National Park Service
U.S. Department of the Interior

South Florida Natural Resources Center
Everglades National Park

STATUS AND TRENDS REPORT

SFNRC Technical Series
2013:3

# Everglades National Park 2013 Indicators of Integrity

Sebring
Ft Pierce
Lake Okeechobee
West Palm Beach
Ft Myers
EVERGLADES AGRICULTURAL AREA
WCA-1
WCA-2
Ft Lauderdale
Naples
BIG CYPRESS NATIONAL PRESERVE
WCA-3A
WCA-3B
Tamiami Trail
Miami
Atlantic Ocean
Ten Thousand Islands
Shark River Slough
Biscayne Bay
Homestead
BISCAYNE NATIONAL PARK
Gulf of Mexico
EVERGLADES NATIONAL PARK
Taylor Slough
Cape Sable
Key Largo
N
0
10
20
40 Miles
Florida Bay
Key West

# Everglades National Park

## 2013 Indicators of Integrity

STATUS AND TRENDS REPORT
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South Florida Natural Resources Center
Everglades National Park
Homestead, Florida

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# TABLE OF CONTENTS

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| **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 |
| **DASM** | Digital Aerial Sketch Mapping |
| **DERM** | Department of Environmental Resource Management |
| **DSD** | Days since a site was last dry |
| **EDDMapS** | Early Detection and Distribution Mapping System |
| **ENP** | Everglades National Park |
| **EPMT** | Exotic Plant Management Team |
| **FHAP** | Fisheries Habitat Assessment Program |
| **FLEPPC** | Florida Exotic Pest Plant Council |
| **NESRS** | Northeast Shark River Slough |
| **NGVD** | National Geodetic Vertical Datum of 1929 |
| **NOAA** | National Oceanic and Atmospheric Administration |
| **NPS** | National Park Service |
| **NSM** | Natural Systems Model |
| **POR** | Period of record |
| **ppb** | Parts per billion |
| **PSU** | Practical Salinity Unit |
| **RECOVER** | Restoration Coordination and Verification Program |
| **SAV** | Submerged Aquatic Vegetation |
| **SEIER** | System-wide Ecological Indicators for Everglades Restoration |
| **SFWMD** | South Florida Water Management District |
| **SRS** | Shark River Slough |
| **TP** | Total phosphorus |
| **TS** | Taylor Slough |
| **UF-FLREC** | University of Florida, Fort Lauderdale Research and Education Center |
| **USFWS** | U.S. Fish and Wildlife Service |
| **USGS** | U.S. Geological Survey |
| **WCA** | Water Conservation Area |
| **WSS** | Western Shark Slough |

# INTRODUCTION

This report, *Everglades National Park 2013 Indicators of Integrity*, is a companion to the 2013 State of Conservation report[1], and was developed in response to reporting requirements of the World Heritage Committee. These two reports together, and the biennial *State of Conservation* reports that will follow, are intended to consolidate information on status and trends of Everglades National Park (ENP) indicators of site integrity: these indicators are physical and biological elements that are key to the integrity and health of the park ecosystem. The content of the two reports is also intended to be broadly applicable in assisting park managers to gauge the overall response of the ENP ecosystem to factors such as water operations changes, climatic variability, and the implementation of Everglades Restoration projects.

Everglades National Park, established in 1947, encompasses about 6,000 square kilometers of subtropical wetland 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 the decades following establishment of the park, large infrastructure projects were being completed in the watershed upstream and to the east, finalizing a vast water management system for south Florida and enabling agricultural and urban development in the region. In 1979, the park was designated a World Heritage Site, and in 1992 was placed on the list of World Heritage Sites in Danger. At the time of being placed on the Sites in Danger list, four major threats were highlighted that had been repeatedly identified as sources of impact to ENP since its inception.

> **Threat 1**. Alteration of the hydrologic regime has 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 natural wetlands and in the invasion of exotic species from the developed environments.
>
> **Threat 3**. Increased nutrient pollution has resulted from runoff from upstream agricultural areas and caused 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.

