

Features

Climate change science in Everglades National Park

By Carol L. Mitchell and Jerome A. Krueger

CLIMATE CHANGE POSES A significant challenge to National Park System units in southern Florida. Everglades National Park has long faced challenges to the preservation of its natural resources because of surrounding water management infrastructure, and is considered one of our nation's most imperiled landscapes. A majority of the park's 1.5 million acres (0.6 million ha) lies below 1 m (3 ft) of elevation and is exposed to the sea. Predictions of 21st-century climate change that include potential sea-level rise of more than 1 m (3 ft), combined with forecasted temperature increases of as much as 5°C (9°F), pose a significant predicament for the future ecological integrity of the park. The risk from sea-level rise, coupled with more than a century of disruption of the region's natural hydrology, is a significant challenge for natural resource management and ecosystem restoration efforts. In recognition of these challenges, climate change issues related to changing plant communities, soils, water quality, habitat loss, and endangered species are being addressed in the context of Everglades' research priorities and planning.

In this article we describe the park's science and resource management program and how we approach climate change-related research and monitoring, providing examples of how we use this information. We will also provide an example of a resource management project designed to increase resilience in the Cape Sable area of the park in response to sea-level rise over the next few decades.

Abstract

Everglades National Park has long been recognized as one of our nation's most imperiled landscapes. A significant portion of the park's 1.5 million acres lies below 1 m of elevation, within projections of the rise of sea level by 2100. Coupled with the century-old disruption of the area's natural hydrology and constraints posed by adjacent urban and agricultural lands on species and habitat movement, the projected impacts from climate change are a significant challenge for both natural resource management and ecosystem restoration efforts. We have initiated, and partnered to accomplish, a wide range of monitoring, research, and simulation modeling activities to describe the current and future influence of climate change on the park. We have also implemented a resource management project designed to provide increased resilience to the Cape Sable area of the park as sea level rises over the next several decades.

Key words

climate change research, Everglades, monitoring, resource management, sea-level rise

The South Florida Natural Resources Center

The South Florida Natural Resources Center (SFNRC) is the natural resources and science arm of Everglades and Dry Tortugas National Parks, and as such is engaged in inventory, monitoring, and natural resource management activities in these two parks. In addition, the SFNRC provides science support for ecosystem restoration not only to Everglades and Dry Tortugas but also to Biscayne National Park and Big Cypress National Preserve, which neighbor Everglades to the east and north, respectively (fig. 1). The SFNRC manages the Critical Ecosystems Studies Initiative (CESI), a technical and scientific program that supports monitoring, research, computer modeling, and resource assessment activities that provide science input to on-the-ground resource managers, to the Everglades National Park superintendent, and decision makers in the U.S. Department of the Interior's (DOI) Everglades Restoration Initiative.

In 2005 the SFNRC began to incorporate climate change and sea-level rise into research and science dissemination activities (www.nps.gov/ever/naturescience/sfnrc.htm). In 2009 the south Florida DOI agencies (National Park Service [NPS], U.S. Fish and Wildlife Service, and U.S. Geological Survey [USGS]) developed science priorities that included a request for proposals to study the effects of climate change and sea-level rise on natural resource management and ecosystem restoration in the national parks and national wildlife refuges of the region.

Determining science needs

Climate change and sea-level rise are two of the many factors that affect natural resource management in the Everglades. Other critical resource concerns are the operation of the vast water management system that provides flood protection and water supply to south Florida residents, impacts of visitor use (particularly boating and fishing in the area of Florida Bay),

