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This monarch butterfly on a successful invasive plant, purple loosestrife, highlights the altering of plant-pollinator relationships as timing of activities and abundance of species change. Photo: taken at Minute Man National Historical Park by Richard Primack.

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Responding to Climate Change

Parting words from Rick Harris

This is the seventh edition of *Science and Management* produced in the Northeast Region. As this is the last edition I will be associated with, I wanted to thank everyone who contributed articles and had a role in the publication itself. Each edition continues to improve as we have tried to provide a thematic content highlighting the great work being accomplished by staff and those who conduct research in parks. In particular, Betsie Blumberg and John Karish deserve special recognition for their efforts.

It has been a career highlight to be associated with such a cadre of professionals and to facilitate this forum for them to share the incredible work they perform in stewardship of our natural and cultural resources. Thank you all for making this last four years so rewarding for me and I look forward to the continuation of *Science and Management* for many years to come.

Northeast Region Parks Respond to Climate Change

Amanda Babson, coastal climate adaptation coordinator for the Northeast Region

This issue of Science and Management highlights examples of various responses by the National Park Service to climate change from around the Northeast Region (NER). These stories demonstrate that the NER is active in all four integrated components of our Climate Change Strategy and Action Plan for 2011-2014: Science, Adaptation, Mitigation, and Communication. As natural resources are already being impacted by climate change, our understanding of future risks is advancing and many parks are leading the way in developing responses. Foremost, the science to better understand climate vulnerabilities and develop adaptation options is underway. Climate change is a relatively new area for many parks and we are building on Inventory and Monitoring programs as well as citizen science efforts to establish the baseline monitoring necessary to detect change. Where historical data are available, comparisons with past observations can indicate what changes are taking place. Studies to understand the sensitivities of important resources to change will help us assess vulnerabilities and set priorities.

A wide variety of science is described in this issue: marsh bird monitoring, shoreline change monitoring, and changes in phenology. While research needs are extensive, many management actions are already being implemented using the best available science. Some of the management projects described in this issue include movable facilities at Assateague Island National Seashore and investigations into protecting cultural resources at Saint-Gaudens National Historic Site. A salamander study at Shenandoah National Park is a project involving both science and management.

Climate change is a complex issue, with different parks experiencing different impacts and having different capacities to respond. Early action on climate change, such as through the Climate Friendly Parks program, was focused on mitigation (reducing greenhouse gas emissions), but recently adaptation has moved to the forefront for many parks. While climate change may seem like a new, additional, issue on top of many more immediate issues, we all manage in the context of climate. What is new is that past climate will be a less reliable indicator of likely future climate. Most of these articles demonstrate that this change is exacerbating many stressors that we are already managing for. Adaptation options will thus be drawn from current management strategies, such as removing barriers to sediment transport, habitat restoration, storm water management, or rerouting visitor access, and from new approaches that require testing and new ways of thinking.

There are a variety of materials and programs available on climate change. As the Coastal Climate Adaptation Coordinator for the Northeast Region, I am available to support parks addressing climate change. I can provide technical assistance with vulnerability assessments, scoping research needs, scenario planning, and evaluating adaptation options. Many universities and partner organizations, such as the North Atlantic and Appalachian Landscape Conservation Cooperatives and the Northeast Climate Science Center, parts of two major Department of the Interior-led initiatives, are developing the science and tools that will be useful to parks. In addition to the examples included in this issue and other ongoing research projects, new efforts are ramping up. As many parks move forward in addressing climate change, it is important to share success stories and lessons learned; this issue aims to share some examples and start new conversations among parks.

Phenology: Its Time Has Come!

By now, most people managing natural resources in national parks have heard of phenology, the study of the timing of biological events as they go through their annual cycles. As weather patterns change, noting the timing of natural events, such as the arrival of migrating birds, can show us how, and how successfully or unsuccessfully, species are responding to these changes. Because of its value as an indicator and importance to ecosystem functioning, phenology is now a vital sign for the Northeast Temperate Network (NETN).

NETN is currently developing methods of monitoring life-cycle events for selected species in collaboration with science coordinator Abe Miller-Rushing and staff at Acadia National Park's (NP) Schoodic Education and Research Center (SERC). Technology will do some of the monitoring; landscapes are already being surveyed by remote sensing from satellites.Ground-based stationary cameras will be deployed to further monitor green-up, as will acoustic devices for recording birds, frogs, bats, and calling insects. Much of the monitoring, however, will be done by citizen scientists. Research at SERC is being conducted, not only on protocols for monitoring, but also on how best to work with volunteers. Observations can be affected by the age and experience of the monitors; the program can take advantage of these differences by placing volunteers where they can be most effective.

The focal habitats for study at Acadia NP, Boston Harbor Islands National Recreation Area (NRA), Saratoga National Historical Park, the Appalachian Trail, and other NETN parks are vernal pools and hardwood forests, which are ecologically important and occur in virtually all of the NETN parks.

A monarch caterpillar on a milkweed: two species being tracked because of concern that such specialized relationships might be disrupted by changes in phenology. Photo: Abe Miller-Rushing.

Great false leopard's bane, an introduced species, hosts an important pollinator, an adrenid bee. Photo: Abe Miller-Rushing.

The key vegetation indicators to be followed are the development of leaves, flowers, and fruits of red maple, sugar maple, garlic mustard, and white wood aster; key animal indicators are the reproductive cycles of spotted salamander, spring peeper, and wood frog, the tent development of eastern tent caterpillar, and the migrations and reproduction of ovenbird.

Right now, little data have yet been collected to tell us how species are doing under current changing conditions, but we do know that the growing season in Maine (190-200 days) is now 90 days longer than it was 100 years ago (100-110). The longer growing season is affecting carbon and water cycles, altering the amount of carbon stored in trees and soils and the amount of water that plants transpire, which in turn affects soil moisture and stream, lake, and groundwater levels.

