National Park Service
U.S. Department of the Interior

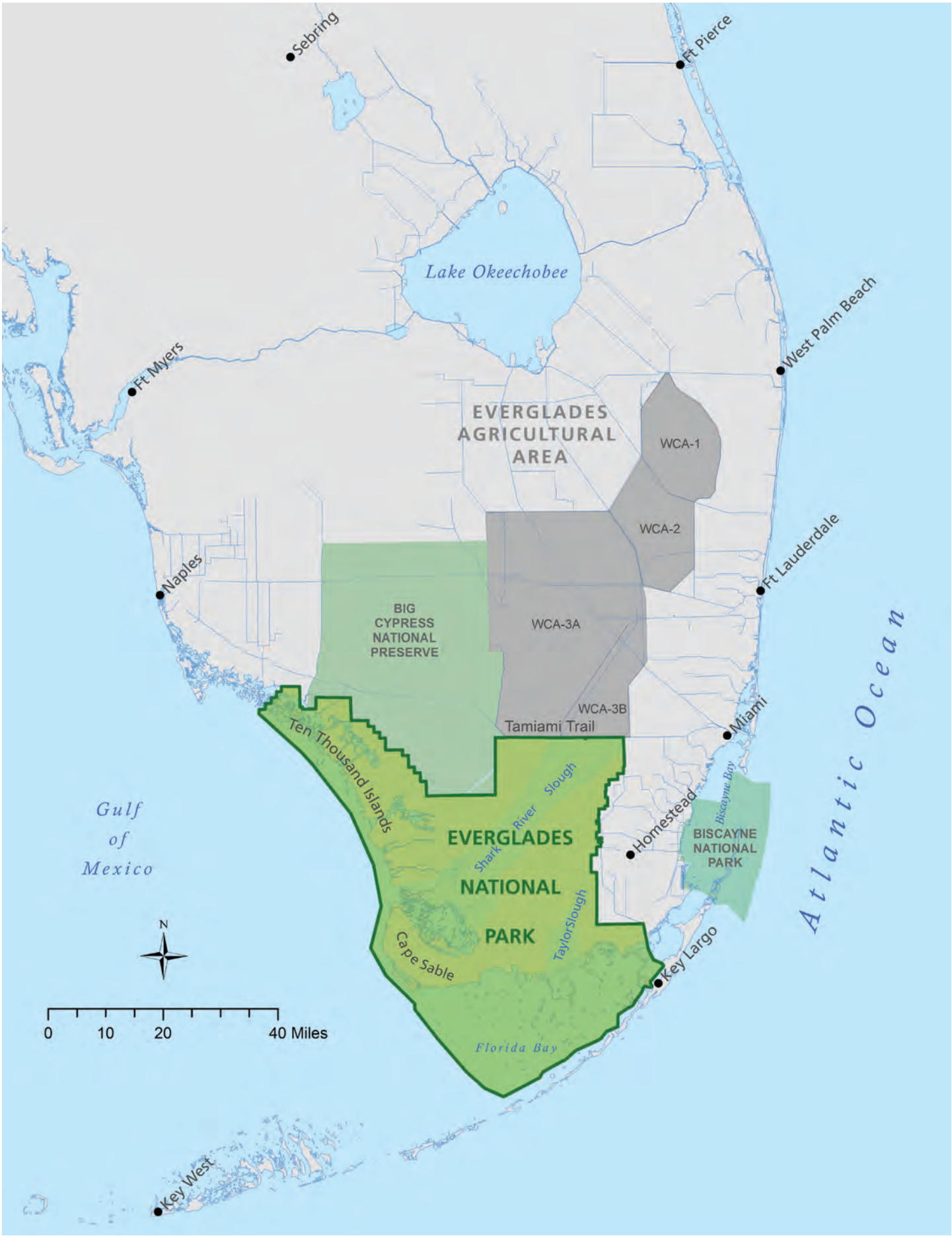
South Florida Natural Resources Center
Everglades National Park

RESOURCE EVALUATION REPORT

SFNRC Technical Series
2013:2

Everglades National Park 2013 State of Conservation

Report to the World Heritage Committee of the IUCN in Response to 36COM7a.14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Everglades National Park

2013 State of Conservation

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South Florida Natural Resources Center
Everglades National Park
Homestead, Florida

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ACKNOWLEDGEMENTS

We sincerely thank Dan Kimball, Nick Aumen, Tylan Dean, Kevin Kotun, Dave Sikkema, and Fred Herling for their thoughtful comments and review of this report. Numerous South Florida Natural Resources Center staff members have contributed content to the Integrity Indicators presented herein. They include Freddie James, Donatto Surratt, Jeff Kline, Mark Parry, Lori Oberhofer, Erik Stabenau, Dave Rudnick, Vicki McGee-Absten, Tracy Ziegler, Jason Osborne, Jonathan Taylor, Hillary Cooley, and Skip Snow. In addition, our partner and collaborator, Joel Trexler, Florida International University, provided the data and analysis for the freshwater fish indicator. Their important contributions reflect the wide range of expertise required to monitor and assess the State of Conservation of Everglades National Park.

Report prepared by Science Communications staff of the South Florida Natural Resources Center:
Managing Editor, Alice Clarke; Technical Editor, Ellen Hardy; Desktop Publishing, Brandon Gamble and Larry Perez; GIS support provided by Caryl Alarcón.

Please reference this report as follows:

Mitchell, C. and R. Johnson. 2013. Everglades National Park: 2013 State of Conservation. South Florida Natural Resources Center, Everglades National Park, Homestead, FL. Resource Evaluation Report. SFNRC Technical Series 2013:2. 43 pp.

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LIST OF ABBREVIATIONS

BMP	Best Management Practices
C&SF	Central and Southern Florida Project
CEPP	Central Everglades Planning Project
CERP	Comprehensive Everglades Restoration Plan
CLNWR	Crocodile Lake National Wildlife Refuge
CPUE	Catch per Unit Effort
COP	Combined Operational Plan
CSOP	Combined Structural & Operational Plan
DOI	Department of the Interior
EAA	Everglades Agricultural Area
ENP	Everglades National Park
EPA	Environmental Protection Agency
FEB	Flow Equalization Basin
FPL	Florida Power and Light Company
GMP	General Management Plan
IUCN	International Union for the Conservation of Nature
LRR	Limited Re-Evaluation Report
MWD	Modified Water Deliveries
NESRS	Northeast Shark River Slough
NGVD	**National Geodetic Vertical Datum of 1929**
NPS	National Park Service
NRC	National Research Council
POR	Period of record
ppb	Parts per billion
SAV	Submerged Aquatic Vegetation
SFWMD	South Florida Water Management District
STA	Stormwater Treatment Area
TP	Total phosphorus
TTNS	Tamiami Trail Next Steps
UNESCO	United Nations Educational, Scientific and Cultural Organization
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
WCA	Water Conservation Area
WSS	Western Shark Slough

BACKGROUND

Report Purpose

Everglades National Park (ENP) was established in 1947 as a public park for the benefit of the people, to preserve the ecological functions and integrity of a representative portion of the original Everglades watershed. It was set aside as a permanent wilderness, preserving essential primitive conditions including the natural abundance, diversity, behavior, and ecological integrity of its flora and fauna. Sixty-five years later, as a result of human-induced modifications to the landscape of south Florida, ENP faces true challenges to achieving this mission and purpose. This report is intended to accomplish three things:

1. Describe the Desired State of Conservation of the park as developed by the World Heritage Committee and the National Park Service (NPS) and establish the status and trends of important indicators of ecosystem integrity. Evaluation of the indicators provides both quantitative and qualitative information that will serve to assess changes to the health of the park as we move further into the 21st century.
2. Describe the current status of the corrective measures that ENP is undertaking to bring park habitats toward the Desired State of Conservation. These corrective measures were originally described in 2006 (http://whc.unesco.org/en/soc/1108) and have undergone modification since that time through the process of planning and implementation. The majority of these corrective measures, especially those affecting the water management system, are under the direct control of the U.S. Army Corps of Engineers (USACE) and the State of Florida. ENP's role is in the review of these projects such that they support to the maximum extent possible the park vision of the Desired State of Conservation.
3. Synthesize the information on the status of integrity indicators as well as the status of corrective measures, providing an assessment of progress as well as further actions required to move ENP toward the Desired State of Conservation.

This report is developed in response to annual reporting requirements of the World Heritage Committee and is intended to consolidate information—on the status of ENP indicators of site integrity and on the progress of Everglades Restoration projects and other corrective measures—which may be utilized in decision-making regarding the status of ENP as a World Heritage site. In addition, the content of this report is intended to be broadly applicable and can assist park managers in the future to gauge the overall response of the ENP ecosystem to factors such as water operations changes, climatic variability, and implementation of Everglades Restoration projects.

Everglades National Park and its Conservation Designations

ENP protects an area of more than 6,000 km^2 in south Florida and is the largest subtropical wilderness reserve on the North American continent (see map of park and region inside front cover). Its location at the interface of temperate and subtropical America, and mix of fresh and brackish water environments, creates a complex of plant and animal communities with high biological diversity. The park includes a full range of the original, pre-drainage Everglades habitats including forested uplands, a diverse mosaic of freshwater wetlands, and coastal wetlands and mangrove forests that transition into the open water marine ecosystems of the Gulf of Mexico and Florida Bay.

In addition to the conservation protections afforded by its designation as a national park, ENP, as a result of the beauty, biological diversity, and vastness of its wetland habitats, has received several other conservation designations. At the Florida State level, the park is designated an Outstanding Florida Water and an Outstanding National Resource Water, providing a high level of legal protection against nutrient pollution and other contamination. An additional federal protection is that of the Wilderness Act of 1964: the majority of ENP (5,247 km^2 or nearly 86% of the current park extent) was provided this additional protection via the declaration of the Marjory Stoneman Douglas Wilderness in 1978.

Three important international organizations have given recognition to the special characteristics of ENP. The United Nations Educational, Scientific and Cultural Organization (UNESCO) in 1976 designated ENP as an International Biosphere Reserve under the Man and the Biosphere program. In 1979, the UNESCO World Heritage Committee, supported by recommendations of the International Union for the Conservation of Nature (IUCN), declared ENP a World Heritage Site and inscribed the park on the World Heritage List during the 3rd session of the Committee. Several natural resources criteria were emphasized in the inscription, including the unique geological processes of the limestone substrate, the juxtaposition of temperate and subtropical species and habitats, the complexity and integrity of biological processes in the park, the large number of bird and reptile species, and the unique threatened and endangered species that reside in the ecosystem, including the Florida panther (*Puma concolor coryi*), Everglades snail kite (*Rostrhamus sociabilis plumbeus*), American alligator (*Alligator mississippiensis*) and American crocodile (*Crocodylus acutus*), and the West Indian manatee (*Trichechus manatus*). In 1987, the park received its third international recognition with its designation as a Ramsar Wetland of International Importance. Such a diversity of designations and protections is indicative of the special place that ENP holds in the consciousness of people from the local level through the international community.

In 2012, ENP received designation under the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (the Cartagena Convention) and, as such, adheres to the convention protocol concerning Specially Protected Areas and Wildlife (SPAW Protocol).

Threats to Everglades National Park

In the last 100 years, the once diverse greater Everglades wetland ecosystem has been reduced by more than 50% as a result of development and drainage (Fig. 1). A vast and effective system of canals, levees, weirs, and pumps, called the Central and Southern Florida (C&SF) water control project, supports agricultural production as well as the growth and current vitality of the urban south Florida environment. The current water management system moves 1.7 billion gallons (6.4 billion liters) of freshwater daily directly to the ocean via canals; prior to drainage, freshwater flowed slowly through the wetlands and was distributed along the coast, supporting a highly productive estuarine environment in the Ten Thousand Islands, Florida Bay, and Biscayne Bay. The same water management system responsible for this unnatural discharge confines remaining freshwater in a series of managed reservoirs upstream of the park, called Water Conservation Areas or WCAs. The operation of the WCAs is designed to provide flood protection and water supply to the urban and agricultural areas to the east (see map of park and region inside front cover).

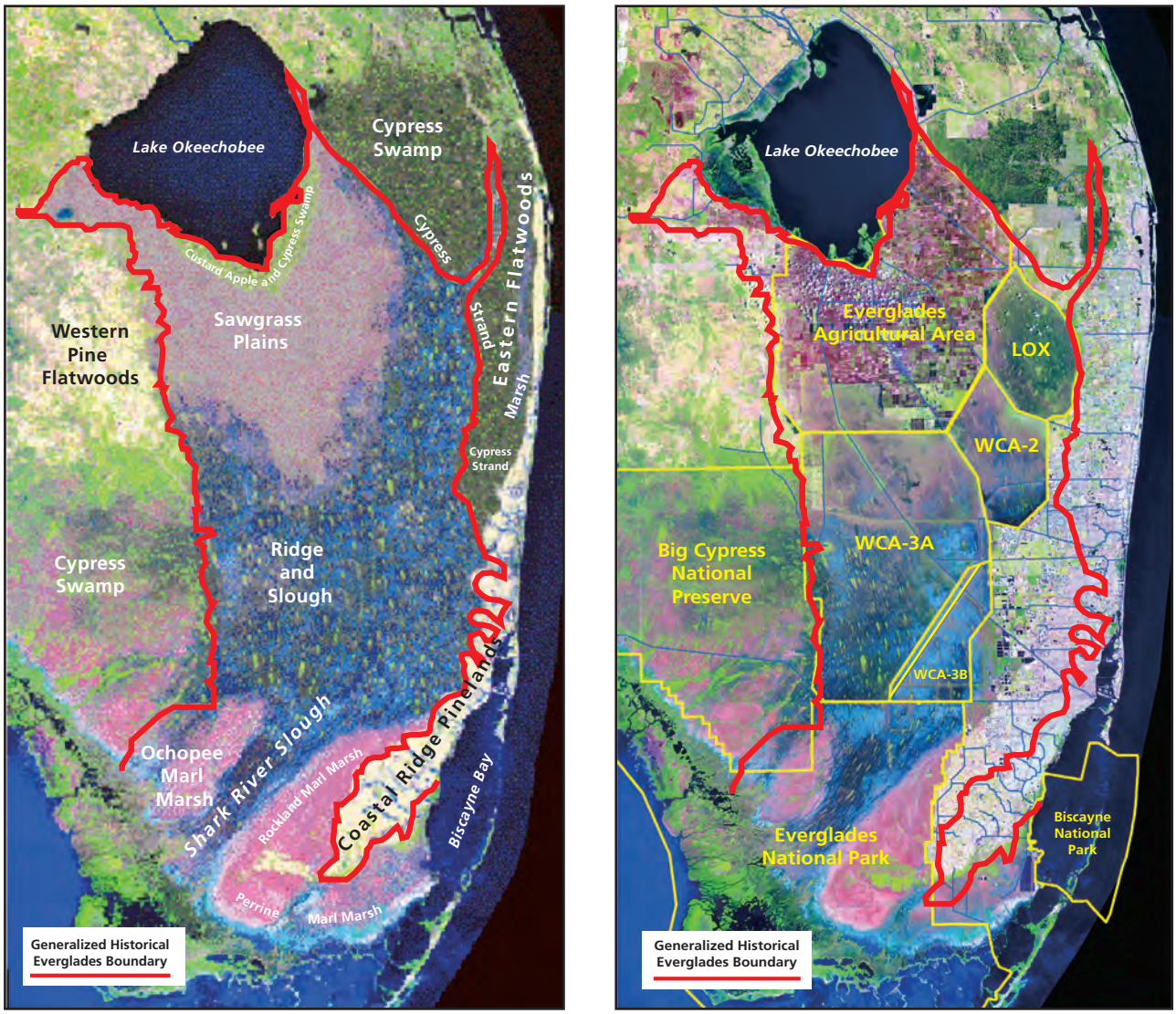


Figure 1. Comparison of the historic south Florida landscape (left) with the highly compartmentalized landscape of today (right). The current landscape illustrates the extent to which characteristics of the historic landscape have been lost to agriculture and urban development. The barriers to sheetflow created by the construction of the levees and canals of the Central and Southern Florida Project resulted in the loss of natural marsh connectivity. (Map adapted from McVoy et al. 2011.)

ENP is located in the far downstream sector of this highly modified watershed. Although water is not actively managed *inside* the park, the effects of water management *outside* the park are felt throughout park habitats: the northeastern sector of the park (called Northeast Shark River Slough, or NESRS) is dry; western Shark Slough (WSS) is too wet; and the estuaries are starved for freshwater, becoming so extremely saline during the dry season that estuarine habitats are stressed and fish and wildlife abundance is reduced. In other words, the basic physical processes underlying the ENP ecosystem have been and continue to be strongly influenced by the management of water for the urban and agricultural system. Given that the physical basis for wetland function is so significantly altered in the park, it is no surprise that the ecological elements of the system—habitats and wildlife—are also profoundly affected.