In 2006, the World Heritage Committee and the United States identified a number of corrective measures to address these threats and that, when implemented, were intended to restore the park to a state where the Sites in Danger listing would no longer be necessary. The corrective measures identified at this time were consistent with the Modified Water Deliveries Project, a large project approved by the U.S. Congress in 1992 that includes a suite of water management infrastructure modifications and associated water operations intended to restore more natural hydrologic conditions to ENP. (For more detail on the corrective measures, see the 2013 State of Conservation report[1].)

After a brief period of time when ENP was removed from the list of World Heritage Sites in Danger, the park was re-inscribed on the list in July 2010. Following this decision by the World Heritage Committee, the United States requested a joint IUCN/World Heritage Committee delegation to evaluate the State of Conservation of the property, and to assist the National Park Service (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, and in 2012 ENP developed a narrative statement of the Desired State of Conservation and selected a suite of "indicators of integrity." These indicators of integrity are the most important aspects of the ecosystem that are expected to benefit from the implementation of the corrective measures, and allow measurement of progress toward the Desired State of Conservation.

## Selection of Indicators of Integrity

The initial suite of indicators of integrity in this volume includes thirteen ecosystem characteristics that range from the physical elements of the system that underlie the biology, to the biological characteristics of both the freshwater and the estuarine/marine system of the park. The indicators were selected after a review of numerous documents associated not only with ENP-specific monitoring, but also with ecosystem-wide monitoring and tracking efforts. Three important contributing documents were: 1) the 2008 *System-wide Indicators for Everglades Restoration*[2], and subsequent dedicated issue

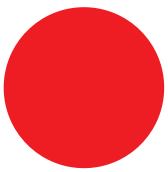
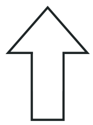
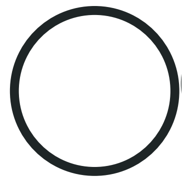
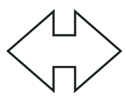
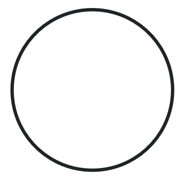
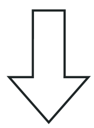
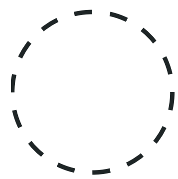
[1] Mitchell, C. and R. Johnson. 2013. Everglades National Park: 2013 State of Conservation. South Florida Natural Resources Center, Everglades National Park, Homestead, FL. Resource Evaluation Report. SFNRC Technical Series. 2013: 2. 43 pp.

[2] Doren, R., J. Trexler, M. Harwell, and G. Best, editors. 2008. Systemwide indicators for Everglades restoration 2008 assessment. Unpublished technical report of the Science Coordination Group, South Florida Ecological Restoration Task Force. 43pp. Available at http://www.sfrestore.org/scg/documents/2008_System-wideIndicatorsReport.pdf

of the journal *Ecological Indicators* 2009[3]), 2) the 2005 Interim Goals and Targets for *Everglades Restoration*[4], and 3) the 2010 *South Florida Ecosystem Restoration Task Force Strategy and Biennial Report*[5]. These indicators are intentionally designed to track changes at a broad spatial scale over long time periods, because the changes desired in the system, as well as the projects developed to provoke those desirable changes, are ecosystem-wide.

The chapters of this report describe each indicator of integrity in detail, giving emphasis to the methodology used to develop, calculate, and assess the indicator within a stoplight reporting framework (Table 1). These chapters are intended to allow future scientists and managers to understand how the indicator was developed, calculated and assessed, and to foster consistency in reporting on the indicators through time.

**Table 1. 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 |

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[3] Doren, R., J. Trexler, M. Harwell, and R. Best. Eds. 2009. Special Issue: Indicators for Everglades Restoration. Ecological Indicators. 9(Supplement 6). ISSN 1470-160X.