The ability to respond readily to changes in phenology is suspected to be one reason that invasive plants are so successful. However, while some species are adjusting their cycles to earlier warming or higher winter temperatures, others are not, a disparity that can have drastic consequences. If the life cycle of a species and that of its food supply are no longer synchronized as they have been, that species will have a hard time surviving. For example, in some locations in the southwestern United States, Edith's checkerspot butterfly, an endangered species, is laying its eggs too late, so that the caterpillars emerge on wilted plants and starve.

Comparing current data to the timing of natural events in the past means accessing a wealth of historical material kept by gardeners, hunters, birders, and others who

recorded observations of interest. Noting the comings and goings of plants and animals was a popular activity in the mid 1800s and early 1900s and these records can be found in diaries saved by family members, museum collections, and in old newspaper "nature" columns. Researchers at SERC are collecting such records wherever they can find them to create a database.

What use is this phenological data to park managers? Managers and interpreters schedule activities around the timing of natural events. To manage some invasives, for example, managers need to know when the plants leaf out or flower. To schedule mowing, they need to know when birds are nesting in the grass so that breeding will not be disturbed. To explain why a species is in decline, they may need to consider the potential for a mismatch in timing between predator and prey or herbivore and plant. Phenology is another source of information managers can use to understand what's happening in the habitats they are stewarding. Interpreters also need this information to schedule outings for visitors to see the mayfly hatch or certain wildflowers in bloom.

Outreach activities at SERC and other educational programs are encouraging citizen scientists to observe and record what's happening around them. Maine's Signs of the Seasons Program organizes volunteers from 4H clubs, Audubon groups, schools, and other sources to monitor a broad range of species found in backyards and schoolyards, such as dandelions, lilacs, and forsythias. Many such groups (including the National Park Service) are collecting data and sharing it through the USA National Phenology Network (http://www.usanpn.org). As citizen scientists become engaged in observing and recording what they see outdoors, they and the public at large are anticipating the insights that these data will yield about how climate change is affecting our world.

Shifting Sands: Monitoring Shoreline Change in Northeastern Coastal Parks

Dennis Skidds, biologist/data manager, Northeast Coastal and Barrier Network (NCBN); Norbert Psuty, director, Sandy Hook Cooperative Research Programs at Rutgers University's Institute of Marine and Coastal Sciences; and Sara Stevens, program manager, NCBN

Anyone who has spent a good length of time on one of the Northeast's many barrier islands soon appreciates the dynamic character of these constantly shifting systems, and one of the most basic and important aspects of these places is the position of the ocean shoreline itself. Storms can overwash dunes and sometimes breach an entire island, creating an inlet where solid land had been only the day before. Global climate change, with its associated effects on sea-level rise and storm characteristics, promises to add yet another layer of complexity to these already dynamic systems.

Figure 1. Structural damage caused by shoreline erosion in the community of Davis Park at Fire Island National Seashore. NPS photo.

The rate and magnitude of change in the location of the shoreline can be a major management concern for parks for a variety reasons (fig. 1). Shoreline position influences almost every aspect of a barrier island's ecology, from the extent and distribution of wildlife habitat for species such as piping plover and seabeach amaranth, to the quality and quantity of available groundwater. Erosional as well as depositional conditions can pose significant threats to the preservation of archeological sites and other cultural resources. Even maintaining basic park infrastructure – a coastal road or a seaside visitor center – can become a major challenge in the face of a changing shoreline.

To make informed, responsible decisions, park managers need information on the magnitude and trends of shoreline displacement, including reliable measurements of erosion and accretion rates in areas containing critical infrastructure or sensitive natural and cultural resources. Recognizing this, the Northeast Coastal and Barrier Inventory and Monitoring Network (NCBN) adopted ocean shoreline position change as one of the primary "vital signs" the network would monitor over the coming years and decades. The overall goals of the NCBN's shoreline position monitoring initiatives are to

- Describe the overall dimensions and rates of change in the shoreline
- Describe seasonal, annual, long-term trends
- Identify areas of significant erosion or deposition
- Provide park staff with the information needed to make effective management decisions.

Shoreline change in the coastal parks of the NCBN is influenced by a variety of factors, both natural and human induced, and many of these factors are themselves being altered under the influence of the effects of global climate change. Seasonal changes in weather patterns, waves, currents, and storms generally result in wider beaches following the calmer summer months and narrower winter beaches associated with the occurrence of winter storms. The nature of the near-shore bathymetry (the ocean depth), longshore sediment transport (the movement of sand parallel to the shoreline), and island overwash events also influence shoreline trends. In addition to these natural drivers, humans have altered the processes of erosion and accretion through the introduction of hardened structures (e.g., seawalls, jetties, groins, revetments, and bulkheads), which cut off sources of sediment coming into the system as well as interrupt the pattern and magnitude of longshore transport.

Global climate change and its associated impact on the rate of sea-level rise in the northeastern United States poses unique problems to monitoring the spatial patterns and persistence of certain coastal habitats. Of particular concern will be the loss of land in coastal areas through erosion and submergence of the coastal landscape, as previously non-vulnerable sites will be exposed to waves, currents, and the impacts of surge penetration. Further, climate change is predicted to lead to changes in storm intensity, frequency, and timing. Due to this wide range of influencing factors (all of which vary from park to park), long-term predictions of shoreline position change are inherently uncertain, and they are likely to become more dynamic and incorporate greater magnitudes of displacement. In order to better understand the overall trends in shoreline change, the NCBN and its partners at Rutgers University's Institute of Marine and Coastal Sciences have developed standardized methods for tracking changes in shorelines over time.

Researchers generally use one of two approaches to address this problem. One method involves the comparison of shorelines derived from remote-sensing products in which a technician or an automated computer program delineates a shoreline using satellite or aerial imagery or elevation models derived from LiDAR data. This method can be very useful in comparing shorelines over large areas or across long time periods when historical imagery is available, but obtaining park-level imagery for long-term, regular monitoring (e.g., once or twice per year) can be prohibitively expensive. Because of this, many monitoring programs, such as NCBN's, utilize a "feature-based" method of mapping shoreline position in the field using GPS technology.