In 1989, the World Heritage Committee recognized that

> *"there is increasing evidence that the major wetlands system of the Everglades in Florida is under considerable threat with the adverse impacts of changes in water quality and quantity arising from a range of developments agricultural, industrial and urban—which are altering the natural systems."*

In 1993, at the request of the United States government, ENP was inscribed on the list of World Heritage Sites in Danger, citing the impacts of Hurricane Andrew in 1992 and various environmental alterations resulting from five decades of development and drainage that are the result of construction and operation of the C&SF project. Four major threats, which had been repeatedly identified as sources of impact to ENP since its inception, were highlighted at the time of the listing of the park on the list of Sites in Danger.

Threat 1. Alterations of the hydrologic regime have resulted in changes in the volume, distribution, and timing of water flows to the park.

Threat 2. Adjacent urban and agricultural growth has resulted in flood protection improvements that alter the park's wetlands and in the invasion of exotic species from urban and agricultural environments.

Threat 3. Increased nutrient pollution has resulted from runoff from upstream agricultural areas and causes alterations in native flora and fauna in the park's freshwater ecosystems.

Threat 4. Impacts to the protection and management of Florida Bay have resulted from reduced freshwater inflows and increased nutrient loadings.

Everglades National Park: A World Heritage Site in Danger

After a brief period of time when ENP was removed from the list of World Heritage Sites in Danger, the park was reinscribed on the list in July 2010. At this time, the World Heritage Committee and IUCN agreed with the United States that the 2006 corrective measures as originally stated were insufficient to secure the long-term restoration and preservation of the Everglades ecosystem. Several specific recommendations emerged from the 2010 decision:

- The Committee encouraged the United States to complete a congressionally directed feasibility study of additional bridging and road-raising along the eastern Tamiami Trail to allow unconstrained water flows beneath the highway, and to secure long-term ecosystem function. The World Heritage Committee considered the implementation of this project as critical to ensuring the restoration and preservation of the Outstanding Universal Value of the property.
- The Committee's 2010 recommendations urged the United States to plan for additional upstream corrective measures beyond those established in 2006, and to reinstate the planned Florida Bay/Florida Keys Feasibility Study.
- The Committee requested that future United States reports include not only progress on the corrective measures (i.e., the restoration projects themselves), but also progress toward the Desired State of Conservation (i.e., hydrologic and ecological measures of the health of ENP).

Following the 2010 World Heritage Committee decision, the United States requested a joint IUCN/World Heritage Committee delegation to evaluate the State of Conservation of the property, and to assist NPS and its partners in developing a statement of Desired State of Conservation for the removal of the property from the list of World Heritage Sites in Danger. The site visit and associated evaluation were completed in January 2011; as a result, in the United States State of Conservation report in 2012, ENP developed a narrative statement of the Desired State of Conservation and selected a suite of "integrity indicators." The integrity indicators are the most important aspects of the ecosystem that are expected to benefit from the implementation of the corrective measures and allow us to measure progress toward the Desired State of Conservation. These integrity indicators and their status were presented in the 2012 State of Conservation Report. In the present report, we have developed a "stoplight" evaluation system that provides information on the current status and trend of each of the indicators and can be used to evaluate our progress toward removal of ENP from the list of World Heritage Sites in Danger.

DEFINING THE DESIRED STATE OF CONSERVATION

In this section of the report, the Desired State of Conservation is described based on the characteristics of the physical factors, primary landscapes, and fish and wildlife in the Everglades ecosystem and the Outstanding Universal Values that led to the inscription of the park on the World Heritage list (Fig. 2). The water-management and land-use changes that have impacted the ecological functions and integrity of the property are also described.

The Physical Environment

Hydrology

Under pre-drainage conditions, persistent rainfall and the gentle north/south slope of the Everglades generated a nearly continuous but slow-flowing sheet of surface water over much of the landscape. The level of the water rose during the rainy season and fell gradually during the dry season, but the central, deepest parts of the Everglades, including the area of ENP called Northeast Shark River Slough (NESRS), very rarely dried out.

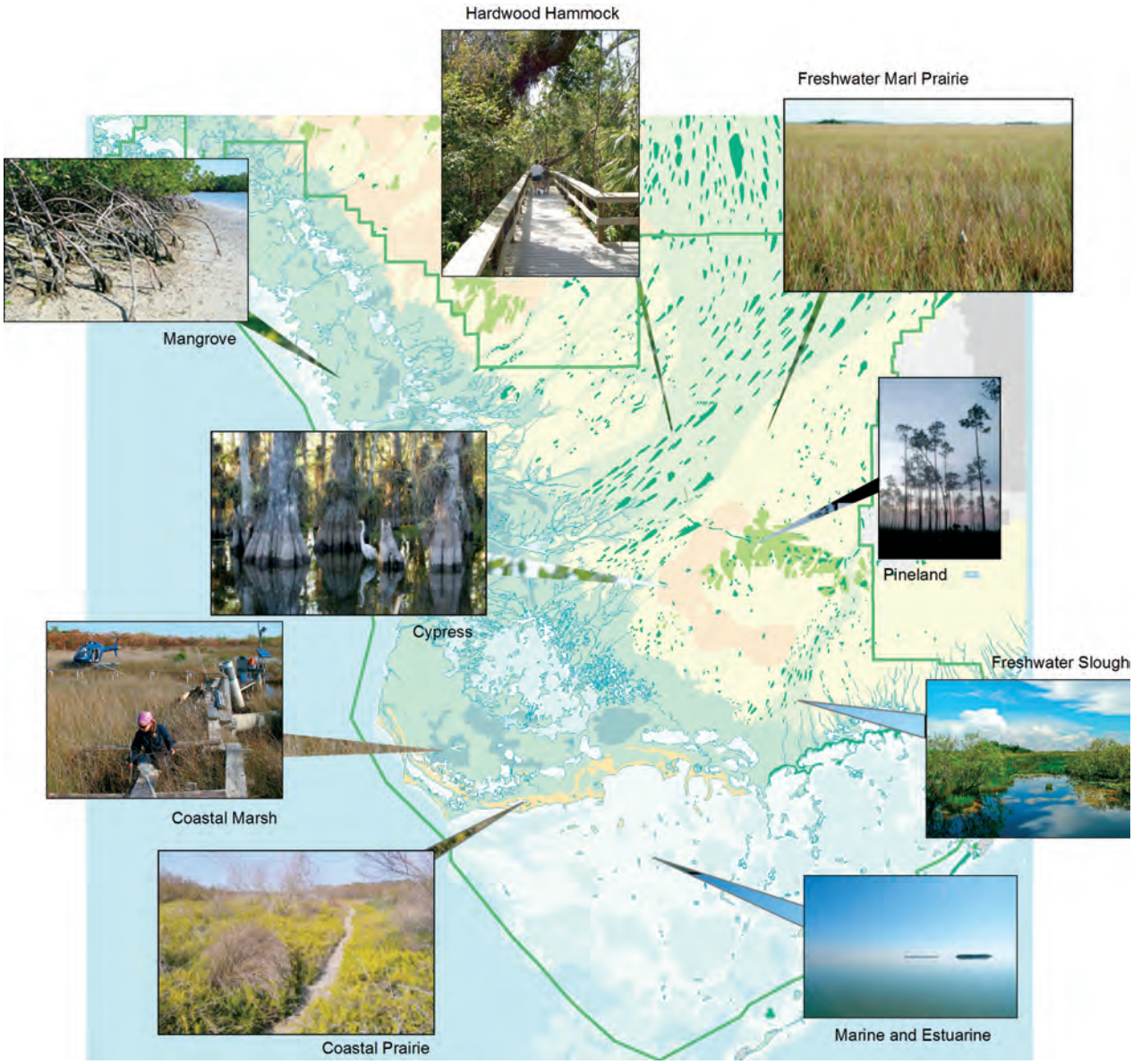


Figure 2. The Everglades ecosystem comprises a wide range of habitats from the upland pinelands to the marine conditions of Florida Bay and the Gulf Coast.

Water management changes over the last century in the Everglades upstream of ENP have diverted water away from the park and eliminated much of this natural, slow-moving sheetflow of water (Fig. 3). In addition, the WCAs in the central Everglades to the north of the park retain stormwater runoff, acting as reservoirs whose hydrology is not in concert with the natural seasonal cycle of rainfall. During drier years, water deliveries to the park are very limited, because available water is stored and used to meet urban and agricultural water demands. During wetter periods, excess water is rapidly discharged into the park, but it does not follow the historic eastern flow-way of NESRS, and instead floods the western marl prairies of ENP. The L–67A/C and L–29 levees—major elements of the C&SF project system—redirect water westward and away from the downstream marshes in WCA 3B and NESRS. This historic eastern flow-way has dried and lost much of its deep water habitat.

The Desired State of Conservation for hydrology in ENP is broadly defined as a system in which more-natural water depths, distributions, and sheetflow patterns have been reestablished in the park. The majority of the water should flow through the historic flow-way of NESRS, the Slough should dry out only very infrequently, and operation of the water management system should allow for natural seasonal patterns of the rise and fall of water levels, in concert with rainfall.

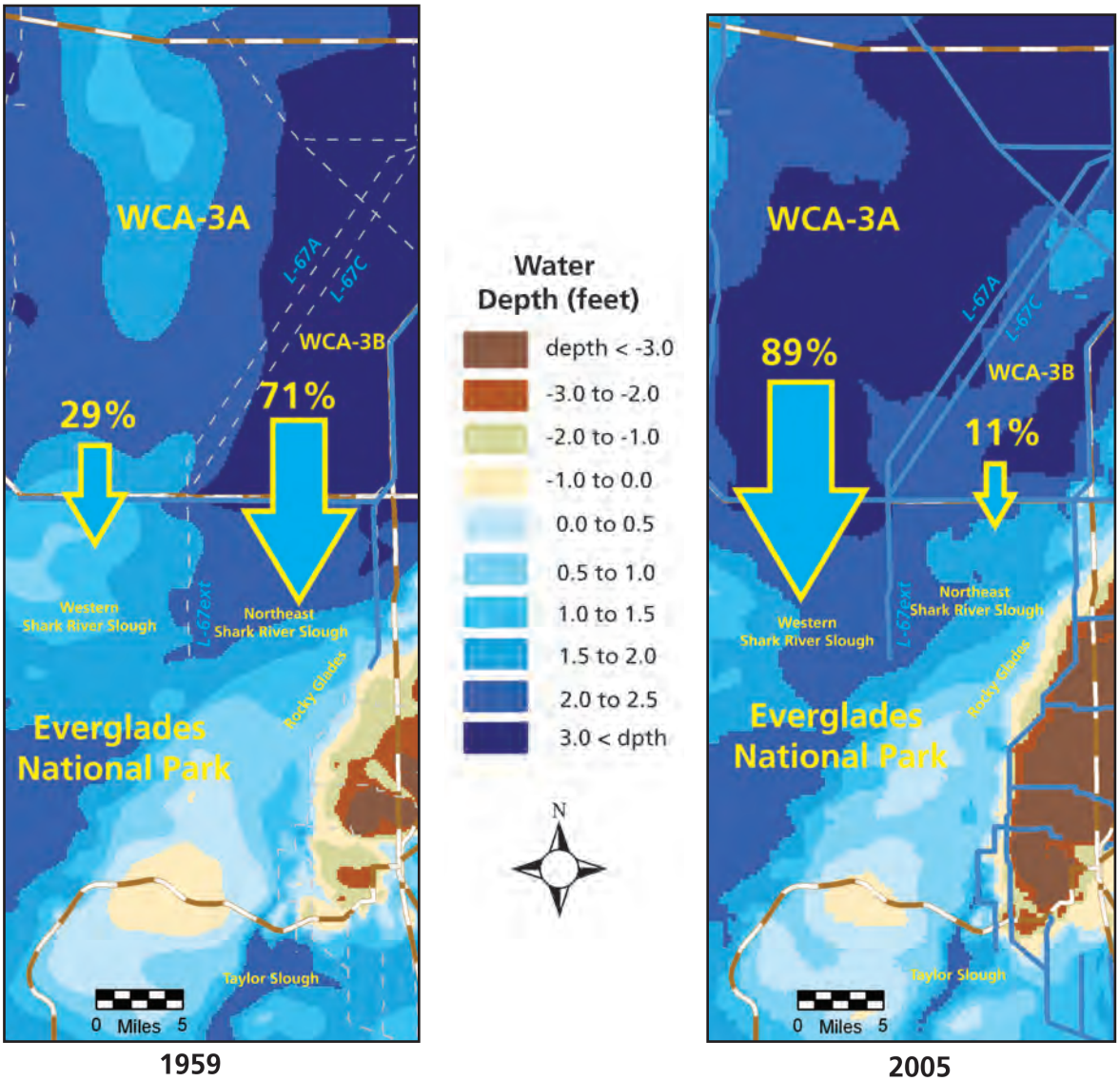


Figure 3. Water depths and flow distributions for two wet years (1959 and 2005) when more than 1 million acre-feet of water was discharged to Shark River Slough in ENP. These two years correspond to the period prior to compartmentalization (1959) and post-compartmentalized Water Conservation Area (WCA) 3 (2005). Prior to compartmentalization, the higher water depths and flow volumes were more confined to the eastern flow-way through Northeast Shark River Slough. Today, as depicted in 2005, the deeper water and greater flows are more confined to WCA 3A and Western Shark River Slough.

Water Quality

Before the advent of industrial agriculture in south Florida, there were minimal external sources of nutrients entering the Everglades, and the slow flow of surface water and warm subtropical climate provided ample opportunity for nutrient uptake and retention by the extensive wetlands. The freshwater marshes developed under conditions of extremely low phosphorus concentrations (less than 10 parts per billion (ppb) of total phosphorus (TP), equivalent to 10 μg L^{-1}) and areas within the park that are far removed from external sources still routinely show TP concentrations that are around the detection limit of 2 ppb. Phosphorus is a limiting nutrient in the Everglades and native flora and fauna are highly sensitive to elevated phosphorus levels.

Today, there exists a distinct north-to-south gradient of nutrients and pollutants from the agricultural areas upstream of the WCAs to ENP, which is still relatively unimpacted. More than 16,200 hectares (ha) of Everglades wetlands, primarily north of the park, show signs of significant eutrophication, and these impacted areas are still increasing in size. In these impacted areas, the algal community called "periphyton," which forms the base of the food chain, is altered in species composition or has disappeared altogether. Reduced oxygen in the water column and increased phosphorus concentrations in the soil have led to conversion of the prairie sawgrass (*Cladium jamaicense* Crantz) and slough mosaic into dense stands of cattail (*Typha spp.*). These cattail stands are uninhabitable to most Everglades fish and wildlife: not only is fish production low in these areas, but also the structure of the cattail vegetation impedes foraging by wading birds and alligators.

The Desired State of Conservation for Water Quality in ENP is to have very low nutrient levels in the water entering the park (less than 10 ppb or less than 10 μg L^{-1}), and to maintain the current status of large areas of the park interior that routinely are around the detection limit of 2 ppb.

The Freshwater Environment: Ridge, Slough, and Marl Prairies

Ridge, Slough, and Tree Island Landscapes with Associated Fish and Wildlife

Shark River Slough forms the central core of the freshwater marshes within ENP and represents the downstream extent of the long-hydroperiod wetlands originally found throughout the Everglades. Consistently deep, slow-flowing water promoted the growth of aquatic vegetation such as white water lily (*Nymphaea ordorata*) in the center of the slough. Over this landscape, thick peat deposits developed and flow-sculpted microtopography in the vegetation and underlying soils was created. Slightly higher sawgrass ridges (that sometimes contain streamlined tree islands or hardwood hammocks) and parallel deeper sloughs formed a patterned peatland that was oriented in the direction of historic water flows. While the ridge and slough plant communities are rather homogeneous, the tree islands are biodiversity hotspots, providing the only dry ground for a suite of plant and animal species that cannot tolerate the prolonged flooding in the adjacent wetlands (Fig. 2). The deeper slough communities are the core areas for primary and secondary biological production in the Everglades, and the continuous flooding in these sloughs is critical for interannual survival of aquatic organisms. The small fish and macroinvertebrates found in these wetlands form the prey base for larger fish, alligators, and wading birds, emblematic species of the Everglades.

The distribution, volume, and seasonal timing of water flows to these ridge and slough habitats have been altered by the construction of the C&SF system, and marsh water quality has been degraded by the introduction of agricultural and urban runoff containing elevated levels of nutrients and contaminants. Within the ridge, slough, and tree island landscape of the park, reduced water flow volumes have resulted in shortened wetland hydroperiods, resulting in peat accretion rates that cannot keep pace with soil oxidation and subsidence, and an increased frequency and intensity of wildfires. Over time, marsh flow velocities have been reduced, and the highly productive deep water sloughs have been filling in. The characteristic ridge and slough microtopography (Fig. 4) is being flattened, and the flow-sculpted patterned peatlands, which are a defining characteristic of the Everglades, are slowly being replaced by large areas of homogeneous sawgrass. The shortened durations of marsh flooding reduce the standing stock of small freshwater fish and macroinvertebrates, and the once abundant wading-bird breeding populations have declined by 70–90% from pre-drainage estimates. Nutrient levels in water entering the park hover just below the water quality limits, and nutrient impacts on periphyton and vegetation have been observed in specific localized areas.

