsidence.
Combination of treatments	Depending on the particular circumstance, combination treatments are often very effective, such as combining crushing with herbicide application. Cutting stems below the water surface and flooding to at least 0.3 m (1 ft) above the cut surface for one month or more is effective. Removal of aboveground plant material by cutting or herbiciding before flooding is also effective. Repeated spot treatment with herbicides is often necessary after initial treatment because of resprouting of rhizomes and seedling germination.

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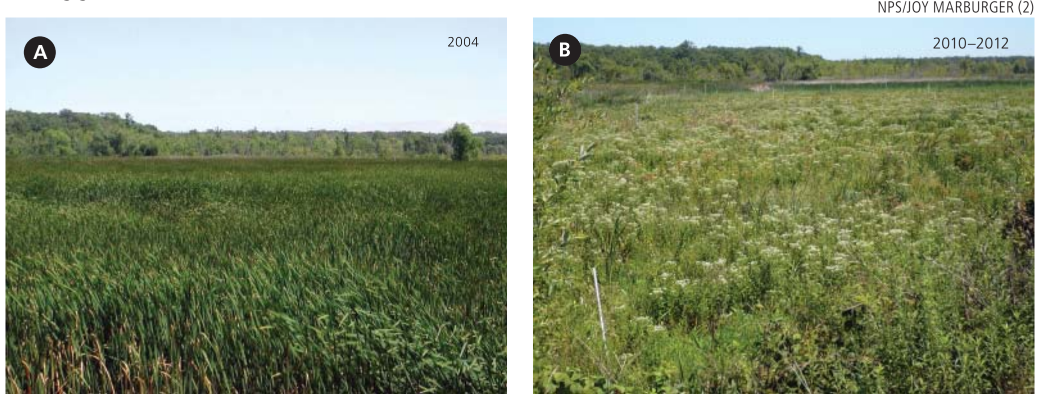

(Photos) Change in wetland vegetation communities after major removal of hybrid cattails in Cowles Bog, Indiana Dunes National Lakeshore: (A) before and (B) after herbicide and mechanical treatment and native plant growth from the seed bank. Restoration practices included cattail treatment with glyphosate herbicide supplemented with planting native plant species and volunteer growth of native plant species from the seed bank.

consequences of invasions caused by cattail hybridization (as well as for other taxa). Managers and scientists need extensive data on hybrid ecology and biology as well as carefully designed field experiments in order to compare parent and hybrid responses to various environmental conditions and to identify potential sites for hybrid zone formation and expansion in wetlands. The following avenues for research exist:

1. Development of additional molecular markers from both nuclear and chloroplast DNA.
2. Determination of the extent of cattail hybridization regionally and nationally, including more detailed summaries of the number of hybrid taxa.
3. Comparison of life history traits, flowering patterns of the species and hybrids, pollen flow, seed fertility, clonal growth, and viable seed production in the taxa.
4. Establishment of seedlings and their growth response to various environments and habitat alterations.
5. Comparison of the ecological effects of cattail hybrids with parental species on biodiversity at various levels of complexity.
6. Management that includes development of rapid hybrid and parental identification as well as various control strategies.
7. Barriers and promoters of hybridization at the molecular, cellular, and landscape levels.
8. Models to predict the mechanisms and routes of hybridization.
9. Climate change impacts on 1–8.

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Acknowledgments

Funding was provided by the U.S. Geological Survey (USGS) Park Oriented Biological Support; National Park Service (NPS) Great Lakes Research and Education Center Internship Program; NPS, Lakewood, Colorado, office of the Water Resources Division; and NPS Midwest Region Regional Block Allocation. We wish to thank the USGS technicians, student interns, volunteers, and park staff at Apostle Island, Cuyahoga Valley, Indiana Dunes, St. Croix, Sleeping Bear Dunes, Pictured Rocks, and Voyageurs for their support and assistance in implementing this project. Staff of the National Park Service who provided permits and helped with the plant and soil collections included Peggy Burkman, Apostle Islands; Sonia Bingham, Cuyahoga Valley; Sue Lehmann, Indiana Dunes; Wendy Smith, GLREC (Indiana Dunes); Robin Mae-rcklein, St. Croix; Lora Loope and Leah Kainulainen, Pictured Rocks; Steve Yancho, Sleeping Bear Dunes; and Steve Windels, Voyageurs.