Twice per year – in the spring when the beach is at its most narrow due to the erosional effects of winter storms, and in the fall when the beach has recovered and is at its widest – NCBN and park staff conduct surveys of the neap-tide high-tide swash line (usually discernible as a wet/dry line accompanied by shell fragments or wrack) using a GPS unit capable of sub-meter accuracy, either on foot or mounted on a four-wheel drive vehicle (fig 2). In order to minimize variability in the data, surveys are conducted within narrow sampling windows centering on neap tide to limit the variation caused by tidal level. (A neap tide occurs in the first and third quarters of the moon when the difference between high and low tide is least; the lowest level of high tide.)

Multiple shoreline datasets collected over the course of several seasons or years are then brought into a GIS environment, and shoreline position change is calculated using the Digital Shoreline Analysis System software developed by the USGS. Statistical measures of the changes in the position of regularly spaced points along the shoreline can then be used to describe the overall dimensions and rates of change and to identify areas of significant erosion or deposition where management actions may be warranted (fig 3).

Annual reports produced by the NCBN describe the short-term variation that occurs over the course of three surveys, usually the spring and fall surveys from one calendar year and the spring survey from the following year. These reports are generally descriptive of the seasonal contrasts that support sediment accumulation during summer and erosion during the winter, but can also

Figure 2. The neap-tide high-tide swash line is mapped on foot or by ATV twice per year using GPS units capable of sub-meter horizontal accuracy. NPS photos.

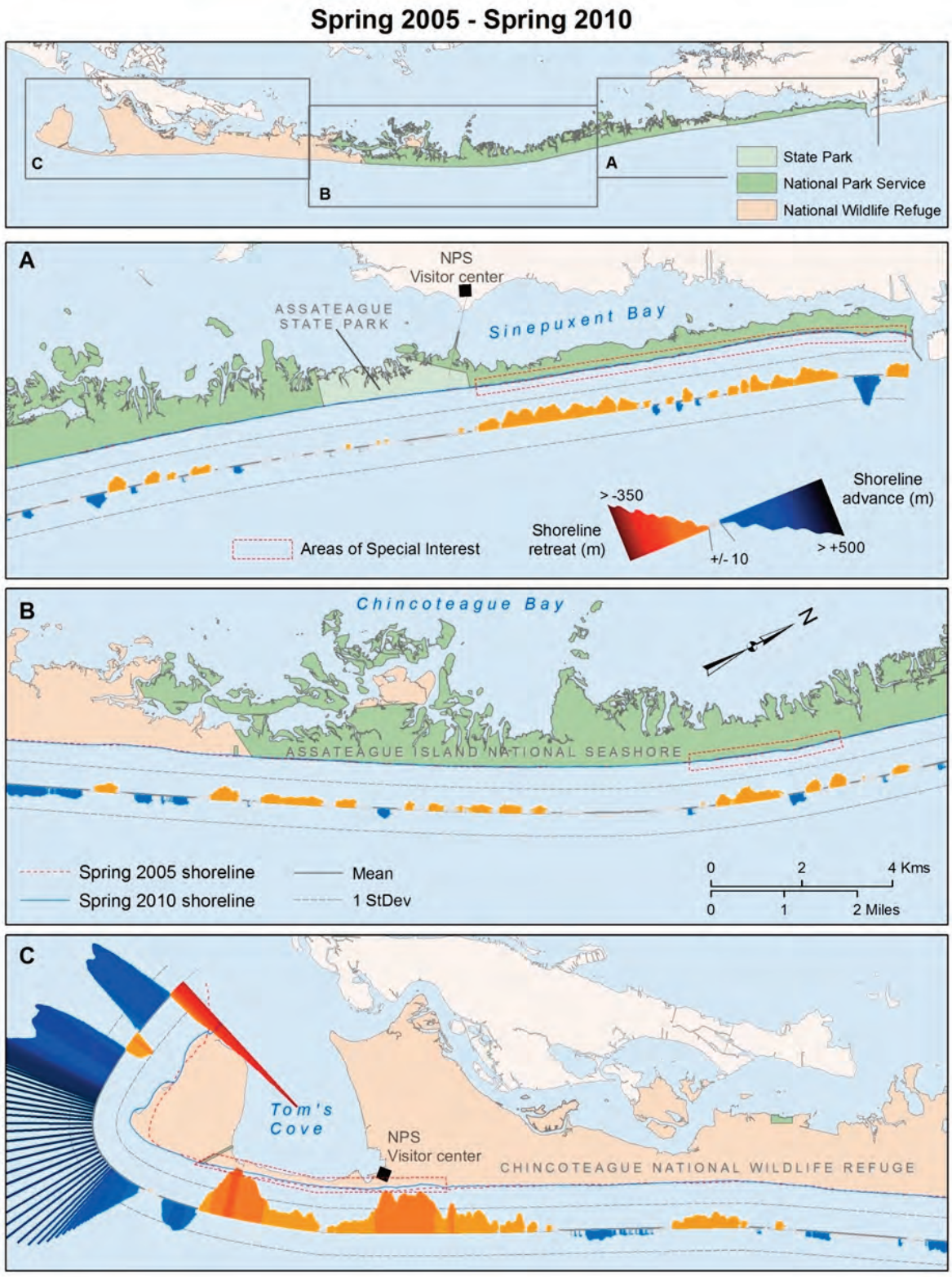

Figure 3. Depiction of long-term shoreline change along Assateague Island between Spring 2005 and Spring 2010 using the program Shoreline Change Mapper (Psuty, N. P., T. M. Silveira, D. Soda. 2011. Shoreline change monitoring at Assateague Island National Seashore: 2005-2010 trend report. Natural Resource Technical Report NPS/NCBN/NRTR—2011/509. National Park Service, Fort Collins, Colorado).

capture the effects of significant storms or human-induced changes from dredging or beach nourishment events. Long-term trend reports, however, are produced whenever at least five years of shoreline data have been collected for a given park. In addition to the seasonal comparisons described in the annual reports, these documents include more robust trend analyses, as well as scientific interpretation and management implications of the observed trends.