The Desired State of Conservation for the ridge, slough, and tree islands landscape is broadly defined as a system that approaches as much as possible the pre-drainage landscape patterns, vegetation, and fish and wildlife communities. A restored ridge and slough system will have re-established microtopography, with water depths and multi-year hydroperiods that can support aquatic vegetation such as white water lily. These habitats will produce high biomass and high densities of native fish and macroinvertebrates as water recedes gradually during the dry season, providing a prey base for large numbers of alligators and a diverse and abundant wading bird community.

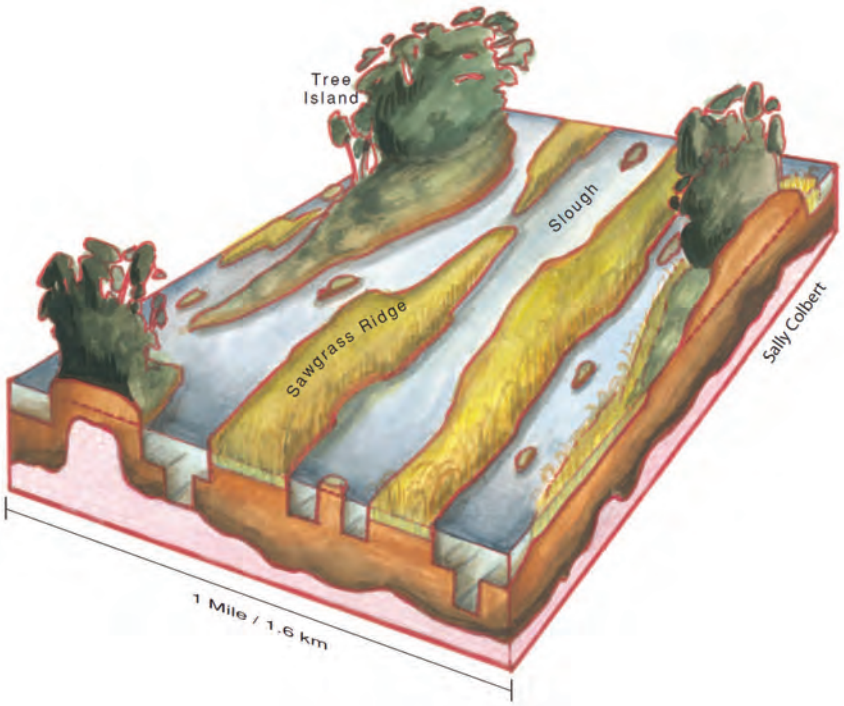


Figure 4. Schematic diagram showing the ridge and sough patterned landscape. Illustration by Sally Colbert; modified from McVoy et al. (2011, p. 67).

Marl Prairie, Hardwood Hammock, and Pineland Landscapes with Associated Fish and Wildlife

Along the flanks of Shark River Slough are slightly elevated marl prairies with interspersed tropical hardwood hammocks and pine rocklands. Unlike the peatlands of the central Everglades slough, water levels naturally drop well below the land surface for several months a year in these marl prairies. The accumulation of organic sediments is inhibited by annual drydowns, so the land surface is covered by thin calcitic marl soils produced seasonally from the inorganic remains of the seasonally abundant periphyton community. The general landscape of the marl prairies supports a complex mosaic of wet prairies, sawgrass, and transitional uplands with high plant diversity. The prairies, especially the eastern marl prairies known as the "Rocky Glades," contain shallow solution holes that historically served as refugia for small fish and macroinvertebrates during the dry season. These solution holes are also important areas for alligator nesting, and wading birds forage in these wetland depressions in the early dry season, when water levels in the sloughs are still too deep. The tropical hardwood forests and pine rocklands occupy the highest ground in the Everglades, and their geographic isolation has led to significant concentrations of rare and endemic plants. Because the water management system has affected the eastern and the western marl prairies of ENP in very different ways, these two areas are described separately, below.

The eastern marl prairies, or Rocky Glades, lay between the developed uplands along the Atlantic Coastal Ridge and the deeper water ridge and slough communities of Shark River Slough. Until the early 1960s, wet season water levels from NESRS would routinely overtop the Rocky Glades and contribute additional inflows to the Taylor Slough watershed. These flows maintained greater water depths and longer flooding durations within the Taylor Slough wetlands than presently and were a critical source of freshwater to central Florida Bay. As the remaining higher ground along the Atlantic Coastal Ridge was occupied, agricultural and urban development expanded westward. In the 1950s and 1960s, canals were excavated into the porous limestone bedrock along the eastern edge of the park to support expanding agricultural and urban activities. The effectiveness of the canals in accumulating and moving water resulted in declining groundwater levels, which thereby reduced water depths and hydroperiods. This change has caused a decrease in periphyton abundance, fish and macroinvertebrate production, and marl soil deposition, and has caused plant communities to shift toward an increased abundance of woody terrestrial species. The encroachment of development has brought an increase in exotic species invasions, and fires have become more frequent and intense, leading to the periodic loss of tree islands and hardwood hammocks. Alligator nesting and wading bird foraging has decreased in these habitats, in response to shifting vegetation communities and the reduced prey base. Finally, in areas that have received direct canal inflows, degraded water

quality has altered native plant and animal communities, and these new pathways have allowed for expansion of invasive exotic fishes.

In contrast to these drier conditions in the eastern marl prairies, the park's western marl prairies became wetter over the last 50 years due to the construction of the L–67 levees that divert water flows westward, so that these flows no longer enter the historically deepest part of the system (NESRS), but are placed directly onto the western marl prairies and thus into western Shark River Slough. In this area, water depths and flooding durations have increased, and in the wettest years, the usual annual marsh drydowns have not occurred. This has moved the wetland plant communities toward a dominance of wet prairie and sawgrass, more typical of the deeper peat-forming areas. This area is also critical habitat for a ground-nesting endangered bird, the Cape Sable seaside sparrow (*Ammodramus mirabilis*), that has seen its nesting success greatly reduced by the increased water depths, extended hydroperiods, and drying pattern reversals caused by changing water management practices.

The Desired State of Conservation for the park's marl prairie, hardwood hammock, and pineland landscapes is broadly defined as a system in which pre-drainage water patterns are restored as much as possible, leading to longer hydroperiods, annual deposition of marl soil, and the re-establishment of a healthy mosaic of native wet prairie grass species interspersed with diverse hardwood hammocks. Severe and multiyear drying down of this habitat will be less frequent than at present. Alligator nesting will be frequent along the transition between the marl prairies and the slough, and wading birds will have more abundant prey and adequate water levels to promote seasonal foraging in these areas. The western marl prairies will become less flooded, and the population of Cape Sable seaside sparrows will increase. The pinelands will retain their current diverse suite of rare and endemic plant species and will serve as habitat for wildlife such as the Florida panther, Florida wild turkey (*Meleagris gallopavo osceloa*), and cavity-nesting birds.

The Coastal and Estuarine Environment: Florida Bay

Coastal Marshes, Prairies, Mangroves, and Florida Bay Landscapes with Associated Fish and Wildlife

To the south and west in ENP, freshwater marshes merge into mangrove-dominated areas with scattered open coastal salt marshes, marking the transition to the saline communities along Florida Bay and the Gulf of Mexico. Along the southwestern Gulf Coast, this transition is marked by dense mangrove forests, dominated by black (*Avicennia germinans*) and white (*Laguncularia racemosa*) mangroves and buttonwoods (*Conocarpus erectus*). Scattered throughout these forests are salt marsh communities that are seasonally inundated by tidal actions and storm surges. These salt marshes are the result of hurricanes that destroyed the mangrove forests and reworked the underlying sediments, forming slightly higher areas that are dominated by saltwort (*Batis maritima*) and black rush (*Juncus roemerianus*). Freshwater flows from the upstream Everglades keep the mangrove-lined creeks in this area fresh to slightly brackish during the rainy season, but they become saline during the dry season.

Florida Bay formed about 4,000 years ago, as rising sea levels began to inundate the low-lying southern end of the Everglades. Seasonal fluctuations of fresh and brackish water created estuarine conditions, highlighting the importance of the hydrologic linkages with the upstream Everglades. The transitional habitats upstream of Florida Bay are open (in contrast to the expansive mangrove forests along the Gulf Coast), with salt marsh communities mixed with scrub red mangroves (*Rhizophora mangle*), and only a narrow strip of dense black and white mangroves found primarily along the immediate Florida Bay shoreline. The lower tidal range in Florida Bay has created a series of brackish ponds and small embayments upstream of the bay that seasonally alternate between fresh and saline conditions. While the dense mangrove forests along the Gulf Coast accumulate relatively thick organic-rich soils and support diverse communities of invertebrates, reptiles, fishes, and birds, the reduced salinity fluxes in the tidal wetlands and scrub mangroves along Florida Bay tend to have lower organic matter production and lower plant and animal diversity.

Florida Bay has an average water depth of approximately 3.0 feet (90 cm). The shallow depth and abundant mud banks restrict water movement and make Florida Bay highly susceptible to extreme variations in salinity that affect the chemistry and ecology of the bay. The bottom of the bay has extensive seagrass beds and benthic algae, which provide important habitat and food for juveniles of species such as pink shrimp (*Farfantepenaeus duorarum*), sea trout (*Cynoscion nebulosus*), and red drum (*Sciaenops ocellautus*), supporting commercial fisheries outside ENP and an active recreational fishery in and around the park. Endangered species such as the West Indian manatee and small-toothed sawfish (*Pristis pectinata*) are found. A variety of wading birds, historically including the endangered wood stork (*Mycteria americana*) and the roseate spoonbill (*Ajaia ajaja*) in great numbers, use the brackish interface between the mangroves and the bay for foraging and nesting.

Over the last 100 years, freshwater inflows to Florida Bay have been reduced by more than 50%, and stormwater runoff from upstream agricultural areas has brought elevated nutrients and contaminants into Florida Bay. In response, the bay has shifted from an estuarine ecosystem toward a more pulsed marine lagoon. Today only the nearshore embayments upstream of the bay have low enough salinity to maintain seasonal estuarine conditions supporting widgeon grass (*Ruppia*) and shoal grass (*Halodule*). In the central portion of Florida Bay, a series of shallow calcareous mud banks are interspersed with deeper basins, which reduce water and nutrient exchange and tidal

flushing. With reduced freshwater inflows and poor water circulation, the central portion of Florida Bay becomes a large evaporation basin and salinities can rise above 70 parts per thousand (twice the salinity of ocean water). Higher salinities in the central bay support turtle grass (*Thalassia*), manatee grass (*Syringodium*), and benthic algal communities more common in marine environments. The algae contain calcium carbonate in their supporting tissue (much like the freshwater periphyton communities) that is released as they die, forming the carbonate-rich sediments that dominate the bay bottom.

In the 1980s, a period of low rainfall reduced freshwater inflow and the resulting high salinity triggered a series of seagrass die-off events in central Florida Bay. As salinity conditions began to exceed the tolerance range for turtle grass, the dense seagrass beds started to disappear. The underlying sediments were no longer stable, and the fine calcareous sediments and their associated nutrients were released into the water column, increasing turbidity and further stressing the seagrass community by reducing available light. At the same time, the released nutrients created conditions that increased phytoplankton production, and algal blooms formed over much of the central bay. Filter feeders like sponges experienced a mass mortality and the loss of seagrass and other benthic organisms greatly diminished the amount of productive nursery habitat for fish and invertebrates. Important animal species such as shrimp, lobster, and sport fish, as well as the threatened American crocodile, were also impacted because their young require low-salinity conditions for optimal growth and survival.

The Desired State of Conservation for the coastal wetlands, mangroves, and Florida Bay is defined as a system in which 1) more natural freshwater flows have been restored and in which the input of nutrients and contaminants has been reduced; 2) algal blooms occur less frequently than at present, and clear, clean water in the bay supports healthy seagrass beds, including an increased presence of widgeon grass and shoal grass; 3) hardbottom communities such as sponges and corals are restored; 4) reduced salinities in the bay provide the conditions for a productive estuarine nursery, supporting region-wide populations of pink shrimp and sport fish as well as improved conditions for the American crocodile; and 5) salinity conditions, combined with more natural water recession rates in the mangrove transition, support wading bird nesting colonies in the area.

Invasive Exotic Species in Everglades National Park Habitats

One of the outstanding universal values cited in the decision to make ENP a World Heritage Site was that of the complexity and intact nature of its natural food webs and the integrity of its biological processes. Exotic species invasions constitute a threat to this Outstanding Universal Value.

The proximity of ENP to the Miami metropolitan area means that the park is susceptible to invasion by exotic species (plants and animals—terrestrial, freshwater, and marine) that are brought in primarily via the landscape/nursery and exotic pet industries. Nearly one-fourth of plant species found in ENP are not native to the area. Most of these species are found in isolated patches or are rarely occurring, but several have become invasive over large areas and these interfere with ecological function in a variety of freshwater wetland and upland habitats in the park. The presence of invasive exotic animals in ENP is less well-studied; however, invasive reptiles, fish, birds, and mammals are a serious threat to the ecological integrity of ENP. Exotic reptile species are becoming established in ENP and surrounding lands, including the Burmese python (*Python molurus bivittatus*), South American tegu lizard (*Tupinambus sp.*), basilisk lizard (*Basiliscus vittatus*), and North African rock python (*Python sebae*). African jewelfish (*Hemichromis bimaculatus*) are now widespread in the freshwater marshes of ENP. Recently, invasive lionfish (*Pterois volitans*) have been found in the marine waters of ENP as well as in other national parks in south Florida.

A general statement of the Desired State of Conservation is that park habitats will reflect as much as possible the natural species composition of the biological communities they represent, and the impact of exotic species on native biota will be nearly imperceptible. The extent and number of exotic invasions into ENP habitats is great; therefore, we do not expect to ever eliminate entirely all exotic species from the park. In this sense, the Desired State of Conservation is similar to that for hydrologic restoration of park habitats: we accept that we will not achieve full return to an historical Everglades biota. The extent to which we can approach the Desired State of Conservation depends on many factors, one of which is the taxa of the exotic species. At this time, four taxonomic groups are the focus of work in ENP: plants, freshwater fish, herpetofauna (reptiles and amphibians), and marine fish. Advances toward the Desired State of Conservation are also dependent on the science to develop appropriate detection and control techniques and on the resources (staff and funding) available to successfully apply early detection/rapid response and control methods. Education and outreach, and examination of potential legislative and policy changes that reduce the risk of introduction of invasive exotic species, are also key to achieving the Desired State of Conservation.

INTEGRITY INDICATORS: DESCRIPTION AND STATUS AS OF 2013

At the Everglades ecosystem level, changes in the quantity, quality, timing, and distribution of water flows are currently the largest determinant of overall ecosystem health. Our goal of restoring more-natural hydrologic conditions is linked to the observation that the regions of the park that are far-re-

moved from water management actions tend to be the most stable and ecologically productive, while the areas closest to water management structures tend to be the most unstable and have lower ecological productivity. Our ecological indicators start with hydrologic parameters (such as water depths and flooding durations) and chemical parameters (such as nutrients and salinity) because these parameters greatly affect primary productivity, which affects emergent vegetation, fish, and macroinvertebrate abundance, which then affects the availability of food for larger fish, wading and shorebirds, and crocodilians.

The presence, diversity, and abundance of invasive exotic species are also important determinants of overall ecosystem health. Work toward the Desired State of Conservation with respect to invasive exotics (especially aquatic invasive species) involves coordination with the hydrologic restoration projects, but also requires specific projects oriented toward reducing the impact of exotic species in ENP and reducing the probability of future invasions.

The 2013 Integrity Indicators that we expect to be improved by implementation of the corrective measures are listed in Table 1. Eleven of these indicators were included in the State of Conservation report for 2012. Here, the list has been updated to include indicators of exotic species invasion. A summary "stoplight" table is provided for each indicator to present each criterion assessed, the Desired State of Conservation for the criterion, the current status of the criterion as a stoplight icon, and the rationale for the status assigned. An explanation of the stoplight indicator colors and arrows is provided in Table 2. The technical basis for each of the integrity indicators is presented in more detail in a companion report (SFNRC 2013).

Table 1. Integrity indicators for freshwater and estuarine ecosystems of Everglades National Park.

The Physical Environment
Indicator 1: Water volume and distribution
Indicator 2: Water pattern and water levels (timing and spatial distribution of surface water depths—hydro-pattern)
Indicator 3: Water quality (total phosphorus and periphyton)
The Freshwater Environment: Ridge, Slough, and Marl Prairies
Indicator 4: Freshwater fish and aquatic invertebrates
Indicator 5: American alligator
Indicator 6: Everglades wading birds
The Coastal and Estuarine Environment: Florida Bay
Indicator 7: Salinity patterns in Florida Bay
Indicator 8: Algal blooms in Florida Bay
Indicator 9: Seagrasses in Florida Bay
Indicator 10: Estuarine fish (sport fish) and invertebrates
Indicator 11: American crocodile
Invasive Exotic Species in Everglades National Park Habitats
Indicator 12: Invasive exotic plants
Indicator 13: Invasive exotic fish and wildlife (freshwater and marine)

Table 2. Stoplight indicator key.