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PS

Shoreline changes in Jamaica Bay, Gateway National Recreation Area, 1924–2006: Implications for shoreline restoration

By Rebecca Boger, Joseph Essrog, and Mark Christiano

Figure 1. East Pond, Jamaica Bay National Wildlife Refuge.

Abstract

Using aerial photos taken in 1924 and 2006, an analysis of shoreline changes over the past 82 years was conducted within Jamaica Bay, an urban estuary associated with Gateway National Recreation Area, located in the New York City metropolitan area. We applied a 15-category land cover/land use classification scheme of the shoreline. The analysis provides a long-term perspective of how the shoreline has changed in this highly urbanized locality before and after Gateway became a national recreation area in 1972. Gateway has been successful in minimizing changes to the shoreline when compared with nonpark areas. Further, park managers can use this shoreline inventory to identify sections of shoreline that may be appropriate for restoration by allowing former protective structures to deteriorate or by removing them, thereby enhancing the ability of shoreline habitats to migrate landward with sea-level rise.

Key words

land cover/land use changes, national park–college partnerships, shoreline, urban estuary

GATEWAY NATIONAL RECREATION AREA (GATEWAY) is one of the few national park areas in the United States that is located in a highly urbanized area and accessible to a large population by public transportation. The Jamaica Bay estuary, located within Gateway, has a long history of development pressure, with 43% of the 103 miles (165 km) of shoreline occupied by a variety of structures (e.g., bulkheads [seawalls] and riprap; Boger et al. 2012). Despite this intensive development, the bay supports diverse coastal habitats and large numbers of migratory species (fig. 1, above, and fig. 2, next page).

The bay's islands and fringing salt marshes are rapidly declining and are converting to mudflat and open water. Numerous factors associated with the urban environment are thought to be contributing to the salt-marsh loss, including nutrient enrichment, dredging, sediment depletion, increased tidal ranges, and sea-level rise, among others (Benotti et al. 2007; Hartig et al. 2002; Swanson and Wilson 2008; Wigand et al., *in press*). Shoreline development likely contributes to marsh loss in Jamaica Bay because the landward migration of marshes, a natural response to sea-level rise, is halted by shoreline structures (e.g., Donnelly and Bertness 2001).

Figure 2. Jamaica Bay is the largest of three units comprising Gateway National Recreation Area. The study involved analyzing changes in land use/land cover along the shoreline of Jamaica Bay, both within and outside the national recreation area.

Gateway has identified a more natural shoreline as a goal in the draft General Management Plan/Environmental Impact Statement (GMP/EIS) in order to "maximize ecosystem functions such as habitat for wildlife, connectivity between the bay and upland habitats, and natural processes such as sediment transport and shoreline migration" (NPS 2013, chapter 2, p. 60). Given the extensive development, Gateway proposes the removal of selected hard structures and restoration of natural shoreline features.

Monitoring the status and trends of resources is critical to achieving the goal of creating a more natural shoreline in a highly modified estuary. Of particular interest for this study is the type of land use/land cover (LULC) along the shoreline, the interface between aquatic and terrestrial habitats. Given the extensive modification of natural environments since European colonization of the area in the 1600s, Gateway inherited a legacy of infrastructure and other land use changes that compound the problems park managers face today from environmental pressures such as pollution, sediment depletion, and invasive species. Boger et al. (2012) documented LULC along the shoreline in Jamaica Bay in 2006 and compared it with periods before and after the creation of Gateway in 1972. The classification techniques they developed are being used to help assess the extent of human impacts on the shoreline and ultimately to assist in planning for mitigation projects. The purpose of this article is to expand the historical analysis of the shoreline to 1924 in order to give park managers a longer-term perspective of shoreline changes to assist in the identification and prioritization of suitable sites for restoration and rehabilitation of natural shoreline features.