This NCBN shoreline monitoring protocol is currently being implemented in six network parks (Assateague Island, Cape Cod, and Fire Island National Seashores; Gateway National Recreation Area, George Washington Birthplace National Monument, and Sagamore Hill National Historic Site), allowing for a comprehensive analysis of shoreline change that is regionally consistent. The NCBN has also partnered with the U.S. Fish and Wildlife Service's newly created Inventory and Monitoring Program-Region 5 to implement the protocol at over a dozen national wildlife refuges in the northeastern United States. In March 2011, NCBN and Rutgers cooperators hosted a two-day training workshop for nearly twenty USFWS biologists and ecologists (fig. 4). In addition, the NCBN protocol was recently adopted at two NOAA national estuarine research reserves: the Jacques Cousteau Reserve in southeastern New Jersey and the Waquoit Bay Reserve on the south shore of Cape Cod, Massachusetts. It is intended that as parks, refuges, and reserves from Virginia to Maine utilize standardized equipment, field methodologies, and data management practices, our ability to monitor shoreline position change at the local and regional levels will be greatly enhanced, and there will be a high degree of comparability among the outputs. Further, the establishment of measures of change conditioned on the basis of morphological response to the seasonal variables of sediment supply and ambient processes will enhance our ability to make management decisions that are more scientifically informed and defensible.

For more information or to view available annual and trend reports for NCBN parks, please visit: http://science.nature.nps.gov/im/units/ncbn/index.aspx .

Figure 4. NPS and USFWS personnel receive training in shoreline position mapping during a two-day workshop at the University of Rhode Island in March 2011. Photo: Norb Psuty.

Monitoring Tidal Marsh Birds: Indicators of Habitat Change

Sara Stevens, program manager, Northeast Coastal and Barrier Network (NCBN) and Dana Filippini, NCBN biological science technician

> *One of nature's greatest gifts is the string of salt marshes that edges the East Coast from Newfoundland to Florida -- a ribbon of green growth, part solid land, part scurrying water. At low tide the salt marsh is a vast field of grasses with slightly higher grasses sticking up along the creeks.... The effect is like that of a great flat meadow.*
>
> *John and Mildred Teal*, Life and Death of a Salt Marsh, 1969

The national parks located along the Northeast Region's coastline contain some of the last remaining tidal marsh habitat in the world. Tidal marsh is found along coasts and estuaries and is determined by its flooding characteristics based on the tidal movement of the adjacent estuary or ocean. The Atlantic coast alone possesses over one-third of the global extent of tidal marsh, making it primarily a North American resource. Not only is tidal marsh considered globally rare, these habitats also contain a high proportion of endemic species making them highly valuable and important for biodiversity conservation and protection.

As one of the key landowners of coastal marsh in the Northeast, the National Park Service (NPS) plays an important role in preserving these areas. Although there are many factors, such as land development and pollution, which contribute to

Salt marsh sparrow (*Ammodramus caudacutus*) with the marsh in the background. Photo: Alyssa Borowske, SHARP, 2012.

the degradation of tidal marshes, global climate change is now considered one of the greatest threats to these treasured habitats. It is estimated that 0.5–1.5% of our coastal wetlands will be lost per year as a result of accelerated sea-level rise related to climate change.

In order to make scientifically sound management and conservation decisions, both at the local and regional scales, it is important to know the current condition of marsh habitat in national parks and if and how rapidly changes in the health of these ecosystems may be occurring. As part of the Northeast Coastal and Barrier Network (NCBN) long-term monitoring program, scientists have identified key indicators for monitoring tidal marsh health. These include vegetation and fish communities, sediment elevation, water levels, and, most recently added to the NCBN program, the abundance and diversity of breeding tidal-marsh birds. Birds are considered excellent indicators of ecosystem health because they are at the top of the food chain. Changes in habitat condition are reflected early on within these populations in terms of their habitat use, as well as feeding and nesting behaviors. For tidal-marsh birds this is especially true due to the fact that many of these species are endemic to marshes.

Indicators such as marsh bird abundance and diversity will help provide an early warning that changes to the marsh system are occurring. In addition to these birds being excellent ecological indicators, monitoring their populations is important simply because trends indicate that many tidal marsh bird species are declining, and many are now considered species of conservation concern. Currently along the North Atlantic coast alone, there are two International Union for Conservation of Nature red-listed species, six Watch List species, 10 Partners in Flight priority species, and 26 Species of Greatest Conservation Need, including tidal marsh sparrows, rails, herons, and bitterns that require tidal marsh habitat for their survival.

For the last two years, as part of a collaborative effort, the NCBN has been partnering on a region-wide project called the Salt Marsh Habitat and Avian Research Project (SHARP) (http://www.tidalmarshbirds.org). Founded by a group of academic, governmental, and non-profit collaborators, the goal of this project is to provide critical information for the conservation of tidal marsh birds. The short-term goal is to collect preliminary data and provide land managers, including NPS resource managers, with information about tidal marsh areas necessary for long-term conservation of tidal marsh birds in the Northeast. Following the identification of key conservation sites along the North Atlantic, the program will continue to provide a consistent platform for monitoring the health of North America's tidal marsh bird community, not only in the face of upland/watershed development, but to the anticipated increases in sea-level rise due to climate change.