Status		Trend		Confidence	
	Warrants Significant Concern		Condition Is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Resource is in Good Condition		Condition is Deteriorating		Low

The Physical Environment

Indicators 1 and 2: Water Volume and Distribution & Water Pattern and Water Levels

Three metrics provide a way to track progress toward the Desired State of Conservation for hydrology. The percentage of water that flows across the Tamiami Trail on the eastern vs. the western sections is monitored. On an annual basis, the majority (about 55%) of this water should flow across the eastern section of the trail, in the main historical flow-way of NESRS. For water volume, a target range is established, in thousands of acre-feet, for the water coming across Tamiami Trail. Third, water depths in NESRS need to increase and need to vary naturally with rainfall. This is monitored using water "stage," or the level of water in NESRS compared to sea level. Corrective measures that improve sheetflow, water depth, and hydroperiod, and reduce seepage losses out of the park, will move ENP in the direction of the Desired State of Conservation for these hydrologic indicators.

Indicator 1. Water volume and distribution.

Criteria	Desired State of Conservation	Condition & Trend	Rationale
Magnitude and distribution of sheetflow	On an average annual basis, 55% of flows should come through NESRS and 45% of flows should come through WSS.		A large disparity continues to exist in the distribution of flows between WSS and NESRS. Over the long term, 77% of the total Shark River Slough flow distribution was delivered to WSS and 23% to NESRS. In 2011, 78%, or almost double the WSS target volume, was delivered to WSS and only 22% was delivered to NESRS.
Average annual water volume into NESRS	On average, a total annual volume of water should be delivered to NESRS of 550,000 acre-feet (acre-ft) with a range of 200,000 to 900,000 acre-ft during years of below- and above-average rainfall, respectively.		Over the period from 1980 to 2013 (34 years), the target was met only 1 time, in 1986 during a dry year. During average and wet years, flow to NESRS was generally less than half the target.

Indicator 2. Water pattern and water levels.

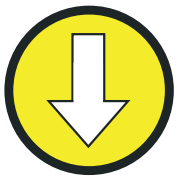
Criteria	Desired State of Conservation	Condition & Trend	Rationale
Water pattern and water levels (timing and spatial distribution of surface-water depth hydropattern)	The target is to achieve annual average water levels (stage) in NESRS of approximately 8.0 feet (ft) National Geodetic Vertical Datum of 1929 (NGVD) during years of average annual rainfall. During years of below- and above-average annual rainfall, the average water level in NESRS would be 7.5 and 8.8 ft, respectively.		NESRS water levels are consistently significantly lower than targets. In no year has the average water level in NESRS even reached the lower range of the target (7.5 ft NGVD).

Indicator 3: Water Quality (Total Phosphorus and Periphyton)

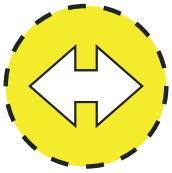
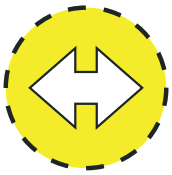
In the pre-drainage Everglades, concentrations of TP in surface water were generally less than 10 μg L^{-1}. TP concentrations are measured at inflow points and internal marsh sampling sites in both Shark River Slough and Taylor Slough, and the concentrations are used to track progress in reducing nutrient levels entering the park. The goal is to be in compliance with all State of Florida and federal water quality standards for TP (including the long-term limit in the Water Quality Settlement between the United States and the State of Florida), and document a trend toward reductions in the spatial distribution of nutrient-impacted areas.

Periphyton is an algal and diatom community in ENP that contributes a large portion of net primary productivity. Periphyton responds quickly to changes in environmental conditions at both small and large spatial scales and thus can be an early ecological indicator of impacts from management activities. In the Everglades ecosystem, even small increases in surface water phosphorus concentrations can decrease periphyton biomass and shift the periphyton community structure, ultimately impacting higher trophic levels. Three metrics associated with periphyton are monitored: periphyton biomass, tissue phosphorus content, and shifts in species composition (Gaiser 2009). Changes in periphyton are reported separately for the two main sloughs in the park, Shark Slough and Taylor Slough, because these two areas are affected by different corrective measures. Corrective measures that improve hydrologic conditions and nutrient levels in the park should produce positive change in ENP periphyton communities in both Shark and Taylor Sloughs.

Indicator 3. Water quality: Total phosphorus and periphyton.

Criteria	Desired State of Conservation	Condition & Trend	Rationale
TOTAL PHOSPHORUS			
Shark River Slough inflow phosphorus concentration	Inflow phosphorus concentrations to Shark River Slough below the target.		Inflow phosphorus concentration is between the long-term limit and phosphorus target.
Shark River Slough interior marsh phosphorus concentration	Interior marsh phosphorus concentrations in Shark River Slough below the target.		Interior marsh phosphorus concentration is below the target.
Taylor Slough and Coastal Basins inflow phosphorus concentration	Inflow phosphorus concentrations to Taylor Slough and Coastal Basins below the target.		Inflow phosphorus concentration is between the long-term limit and phosphorus target this year, but concentrations have increased since October 1992.
Taylor Slough and Coastal Basins interior marsh phosphorus concentration	Interior marsh phosphorus concentrations in Taylor Slough and Coastal Basins below the target.		Interior marsh phosphorus concentration is below the target and concentrations have declined since October 1992.

Indicator 3 continued. Water quality: Total phosphorus and periphyton.

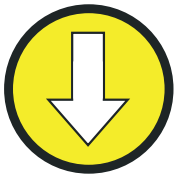
Criteria	Desired State of Conservation	Condition & Trend	Rationale
PERIPHYTON			
Shark River Slough periphyton tissue phosphorus content	25% or less of Shark River Slough stations are coded yellow or red.		More than 25% of monitored stations in Shark River Slough were coded yellow or red for periphyton tissue phosphorus content, exceeding the desired state.
Shark River Slough periphyton biomass	25% or less of Shark River Slough stations are coded yellow or red.		More than 25% of monitored stations in Shark River Slough were coded yellow or red for periphyton biomass phosphorus concentration, exceeding the desired state.
Shark River Slough periphyton composition	25% or less of Shark River Slough stations are coded yellow or red.		The condition was not assessed this year, but last year more than 25% of monitored stations in Shark River Slough were coded yellow or red for periphyton composition and this pattern is expected to continue for the next few years, exceeding the desired state.
Taylor Slough periphyton tissue phosphorus content	25% or less of Taylor Slough stations are coded yellow or red.		25% or less of monitored stations in Taylor Slough were coded yellow or red for periphyton tissue phosphorus content, but the area is on the cusp of yellow, and reductions in hydroperiods, water depth, or increased nutrient loading may lead to declines in the indicator.
Taylor Slough periphyton biomass	25% or less of Taylor Slough stations are coded yellow or red.		25% or less of monitored stations in Taylor Slough were coded yellow or red for periphyton biomass phosphorus concentration.
Taylor Slough periphyton composition	25% or less of Taylor Slough stations are coded yellow or red.		The condition was not assessed this year, but last year more than 25% of monitored stations in Taylor Slough were coded yellow or red for periphyton composition and this condition is expected to continue over the next few years, exceeding desired state.

The Freshwater Environment: Ridge, Slough, and Marl Prairies

Indicator 4: Freshwater Fish and Aquatic Invertebrates

Fish and aquatic invertebrate assemblages play an important role in Everglades food webs and can be used as an indicator of ecosystem health. Factors that influence the fish and aquatic invertebrate populations cascade up the food web and influence species such as alligators and wading birds. The Desired State of Conservation is to maximize densities of small-sized freshwater fishes and aquatic invertebrates in a manner consistent with contemporary knowledge of the pre-drainage Everglades ecosystem. The near-term goal is a measurable positive trend in fish abundance that can be verified by monitoring field conditions and using models developed to predict population densities of freshwater fish and invertebrates relative to target hydrologic conditions (Trexler et al. 2003). As with periphyton, freshwater fish metrics are reported for Shark Slough and Taylor Slough separately. Corrective Measures associated with increasing the duration of low nutrient surface water flooding (in both the ridge and slough and marl prairie communities) will contribute to increased freshwater faunal assemblages and promote a more natural species composition.

Indicator 4. Freshwater fish and aquatic invertebrates.

Criteria	Desired State of Conservation	Condition & Trend	Rationale
Shark River Slough overall	Abundance is maximized in a manner that reflects pre-drainage conditions.		Fewer fish were present than expected based on rainfall conditions and drought-tolerant species were abundant. Represents a decline in condition from previous years.
Taylor Slough overall	Abundance is maximized in a manner that reflects pre-drainage conditions.		Moderately fewer fish were present than expected based on rainfall conditions and drought-tolerant species were abundant. Represents a decline in condition from previous years.

Everglades researchers monitor freshwater fish and invertebrates using a variety of field equipment, including throw traps and dip nets. NPS photo.

Indicator 5: American Alligator

The American alligator is a keystone species that functions as an ecosystem engineer, directly or indirectly influencing nearly all aquatic life in the Everglades (Beard 1938, Craighead 1968, Mazzotti and Brandt 1994, Simmons and Ogden 1998). Alligators are important indicators of Everglades ecosystem health because they are responsive to hydrologic change; these characteristics make them ideal candidates for inclusion in long-term studies that track restoration progress. Alligators were abundant throughout the pre-drainage Everglades, but the highest densities were in the marl prairies and along the freshwater fringe of the mangrove communities within ENP. Alligators are much less common in these areas today because of reduced and highly variable water depths and hydroperiods in the marl prairies, and reduced freshwater flows and elevated salinities in the southern coastal marshes. Several metrics are monitored that together provide a picture of the status of alligators in ENP: total nesting effort and nesting success, nest density and distribution, and number of alligators in the park.

As a keystone species, alligators influence nearly all aquatic life in the Everglades. NPS photo by Sarah Zenner.

Indicator 5. American alligator.

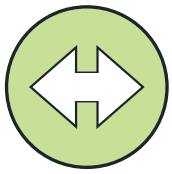
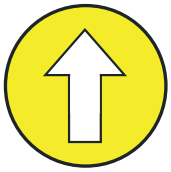
Criteria	Desired State of Conservation	Condition & Trend	Rationale
Positive trend in nesting effort	Increasing trend in nesting effort throughout all freshwater marshes, particularly peripheral marshes historically believed to support the majority of nesting effort. The target is nesting effort consistent with a restored Everglades ecosystem.		Nesting effort has increased significantly since 1985; recent trends show more stability during poor to moderate conditions and record numbers during favorable conditions.
Positive trend in nest success	Increasing trend in nest success and reduced failure due to flooding of egg cavity. The target is nest success levels consistent with a restored Everglades ecosystem.		Nest success continues to be highly erratic due both to extreme natural and managed seasonal hydrologic fluctuation.
Positive trend in nest density/ distribution	Increasing trend in density of nests across hydrologic basins, particularly within shorter hydroperiod peripheral marshes. The target is nest density and distribution consistent with a restored Everglades ecosystem.		Nest density and distribution throughout freshwater hydrologic basins of ENP have demonstrated an increasing trend in recent years.
Positive trend in alligator abundance	Increasing trend in abundance for all size classes of alligators within freshwater wetlands. The target is an abundance of alligators consistent with a restored Everglades ecosystem.		Results of spotlight surveys indicate reduced abundance estimates in all size classes within ENP.

Indicator 6: Everglades Wading Birds

The great abundance and diversity of wading birds—the herons, egrets, ibises, and storks—is a defining characteristic of the Everglades, and a significant reason for the creation of ENP. Since wading birds are relatively easy to monitor across the landscape and much is known about their habitat requirements and historical nesting patterns, they are excellent indicators of environmental conditions in the Everglades. Wading birds breeding in the Everglades require easily available and abundant aquatic prey, which are dependent on a variety of environmental factors including the quantity, distribution, and timing of water flows.

In the pre-drainage Everglades, the largest and most persistent nesting colonies were at the marsh/mangrove ecotone in the southern portions of ENP. Large "super colonies" would form in response to peaks in prey-base availability, following years with high wet-season water levels and very stable dry-season recession rates. In the post-drainage Everglades, wading bird populations have experienced a 70–90% reduction in abundance, and the major nesting areas have shifted northward into the impounded central Everglades (WCAs). A number of key species, most notably the endangered wood stork, have also experienced a shift in the timing of reproduction, initiating nesting later into the dry season because water levels in the impounded central Everglades tend to recede more slowly. Under these conditions, fledglings emerge near the end of the dry season, and in years when wet season rainfall begins early, water levels rapidly rise, dispersing the prey base, and the nests fail.

Indicator 6. Everglades wading birds.

Criteria	Desired State of Conservation	Condition & Trend	Rationale
Increase the total number of pairs of nesting birds in south Florida	Maintain or increase current total numbers of nesting birds in ENP mainland colonies to a level consistent with a restored Everglades ecosystem.		Absolute size of breeding populations of ibises, storks, and long-legged wading birds declined sharply from the 1930s to the 1970s. Since the mid-1980s, nesting numbers in ENP are trending up. Numbers fluctuate greatly from year to year.
Month of wood stork nest initiation	Month of wood stork nest initiation should be November or December.		Nest success continues to be highly erratic due both to extreme natural and managed seasonal hydrologic fluctuation. Trend is improving slightly, but storks continue to fail because of late nest initiation.
Proportion of nests located in ENP headwaters	At least 70% of all wading bird nests should be located in the headwaters ecotone of the mangrove estuary of Florida Bay and the Gulf of Mexico (ENP).		Recent trends are positive, especially for storks, but distant from the 70% target.
Mean interval between exceptional white ibis (*Eudocimus albus*) nesting years	Mean interval between exceptional white ibis nesting years (≥13,000 nesting pairs) should be 1–2 years.		The trend is positive and consistent in recent years. This interval now consistently exceeds the target for restoration and has shown dramatic improvement in the last decade.
Ratio of wood stork and white ibis nests to great egret nests	Ratio of the combination of wood stork and white ibis nests to great egret nests should be 30:1, which is characteristic of the community composition of pre-drainage conditions.		Current ratio (2:1) is well below the 30:1 ratio that is considered to be representative of healthy nesting conditions. Ratio appears to have stabilized and has not moved much in the last 10 years (range ~1.5:1 to 4:1).

The Coastal and Estuarine Environment: Florida Bay

Indicator 7: Salinity Patterns in Florida Bay

Salinity is the driving parameter controlling the major ecological processes in estuarine ecosystems, including the distribution of aquatic plants and animals, overall biological productivity, and nutrient cycling. In the pre-drainage ecosystem, freshwater inflows were more persistent, and stable estuarine, low-salinity conditions existed over large areas along the park's coastline along the Gulf of Mexico and throughout much of Florida Bay. In the post-drainage Everglades, water flows are diverted away from the park, causing the southern coastal ecosystems to receive less freshwater and become more marine. Three metrics are used to track the progress of salinities in Florida Bay toward the desired pre-drainage, low-salinity conditions. These are 1) the amount of time during the year that salinities are in the desired range; 2) a measure of the difference between observed salinities and the desired low-salinity conditions; and 3) a measure of the frequency of extreme high-salinity events. The goal is to have each of these measures reflect pre-drainage, low-salinity conditions.

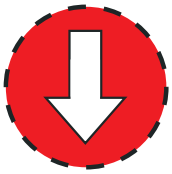
Indicator 8: Algal Blooms in Florida Bay

Florida Bay has a history of having highly variable water quality conditions, with algal bloom episodes that can last from weeks to even years. Blooms sustained for more than several months can be damaging to seagrass habitat and fauna, especially sponges. The last period of extended blooms was during 2005–2007. Conditions subsequently improved. In order to better understand causes of bloom variability and responses to Everglades restoration, the park has deployed and tested new automated sensors that provide prolonged high-frequency measurements ("continuous monitoring"). Field methodologies and data analysis are still being refined, but initial results from continuous monitoring indicate the presence of much higher bloom concentrations (indicated by concentrations of the algal pigment, chlorophyll *a*, in the water column, reported in ppb) than have been detected recently by grab sampling and analysis. We are still investigating these findings and also need to develop an understanding of "baseline" concentrations with this new methodology. Given the early stage of this methodological development, current data should be treated cautiously, but suggest elevated levels of chlorophyll *a* in the north-central coastal zone.

Indicator 7. Salinity patterns in Florida Bay.

Criteria	Desired State of Conservation	Condition & Trend	Rationale
Amount of time during the year that salinity is in the desired range	Salinity is within the interquartile range of the desired pre-drainage conditions 50% of the time.		Salinity conditions overlap with desired conditions only during 2 months at the end of the dry season. Conditions are variable but exhibit no year-to-year trend.
Difference between observed mean salinities and desired mean salinities	The mean salinity is within the variability of the mean salinity of desired pre-drainage conditions.		The mean salinity is above desired mean salinity throughout the year. The degree of difference over the period of record (POR) is variable but largely driven by precipitation and shows no year-to-year trend.
Occurrence of extreme high-salinity events	Salinity does not exceed the 90th percentile defined by the desired conditions more frequently than 10% of the time.		Salinity exceeds the 90th percentile of the desired conditions much more frequently than desired and shows no year-to-year trend.