[4] RECOVER. 2005. Interim Goals and Targets for Everglades Restoration. Available at http://74.223.38.247/pm/recover/igit_subteam.aspx

[5] South Florida Ecosystem Restoration Task Force. 2010. Strategy and Biennial Report. 64 pp. Available at http://www.evergladesrestoration.gov/content/documents/strategic_plan_biennial_report/2010_sbr.pdf

# SECTION 1: THE PHYSICAL ENVIRONMENT

NPS photo by G. Gardner

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

**Kevin Kotun,** Everglades National Park, South Florida Natural Resources Center; Kevin_Kotun@nps.gov

### *Background and Importance*

The peat lands of the Everglades form a pattern of corrugations that are parallel to the direction of water flow. This defining characteristic is referred to as the ridge and slough landscape, the largest landscape type in the Everglades (Fig. 1). Hydrology plays a supporting role in forming and maintaining this landscape and associated habitats.

One of the areas dominated by the ridge and slough landscape is Shark River Slough (SRS), the primary drainage in Everglades National Park (ENP). SRS is, by convention, divided into Western Shark Slough (WSS) and Northeast Shark River Slough (NESRS). This convention stems from the original boundaries of ENP, established in 1947, which did not include NESRS inside the park. Land parcels in NESRS remained privately owned by parties anticipating future development. The main channel of SRS is located in NESRS, whereas WSS is at a higher elevation on the edge of the main channel.

The Central and Southern Florida Project (C&SF), authorized in 1948, set out to manage regional water resources, primarily to control flooding and provide water supply for agricultural and urban uses. In doing so, by 1962, all of the free-flowing Everglades system, except for ENP and NESRS, was converted to large, shallow reservoirs (Water Conservation Areas, or WCAs) surrounded by earthen levees. Because NESRS was not part of ENP at that time, the C&SF focused on supplying water to ENP via WSS while the private property in NESRS was "protected" from regional inflows by the C&SF levee system. NESRS was always considered to be a key component of SRS; however, it was not until it was cut off from the Everglades system that the consequences of not including it in the original park boundary were fully realized. One of the consequences was a degradation of the ridge and slough landscape as a result of reduced surface water flow and water levels. Without sufficient depths of water, NESRS experienced soil loss as well as vegetation encroachment into the sloughs, eventually filling them and eliminating open water habitat.

The changes in water distribution between WSS and NESRS that were the result of impounding the WCAs can be seen in Figure 2, which shows the depth of water in the Everglades following two large rainfall events. Panel A shows the water-level distribution after a large rainfall event in 1959 prior to the impoundment of the WCAs and the panel B shows the water-level distribution after a large rainfall event in 2005.