In correlation with SHARP, the NCBN is developing an intensive tidal marsh bird monitoring program as part its Strategy for enhanced monitoring…to address the effects of rapid climate change (Stevens et at. 2010). The network has hired a biological science technician, Dana Filippini, to work with the NCBN parks and manage the new marsh bird monitoring program. The network has expanded upon the SHARP program by increasing the number of sites and points currently being monitored in each of the parks and developing a citizen-science based program. This will provide very specific park-based information to managers, along with the more regionally-based information provided by SHARP.

Once up and running, NCBN volunteers and staff will be hiking through rough, wet terrain, or paddling kayaks to GPS-designated points early in the morning during the spring and summer months. Using mp3-players, volunteers will play recorded calls of tidal marsh species expected to be present, and listen to and record responses, or "call-backs," from birds close by. Recordings will include those of species such as secretive rails and bitterns and others such as salt-marsh sparrows and willets. At the same time, information about surrounding vegetation will also be collected. These data will provide park-specific information on the current and long-term condition of marshes and their representative species.The NCBN program should be in full swing by the summer of 2013.

Stevens, S., B. Mitchell, M. Brown, P. Campbell. 2010. Strategy for enhanced monitoring of natural resource condition in North Atlantic coastal parks to address the effects of rapid climate change. Natural Resource Report NPS/NCBN/NRR—2010/272. National Park Service, Fort Collins, Colorado.

Using Structured Decision-Making To Address the Uncertainty of Climate Change

Jeb Wofford, fish and wildlife biologist, and Evan H. Campbell Grant, wildlife biologist, USGS Patuxent Wildlife Research Center

The Shenandoah salamander (*Plethodon shenandoah*) is a federally endangered species found only in Shenandoah National Park (NP). Because this salamander is restricted to a range of less than six square kilometers and is found only in habitats over 900 meters elevation within the park, it is possible that climate change will negatively impact the species. And, because a range shift is unlikely without management intervention, species extinction is a very real possibility. Nevertheless, data are limited, uncertainty is great, and policy and legal guidance regarding management of this federally listed species and its habitat is complex.

Shenandoah NP, The Amphibian Research and Monitoring Initiative of the U.S. Geological Survey (USGS), The Smithsonian Institution, Towson University, and The University of Virginia (UVA) are cooperating in a National Park Service (NPS) Climate Change Response Program project to develop fine-scale climate change projections for high-elevation habitats in Shenandoah NP and to determine the potential impacts on the Shenandoah salamander. The project uses a structured decision-making process to identify potential adaptive management actions while formally considering uncertainty or conflicts in climate models, response of the species to management, and park policy or other legal mandates. Starting in 2011, park natural resource staff and cooperators initiated field data collection and modeling efforts to identify the level of scientific uncertainty for the project. Simultaneously, the park and cooperators began a structured decision-making (SDM) process to better understand policy and management-related uncertainty.

The Shenandoah Salamander
Photo: Ann and Rob Simpson.

SDM provides a formal process for making complex decisions more manageable, adaptable, and transparent. The process is comprised of six interrelated parts, which are addressed in succession and depend on values-based objectives. Objectives are articulated by a "decision maker," who can be a single person or a consortium of parties responsible for implementing a decision. SDM is often an iterative process that involves a monitoring component that allows for an adaptive management approach. The components of a structured decision-making process are as follows:

1. Define the problem (identify the problem origins, decision maker, legal and regulatory context, and the essential elements of the decision)
2. Specify the objective(s) and measureable attributes
3. Identify creative management alternatives which are focused on achieving the objectives
4. Identify the consequences for each alternative (via quantitative or qualitative predictive models
5. Clarify the trade-offs between different alternatives and objectives
6. Decide and implement an action or actions and monitor system-state changes.

In January 2011, a "science" group consisting of park staff, U.S. Fish and Wildlife (USFWS) personnel, USGS decision modelers and herpetologists, and UVA climatologists met to develop a basic SDM decision model to inform an adaptive management plan for the Shenandoah salamander. The group articulated the initial problem statement (i.e., climate change has the potential to increase the extinction risk of an endangered, high-elevation species) and set a fundamental objective of maximizing the likelihood of persistence of the species within its native range. Additional objectives included following NPS policy (while considering that actions needed to meet the salamander persistence objective might conflict with some NPS policies), minimizing costs of the management action, and maximizing public acceptance of the action. The working group then developed a long suite of potential management actions that had some perceived potential to achieve the resource management objectives. This involved creative "outside the box" thinking as the decision analysis is most informative when a wide breadth of technically possible diverse options is considered. These actions included vegetation manipulation via chemical, mechanical, and natural means; soil and rock manipulation; elimination of direct human activity (i.e., trails); humidity and temperature control (via shade cloths, sprinkler systems, etc.); and actions targeted at the species directly, such as managed relocation.

A variety of models were constructed to evaluate each action with respect to the fundamental objective of interest (i.e., salamander persistence) under different climate change projections as determined by climate scientists in the group. When data were not available for development

of the models, experts in the group provided estimated values. The group participants rated how well each management action met the other objectives in the decision (e.g., cost, public perception, etc.) and ranked the objectives under a variety of biological and management scenarios (e.g., salamander persistence likelihood is high and a proposed action is unlikely to further improve the likelihood of persistence vs. salamander persistence is unlikely and a proposed action is highly likely to improve the likelihood of persistence) -- this helps to incorporate the decision maker's preferences when considering the suite of possible management actions. These preferences are important because some management actions may be most useful for achieving a single objective (e.g., reducing extinction risk of the salamander) while being least desirable on another objective (e.g., cost). Ultimately, the group constructed a quantitative model that is being used to provide an assessment of how well each action might meet every objective simultaneously.

The initial "prototype" decision analysis suggested that, given current information, the status quo (i.e., current park management with monitoring) or some type of an assisted migration management action was optimal across all objectives. The choice between these two actions strongly depended upon the park's confidence that climate change would have a negative effect on the species' persistence. A large benefit of this process was that it clarified and documented that the park should at least consider active management actions. The process also provided insight into key uncertainties that were likely to have a large influence on which management action would be preferred. Identifying these "critical" uncertainties focused data collection for the following field season on the uncertainties that were deemed likely to be most relevant to the decision. These uncertainties included aspects of species' distribution, especially whether the species occurs outside its known historic range and a better definition of the lower elevational boundary of the species distribution.