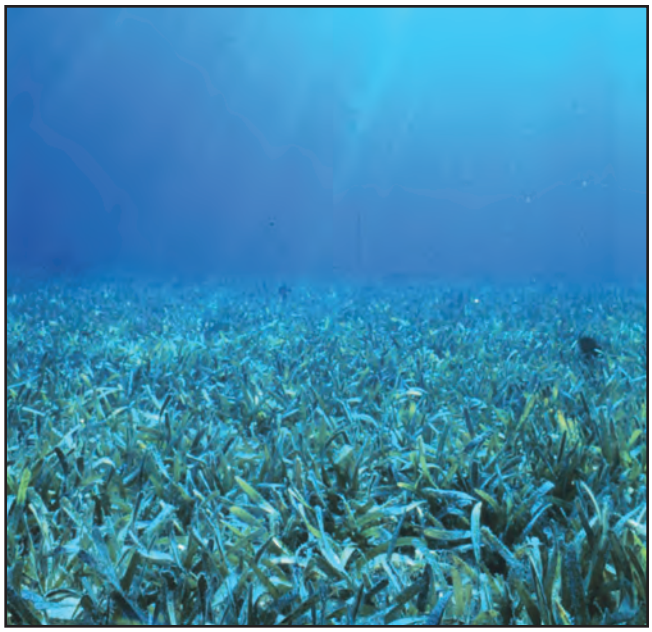
Indicator 8. Algal blooms in Florida Bay: Chlorophyll *a* concentration.

Criteria	Desired State of Conservation	Condition & Trend	Rationale
Central Florida Bay (Whipray Basin) chlorophyll *a* concentration	Average monthly concentrations below 1 ppb.		Levels were below threshold levels throughout 2012. Continuous monitoring methods are still being refined, and elevated levels (as high as 23 ppb) have been recorded in previous years.
Northern Florida Bay (Garfield Bight and Terrapin Bay) chlorophyll *a* concentration	Average monthly concentrations below 1 ppb.		Elevated levels were recorded in 2012 at both northern sites, including period of extremely high levels (12 to 21 ppb) for 5 months in Terrapin Bay. Continuous monitoring methods are still being refined, but initial results indicate poor and declining conditions.
Western Florida Bay (Buoy Key) chlorophyll *a* concentration	Average monthly concentrations below 1 ppb.		Levels were below threshold levels throughout 2012. Continuous monitoring methods are still being refined, and elevated levels (as high as 25 ppb) have been recorded in previous years.
Southern Florida Bay (Peterson Key) chlorophyll *a* concentration	Average monthly concentrations below 0.5 ppb.		Levels were below threshold levels throughout 2012. Continuous monitoring methods are still being refined.

Seasonal fluctuations of fresh and brackish water in the historic (pre-drainage) Everglades created estuarine conditions in Florida Bay. NPS photo by William Perry.

Indicator 9: Seagrasses in Florida Bay

The seagrass indicators are created from a set of metrics including spatial extent, abundance, species dominance, and presence of target species, which are monitored throughout Florida Bay. The Abundance Index combines all four metrics and reflects the status and health of the seagrass community as a whole, emphasizing abundance and spatial extent of seagrasses in Florida Bay. For the Abundance Index metric, the Desired State of Conservation is a long-term positive trend in community composition (abundance and extent) of submerged aquatic vegetation (SAV) in the Florida Bay ecosystem. The Target Species Index is a measurement of the frequency of occurrence of the desirable non-dominant SAV species that are expected to increase with increased freshwater flow to Florida Bay *(Halodule, Ruppia)*, resulting in improved habitat quality (Madden et al. 2009). For the Target Species Index, the desired State of Conservation is a long-term positive trend toward restoration conditions in the distribution of *Halodule* and *Ruppia* in the Florida Bay ecosystem. Indicator targets vary spatially and are zone-specific due to the complexities of the bay bottom and associated factors.

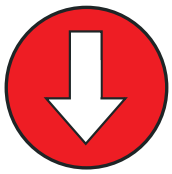
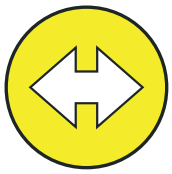


Seagrass beds provide extensive food and habitat for juveniles of numerous marine species. NPS photo.

Indicator 9. Seagrasses in Florida Bay.

Criteria	Desired State of Conservation	Condition & Trend	Rationale
NORTHEASTERN ZONE			
Seagrass abundance	Abundance of seagrass consistent with a restored Everglades ecosystem.		Aggregate Abundance Index is in the good range, with signs of recovery from the 2005–2008 algal bloom. However, moderate concern is warranted because salinity levels in the area remain high.
Target Species Diversity	Seagrass species diversity and niche diversity consistent with a restored Everglades ecosystem.		Good measurements of current species mix along with the presence of subdominants (*Halodule* and *Ruppia*). Desired mixed-species communities have not yet established.
TRANSITION ZONE			
Seagrass abundance	Abundance of seagrass consistent with a restored Everglades ecosystem.		Aggregate Abundance Index was fair for 2010–2011, since density levels fell in 2006.
Target Species Diversity	Seagrass species diversity and niche diversity consistent with a restored Everglades ecosystem.		A good mix of target species decreased during 2006–2007 and has yet to recover due to dominance of turtle grass.

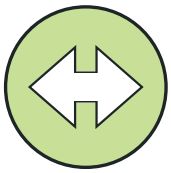
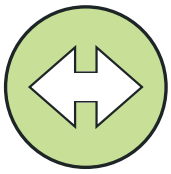
Indicator 9 continued. Seagrasses in Florida Bay.

Criteria	Desired State of Conservation	Condition & Trend	Rationale
CENTRAL ZONE			
Seagrass abundance	Abundance of seagrass consistent with a restored Everglades ecosystem.		Aggregate Abundance Index was fair for 2010–2011, since improving from poor in 2008.
Target Species Diversity	Species diversity and niche diversity consistent with a restored Everglades ecosystem.		Reflects the increasing presence of target species of *Halodule* and *Ruppia*.
SOUTHERN ZONE			
Seagrass abundance	Abundance of seagrass consistent with a restored Everglades ecosystem.		Poor rating due to reduced and declining densities of seagrass in this area.
Target Species Diversity	Species diversity and niche diversity consistent with a restored Everglades ecosystem.		Fair after improving in 2009 from several years in the poor range. Species dominance component improved to fair.
WESTERN ZONE			
Seagrass abundance	Abundance of seagrass consistent with a restored Everglades ecosystem.		High scores in the Abundance Index, sustaining improvement from 2008.
Target Species Diversity	Species diversity niche diversity consistent with a restored Everglades ecosystem.		Reflects good scores because the target species component increased.

Indicator 10: Estuarine Fish (Sport Fish) and Invertebrates

The abundance and availability of the four native sport fish species chosen indicate the condition of nearshore marine and estuarine communities because each of these species relies on this region for its entire life cycle. Sport fish are monitored using a metric called "catch per unit effort" or CPUE, which tracks the catch success of fishermen who are targeting the particular species in the bay. The Desired State of Conservation for the sport fish species is a stable to increasing trend in CPUE, indicating sustainable recreational use and environmental conditions. Unlike some other indicators in this suite, the Desired State of Conservation for sport fish may be met before full freshwater restoration is achieved, because it is currently based on the standard of sustaining conditions experienced over the last two decades. With additional analysis, we may be able to more fully develop this indicator and its associated State of Conservation with respect to restoration of freshwater flows. Pink shrimp density is sampled in the spring and the fall and has been shown to closely track upstream water management changes. The desired condition for pink shrimp is to have densities at or above those recorded during the pre-restoration baseline at the majority of sites in Florida Bay and along the southwestern coast of ENP.

Indicator 10. Estuarine fish (sport fish) and invertebrates.

Criteria	Desired State of Conservation	Condition & Trend	Rationale
Trend in snook (*Centropomus undecimalis*) catch per unit effort (CPUE)	The target is the CPUE levels during 2007–2009, or at least a stable CPUE trend, indicating sustainable recreational use and environmental conditions.		Snook populations declined in response to a cold-spell kill in 2010. The CPUE has indicated a return to a stable condition but has not yet indicated recovery.
Trend in red drum (*Sciaenops ocellata*) CPUE	The target is a stable to increasing trend in CPUE, indicating sustainable recreational use and environmental conditions.		Red drum CPUE has been relatively stable for the POR and has increased in recent years.
Trend in spotted seatrout (*Cynoscion nebulosus*) CPUE	The target is a stable to increasing trend in CPUE, indicating sustainable recreational use and environmental conditions.		Spotted seatrout CPUE has been relatively stable for the POR, with indications of a slightly increasing trend since 2004.
Trend in gray snapper (*Lutjanus griseus*) CPUE	The target is a stable to increasing trend in CPUE, indicating sustainable recreational use and environmental conditions.		Gray snapper CPUE has been relatively stable for the POR, with indications of an increase in CPUE since 2006.
Pink shrimp (*Farfantepenaeus duorarum)* density	The target is densities at or above those recorded during the pre-restoration baseline at the majority of sites in Florida Bay and along the southwestern coast of ENP. Note: restoration projects are not yet complete.		Pink shrimp density was generally below baseline levels and showed a declining trend at most sites compared to the pre-restoration baseline.

Indicator 11: American Crocodile

The American crocodile (*Crocodylus acutus*) functions as an ecosystem indicator in the coastal areas of the Everglades because its lifecycle is responsive to patterns of freshwater flow to the estuaries and resultant nearshore salinity patterns. American crocodiles were federally listed as "endangered" by the U.S. Fish and Wildlife Service (USFWS) in 1975, largely due to extensive habitat degradation (including nesting sites) and over-hunting. Crocodile recovery has been a story of cautious success in south Florida. While still in need of continuing protection, there are more crocodiles in more places today than there have been for at least the prior 35 years, thus leading to USFWS reclassification to "threatened" in 2007.

The most important metrics believed to directly relate crocodiles to hydrologic restoration include nest distribution/nesting effort, and differential growth and survival from hatching to late juvenile stages. Crocodiles nest in the late dry season primarily in elevated, sandy areas along the mangrove shoreline. The hatchlings have to migrate inland from their nesting sites to nursery areas because they cannot tolerate high salinity. Water management changes have reduced freshwater inflows to the coast of south Florida, creating longer hatchling migration distances and affecting the growth, survival, and dispersal of juvenile crocodiles.

Periodic sampling of these metrics in crocodiles has been underway in ENP and surrounding areas since 1978. Three metrics are reported: the total number of American crocodiles, reproductive effort (nesting effort, nest success, and nest distribution), and hatchling and juvenile growth and survival.

Hatchling crocodiles require low-salinity, estuarine conditions to thrive. Photo by Jemeema Carrigan, University of Florida.

Indicator 11. American crocodile.

Criteria	Desired State of Conservation	Condition & Trend	Rationale
Trend in total population	Population increase consistent with a restored Everglades ecosystem. Occupation throughout historic range.		Total population and distribution has exhibited an increasing trend; historic population is uncertain.
Trend in reproduction	Increasing trend in nesting effort, distribution, and success in ENP, including historical nesting sites in northeastern Florida Bay. Increasing trend in growth and survival of juvenile crocodiles, consistent with a restored Everglades ecosystem.		Reproductive effort within some areas of ENP has exhibited an increasing trend and is the best indicator of continued species recovery.
Trend in hatchling-juvenile growth and survival	Reduced salinity regimes occur, encouraging rapid hatchling growth rates (approaching mass ≥200 g 3–4 months post-hatching) and allowing juveniles to more rapidly reach total length ≥75 cm.		Survival is directly linked to increased hatchling-juvenile growth rates, which increase with lower salinities. Hatchlings within ENP consistently exhibit lower growth rates than adjacent nursery sites.

Invasive Exotic Species

The corrective measures established for ecosystem restoration include numerous modifications to the water management system to improve hydrologic parameters and to lower the input of nutrients to the ecosystem. Some of these hydrologic corrective measures, such as the reconnection of previously separated water bodies by removal of levees or construction of pump stations, may actually increase the potential for the invasion of exotic species into the park (Kline et al. 2013). This issue has been recognized by the agencies implementing Everglades Restoration; however, solutions are complex and require a high degree of innovation.

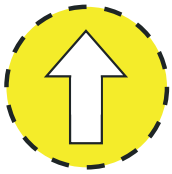
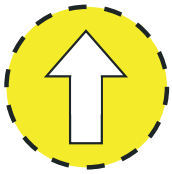
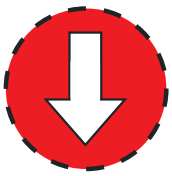
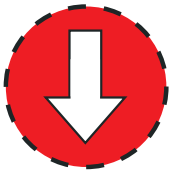
ENP is working to maintain and expand existing successful control of invasive exotic species and maintenance programs, primarily for plants. Control programs are not established for invasive exotic fish (freshwater or marine) or wildlife (particularly herpetofauna); therefore, the park is working to keep track of existing and new invasions and is investing in research, in early detection and rapid response where possible, and on education, outreach, and working with policymakers. The park has not yet established formal corrective measures with the World Heritage Committee with respect to exotic species. This report builds on the 2012 World Heritage report in the development of indicator metrics and statements of desired conditions.

Indicator 12: Invasive Exotic Plants

Although hundreds of exotic plant species are found in ENP, four exotic plant species have the most ecological impact and thus are of the highest management priority in ENP: melaleuca (*Melaleuca quinquenervia*), Australian pine (*Casuarina equisetifolia*), Old World climbing fern (*Lygodium microphyllum*), and Brazilian pepper (*Schinus terebinthifolius*). The desired state of these exotic plants and their management in ENP is species-dependent and reflects management's efforts to balance management feasibility with minimizing alteration to the natural environment. The targets described here reflect the feasibility of management to reach the stated goal of restoring as much as possible the natural species composition of the biological communities in the park. For melaleuca and Australian pine, the desired management state is less than 1% cover of these species per km^2 throughout the park. The desired management state for Old World climbing fern is defined as less than 5% cover per km^2 throughout the park. The desired management state for Brazilian pepper is defined as less than 5% cover in specific project areas that are of high management priority. The desired management state of the other additional collective exotic plant species are defined as less than 1% cover per species per km^2 in areas currently containing these species, preventing the expansion of these species to new areas, and monitoring and control of newly detected species. The percent cover of these invasive exotic plant species is measured during annual overflights throughout park habitats, through a technique called digital sketch mapping.

Crews work to remove a large stand of melaleuca in Everglades National Park. NPS photo by Hillary Cooley.

Indicator 12. Invasive exotic plants.

Criteria	Desired State of Conservation	Condition & Trend	Rationale
Melaleuca quinquenervia	Less than 1% cover per km^2 is present in currently infested areas and area of infestation is not expanding.		Most park invasive plant management effort is directed at this species. Chemical and bio-control agents are effective. Number of infested acres has decreased during the past 10 years.
Casuarina equisetifolia	Less than 1% cover per km^2 is present in currently infested areas and area of infestation is not expanding.		*Casuarina* is second in terms of the amount of effort dedicated to management. Chemical control is effective, but access to some remote infestations is difficult. No effective bio-control exists. Number of infested acres is decreasing.
Lygodium microphyllum	Less than 5% cover per km^2 is present in currently infested areas and area of infestation is not expanding.		Management activity is limited by remoteness but is effective on dense infestations. Hope exists for development of an effective bio-control.
Schinus terebinthifolius	Less than 5% cover per km^2 is present in currently infested areas and area of infestation is not expanding.		Management of this species is limited to specific areas of high priority. No effective control currently exists for use in remote areas. No effective bio-control exists. Overall, the area of infestation is increasing.
Additional collective exotic plant species	Less than 1% cover per km^2 is present in currently infested areas and area of infestation is not expanding.		Management efforts for these species are currently limited to areas of high concern such as those with high visitor use or areas with threatened and endangered species that may be impacted by the presence of exotic plants. Chemical controls and effective bio-controls differ by species. The overall area affected by the combination of these plants is increasing.

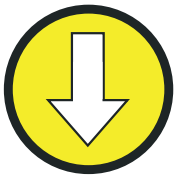
Indicator 13: Invasive Exotic Fish and Wildlife

Prevention of new introductions and suppression of existing established populations is key to the management of exotic fish and wildlife, especially in reference to exotic herpetofauna such as reptiles and amphibians in ENP. Unlike the current situation with exotic plant control, few to no proven technologies are available to control or eliminate exotic fish and wildlife once they are established. Therefore, metrics such as 1) rate of introduction of new species to the park, 2) spatial spread of newly introduced exotics, and 3) relative abundance of exotic species compared to the native species community are important indicators of the current and future impact of invasive exotic species on ENP. In addition, the introduction of top predators such as the Burmese python (*Python molurus*) or the lionfish (*Pterois volitans* and *P. miles*) can have cascading effects throughout the ecosystem as prey communities shift in density and distribution as a result of novel, intense predation pressure (Salo et al. 2007). Where available, data on the impact of exotic species on native prey communities is used in assessment of status and trends.