Methods

Shoreline position and LULC classification based on the 1924 aerial photos followed procedures described by Boger et al. (2012) for their analysis of the 1951, 1974, and 2006 imagery. The 1924 photos were acquired through the New York Bureau of Engineering and are available at the New York Public Library (http://digitalgallery.nypl.org/nypldigital/dgkeysearchresult.cfm?parent_id=855142). Using a geographic information system (GIS), we georeferenced the 1924 photos with the rectified 2006 aerial photo data set and a data set of buildings created by the New York City Department of Information Technology and Telecommunications (DOITT). The building data set has a horizontal spatial accuracy of ±2 feet (0.6 m). In addition to the 2006 aerial photos for the Boger et al. (2012) analysis, we used 2008 U.S. Geological Survey orthoimagery available at seamless.usgs.gov. Despite the great number of modifications that have been made to the shoreline since the 1924 photos, we were able to locate several common points among the 2006, 2008, and building data for use in georeferencing the 1924 photos. When georeferencing, we were not satisfied with fewer than 10 data points and worked toward identifying 20 or more in order to seek the least RMS (root-mean-square) error possible.

Once we had rectified the 1924 base imagery, we drew the shoreline and classified its segments as one of 16 possible categories (table 1, next page). We modified the Boger et al. (2012) classification scheme to include an agricultural category, an LULC classification that did not exist in the 1951, 1974, and 2006 imagery, but was present in 1924. At that time agriculture was scattered at various locations around what is now the urban New York City metropolitan area, with the entire agricultural shoreline length less than 1.2 miles (2 km). Although agriculture is an example of human modification, we included it as a natural vegetation class when comparing changes over the years.

After completing the shoreline analysis, we exported the data from GIS software to a spreadsheet program for summarization and to create charts. We then examined the LULC for the entire Jamaica Bay shoreline and for changes that have occurred (1) within the national recreation area boundary, (2) within the bay only (i.e., without the creeks), and (3) along the many creeks that feed into the bay.

Results and discussion

In 1924 a large portion (29.72%) of the Jamaica Bay shoreline had already been developed (table 2, page 73). Then, as a result of further development between 1924 and 2006, there was a large loss of vegetated shoreline while both sandy shoreline (excluding creeks) and developed shoreline made gains (fig. 3, page 73). Overall, undeveloped shoreline (sand and vegetation combined) decreased from 1924 to 2006 by approximately 13% for the entire study area. It is important to keep in mind, though, that we mapped only the shoreline and that intense development often occurs immediately landward of the undeveloped shore, as can be seen in the 1924 and 2006 aerial photos. Within Gateway, the decrease in undeveloped shoreline is only 10%, with 70% of that change taking place from 1924 to 1951. Creeks lost more than 16% of both sand and vegetated (undeveloped) shoreline, reflecting the rapid development of the upland areas surrounding the bay that began in the late 1920s. Jamaica Bay, meanwhile, experienced a 14% rise in bulkhead construction since 1924.

The photomosaics shown in figs. 4A and 4B on page 74 present the georeferenced aerial photos taken in 1924 and 2006, respectively, and serve as examples of the final products for all years examined in this study. From 1924 to 1951, sand beaches increased in extent while vegetated shoreline decreased. This was followed