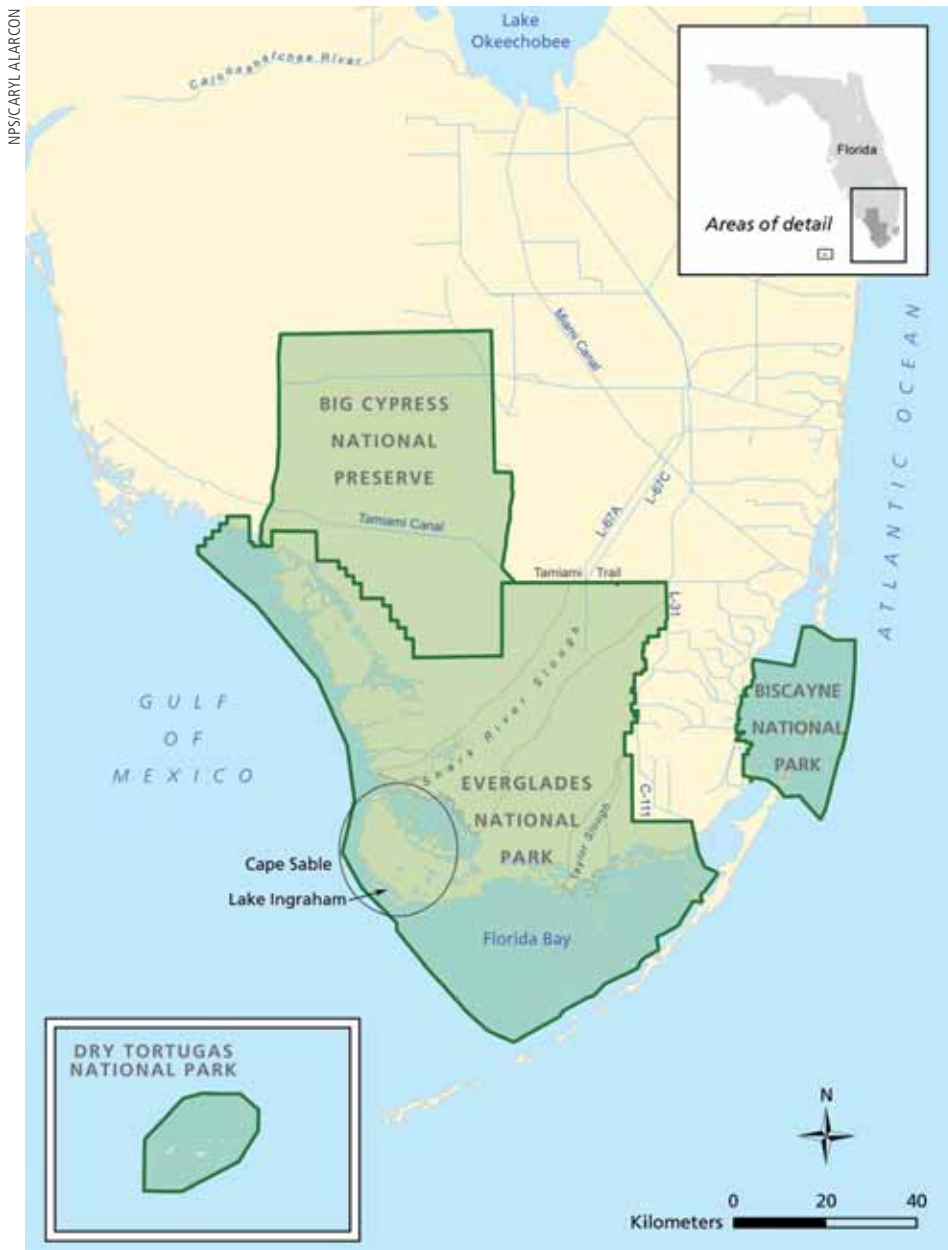


Figure 1. The South Florida Natural Resources Center provides science support for ecosystem restoration to four national park areas in south Florida. A major science initiative of the center is monitoring effects of sea-level rise on freshwater marsh areas of Cape Sable.

exotic invasive species, water-quality problems resulting from nutrients and contaminants, and changes to the urban and agricultural landscape along the eastern border of the park. These concerns overlie an ecosystem mosaic that includes rare and endangered species, keystone species, and critical habitat, and constitute a more immediate threat to park resources than either climate change or sea-level rise.

Nevertheless, it is clear that forecasted changes in precipitation as well as rising sea level are expected to strongly affect Everglades National Park in the future (Pearlstone et al. 2009), and that these changes will interact substantially with all the other resource threats now faced by the park. Everglades National Park requires science and analyses that will assist in decision making for natural resource management,

as well as analyses that will allow us to create and defend science-based positions and decisions regarding the interagency ecosystem restoration program in south Florida. Thus, science questions and resource management projects that match all the above categories—critical habitats or species, current threats, and future climate change—become a high priority for action in Everglades. The matching of proposed climate change science projects with current resource issues as well as with predicted climate change effects is a basic science planning strategy that may be useful to other parks facing climate change-related management challenges.

Climate change science is contributing to natural resource management

Everglades National Park is engaged in two climate change projects that directly contribute to natural resource management.

Cape Sable restoration. Cape Sable is a coastal ecosystem in the extreme south-western corner of Everglades National Park, at the mouth of Shark River (figs. 1 and 2). This area was historically known as a place where freshwater marsh was separated from salt-marsh and estuarine habitats by a long, low natural feature called the “buttonwood embankment.” In the 1920s and 1930s, before the creation of the park, settlers dug a series of drainage canals through the embankment, which have grown in size and increased the loss of freshwater from the system, allowing the intrusion of tide-driven saltwater far up into the freshwater marsh habitats. The resulting collapse of the freshwater marsh upstream of the cape, and transformation to open brackish water habitat, have become more extensive over the past 30 years. Furthermore, Lake Ingraham, formerly isolated from tidal influences, has

become heavily sedimented and significantly more saline (see fig. 2).