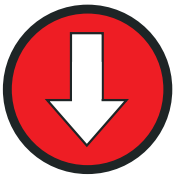
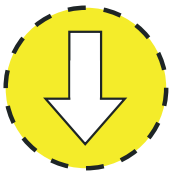
For exotic freshwater fish, the Desired State of Conservation is a decrease in the rate of new introductions and a freshwater fish assemblage composed of native species. A relative abundance of exotic fish >2% represents significant concern, from >0 to <2% indicates moderate concern, and 0% indicates good condition (Doren et al. 2008). For exotic herpetofauna, the desired State of Conservation is similar: a decrease in the rate of and eventual elimination of new introductions to ENP. This indicator for herpetofauna is dependent on a number of factors outside NPS control: primarily, legislation and policies that regulate the importation, trade, and keeping of herpetofauna in the United States and the State of Florida. In addition, for herpetofauna, we have included three species present in the park as indicators of the effectiveness of control and removal activities. For exotic marine species, the main focus at this time is on lionfish. Currently only six lionfish have been sighted in ENP, and the Desired State of Conservation is to minimize and eventually eliminate lionfish through periodic and repeated monitoring and targeted removal efforts.

Given the fast-changing panorama of exotic species introductions in south Florida, this indicator of the State of Conservation of ENP, and the ways in which exotic species impact is assessed, is likely to continue to develop and change in the coming years.

Indicator 13. Invasive exotic fish and wildlife (freshwater and marine).

Criteria	Desired State of Conservation	Condition & Trend	Rationale
A. FRESHWATER FISH			
Rate of new introductions of exotic fish	Rate of new introductions of exotic fishes is decreasing over time.		Since 2000, eight new exotic fish species have been observed in ENP, an increase in the rate of introductions.
Relative abundance of exotic fishes in Shark River Slough	Freshwater fish assemblage is dominated by native species and contains less than a 2% relative abundance of exotic individuals.		Exotic species are present, but relative abundance continues to be less than 2% threshold in monitored sites.
Relative abundance of exotic fishes in Taylor Slough	Freshwater fish assemblage is dominated by native species and contains less than a 2% relative abundance of exotic individuals.		Exotic species are present, but relative abundance continues to be less than 2% threshold in monitored sites.
Relative abundance of exotic fishes in ENP-wide annual sample	Freshwater fish assemblage is dominated by native species and contains less than a 2% relative abundance of exotic individuals.		Exotic species are present, but relative abundance has been less than the 2% threshold at monitored sites since the January 2010 cold weather event. However, exotic species were collected at more sites in October 2011 than in 2010, suggesting an undesirable trend.

Indicator 13 continued. Invasive exotic fish and wildlife (freshwater and marine).

Criteria	Desired State of Conservation	Condition & Trend	Rationale
B. HERPETOFAUNA			
Rate of new herpetofaunal introductions in and around ENP	Minimize and eliminate new invasive herpetofaunal introductions to ENP.		Florida has more established exotic herpetofauna than any other place in the world (Krysko et al. 2011). ENP is at high risk for additional invasions of exotic herpetofauna.
Containment and control of established populations: Burmese python	Burmese python population in the park is contained and decreasing.		Burmese pythons are now widespread and are having negative impacts on native species.
Response efforts to known invasives adjacent to ENP: North African python	Known invasives adjacent to ENP are eliminated prior to establishment in the park.		Response to a small and contained population of North African pythons adjacent to ENP demonstrated that removals can be effective for small areas. Full eradication may not be possible.
Response to recent introductions to the park: Argentine tegu	Recent introductions to the park are effectively addressed and populations of incipient invasives are eliminated.		Tegus have recently moved into ENP but reproduction has not yet been detected. Trapping is possible but resources (staff and funding) are inadequate. The extent of spatial distribution of tegus inside the park is uncertain.
C. MARINE SPECIES			
Lionfish density	Minimize the number of lionfish in Florida Bay.		Lionfish density in mangroves and on seagrass beds often exceeds density on reefs (Barbour et al. 2010, Claydon et al. 2010).
Biomass of prey species	Minimize the impact from lionfish on post-settlement native fish and invertebrate populations.		Lionfish will have a large impact on prey species.
Distribution of lionfish	Minimize the spatial distribution of lionfish.		Lionfish are able to invade any habitat type within Florida Bay.

CORRECTIVE MEASURES: MOVING TOWARD THE DESIRED STATE OF CONSERVATION

In response to the four major threats to the integrity of ENP ecosystems, the United States and the State of Florida have, since the 1993 listing of the park on the list of Sites in Danger, made substantial investments into region-wide Everglades Restoration initiatives. By the mid- to late-1990s, the Federal government began construction on two major water engineering projects, the Modified Water Deliveries (MWD) and C–111 South Dade projects, which were designed to improve water deliveries to and reduce groundwater seepage losses from ENP. At the same time, as a result of a federal water quality Consent Decree, the State of Florida began work on the Everglades Construction Project and Long-Term Plan, constructing a series of man-made wetlands (stormwater treatment areas (STAs) and implementing Best Management Practices (BMPs) to reduce nutrients entering the Everglades ecosystem from the agricultural areas south of Lake Okeechobee (National Research Council 2008, 2010, and 2012). An additional large-scale restoration program, called the Comprehensive Everglades Restoration Plan (CERP), is a joint Federal/State of Florida effort that was conceptually designed during the mid- to-late 1990s. CERP was approved and authorized by Congress in 2000 for further planning and implementation (www.evergladesplan.org).

These four large projects, regional in scope and multi-decadal in implementation, together are intended to make structural and operational changes to the water management system that should restore significant ecological function, ecosystem resilience, and fish and wildlife abundance to ENP, as well as to other parts of the south Florida ecosystem. On-the-ground implementation of features (such as removal of levees, filling of canals, or addition of flow-ways), and changes to water operations (such as water control plans that allow more water to reach the park) are expected to bring about positive change in hydrologic and ecological indicators of ecosystem integrity. In 2006, the United States proposed and the World Heritage Committee accepted these projects as *benchmarks* toward recovery of ENP. Individual elements of these large projects were identified as *corrective measures* that, when implemented as originally conceived and described, are expected to bring about specific, measurable, and positive changes to integrity indicators, including both hydrologic and ecological metrics, within the park.

Corrective Measures, Constraints, and Restoration Progress

The landscape of south Florida is one of the largest, most highly engineered, and closely operated water management systems in the world. It was designed specifically, and is currently operated specifically, to provide flood protection and water supply to the urban and agricultural areas of Miami, Fort Lauderdale, and West Palm Beach. All of the above-mentioned large-scale projects assure that legal levels of flood protection, as well as water availability for people, will not be diminished as a result of implementation of restoration project features. In the very important case of NESRS in the park, flood-protection features must be finished prior to implementation of restoration features that bring water back to areas that have been too dry for decades.

These constraints are integral to the work on restoration of the natural system and can change rapidly as urban development moves closer to the natural system and as the face of agriculture in south Florida changes in response to economic factors. Although the overall purpose and vision of the large-scale restoration projects remains the same, this backdrop of shifting constraints (encompassing legal and economic issues as well as land use) provokes changes in the scope and timing of implementation of restoration corrective measures. Reductions in scope of one large-scale project may mean that another project takes up the slack, albeit at a slower pace and with modified features. The major concepts—restoring flow through removal of barriers, reducing nutrient inputs into the natural system, stopping the loss of water from the natural system (seepage control)—remain the same, while the official title and agency "home" of the project and/or its components and the associated engineering solutions are highly mutable through time.

The current status of the corrective measures established in 2006 to track progress on engineered restoration features is provided in Table 3. The table includes the original benchmarks and corrective measures that were identified in 2006, the status of those measures in 2012, and the status as we move into 2013. By examining a particular corrective measure through time, the effects of shifting constraints as well as the changing nature of planned solutions is evident. Also included in the table is the "Park Need." This column describes in conceptual terms what is needed for restoration: protection of the built system (flood protection), delivery of water in consonance with rainfall patterns, nutrient reduction, removal of barriers to flow, and increase in water levels in the park. This column provides an anchor for the corrective measure that allows tracking of the logical, ecosystem-based origin of a particular action through time and as the action (i.e., corrective measure) travels through various projects.

A number of significant changes to the corrective measures occurred during 2012, in both the implementation and the planning arenas.

Implementation of Corrective Measures

- Corrective Measure 1B (rainfall-driven water deliveries): The water control plan called the Everglades Restoration Transition Plan was implemented, moving slightly more water into ENP. However, during 2012 the water control plans that would move significant quantities of water into NESRS (previously called Combined Structural and Operational Plan (CSOP) and Combined Operational Plan (COP) were delayed. These plans as originally envisioned in 2006 are not included in any current project schedule. Our best assessment at this time is that changes to water management operations are going to move forward more slowly than originally planned, and in small increments, using field tests.
- Corrective Measure 1C (removal of barriers to flow): Construction of the Tamiami Trail 1-mile bridge and associated road-raising is progressing as planned, with completion of the bridge expected in the spring of 2013 and completion of the entire project in mid-2014.
- Corrective Measure 1C (removal of barriers to flow): The Decompartmentalization physical model along the L–67 levees and canals is under construction, and testing outside ENP for the ecological effects of additional water volume and sheetflow should begin in 2013. This is an initial and experimental first step toward restoring sheetflow in areas upstream of ENP.
- Corrective Measure 2C (seepage control): Construction of the 2-mile-long rock-mining shallow seepage barrier pilot project just south of Tamiami Trail was completed in the spring of 2012. The pilot is being monitored for effectiveness and, if appropriate, this type of shallow seepage barrier would be extended along the eastern border of ENP. The technical evaluation of the pilot project is being conducted within the Central Everglades Planning Project (CEPP) effort, described below. The shallow seepage barrier is intended not only to keep ENP seepage from affecting adjacent agriculture and urban locations, but to keep the water in the park for hydrologic restoration.
- Corrective Measure 4B (water to Florida Bay): Phase 1 (Western Project) of the C–111 Spreader Canal project was completed in spring of 2012 and began operating in July 2012. Phase 1 is a seepage management project designed to retain water in Taylor Slough and allow it to reach Florida Bay. The effects of this project on ENP natural values are being monitored currently, and initial signals from the project are positive. The schedule for additional phases of the project, to reach the full project scope as originally designed in the CERP, is dependent on Congressional authorization and as such, timing is uncertain.

Planning Changes to Corrective Measures

- Corrective Measure 1B (rainfall-driven water deliveries): A new, longer-term initiative referred to as the Central Everglades Planning Project (CEPP) is nearing completion of its general design and environmental assessment phase. The CEPP is an evolution of the Comprehensive Everglades Restoration Plan (CERP). This project would implement a new rainfall-driven water delivery plan for Water Conservation Areas 3A/3B and the Shark River Slough portion of ENP. The general design of this project is expected to be authorized in 2014, but construction is not expected to begin before 2022. New targets and operational approaches from CEPP may encourage the redistribution of water into NESRS before that date.
- Corrective Measure 1C (removal of barriers to flow): The next, more detailed phase of planning/design for the Tamiami Trail Next Steps (TTNS) project is underway as of October 2012. Final design for Phase 1 of this project (2.6 miles of a total of 5.5 additional miles of bridging, and associated road-raising) is scheduled for completion in 2014. The source and timing of funding for implementation of this project are unknown at this time.
- Corrective Measure 1C (removal of barriers to flow): The first phase of planning and design for the Decompartmentalization and Sheetflow Enhancement project has advanced almost to the selection of a preferred alternative. The design for these features, (partial canal filling, and a hydropattern restoration feature) has been incorporated into the CEPP project.
- Corrective Measure 2C (seepage control): Construction of the C–111 northern detention area, critical to the functioning of the MWD project, is delayed due to differences between the USACE and the South Florida Water Management District (SFWMD) regarding the funding source for the project. The current schedule indicates construction of this project in 2017.
- Corrective Measure 3 (water quality): The first phase of water quality treatment efforts (1992–2009) were not resulting in desired decreases in TP concentrations; therefore, the State of Florida agreed to a second phase. This second phase includes an almost-completed 4,800-ha expansion of STAs north of the park, and an additional suite of projects under the Restoration Strategies agreement, signed by the State of Florida and the U.S. Environmental Protection Agency (EPA) in June 2012. This agreement is for the expansion of STAs upstream of the Water Conservation Areas (WCAs) in order to clean existing agricultural runoff from the Everglades Agricultural Area. In addition, a

shallow reservoir called a Flow Equalization Basin (FEB) will be constructed to improve the phosphorus removal capability of the STA that most directly affects the water quality of park inflows. An initial suite of these new water quality treatment features, including those most important to the park, is scheduled to be constructed by 2016, with the remainder to be completed by 2025. The water quality treatment features in the Restoration Strategies agreement will allow for changes to the distribution of the existing water that currently reaches the northern border of ENP, but will not allow for increasing the overall volume of water deliveries to the northern border of ENP. A third phase of water quality treatment will be constructed under CEPP, which calls for an additional FEB to assist in the treatment of the additional flows to the park anticipated under this new restoration project.

Table 3. Everglades National Park – History and Status of Corrective Measures.

Park Need	Corrective Measure (established 2006)	Status of Corrective Measure 2012	Status of Corrective Measure 2013
Threats 1 and 2: Alterations to the natural hydrologic regime, and adjacent urban and agricultural growth			
Public ownership of lands in the East Everglades is a prerequisite to re-establishing water flows in Northeast Shark River Slough (NESRS).	1A: Complete East Everglades Expansion Area land acquisition (approximately 44,000 hectares (ha)).	1A: Land acquisition is 99% complete, 300 ha of commercial lands remain, and the funds are in the 2012 National Park Service (NPS) budget. An Environmental Impact Statement is in preparation regarding the largest parcel (Florida Power and Light Company (FPL) utility corridor).	1A: Land acquisition is 99% complete though six of the largest parcels remain in private ownership, totaling 300 ha. Funds for acquisition remain in the NPS budget. An NPS decision on the pathway for acquisition of five of the six parcels is expected in 2013. NPS is preparing an Environmental Impact Statement for acquisition of the sixth and largest parcel (a utility corridor of approximately 134 ha). Estimated completion date is spring 2014.
The inhabited area adjacent to the park, called the 8.5 Square Mile Area, must be protected from flooding in order to allow water flows into NESRS.	1B: Complete flood mitigation features in the 8.5 Square Mile Area.	1B: Construction of the flood mitigation features for the 8.5 Square Mile Area was completed in 2009. A field test was initiated and indicated that additional structural and operational changes were needed to achieve full protection for the area and benefits for the park.	1B: Construction of the flood mitigation features for the 8.5 Square Mile Area was completed in 2009. Monitoring data indicated that additional work was needed to achieve flood protection goals. A "connector canal" modification was designed in 2012 and construction will be completed in 2013. Completion of this project will remove one of the main barriers to increasing water levels in the L–29 canal.

Table 3 continued. Everglades National Park – History and Status of Corrective Measures.

Park Need	Corrective Measure (established 2006)	Status of Corrective Measure 2012	Status of Corrective Measure 2013
A water control plan defining water operations that will improve rainfall-based water deliveries and promote increased sheetflow to ENP, while maintaining flood control and water supply requirements is necessary.	1B: Complete the Water Control Plan (CSOP) for the Modified Water Deliveries (WMD) and C–111 South Dade Projects. This Corrective Measure is the same as Corrective Measure 2B.	1B: A new Everglades Restoration Transition Plan is scheduled for implementation in 2012, which moves slightly more water into NESRS. The Combined Operational Plan (COP) is an evolution of the CSOP and builds on the Transition Plan with operational formulas designed to increase NESRS inflows. The COP is expected to be complete by May 2013.	1B: Everglades Restoration Transition Plan operations have been implemented. A water operations field test is being designed and agreed upon between the U.S. Government and the State of Florida that should address water quality concerns associated with increases in flow to NESRS. This field test is expected in early 2013 and will last for 2 years. The CSOP and the COP plans have been eliminated from the MWD project, and future water control plans will be developed at the conclusion of the field test. Changes to water operations are likely to move forward very slowly and in small increments. Substantial change will occur only when raising and bridging the Tamiami Trail is complete as envisioned in the Central Everglades Planning Project (CEPP—a new element of the CERP) and the Tamiami Trail Next Steps (TTNS) project. Timeline for completion of these projects is >10 years from now.

Table 3 continued. Everglades National Park – History and Status of Corrective Measures.