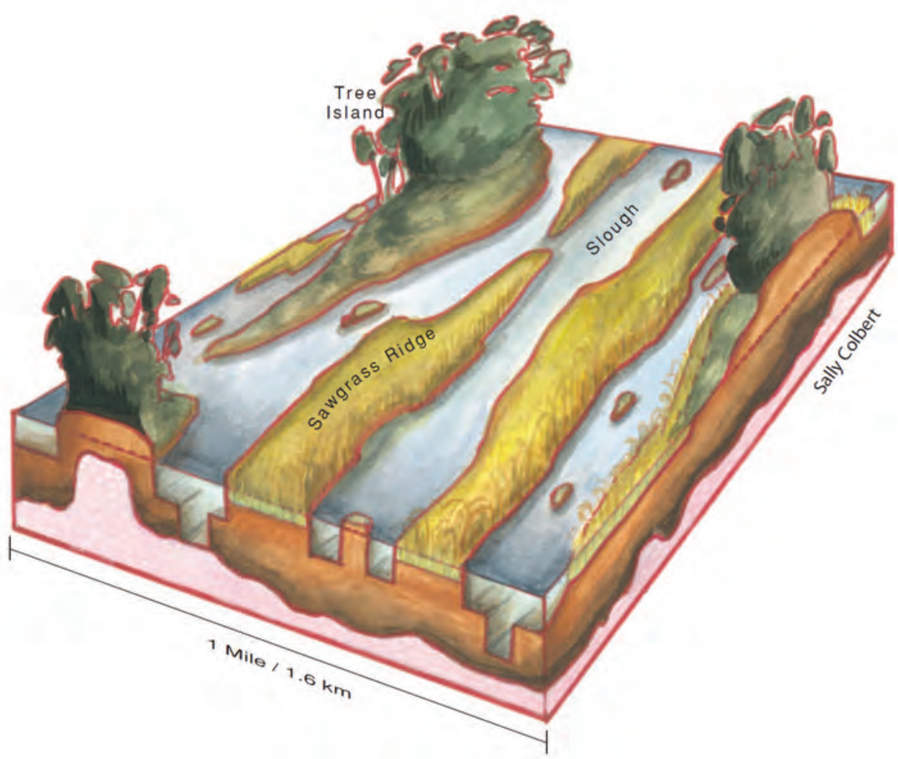



**Figure 1. Schematic diagram showing the ridge and slough patterned landscape.** Illustration by Sally Colbert; modified from McVoy et al. (2011, p. 67).

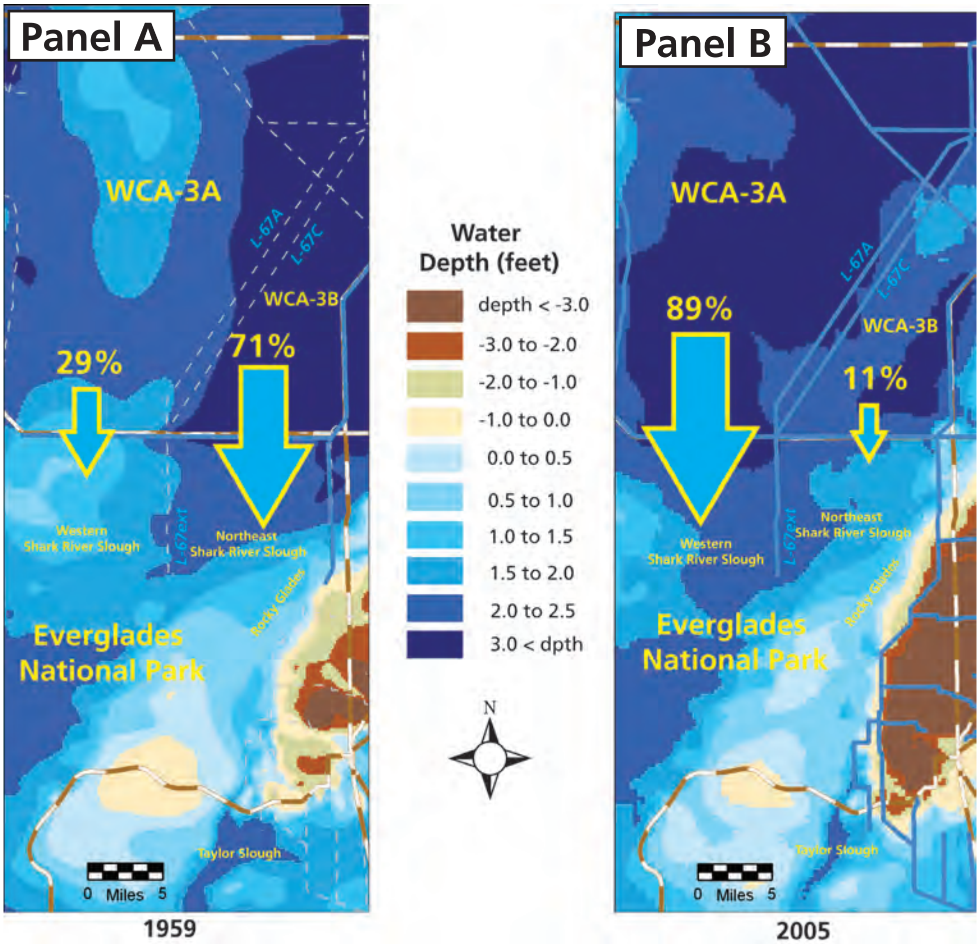



**Figure 2. Water depths and flow distributions for two wet years.** Panel A illustrates wet conditions prior to the impoundment of the Water Conservation Areas; Panel B illustrates wet conditions following the impoundment of the Water Conservation Areas. Dashed lines represent water management features that were not present until 1962.