Collaboration

The Department of Earth and Environmental Sciences at Brooklyn College of the City University of New York (CUNY) works closely with Gateway staff on a variety of research and education projects. The Department of Earth and Environmental Sciences is revising many of its programs and encourages activities that involve students working with local organizations on place-based projects that have meaningful applications. Education research reveals that exposure to science research that is collaborative, place-based, and of local relevance encourages students to pursue science, technology, engineering, and mathematics (STEM) careers, particularly for under-represented groups, which comprise a large percentage of the student body at Brooklyn College (Connell et al. 1995; Lemke 2001; Roth and Tobin 2007; Rumberger 2004). By working on internships, course term projects, or individual research involving local organizations, students recognize the usefulness of their skill development (Edelson et al. 2006) and become motivated by being exposed to career opportunities. This in turn improves student recruitment and retention (Miele and Powell 2010). The National Park Service is also interested in attracting qualified science students to pursue careers in resource stewardship and fosters collaboration with educational institutions that develop students with STEM skills. Thus project collaborations such as that described here are a win-win situation in which both collaborators are able to fulfill their respective goals and objectives.

Table 1. Classification scheme for land use/land cover analysis of Jamaica Bay shoreline, 1924

Classification	Human Modified or Undeveloped	General Class	Description
Residence	Human Modified	Structure	One or a series of residential structures directly on the shoreline
Commercial	Human Modified	Structure	One or a series of commercial buildings or lots directly on the shoreline
Parking Lot	Human Modified	Structure	Stand-alone parking lot directly on the shoreline
Bridge	Human Modified	Structure	Base of a bridge that extends out over water
Dock	Human Modified	Structure	Dock or boardwalk built directly on the shoreline
Pier	Human Modified	Structure	Base of a pier that extends out over water
Road	Human Modified	Road	Paved or unpaved road built along the shoreline
Beach Developed	Human Modified	Structure	Bare sand beach within 50 meters (164 ft) of development
Steel Concrete Bulkhead Vegetation*	Human Modified	Bulkhead	Steel or concrete bulkhead or riprap in front of vegetated area
Steel Concrete Bulkhead Developed	Human Modified	Bulkhead	Steel or concrete bulkhead or riprap in front of developed site
Rock Bulkhead Vegetation	Human Modified	Bulkhead	Rock bulkhead in front of vegetation
Rock Bulkhead Developed	Human Modified	Bulkhead	Rock bulkhead in front of developed area
Other	Human Modified	Structure	Other human modification
Undeveloped Sand	Undeveloped	Sand	Bare sand beach in front of vegetation
Undeveloped Vegetation	Undeveloped	Vegetation	Vegetation growing directly on the shoreline
Agriculture	Human Modified	Vegetation	Vegetation grown for food production

* Bulkheads are also called seawalls, a form of coastal defense.