Park Need	Corrective Measure (established 2006)	Status of Corrective Measure 2012	Status of Corrective Measure 2013
Removal of barriers to water flow within Water Conservation Area 3 (WCA 3) upstream of the park is needed to enhance sheetflow and marsh connectivity into NESRS.	1C: Construct water conveyance structures on the L–67A, L–67C, and L–29 canals and levees. In 2006, both the MWD project, and the CERP WCA 3 Decompartmentalization and Sheetflow Enhancement Project (Decomp) included projects to degrade levees and fill canals within WCA 3, north of the park.	1C: The L–67A, L–67C, and additional L–29 water conveyance structures have been deleted from the MWD project. The Decomp project includes three phases that were scheduled to begin in 2009. Progress has slowed and a Decomp field test along the L–67 canals to evaluate the benefits of reconnecting WCA 3A and 3B is now planned for 2013. The first phase of Decomp (plugging portions of the Miami Canal in northern WCA 3A) is now being merged with the Central Everglades Planning Project (CEPP).	1C: The Decomp physical model along the L–67 levees and canals is under construction. Construction components are expected to be complete in early 2013, and data will be collected during 2013 and 2014. The test is scheduled to conclude in 2014. Phase 1 of the Decomp project is incorporated into the CEPP, which is also examining changes to the L–67 levees and canals. The scope of alternatives ranges from small to large modifications to the L–67 structures. Schedule for completion of conceptual planning for CEPP is the end of 2013. The CEPP project then moves forward to Congress for authorization and funding. Timeline for completion of this project is >10 years from now. The CEPP plan to move water from WCA 3 to NESRS is needed in the same timeframe as required by the TTNS project.

Table 3 continued. Everglades National Park – History and Status of Corrective Measures.

Park Need	Corrective Measure (established 2006)	Status of Corrective Measure 2012	Status of Corrective Measure 2013
Removal of barriers to water flow along the Tamiami Trail is needed to enhance sheetflow and marsh connectivity into NESRS. Both bridges and modifications to the roadway are needed in order to raise water levels in the park while avoiding water damage to the road itself.	1C: Tamiami Trail bridging and roadway modifications.	1C: The 2008 Tamiami Trail 1-mile bridge and limited road-raising project (2008 LRR) began in late 2009. This project will provide modest flow increases into NESRS and is scheduled for completion in late 2013. Additional bridging is planned via the TTNS project. The recommended plan would add up to 5.5 miles of bridges and raise the remaining roadway to allow for unconstrained flow into NESRS. The Final Environmental Impact Statement for this project was completed in December 2010. Congress authorized the project in 2012 with the goal of completing construction by 2017–2018.	1C: The 2008 Tamiami Trail 1-mile bridge and limited road-raising project will provide modest flow increases into NESRS and is now scheduled for completion in spring of 2014. An NPS project to design and construct 2.6 miles of additional bridging is underway as of October 2012. Planning and final design should be complete by June 2014 and, depending on the availability of funding, a design and build contract should be awarded by the end of 2014, with construction completed by 2018. Raising the remainder of the Tamiami Trail roadway is still required in order to restore more-natural water levels to NESRS without compromising the roadway. The funding and timing of this work is unknown at this time.

Table 3 continued. Everglades National Park – History and Status of Corrective Measures.

Park Need	Corrective Measure (established 2006)	Status of Corrective Measure 2012	Status of Corrective Measure 2013
Water in NESRS and Taylor Slough needs to be retained inside the park via seepage management features. This water should flow down the historic sloughs, increasing water depths and hydroperiods in the park. Currently, lowered water levels in urban and agricultural areas east of the park draw large amounts of water out of the park via seepage.	2A: Complete C–111 land exchange between the South Florida Water Management District (SFWMD) and NPS. This is required to construct the C–111 detention areas.	2A: A land exchange between the SFWMD and NPS was approved by Congress in 2006.	2A: The land exchange is complete and no additional real estate is required for completion of the C–111 detention area projects.
	2B: See 1B.		
	2C: Complete the construction of C–111 detention-area features from the 8.5 Square Mile Area south to the area known as the Frog Pond. These features include northern and southern components. The detention areas reduce seepage losses along the portions of the eastern ENP boundary. An existing pump station (S–356), constructed by the MWD project, is available for use to help retain water in NESRS. CERP included an ENP Seepage Management project that would add additional S–356 pump stations as well as a subsurface seepage barrier by 2015.	2C: The construction of a portion of the C–111 southern detention areas on these lands was completed in 2009. There is currently a gap in the eastern ENP seepage management system due to delays in construction of the C–111 North Detention Area, which is now scheduled for completion in 2017. Operation of the S–356 pump station is held up due to water quality concerns. A CERP 2002 seepage pilot project has stalled and is on hold while a shallow seepage barrier test is being conducted by a private rock-mining group. Future actions are dependent on these test results.	2C: Operation of the C–111 southern detention-area components and their effects on park ecology are being assessed. Construction of the C–111 northern detention area is still delayed, scheduled for completion in 2017. The water operations field test described in 1B should address water quality concerns associated with increases in flow to NESRS. This test is expected in early 2013 and will last for 2 years. Construction of the rock-mining shallow seepage barrier pilot (2 miles) was completed in spring of 2012. The feature is being monitored for effectiveness, and depending on results, may lead to an additional 3–5 miles of shallow seepage barrier in the near future. Additional seepage management to restore water levels in NESRS while maintaining flood protection is envisioned in the CEPP and would follow the schedule of design and implementation for that project.

Table 3 continued. Everglades National Park – History and Status of Corrective Measures.

Park Need	Corrective Measure (established 2006)	Status of Corrective Measure 2012	Status of Corrective Measure 2013
Threat 3: Increased nutrient pollution from upstream agricultural areas			
Water entering the park must be low in nutrients, with concentrations of phosphorus in surface water <10 parts per billion (ppb), as established by the State of Florida. Total phosphorus (TP) concentrations above this level lead to imbalances in flora and fauna. Water needs to be cleaned upstream of the park, via improvement of agricultural practices and the implementation of stormwater treatment areas (STAs). Reduction of nutrient loading will contribute to healthier freshwater Everglades wetlands, as well as a healthier estuary in Florida Bay.	3A: Implement upstream water quality source controls or Best Management Practices (BMPs) and construct man-made wetlands or STAs to achieve the long-term TP limits for water flowing into Shark River Slough and the Taylor Slough/Coastal Basins. In 2008, a Federal Court found that delay in achieving the State of Florida Phosphorus Threshold Rule (<0.01 mg per liter for the Everglades) was a violation of the Clean Water Act. The court directed the U.S. Environmental Protection Agency (EPA) to develop a plan for compliance for runoff from the Everglades Agricultural Area (EAA).	3A: New agricultural BMPs and the construction of more than 18,200 ha of STAs have reduced phosphorus loadings to the Everglades by approximately 70–80%. In spite of these actions, TP concentrations at Shark River Slough inflows were at the long-term compliance limit (the 90th percentile of the Outstanding Florida Waters baseline) for 2008, 2009, and 2010. TP concentrations in 2011 were well below the long-term limit. TP concentrations at the Taylor Slough/Coastal Basin inflows have been well below the long-term TP limit for many years. In spite of this, localized nutrient impacts are occurring in the headwaters of Taylor Slough. In 2010, the U.S. EPA filed an Amended Determination, stating that expanded source controls and ~17,000 ha of additional STAs and new Flow Equalization Basins (FEBs) would be needed to achieve the required TP reductions. Fewer than 4,900 ha of new STAs are expected to be completed by 2013, while ~23,000 ha of publicly owned EAA lands will need to be converted into expanded STAs and new FEBs by 2018 to meet the new EPA requirements.	In June 2012, the State of Florida and the EPA reached a consensus on additional remedies needed for improving water quality in America's Everglades. They also agreed on a Water-Quality-Based Effluent Limit for STA discharges, to be enforced by permits that, if achieved, will ensure that park waters meet the 10 ppb target. The SFWMD will complete six projects that will create more than 2,630 ha of new STAs and 110,000 acre-ft of additional water storage through construction of Flow Equalization Basins (FEBs). These FEBs are upstream water storage features intended to provide a more steady flow of water to the STAs downstream, helping to maintain desired water levels and flows needed to achieve optimal water quality treatment performance. It is possible that the FEBs also will have some TP removal ability within their footprints. The component of these remedies that affects park water quality most directly—an FEB—is scheduled to be constructed by 2016. All of the proposed remedies are scheduled to be completed by 2025. In order for CEPP to be implemented, an additional FEB upstream of the park is needed to ensure that additional future inflows to the park meet the water quality targets.

Table 3 continued. Everglades National Park – History and Status of Corrective Measures.

Park Need	Corrective Measure (established 2006)	Status of Corrective Measure 2012	Status of Corrective Measure 2013
Threat 4: Impacts to the protection and management of Florida Bay (reduced freshwater inflows and increased nutrient loadings).			
Increasing natural freshwater flows from NESRS and Taylor Slough into the downstream estuaries will contribute to healthier and more diverse seagrass communities and increase fish and invertebrate productivity in Florida Bay.	4A: Complete construction of the C–111 Detention Area features from the 8.5 Square Mile Area to the Frog Pond and implement CSOP operations. Implementing rainfall-driven pumping operations based on marsh water levels as envisioned in CSOP will reduce the likelihood of pumping nutrient enriched groundwater into ENP marshes.	4A: Construction was completed on the 8.5 Square Mile Area flood mitigation features and the C–111 South Detention areas in 2009. Remaining is the C–111 North Detention area, currently scheduled for completion in 2017.	4A: The C–111 North Detention area is still not complete; it is scheduled for completion in 2017. The CSOP and the COP plans have been eliminated from the MWD project, and future water control plans will be developed at the conclusion of the water operations field test described in 1B. Changes to water operations are likely to move forward very slowly and in small increments, with substantial change occurring only when raising and bridging the Tamiami Trail is complete as envisioned in the CEPP and TTNS projects (more than a decade). Rainfall-based pumping operations will be encouraged in the water control plan for ENP.
	4B: Complete the C–111 Spreader Canal and revised water management operations to include rainfall-driven operations.	4B: Construction of Phase 1 of the C–111 Spreader Canal project (Frog Pond Detention area and Aerojet seepage control features) is scheduled for completion in 2012.	4B: Phase 1 Western Project of the C–111 Spreader Canal project was completed in spring of 2012 and began operating in June 2012. The effects of this project on adjacent park wetlands and on Florida Bay are being monitored and will be evaluated after 3 years of monitoring (2015). Initial signals are positive. Rainfall-driven operational controls have not yet been implemented but will be incorporated into future water control plans. The remaining phases of the C–111 Spreader Canal project are not currently scheduled.

A SYNTHESIS OF THE STATUS OF CORRECTIVE MEASURES AND INDICATORS OF INTEGRITY

Distinct progress has been made in the last two decades on a number of hydrologic corrective measures needed to address the threats to ENP and restore the desired State of Conservation. As part of the C–111 South Dade project, which was intended to restore historic hydrologic conditions in the Taylor Slough, Rocky Glades, and eastern Panhandle areas of ENP, to protect the natural values of ENP, and to help restore freshwater flows to Florida Bay, a series of detention areas designed to maintain flood protection for agricultural lands to the east of the park border while retaining water inside the park was constructed from about 1995 to the present. A number of flood mitigation features (8.5 Square Mile Area levee system and pump station) and seepage management features (S–356 pump station) have been constructed via the MWD project in the same time period. A levee (L–67 extension) inside the park has been partially removed. Since 1992, the State of Florida implemented more than 18,200 ha of treatment wetlands, and these features, along with the implementation of BMPs within the agricultural sector, have assisted in reducing phosphorus loadings to the Everglades by more than 70%.

More recently, the first steps toward removal of barriers to water flow, the Decomp physical model and the Tamiami Trail 1-mile bridge project, are under construction at the time of this report, and detailed planning is underway for additional bridging and road-raising of the Tamiami Trail. A formal change to the water operations plan implemented during 2012 is intended to move slightly more water into ENP. In cooperation with the private sector, innovative engineering solutions to help address seepage management from NESRS are being tested, and a project to retain water in the Taylor Slough region of the park (C–111 spreader) and to begin to provide additional flow to Florida Bay began operating in 2012. An extremely important step in 2012 is the Everglades Restoration Strategies water quality agreement signed between the Federal and State of Florida governments. This plan allows finished water quality features to begin functioning now and includes enforceable point-source effluent limitations, as well as the construction on a specified schedule of additional water treatment features that are required in order to better distribute current water inflows to ENP beginning in 2016. The CEPP was initiated, and is engaged in an interagency planning process to design the removal of barriers upstream of ENP and bring a significant amount of additional water to the park, while continuing to manage for flood protection and water supply.

Even though these are significant advances, the park is still far from reaching the Desired State of Conservation. Small but critical components of the MWD and C–111 South Dade projects remain unfinished, and these are required precursors to the ability to put additional water into NESRS. For example, although 99% of private land parcels have been acquired by the NPS, the fate of six parcels, including the Florida Power and Light Company (FPL) parcel (which may result in a potential powerline transmission corridor on the eastern border of the park), is still not resolved. Unless these lands issues are resolved (by some means such as flood mitigation, acquisition, or other), additional water cannot be delivered to NESRS. A final north detention area, which is part of the C–111 South Dade project and essential as flood mitigation for the needed increased water levels in NESRS, has been on hold for several years and is now tentatively scheduled for construction in 2017.

These restoration project features and operations are intended to improve conditions for habitats, fish, and wildlife, and the status of the indicators of ecological integrity at this time appears to be a good reflection of the status of the corrective measures. For example, although we are closer to being able to change the distribution of flows along the Tamiami Trail through the implementation of the 1-mile bridge project, 2012 field measurements still reflected that the vast majority of water coming across the northern border of ENP is through the western sector, and not the desired eastern sector of the Trail. Water levels in NESRS are still below the target.

Total phosphorus (TP) entering NESRS has decreased (i.e., a positive result) since the mid-1980s, and this may be due to the implementation of upstream BMPs and the construction of treatment wetlands since the mid-1990s, as mentioned above. However, measurements of phosphorus inflow to NESRS in the last decade have hovered right around the legal limit, indicating a need for concern and requirements for additional water quality features if water volume is to be increased to the park. Periphyton communities in the park, especially those observed in NESRS, also indicate a need for concern regarding water quality.

Freshwater fish and macroinvertebrates, especially in NESRS, are far from the Desired State of Conservation, with numbers lower than expected and drought-tolerant species making up a large proportion of the small fish community. Measures of the health of the American alligator population indicate that improvement is still needed in habitat conditions. Although nesting effort has increased since 1985 (i.e., more nests are being built), the success rate of nests continues to be erratic due to extreme hydrologic variation (both naturally induced and managed), and alligator abundance in the park has recently decreased. Measures of the status of wading birds give a mixed picture: abundance counts in the park show an increasing trend in the last several decades, and conditions appear to be good for species such as the white ibis. However, wood storks are still initiating nesting too late in the season, resulting in erratic nest success due to natural and managed hydrologic variation, and the proportion of wood stork and white ibis nests is still far from the desired condition.

The status of integrity indicators for the coastal zone and Florida Bay also indicate that corrective measures must

continue to be implemented in order to reach the Desired State of Conservation. Mean salinities in Florida Bay are still higher than those that support desired estuarine conditions, and no discernible trend toward desired conditions was found over the last 10 years. Measures of the potential for algal blooms indicate a continued need for concern. Measures of seagrass abundance and diversity indicate that some recovery has occurred since the die-offs in the mid-1980s and that trends are improving in the northeast zone. However, the abundance and diversity of seagrasses over most of Florida Bay are still at less-than-desired conditions. Sport fish abundance, as measured by fishermen's catch, is good and has remained relatively stable for the last several years, with the exception of the snook population which suffered due to an extended cold spell in the winter of 2010. Juvenile pink shrimp, very sensitive to estuarine salinities, are still showing poor conditions with a negative trend. The American crocodile is increasing in total population and reproductive effort is improving, while the measure most closely related to upstream hydrologic conditions—hatchling growth and survival—is still lower in ENP than in nursery sites adjacent to the park.

Measures of invasive exotic species indicate severe problems. ENP programs to control and reduce the presence of invasive exotic plant species are limited to only two of the four problem species due to funding limitations. Measures of exotic fish and herpetofauna invasions are uniformly negative, with increasing numbers of introductions and widespread invasions over the past 10–15 years. The Burmese python invasion has grown in the past decade, and although the 2010 cold spell may have slowed population growth, the species is still found in abundance in and around the park. Researchers have implicated the Burmese python in the reduction of sightings of small mammals in ENP during the past 10 years (Dorcas et al. 2012); thus, not only is the mere presence of the species a negative impact, the species may be reducing native prey populations directly by predation. Several other herpetofaunal species are either beginning an invasion (Argentine tegus) or poised at the border of the park (North African python). The first invasion of a top marine predator, the lionfish, was recorded during the last 4 years, and although this species is not yet being seen in large numbers in the park, it has increased substantially in adjacent habitats and is known to have negative effects on native coral reef fish species in the Caribbean. The park currently has no new programs to deal with this emerging issue of exotic fish and wildlife (either freshwater or marine); existing programs and staff have been redirected to work on this, which means that other natural resource needs of the park go unfulfilled and the available resources are insufficient to deal with the problem on the scale that it requires.

Proposals for new program funding at the level of NPS and U.S. Department of the Interior (DOI) have been developed and submitted; these are currently under consideration but have not yet been implemented.