This figure illustrates how the deeper water, and consequently water flow, has been redirected to the west and away from the main channel of SRS. Prior to impoundment of the WCAs, approximately 70% of the total flow went to NESRS compared to less than 20% in more recent times.

In 1989, more than 40 years after the original park boundaries were established, Congress authorized the expansion of ENP to include NESRS. Re-establishing the hydrology and restoring the ridge and slough landscape feature in this area has been a major focus of Everglades restoration and also a fundamental aspect of characterizing the desired State of Conservation, which includes three hydrologic indicator metrics: (1a) magnitude and distribution of sheet flow, (1b) average annual water volume delivered to NESRS, and (2) water pattern and water levels. The desired State of Conservation for each of these metrics is restoration of a more natural balance of hydrology between WSS and NESRS. The targets for the desired State of Conservation were derived from analysis of observed data as well as model simulations that mimic the natural, undeveloped system.

### *Desired State of Conservation*

**Indicator 1a: Magnitude and Distribution of Sheet Flow**

The target is to consistently deliver 55% of the annual SRS total flow volume to NESRS with the remaining 45% delivered to WSS.

**Indicator 1b: Average Annual Water Volume into Northeast Shark River Slough**

On average, deliver a total annual volume to NESRS of 550 kiloacre-feet (kac-ft) with a range of 200 to 900 kac-ft during years of below and above average rainfall, respectively.

**Indicator 2: Water Pattern and Water Levels**

The target is to achieve annual average water levels (stage) in NESRS of approximately 8.0 feet (ft) National Geodetic Vertical Datum 1929 (NGVD) during years of average annual rainfall. During years of below and above average annual rainfall, the annual average water level targets in NESRS would be 7.5 and 8.8 ft, respectively.

## *Description of Indicator Monitored*

Flow measurements and water level monitoring, conducted by the U.S. Geological Survey (USGS), provides the information necessary to evaluate the hydrologic indicators. The USGS has been measuring the flow of water across the Tamiami Trail since 1939. The dataset consists of daily flow values and is used to evaluate the magnitude and distribution of sheet flow (Indicator 1a) and the average annual water volume to NESRS (Indicator 1b). Indicator 2, water pattern and water levels, is evaluated using water level monitoring at USGS gage NESRS2, which has a period of record that began in July 1976.

The hydrologic indicators are sensitive to both climatic conditions and water management operations. Given that rainfall amounts vary naturally, we make an effort to factor rainfall out of the indicator to focus on the effects of water management operations. That is, for example in the case of Indicator 2, the target water level is lower for the drier years and higher for the wetter years. Similarly, rainfall is also a factor for Indicator 1b, in which the flow target is higher for wetter years.

Given that the water management system is regional in nature, we use a regional rainfall dataset provided by the National Oceanographic and Atmospheric Administration (NOAA). This regional dataset, Florida region 5, is a composite of all NOAA rain gages that are located within the Lake Okeechobee – Everglades drainage basin. For this evaluation, below average rainfall years are defined as the lowest 37.5% of annual total rainfall, above average rainfall years are defined as the highest 37.5% of the annual total rainfall, and average years are defined as the central 25% (i.e., from the 37.5 to 62.5 percentile) of the annual totals.

## *Status of the Indicator in the Current Year and Trends during 1980–2013*

### Indicator 1a: Magnitude and Distribution of Sheet Flow

The spatial distribution of water was evaluated by comparing the portion of flow that was directed to NESRS relative to the total flow delivered to both WSS and NESRS. Because the target for this metric does not vary with rainfall, there is no need to segregate the data based on annual rainfall. A stacked bar graph of annual total NESRS (bottom portion) and WSS (top portion) flow is shown in Figure 3. The 55% NESRS target for each individual year is represented as a light blue dash. If the NESRS bar is higher than the blue dash (i.e., the target), then the NESRS 55% flow target was met for that year. Based on these data, the target of passing 55% of the total flow to NESRS was only achieved in 3 of the 34 years (1990, 1991, and 2008), with 1988 coming very close to the target. These were years of very low total flow into the park (Fig. 3), and they correspond to rainfall years in the low category. This graphic illustrates that, in general, the higher the total flow, the farther we are from the target.