Shenandoah salamanders are only found in rocky high-elevation habitats in Shenandoah National Park. NPS photo.

In April 2012, another structured decision-making workshop was held which included additional staff from Shenandoah NP (superintendent, deputy superintendent, and the chief of natural and cultural resources) and staff from the NPS Washington Office's Climate Change Response Program and Natural Resource Stewardship and Science Division and the Northeast Region. The workgroup reviewed the science team's initial decision analysis with a particular focus on evaluating considerations of NPS policy and better defining the policy objective within the context of climate change. This "policy" group provided an additional range of perspectives to help represent a future superintendent's decision framework. Additionally, representation from multiple levels of the NPS could inform future higher level support for a superintendent's decision, should that decision be controversial.

Ultimately, this group agreed that the objectives were appropriately identified and that the list of objectives was complete. They then weighted the objectives independently, so that the range of interpretations of weights could be captured. Working through the weighting process with this group again resulted in a decision model that suggested that the status quo or assisted migration was most likely to adequately meet most objectives simultaneously. And, as in the prior workshop, the apparent likelihood of climate change having a negative impact on the salamander influenced the choice between the status quo and the assisted migration action – as the confidence in the "bad for salamander" (i.e., warmer and drier) climate change scenario increased, assisted migration became the preferred decision. Specifically, assisted migration became preferred when the confidence in predictions of a warmer and drier climate (as estimated by the decision model) approached 60%.

It was clear in the process that the most relevant factor was determining the urgency of the need for action. Current population viability analyses (PVA) on the species indicate that, over the next 60 years, the probability for species extinction changes from approximately 0% to 30%, when comparing a "no climate change" vs. "warmer and dryer climate change" scenario, respectively. The group did not consider these values suggestive of an urgent problem given all the recognized uncertainties. As such, the NPS decision makers at the workshop indicated that they would not advocate (at least in the short term) active manipulative management actions unless there was a high level of scientific agreement on the urgency,

a clear understanding of the specifics of the threat, and a high degree of confidence in the results of the action. The group suggested that this scientific consensus should be documented by more than peer-reviewed literature, and a major recommendation from the workshop included the creation of a scientific review group to evaluate the state of the science on the issue and to review the assumptions and results from the current project. Because any actions taken under the assumption that climate change is the primary threat could be maladaptive if other stressors are instead the source of the decline, the group indicated that climate change should be implicated as a primary threat to the species prior to an action being taken, and that the burden of proof was to establish the existence of a climate change threat within the context of other existing stressors - not to prove the lack of the existence of this threat. The group acknowledged that active management actions to help organisms adapt to climate threats are currently more "experimental" than common practice and may receive a higher level of scrutiny due to political or societal pressure, thus potentially requiring more substantial evidence than actions targeting more "traditional" threats.

Of important note for park managers, NPS decision makers expressed caution regarding active management actions when operating within the context of climate change – an environmental threat that may require more radical actions and reinterpretation of historic policy positions. Regardless of any climate change threat, the group noted that because habitat manipulation can easily be maladaptive, Endangered Species Act and NPS policy implications call for thorough and careful consideration before taking action. Recurring points of discussion in the workshop were gaps in information (i.e., uncertainty) and the degree of urgency for the need to act. The current decision model helped inform this urgency (via a PVA) and also suggested that reducing uncertainty related to climate change was more important to the decision than reducing uncertainty about certain aspects of the species biology (e.g., competition effects). The policy group recognized that, had the population viability modeling suggested a more imminent extinction threat, it is possible that the group's members would have weighted the identified objectives differently and then obtained a different preferred management action from the model. USGS and UVA scientists are currently collecting new data in the park that may further elucidate the projected climate effects on population viability projections (thus altering the urgency for action), suggesting a need to revisit decision models as new information becomes available.

Because any manipulative action targeted at the salamander or its habitat would require Section 7 endangered species consultation with the USFWS, the decision model can provide well-documented information to inform the consultation process, particularly when USFWS is directly involved in development of the model. In addition, this decision model may prove very useful for making management decisions about others of the many rare high elevation salamander species found across the southern Appalachians.

SDM provides an excellent format for assessing and responding to complex natural resource problems. The structure itself supports a formal means to make inquiries into assumptions, to document science-based decisions, and to identify the range of individual perceptions of "the problem." At times, the process requires the assessment and discussion of conflicting or subjective positions of scientists and decision makers. Nevertheless, the formal structure of the process, which is explicit, transparent, and interactive, provides the means to solicit this information in a neutral manner from relevant decision makers, groups, or stakeholders. Ultimately, the goal is to provide transparent information to better understand decision problems, to appropriately prioritize research, and, perhaps most importantly, to prevent unanticipated roadblocks from appearing at the very end of a decision-making process.

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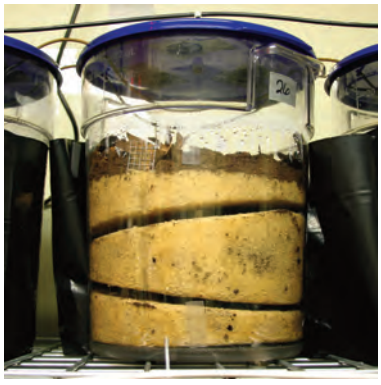

USGS scientists study captive Shenandoah salamanders by manipulating temperature and humidity in experimental enclosures such as this one in order to better understand how a changing climate might influence salamander behavior and survival. NPS photo.