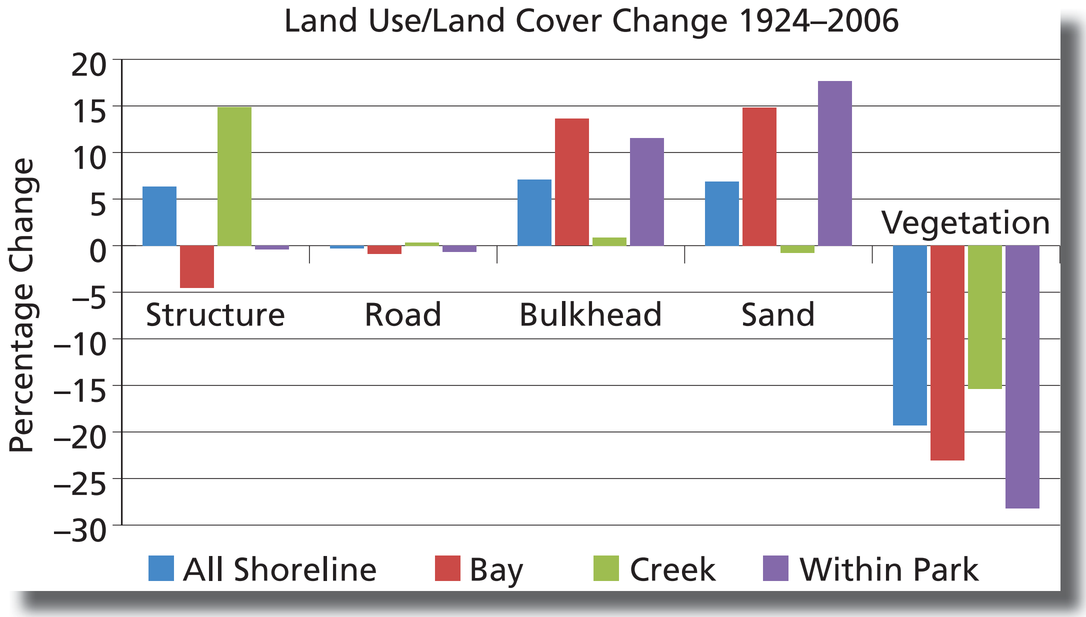

Figure 3. Land use/land cover change 1924–2006.

Table 2. Percentages of LULC for 1924 and 2006

	1924		2006	
Classification	All Shoreline (%)	Within Park (%)	All Shoreline (%)	Within Park (%)
Human Modified*	29.72	19.91	42.87	30.42
Residence	10.18	8.30	10.14	8.98
Commercial	2.84	1.64	12.02	2.11
Bridge	0.38	0.38	0.48	0.31
Dock	0.56	0.25	0.34	0.12
Pier	0.23	0.10	0.23	0.40
Paved Road	3.14	0.65	2.86	0.00
Beach Developed	3.84	4.45	1.05	2.71
Steel or Concrete Bulkhead (Vegetation)	3.36	2.37	0.78	1.33
Steel or Concrete Bulkhead (Developed)	1.55	0.65	4.00	5.70
Rock Bulkhead (Vegetation)	1.74	0.25	1.07	1.93
Rock Bulkhead (Developed)	1.08	0.34	8.97	6.21
Other	0.85	0.53	0.34	0.00
*Human Modified (reclassified)				
Structure	18.85	15.65	25.19	15.24
Road	3.14	0.65	2.86	0.00
Bulkhead	7.73	3.61	14.82	15.18
Subtotal	29.72	19.91	42.87	30.42
Undeveloped				
Sand	8.79	15.98	15.67	33.67
Vegetation	60.75	64.11	41.47	35.91
Agriculture	0.74	0.00		
Subtotal	70.28	80.09	57.14	69.58
Total	100.00	100.00	100.01	100.00