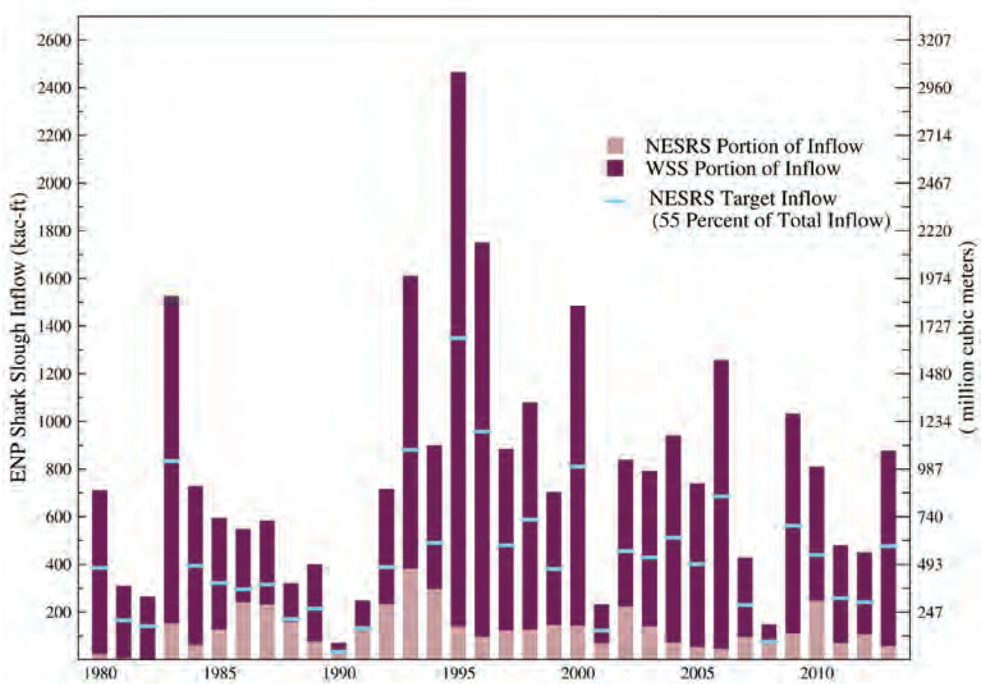



**Figure 3. Annual total flow into Shark Slough by region and in relation to annual target for Northeast Shark River Slough.**

### Trend

Although the target for this indicator does not vary with rainfall conditions, we tend to be closer to the target during low flow/rainfall years. Therefore, for the trend analysis, the years were categorized by rainfall and the trends are shown in Figure 4. The slope of the least squares regression line through the data points varies from slightly negative to slightly positive; however, none provide a level of confidence necessary to confirm a trend given the variability and small number of data points.

ceive less water during the wetter years such that, as the rainfall increases, inflows into NESRS decrease. Conversely, and more intuitively, flow to WSS increases as rainfall increases.

### Trend

Trend lines for this indicator are displayed in Figure 6. Again, the annual data points are categorized by rainfall conditions and there is no statistical confidence of a trend for any of the rainfall categories.