Climate Change and Cultural Resources: Bridging the Relevancy Gap

Rick Kendall, superintendent, Saint-Gaudens National Historical Site, and Marcy Rockman, climate change adaptation coordinator for cultural resources in the Washington Office

The National Park Service (NPS) Climate Change Response Strategy makes clear the wide scope of impacts climate change is anticipated to have on our grand national landscapes. The strategy contains pictures of threatened glaciers and coastal resources, sustainable energy and transportation projects, and wildlife that will be negatively impacted as a result of global climate change. Glacier National Park without glaciers and Assateague Island National Seashore completely inundated by rising seas are iconic mental images of the impacts of climate change on natural features. But what if the park where you work does not contain threatened glaciers or vulnerable coastline? What if the species list at the park where you work does not contain vulnerable, charismatic plants and animals that may have their habitats impacted with changing climate? What if the fundamental resource at the park where you work is an historic building, a cultural landscape, an archaeological site, a sculpture, or another cultural resource? How will climate change impact these resources and how can you help visitors to these places understand that climate change impacts all parks, not just those with mountains and shorelines?

The 397 NPS units include more than 170 national historic sites, national historical parks, national battlefields, and national military parks. The number goes even higher if national cemeteries and national monuments that preserve primarily historic or cultural features are counted. At many of these sites, the potential impacts of climate change on a park's fundamental cultural resources are not obvious. Employees may believe that because they do not see their park's story reflected in the NPS Climate Change Response Strategy or other current documents that their park is immune from the impacts of climate change. And if employees don't recognize the potential impacts of climate change on the resources of their park, it is unlikely that visitors will grasp the concept that all 397 national park units are threatened by what is a truly global phenomenon.

Assessing and interpreting the impacts of climate change on cultural resources is not limited to historical parks and sites. Servicewide, there are more than 27,000 significant historic structures and more than 66,000 archaeological sites located on park lands. Natural parks contain cultural landscapes ranging from NPS-constructed historic areas to historic vista points that are every bit as important to visitor enjoyment as a pristine natural environment.

Goal 7 of the Climate Change Response Strategy notes that climate change will affect cultural resources, requiring expansion of inventory and monitoring of archaeological sites, additional curation and preservation capacity, and strengthened partnerships with traditionally associated peoples. However, while it notes that best available science should be used to develop, prioritize, and implement management for climate-sensitive cultural resources, it does not yet outline what those management practices should address and what and where those climate-sensitive resources might be.

Recognizing that there is a relevancy gap between the effects on natural phenomenon of climate change and its potential direct and indirect effects on cultural resources, the NPS is working to remedy some of the perceived deficiencies in addressing and interpreting the impacts of climate change on cultural resources. The NPS now has a climate change adaptation coordinator for cultural resources, Marcy Rockman, Ph.D., who is part of the Climate Change Response Program. Dr. Rockman, an archaeologist by training, is addressing many of these issues for the first time and is assembling a trove of information on the impacts of climate change to every stripe of

In melting permafrost in Alaska, a remnant ice patch site discovered in Lake Clark National Park and Preserve in 2009 yielded this late prehistoric antler arrow point. Photo courtesy of J. Schaaf.

cultural resources, as well as on methods of translating information about human societal response to those impacts for education and adaptation planning.

In addition to cultural resources now having a full-time climate change coordinator, the George Wright Climate Change Internship Program is also providing support towards making the impacts of climate change relevant to historic and cultural sites. This summer, Saint-Gaudens National Historic Site in New Hampshire will be hosting an intern who will explore the effects of climate change on cultural resources. The intern's goal will be to develop a series of tools to educate staff and visitors to historic and cultural sites about the impacts of climate change on a full range of cultural resources. What does increased rainfall in summer and reduced snowfall in winter mean for the management of monuments, statues, and archaeological sites? Could climate change lead to damage to historic buildings through thermal stress, microbiological growth, or changes in precipitation pH? Will increased wind speeds and changes in prevailing wind directions from climate change lead to wind or moisture damage of porous cultural materials? Will extended drought caused by climate change lead to the eventual destruction of cultural landscapes? Such potential harm to cultural resources could affect any park in the system, whether on the coast or inland. The goal of this project is to document observations of these phenomena, assemble them in a user-friendly format, and make them available to interpreters, cultural resource specialists, and park managers responsible for preserving cultural and historic resources.

If you are a cultural resource manager or an interpreter of cultural resources and would be interested in contributing to this effort to better understand and interpret the effects of climate change on cultural resources in our national parks, please contact Marcy Rockman (marcy_rockman@nps.gov) in the Washington office or Rick Kendall (rick_kendall@nps.gov) at Saint-Gaudens National Historic Site. The thoroughness of this survey and evaluation very much depends upon the contributions of experts in the field that are seeing these changes as they happen on the ground. We would welcome genuine, documented examples from the parks that illustrate the impacts that changing climate is already having on cultural resources in national parks.

The Cockspur Lighthouse at Fort Pulaski NM demonstrates the need for adaptation strategies to respond to the rising sea. Notice the high water line at the base of the lighthouse. Current projections indicate sea level in this area may rise as much as 2.3 feet over the next 50 years. NPS photo.

Facilities at Assateague Move With the Changing Landscape

Seashores are dynamic places where tides roll in and out, winds blow dunes around, and storms erode beaches and deposit sand landward. In recent years, conditions have become increasingly variable on Assateague Island, requiring managers to make big decisions about how to cope. As facilities manager Ish Ennis puts it, "You can fight it, you can empty the island of all structures, or you can modify." At Assateague, management has chosen to modify.

To adapt to ever-changing conditions, the facilities at Assateague are now portable. The rest rooms, showers, and cabanas sit on pallets of easy-to-clean composite lumber and are sized to fit on tractor trailers when they need to be relocated. Boardwalks of the same material, needed for visitors with disabilities, are also portable. Water for showers comes from a single well and can be piped to any spot within a thousand feet of the well wherever shower towers are placed.