Suitability of Timeframe for the Implementation of Corrective Measures

A great part of the challenge in implementation of corrective measures is in making sure that objectives for restoration originating two decades ago—when attention was brought to the declining state of ENP resources, the park was placed on the list of Sites in Danger, and the MWD and C–111 South Dade projects were designed and authorized—are not lost in the extended planning, authorization, and funding process. Two decades later, the MWD and C–111 South Dade projects are nearing completion, and the final features required (including completion of the 1-mile Tamiami Trail bridge project, final land acquisition, completion of the north detention area, and correcting flood mitigation features in the 8.5 Square Mile Area) are currently scheduled to be completed by about 2017. However, the completion of these named features does not guarantee the delivery of additional clean freshwater to the historical flow-way of ENP.

For example, although many of the original objectives of the MWD—as stated in the project Purpose and Objectives in 1992 and reaffirmed in 2006 by means of draft plans (CSOP) for combining the structures and operations of water management around the park—will be fulfilled at the time the project is officially deemed complete, at least one still remains to be achieved. The objective "*Restoring WCA 3B and Northeast Shark Slough as a functioning component of the Everglades hydrologic system*" (USACE 1992) was not implemented as envisioned due to funding constraints and a more incremental approach to new water operations. However, that objective has not been lost; it is now being incorporated with support from both Federal and State of Florida partners into new projects, specifically the CEPP.

In order for the park to experience substantial hydrologic restoration and associated improvements in the indicators of ecological integrity, commensurate with the original corrective measures established in 2006, several major but separate project efforts must be coordinated in the next 5 to 10 years. At the time of this writing, the project that will create the ability to redistribute substantial water into NESRS (i.e., appropriate *distribution*) is the Tamiami Trail Next Steps: the project to create an additional 5.5 miles of bridging and associated road-raising at the northern border of the park. Detailed planning for the first phase of that project—2.6 miles of bridging and fully raising the road—is underway; however, the funding and timing of construction is uncertain. Critical to the ability to redistribute water to NESRS is the *quality* of that water: the Everglades Restoration Strategies project signed last year is scheduled to provide additional water treatment for the park by about 2016 and substantial clean water for other areas of the ecosystem by 2025. A third major project—the CEPP project—is intended to remove barriers to flow upstream of the park, direct flows under the Tamiami Trail bridges, and provide sufficient seepage management to allow water stages and depths to rise in NESRS (i.e., water *quantity*) without

affecting the agricultural and urban areas to the east. This project is in an initial planning phase, but is part of a national effort by the USACE to substantially streamline planning and authorization of major water management projects, and the current estimate is that planning, authorization, and construction of this project, along with a comprehensive water control plan (to address *timing*), should occur starting in about 2022.

To address the question of suitability of these current timelines for hydrologic restoration, the assessment of indicator status and trend presented here is pertinent, as is the most recent report from the National Research Council (NRC) of the National Academies (National Research Council 2012). Our current assessment of indicator status and trends shows little change in the field for hydrologic measures of restoration, and ecological indicators, with a few exceptions, tend to show poor or cautionary status and often declining trends. In 2012, the NRC evaluated 10 ecosystem attributes for the larger Everglades ecosystem and assessed the overall state of the ecosystem as "seriously degraded." As with the current report, the NRC emphasized that hydrologic restoration has made little progress in the field and that attributes associated directly with hydrology tend to be degrading, whereas implemented projects to improve water quality have had positive effects on most of the attributes measured, but that cattail coverage (a long-term integrator of water quality pollution) continues to expand. The Council stated that "substantial *near-term* [emphasis in original] progress to address both water quality and hydrology in the central Everglades is needed to prevent further declines."

A dedicated, focused effort by the United States and the State of Florida to substantially complete the three major projects cited above (Tamiami Trail Next Steps, Everglades Restoration Strategies, and Central Everglades Planning Project) within the next 10 years is required if we are to expect a slowing of ecosystem degradation and tangible improvements to ENP indicators of site integrity.

Following the completion of the 1-mile bridge along the Tamiami Trail, crews commenced removal of the existing roadway in May of 2012. NPS photo.

ADDITIONAL INFORMATION REQUESTED BY THE WORLD HERITAGE COMMITTEE IN 36COM7A.14

The ENP General Management Plan: Connections with the Desired State of Conservation and Corrective Measures

It is noteworthy that the corrective measures originally identified by the World Heritage Committee and ENP in 2006 are almost exclusively associated with ecosystem restoration projects implemented *outside* of park boundaries and have overarching effects on the hydrology and water quality of ENP. During the ENP General Management Plan (GMP) development process, managers deliberately chose not to address ecosystem restoration issues in detail and instead focused primarily on management of lands and resources *inside* park boundaries. Nonetheless, these two efforts necessarily connect in several places: primarily in the statements of desired conditions in the GMP (these are broader than and consistent with the Desired State of Conservation statements in the current report), but also in broad statements within the GMP that commit ENP to continued work with stakeholders and to strengthening of partnerships for management of the park as a critical component of the south Florida ecosystem.

The intent of the GMP is to manage park lands, visitor services, and visitor activities in such a way that the desired conditions for ENP resources and visitor experiences are attained and maintained. A suite of management alternatives is presented in the plan for consideration. At the time of this writing, the ENP Draft GMP has undergone an extensive, multi-year process of public review and comment. The current revision will lead to completion of the Final GMP in 2014, including selection and adoption of the NPS preferred alternative.

The GMP focused on several major planning issues and concerns that were identified early in the process, including management of the lands encompassing NESRS (called the East Everglades Addition), wilderness assessment and management, visitor use (boating, visitor facilities, and user capacity), park stewardship, and climate change. The GMP includes several important statements that connect internal park management with the elements of external threat that are described in this report and that are being addressed through the evolution of the corrective measures originally established in 2006. Several of these statements follow:

> Marine, estuarine, freshwater, and terrestrial habitats are managed from an ecosystem perspective, considering both internal and external factors affecting visitor use, environmental quality, and resource stewardship.

> … NPS managers adapt management strategies to changing ecological and social conditions and are partners in regional land planning and management…. The resources and processes of the national park retain a significant degree of ecological integrity. Management decisions about natural resources are based on scholarly and scientific information and on the national park's significant resources….Human impacts on resources are monitored and harmful effects are minimized, mitigated, or eliminated.

> Hydrologic conditions within Everglades National Park and the south Florida ecosystem are characteristic of the natural ecosystem prior to European American intervention, including water quality, quantity, distribution, and timing. Water levels and timing of water deliveries reflect quantities resulting from natural rainfall and are distributed according to pre-engineered drainage patterns. Water is free of introduced agricultural nutrients and urban-related pollutants.

> ….natural processes…enhance and maintain native plant communities. Communities [are] representative of an ecologically functioning subtropical wetland system. Natural wildlife populations and systems are understood and perpetuated…. Naturally functioning and healthy fisheries are maintained as an important component of the ecology of Florida Bay and other waters in the park. …populations of invasive nonnative fish and wildlife species [are managed] wherever such species threaten park resources or public health and when control is prudent and feasible.

The NPS preferred alternative contained in the Draft GMP includes a number of actions that would add value to the corrective measures underway to restore the park to the Desired State of Conservation. For example, a park Advisory Committee is to be created, and this committee would maintain important links between park managers, representatives of other resource agencies, and the local public. Strengthening of links in communication is important to all phases and levels of management decision-making by allowing park managers to better perceive the interests and desires of stakeholders, and by allowing stakeholders to better perceive and participate in accomplishing the long-term mission and restoring desired conditions for park resources and visitors. The presence of an Advisory Committee should assist in streamlining planning and decision processes not only for projects inside the park, but also for the ecosystem restoration projects that collectively make up the corrective measures.

A number of actions outlined in the GMP have to do with management of visitor access and use of the resources of Florida Bay. Several corrective measures are underway to restore freshwater flows to Florida Bay and thus lead to

improvements in seagrass habitat and fisheries. The GMP takes additional and important steps of establishing "pole and troll" zones, areas where only non-combustion forms of transport (i.e., paddling, push poles, and electric trolling motors) are allowed. In addition, a mandatory boater education program, a boating safety and resource protection plan, and other protective measures within Florida Bay would be developed. When fully implemented, the combination of more natural, clean freshwater, with increased protection of benthic habitat and wildlife resources through zoning and user education, is expected to provide a high level of protection for Florida Bay, improving ecological integrity and allowing for healthy seagrass habitat and an abundant estuarine fishery.

In addition, the Draft GMP proposes a large section of the East Everglades Addition lands (added to the park's authorized boundary in 1989) to be considered as wilderness, under the Wilderness Act of 1964. The East Everglades Addition lands largely correspond to the area of NESRS, which is the focus of many of the corrective measures currently being developed to address threats to ENP, and discussed extensively in prior sections of this document. A wilderness designation for the Addition lands would provide additional protections to that sector of the park once the corrective measures are in place and the area is on track toward the Desired State of Conservation.

Based on the expected GMP approval in 2014, the establishment of the ENP Advisory Committee and actions to educate park users could begin to take place within one year of final approval. The process to determine pole and troll zones has already begun with the implementation of a pilot project in 2011 and the rationale for additional pole and troll zones described in the Draft GMP. The pilot project is being evaluated currently, and those results together with public input on the Draft GMP will be used to identify the strategy for establishing and managing additional pole and troll zones. Therefore, a number of constructive actions under the GMP are likely to be implemented prior to complete implementation of the corrective measures.

Establishment of additional designated wilderness within ENP requires a recommendation by the President and a legislative designation by the U.S. Congress. This, in addition to the length of time needed to implement corrective measures that benefit NESRS, means that any future wilderness designation for this area would likely take several years or more, following GMP approval.

Additional Conservation Issues of Significance and Actions Needed to Address Them: Invasive Exotic Species and Climate Change

Two major conservation issues that were not contemplated at the time the 2006 corrective measures were established are invasive exotic species and climate change. Invasive exotic species have been included in this report, via the establishment of integrity indicators that monitor and track the desired State of Conservation (Indicators 12 and 13). ENP is engaging in actions to address this threat to site integrity, although additional actions and funding are needed.

Regarding climate change, the ENP General Management Plan speaks to this issue in a broad way and provides guidance for park management in several aspects. First, the GMP states that the vulnerability of the Everglades area to sea-level rise is moderate to high, based on the U.S. Geological Survey Coastal Vulnerability Index. With this in mind, the GMP outlines several strategies for the park to use in addressing the anticipated effect of climate change on park resources. Research to identify natural resources at risk from climate change, formation of partnerships with other management entities to maintain regional habitat connectivity, restoration of key ecosystem features to increase ecosystem resilience, and minimization of the impacts of other stressors on park resources are all important aspects of the overall ENP strategy to address climate change and sea-level rise impacts to park natural resources. ENP has initiated several studies to assess the potential impact of sea-level rise on park resources, including a literature review (Pearlstine et al. 2009) and a project to estimate the vulnerability of rare coastal plants to changes in salinity. Additional scientific studies are planned for the next several years, and the park is poised to undertake comprehensive climate-change planning as soon as the GMP is approved. Wayside exhibits are being developed to illustrate the risk sea-level rise poses to park resources and to open a conversation with visitors regarding climate change.

SUMMARY

The suite of corrective actions currently in progress—particularly the work to raise and bridge the Tamiami Trail, the work to improve water quality, and the work to remove barriers to flow in the central part of the Everglades—is intended to provide the conditions for improvement to the indicators of ecological integrity in ENP. The final step of modifying the water operations to bring additional clean water to NESRS is a critical one. These actions are expected to be complete in the next decade, and along with the additional protections to be implemented after approval of the GMP in 2014—establishment of an Advisory Body, additional wilderness designation, management/zoning of visitor activity (especially in Florida Bay) and outreach—should provide long-awaited conditions for improvement in ENP outstanding universal values. ENP intends to focus its major efforts on completion of these actions, along with implementation of additional programs to address exotic species and climate change, in the coming years.

REFERENCES

Barbour, A.B., M.L. Montgomery, A.A. Adamson, E. Diaz-Ferguson, and B.R. Silliman. 2010. Mangrove use by the invasive lionfish *Pterois volitans*. Marine Ecology-Progress Series 401:291–294.

Beard, D.B. 1938. Everglades National Park project: Wildlife reconnaissance. U.S. Department of Interior, National Park Service, Washington, D.C.

Claydon, J.A.B., J. Batchasingh, M.C. Calosso, S.E. Jacob, and K. Lockhart. 2010. Invasive red lionfish in shallow habitats of the Turks & Caicos Islands. Proceedings of the 63rd Gulf and Caribbean Fisheries Institute. Gulf and Caribbean Fisheries Institute, San Juan, Puerto Rico, November 2010:315–319.

Craighead, F.C., Sr. 1968. The role of the alligator in shaping plant communities and maintaining wildlife in the southern Everglades. Florida Naturalist 41:2–7, 69–74, 94.

Dorcas, M.E., J.D. Wilson, R.N. Reed, R.W. Snow, M.R. Rochford, M.A. Miller, W.E. Meshaka, Jr., P.T. Andreadis, F.J. Mazzotti, C.M. Romagosa, and K.M. Hart. 2012. Severe mammal declines coincide with proliferation of invasive Burmese pythons in Everglades National Park. Proceedings of the National Academy of Sciences. doi:10.1073/pnas.1115226109.

Doren, R.F., J.C. Trexler, M. Harwell, and G.R. Best, editors. 2008. System-wide indicators for Everglades Restoration 2008 Assessment. Unpublished technical report. 43 pp.

Gaiser, E. 2009. Periphyton as an indicator of restoration in the Florida Everglades. Ecological Indicators 9:S37–S45.

Kline, J. L., W.F. Loftus, K. Kotun, J.C. Trexler, J.S. Rehage, J.J. Lorenz, and M. Robinson. 2013. Recent fish introductions into Everglades National Park: An unforeseen consequence of water management? Wetlands. doi:10.1007/s13157–012–0362–0.

Krysko, K.L., J.P. Burgess, M.R. Rochford, C.R. Gillette, D. Cueva, K.M. Enge, L.A. Somma, J.L. Stabile, D.C. Smith, J.A. Wasilewski, G.N. Kieckhefer III, M.C. Granatosky, and S.V. Nielsen. 2011. Verified non-indigenous amphibians and reptiles in Florida from 1863 through 2010: Outlining the invasion process and identifying invasion pathways and stages. Zootaxa 3028:1–64.

Madden, C.J., D.T. Rudnick, A.A. McDonald, K.M. Cunniff, and J.W. Fourqurean. 2009. Ecological indicators for assessing and communicating seagrass status and trends in Florida Bay. Ecological Indicators 95:S68–S82.

Mazzotti, F.J., and L.A. Brandt. 1994. Ecology of the American alligator in a seasonally fluctuating environment. Pages 485–505 *in* Davis, S., and J. Ogden, editors. Everglades: The ecosystem and its restoration. St. Lucie Press, Delray Beach, Florida.

McVoy, C.W., W.P. Said, J. Obeysekera, J. Van Arman, and T. Dreschel. 2011. Landscapes and hydrology of the predrainage Everglades. University Press of Florida, Gainesville, Florida, 576 pp.

National Research Council. 2008. Progress toward restoring the Everglades: The second biennial review – 2008. National Academies Press, Washington, DC. 324 pp.

National Research Council. 2010. Progress toward restoring the Everglades: The third biennial review – 2010. National Academies Press, Washington, DC. 311 pp.

National Research Council. 2012. Progress toward restoring the Everglades: The fourth biennial review – 2012. National Academies Press, Washington, DC. 244 pp.

Pearlstine, L.G., E.V. Pearlstine, J. Sadle, and T. Schmidt. 2009. Potential ecological consequences of climate change in south Florida and the Everglades: 2008 literature synthesis. National Park Service, Everglades National Park, South Florida Natural Resources Center, Homestead, Florida. Resource Evaluation Report. SFNRC Technical Series 2009:1. 35 pp. Available at http://www.nps.gov/ever/naturescience.htm

Salo, P., E. Korpimaki, P.B. Banks, M. Nordstrom, and C.R., Dickman, 2007. Alien predators are more dangerous than native predators to prey populations. Proceedings of the Royal Society B-Biological Sciences 274:1237–1243. doi:10.1098/rspb.2006.0444.

Mitchell, C. and R. Johnson, Editors. 2013. Everglades National Park: 2013 Indicators of Integrity. South Florida Natural Resources Center, Everglades National Park, Homestead, Florida. Status and Trends Report. SFNRC Technical Series 2013:3.91 pp.

Simmons, G., and L. Ogden. 1998. Gladesmen. University Press of Florida, Gainesville, Florida.

Trexler, J.C., W.F. Loftus, and J. Chick. 2003. Setting and monitoring restoration goals in the absence of historical data: Monitoring fishes in the Florida Everglades. Pages 351–376 *in* Busch, D., and J.C. Trexler. Monitoring ecoregional initiatives: Interdisciplinary approaches for determining status and trends of ecosystems. Island Press, Washington, DC.

USACE. 1992. Modified water deliveries to Everglades National Park. General design memorandum and Final Environmental Impact Statement, Central and Southern Florida Project for flood control and other purposes. U.S. Army Corps of Engineers, Jacksonville District, Jacksonville, Florida.

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