These changes were wrought by human activities; however, the rise of sea level along the southern coast of Florida is expected to accelerate these changes in the habitats along the cape. In order to understand the effects of the canals, the CESI program funded Dr. Harold Wanless of the University of Miami to study the evolution of the canals and the rate of sedimentation into Lake Ingraham (Wanless and Vlaswinkel 2005). This study emphasized that significant change in the Cape Sable area is inevitable because of the canals, sea level, and tropical disturbances. In 2010, \$7 million in American Recovery and Reinvestment Act funding supported repair and reinstallation of plugs in two of the major canals that allowed the unnatural intrusion of saline water into the freshwater marsh (fig. 3). Though park staff realizes that over the next century these plugs may be affected by rising sea level, the project provides a higher level of safety to visitors, who commonly travel by canoe and kayak in the Cape Sable backcountry, and natural resource benefits that include redirection of tidal flows through natural channels that should enhance the resilience of the Cape Sable ecosystem during this period of change (SFNRC 2008).

Dewitt Smith, SFNRC scientist, is managing a hydrologic monitoring program upstream and downstream of the new plugs, as well as in canals that have not yet been plugged. These data will allow us to determine the effects of the plugs on salinity patterns in the freshwater marshes upstream of the buttonwood embankment. Remote imaging, available before and after canal plugging, can also provide data regarding physical changes to the upstream freshwater marshes. These sources of information should give us a sense of how the plugs may be affecting the resilience of these coastal freshwater habitats over the next decades.

The relative tolerance of rare species to changes in salinity can allow managers to propose and prioritize actions needed to conserve these species.

Management of rare plant species in coastal hammocks. In 2010 a CESI project was funded to provide resource managers information about plant species of management concern in coastal habitats in Everglades National Park. Investigators Sonali Saha (Institute for Regional Conservation) and Jimi Sadle (Everglades National Park) are gathering information on plant community composition and relative abundance of species in two types of coastal hammocks, and are monitoring salinity in the soil and groundwater. Hammocks are isolated islands of trees, upland shrubs, and herbs found in the freshwater and coastal marsh habitats of the Everglades (fig. 4). These field data form a baseline for future monitoring and detection of changes in relative abundance of species as the coastal hammock ecosystems respond to increasing salinity in the soil and groundwater. In addition, these investigators are conducting experiments to determine the salinity tolerance of a select number of species.

This baseline plant inventory will be useful to resource managers in several ways. First, the relative tolerance of rare species to changes in salinity can allow managers to propose and prioritize actions needed to conserve these species. Second, the experimental and field data on salinity tolerances can be analyzed in conjunction with predicted changes in salinity that are the joint result of sea-level rise and restored freshwater flows to the coast. Such information is useful for planning ecosystem restoration—providing for the appropriate quantity of freshwater needed to support optimal soil and groundwater salinity conditions for coastal hammocks.

Determining freshwater needs of south Florida parks

Climate change science is contributing to ecosystem restoration by addressing this important issue in the following ways:

Everglades physical monitoring network. Everglades National Park manages an extensive network of monitoring stations that record numerous variables associated with hydrology, salinity, and climate. Park science staff is able to leverage the information derived from monitoring to better understand and evaluate risk related to the response of habitats and species to factors such as sea-level rise. In this issue of *Park Science* (see page 26) Erik Stabenau and his colleagues relate their observations about measured changes in sea level in Florida Bay and the role that restoration of freshwater flows would play in counteracting saltwater intrusion in our coastal ecosystems. In essence, restoring more natural flow volumes and patterns improves ecosystem resilience in both freshwater and estuarine habitats.

Climate change habitat suitability modeling. Park biological resources staff is leading a collaborative effort with the USGS to develop modeling tools capable of producing robust estimates of climate change effects on the suitability of habitat for 21 species of nonmarine threatened and endangered vertebrates, such as the American crocodile (fig. 5). This effort, which includes representatives of the major federal and state agencies involved in biodiversity conservation, uses an open-code, ensemble modeling approach that

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Figure 2. Aerial view of Cape Sable (identified by the long white beach at the left of the photo) and Lake Ingraham (tan-colored area, center), Everglades National Park, January 2011. The buttonwood embankment is visible as a pale linear feature between Lake Ingraham and the more fresh, open water habitats at the right. Work to plug one of the canals is visible in the center as four white dots.