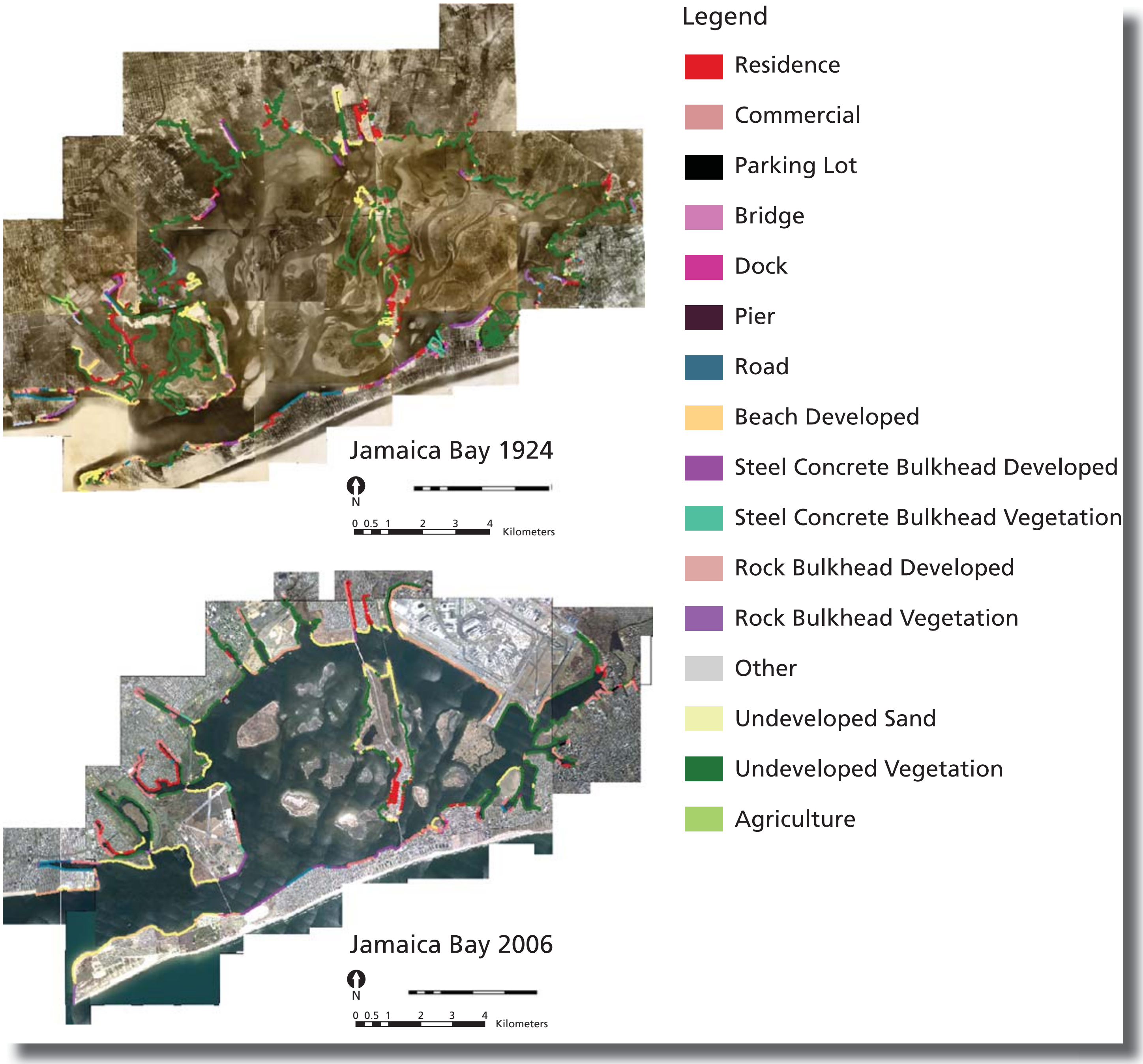

Figure 4A (top) and 4B (bottom). Aerial photomosaics of the Jamaica Bay shoreline in 1924 (A, top) and 2006 (B, bottom).

by the opposite effect, an increase in vegetation and a decrease in sand beaches, from 1951 to 1974. Finally, vegetated shoreline decreased and sandy shore (except in creeks) increased from 1974 to 2006. Major construction projects, such as the building of two airports, have changed the appearance of Jamaica Bay considerably since 1924; however, despite construction of John F. Kennedy International Airport and a number of landfills rimming the bay, relatively little change has occurred in the proportion of human-made features other than bulkheads over the period 1924–2006.

The next phase of the research will delineate historical land use/land cover change along the shoreline of Staten Island, starting with recent aerial photography and then working backward in time as we did with the Jamaica Bay analysis. Additionally, we will develop protocols applicable to more detailed analysis of the changes occurring on the vegetated shorelines. Instead of classifying all natural vegetation as one group, we will differentiate the fringing marshes from other forms of vegetated shorelines. The conversion of sandy beaches to vegetated areas may indicate loss of fringing marshes. A time perspective of fringing marshes along the shoreline can assist in the identification of historical marsh extent and rates of marsh loss. With the expectation of future extreme events like Hurricane Sandy, vegetation may make the shoreline and areas farther landward more resilient by lessening erosion, habitat loss, and damage to human-built structures. As noted by Nordstrom and Jackson (2013), an assessment of the condition of shoreline structures would identify which structures should be left as is, removed, or allowed to deteriorate naturally. As sea level rises, landforms migrate inland, although the urbanized area surrounding Jamaica Bay limits this natural process. Armed with a historical shoreline analysis and a structural assessment, park managers will be better informed to reach their goal of maximizing ecosystem functions (NPS 2013).

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