The restrooms, referred to as " Romtecs©" after the company that makes them, contain vault toilets that use no water. Waste drops into an underground tank that can be

This cabana, or changing room, contains three stalls. Next to it are two Romtecs (rest rooms). Note the post between the buildings: that's a shower tower. These outdoor showers have several heads so that several people can use them at the same time, and have low heads for washing sandy feet. NPS photo.

The parking lot (right) is made of clay surfaced with clam shells which are movable and sustainable. In the background on the left is the ocean. In front of it is the beach, and on the right is the marsh. In the middle, the small building is a Romtec. NPS photo.

These boardwalks, made of composite lumber, can be easily moved to new locations at the beginning of each season or whenever needed. NPS photo.

easily moved to a new site wherever a hole is open to receive it. Romtecs© are called "sst," sweet smelling toilets, because air is circulated through the rest rooms so efficiently that there is no odor; the system works very effectively on this sunny and windy island.

In the Virginia District of the island where the shore is even more dynamic than in Maryland, these structures are picked up and taken to the mainland at the close of each season, and whenever big storms are predicted. The next spring, Ish Ennis says, there may be dunes and washes where the surface was level before. The portable structures can be set up wherever it is currently most suitable. One year the staff wanted to be creative and configured the facilities into a V shape, but the new design was not as popular as expected. Ennis observed that "visitors just want things to be convenient. They don't appreciate creativity as much as we do."

Parking lots in the Virginia District are made with a clay base and clam shell surface. As the sea encroaches, the material can be scooped up and laid down to become a parking lot farther from the coast. This flexibility allowed a parking lot in the Maryland District to be efficiently redesigned. It has been repositioned farther to the west and reconfigured so that a nearby big primary dune can migrate naturally westward.

Movable buildings and parking lots are ways of managing changes in the park's environment, but the park has also made changes to become "greener." There is a new ranger station that sits on pilings above the 100-year floodplain elevation. Adjacent to the ranger station is a new 22 KW photovoltaic solar array that generates electricity for the station and the campground office, as well as a nearby concession that is run by the park's friends group. Well water is pumped to showers using power from photovoltaic

panels set on a truck that goes wherever it's needed. Five new solar-powered overhead lights were also recently installed to illuminate the public parking lot adjacent to the Barrier Island Visitor Center. These highly efficient LED lights are powered by batteries which, in turn, are recharged by solar panels. The lights are operable at varying intensities; a feature that allows lighting levels to be adjusted to the actual need rather than maintaining a constant brightness all night long. This new lighting system was designed to prevent unnecessary light pollution and help protect Assateague's night skies. Much of the seashore is well removed from major sources of unnatural night lighting and, as a result, has some of the darkest night skies in the region.

While the greening of facilities at Assateague is all that can be done to fight climate change, modifying facilities to make them mobile is the best that can be done at the seashore to adapt to climate change.

Photovoltaic panels on a trailer power the pump that brings water to the showers. Note the pvc pipe coming out of the ground to the left of the wheel. The power is carried by cable down the pipe to the pump in the well. NPS photo.

Climate Friendly Parks

Holly Salazer, regional air resources coordinator

The Climate Friendly Parks (CFP) program began in 2002 to assist NPS staff in becoming more sustainable in daily park operations and provide tools to communicate sustainability and climate change to park staff, partners, and visitors. Director Jarvis affirmed the NPS commitment to sustainability in his 2011 Call to Action where "Going Green" and reducing greenhouse gas emissions were identified as top priorities for the NPS in the 21st century. The Northeast Region Climate Change Strategy and Action Plan for 2011-2014 also identifies CFP workshops as a way to meet regional climate change mitigation goals. And finally, in April of this year, the NPS commitment to sustainability was re-affirmed in the NPS Green Parks Plan. The Green Parks Plan involves all aspects of park operations and management, from water consumption to waste management to energy consumption. The CFP program is a perfect tool to help parks attain the goals of all of these initiatives. Through the CFP program, parks will complete an inventory of greenhouse gas emissions from all sectors of park operations. Once an inventory is complete, a two-day workshop will bring together WASO, regional, and park staff to identify what actions a park can take to reduce greenhouse gas emissions and incorporate sustainability into the different aspects of park daily activities.

Sources of emissions that parks target are varied. To inventory greenhouse gas (GHG) emissions, the activities that produce the emissions are grouped into sources, which include stationary combustion, purchased electricity, mobile combustion, landfilled waste, wastewater treatment, fertilizer application, forest management, and oil and natural gas activities. Once a park determines baseline emission levels, the park can set emission reduction targets. In order to achieve emission targets, a park develops an Action Plan that outlines the mitigation actions the park will implement to reduce GHG emissions. For example, a park can switch out incandescent light bulbs for compact fluorescent light bulbs or transition fleet vehicles from conventional fuels to hybrid vehicles or alternative energy vehicles (e.g., natural gas). Many parks have already completed an Energy Audit. The results of the energy audit can be used to both complete a emission inventory and to determine what actions will best help the park to save energy, and costs.

In the Northeast Region, nine parks have participated in a CFP workshop and certification process. This summer, in response to a call from the Regional Director, additional parks have submitted a CFP application and expressed their interest and commitment to complete a workshop and determine how they too can reduce GHG emissions at their park.

The NPS CFP website provides the application form as well as additional information for each step of the process. A "CFP Program Guidance" document has been developed to address questions that you may have with the program and lays out a specific timeline and goals to ensure a successful CFP workshop. The website address is http://www.nps.gov/climatefriendlyparks/. Holly Salazer, regional air resources coordinator, can also answer any questions you may have. She can be reached at 814-865-3100 or holly_salazer@nps.gov .

Sound science is the foundation for good resource management decisions. The National Park Service invests in science programs to responsibly protect and manage the precious resources entrusted to our care. The power of this research is multiplied when the information is shared. This publication, *Science and Management*, is brought to you from the Northeast Region's Natural Resources and Science Division. Its goal is to share with park staff, scientists, and the public the innovative resource management work being done throughout the region.

Dennis Reidenbach

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e.e. cummings