Figure 3. Aerial view of nearly completed dam at East Cape Canal, Cape Sable, Everglades National Park. The dams are expected to add resilience to upstream freshwater ecosystems by reducing unnatural intrusion of saltwater into the area.

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Figure 4. Buttonwood hammocks, named for the predominant overstory tree species, are found along the southern coast of Everglades National Park. The understory community contains several rare and endangered plant species, which are the subject of study to determine priorities for management action as sea-level rise affects groundwater and soil salinities in the hammocks.



Figure 5. Everglades National Park scientists are collaborating with the USGS to create state-of-the-art models to forecast climate change effects on threatened and endangered species in the Everglades, such as the American crocodile. Global Climate Model (GCM) predictions indicate that suitable habitat for the American crocodile will disappear from much of the Caribbean. South Florida is predicted to retain climate conditions for suitable habitat, and areas of the Gulf Coast and the western coast of Mexico are predicted to gain areas where climate conditions are suitable for development of American crocodile habitat.

USGS/STEPHANIE ROMANACH



Figure 6. Resource managers measure irradiance above a mangrove forest through the use of net radiometer and up- and down-facing quantum sensors mounted on a tower at 90 feet (27 m). Irradiance is one factor, along with atmospheric carbon and other physical factors, that influences the cycling of carbon through the mangrove ecosystem. Shark River is visible in the distance. This tower is associated with the project to measure carbon dynamics in mangrove forest.

maximizes the utility of the product by making it easily modifiable and transferable to other groups involved in conservation decision making. The goal is to understand how climate change will affect distribution of these species and allow managers to understand shifting habitat availability and needs (NPS, Everglades National Park, L. Pearlstine, landscape ecologist, personal communication, 15 July 2011).

Measurements of carbon dynamics in mangrove forest. An understanding of carbon dynamics of an ecosystem is essential for determining how climate change can alter existing plant communities. The mangrove forests of Everglades National Park are experiencing rapid environmental changes associated with upstream water management practices, fluctuating salinity gradients, sea-level rise, and natural disturbances such as hurricanes. SFNRC scientists Vic Engel and Jordan Barr are

working with several research cooperators using a meteorological tower and on-the-ground methods to describe carbon cycling in the mangroves and determine how at risk the mangrove habitat is from the combined effects of these disturbance variables (fig. 6) (Barr et al. 2009). This tower is part of a national network of carbon flux sites that share data and resources to understand the role of terrestrial ecosystems in climate change (<http://public.ornl.gov/ameriflux>). The work in quantifying carbon flux in Everglades mangroves will help to shape future NPS positions regarding the amount of freshwater needed for ecosystem restoration.

Hydrologic modeling and modeling of Florida Bay. Everglades National Park and other agencies involved in south Florida ecosystem restoration rely on hydrologic and other models of the physical system to assess effects of proposed restoration actions. Although these models

were developed primarily to determine the effects of changes to the quantity and timing of upstream freshwater flow, there has also been a need to determine how proposed changes in freshwater flow affect salinity patterns in estuaries such as Florida Bay. The CESI program has funded several projects to link upstream freshwater models with coastal salinities (Nuttall 2002; Marshall 2009). These models allow evaluation of effects of upstream flow conditions on coastal salinities; however, they are not designed to capture how downstream change (i.e., sea-level rise) would affect estuaries. New analyses are needed that allow integration of the effects of both upstream flow conditions and sea-level rise on salinities in Florida Bay and other coastal habitats in Everglades, such as the Cape Sable area.

Forecasted changes in precipitation as well as rising sea level are expected to strongly affect Everglades National Park in the future . . . these changes will interact substantially with all the other resource threats now faced by the park.

Future climate change research efforts

While SFNRC staff has participated in numerous successful climate change science efforts, significant challenges remain. It is vital to expand our efforts to understand the expected magnitude of climate change effects on the Everglades and its natural resources. We will also need to retain and adapt our hydrologic and ecological monitoring networks to the coastal environment as it advances landward. We need to gain an understanding of the interaction between forecasted climate change and invasive species to adapt our management, control, and containment of these species. Like parks in other areas, south Florida parks require reliable local physical climate change models, specific to the Everglades region, to improve our understanding of the interaction of upstream freshwater flows with sea-level rise along the coast. These local models, downscaled from the suite of accepted global climate models, will help us make informed decisions regarding not only resource management but also proposals for infrastructure or changes to visitor use of different park areas.

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