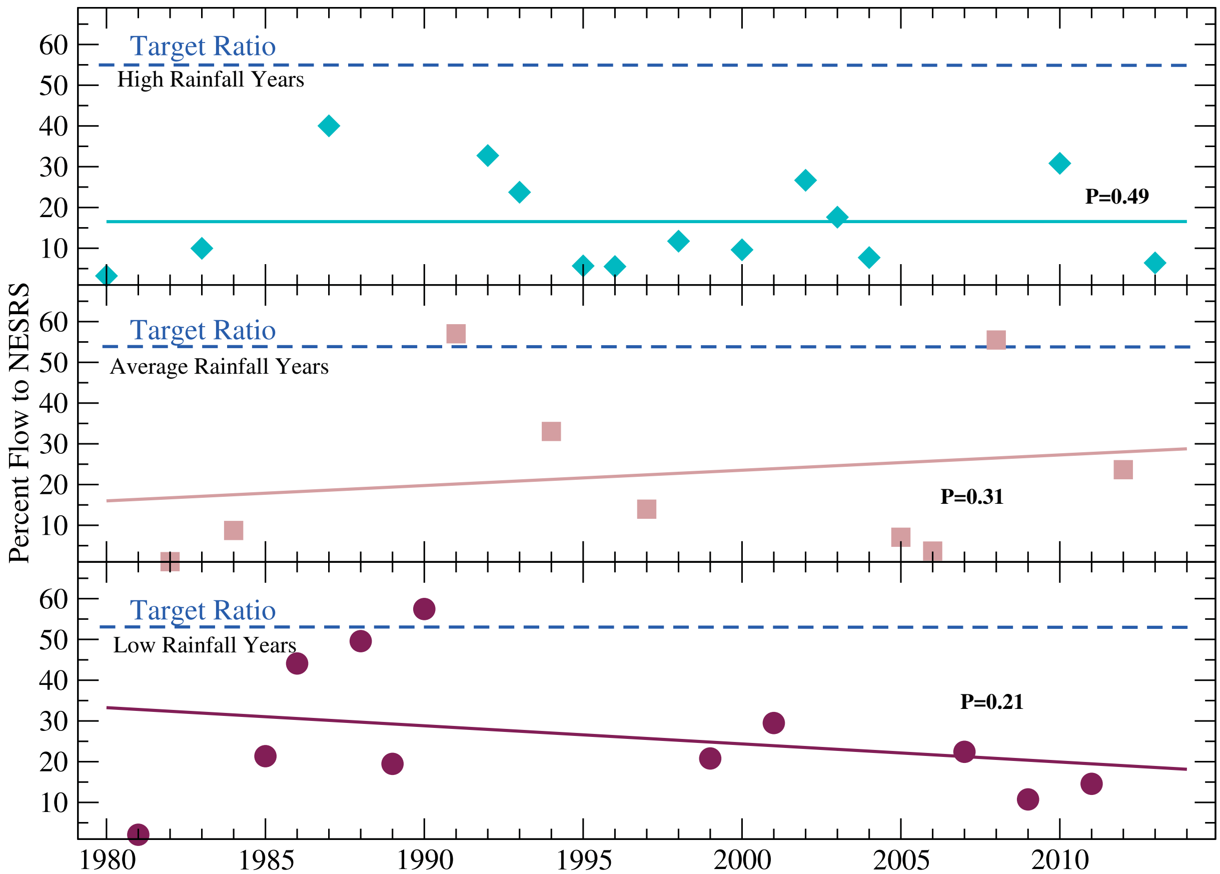



**Figure 4. Trends in percent flow to Northeast Shark River Slough (NESRS) by rainfall category.** The p-values are the result of one-tailed statistical tests of the slope of the regression line. In this context, p-values above 0.05 indicate that there is not enough evidence to confidently declare that the trend shown actually exists.

### Indicator 1b: Average Annual Water Volume to Northeast Shark River Slough

Flow targets vary depending on the amount of annual rainfall; consequently, the years were segregated to evaluate the water volume indicator. Each year is categorized by the rainfall as low, average, or high, and the annual flow is presented in a box plot for each category (Fig. 5). The whiskers of the box plots extend up and down to the 90th and 10th percentiles. These data indicate that the NESRS target is only approached during dry years and then, only at the 90th percentile of the low rainfall years (approximately once every 10 low rainfall years). This graphic also illustrates a trend in that NESRS tends to re-

### Indicator 2: Water Pattern and Water Levels

The NESRS2 gage, located in the central portion of NESRS, is used to evaluate this metric and the target water level varies with annual rainfall. For wet years, the target is for the annual maximum water level to reach 8.8 ft, 8.0 ft in average years, and 7.5 ft in dry years. The annual maximum water level for each year is plotted in Figure 7 along with the three targets. The data again have been categorized by the amount of rainfall in each year as described in the section Description of Indicator Monitored. The target is met if the annual maximum water level for a given year equals or exceeds the target for that year's rainfall category. These data indicate that the target

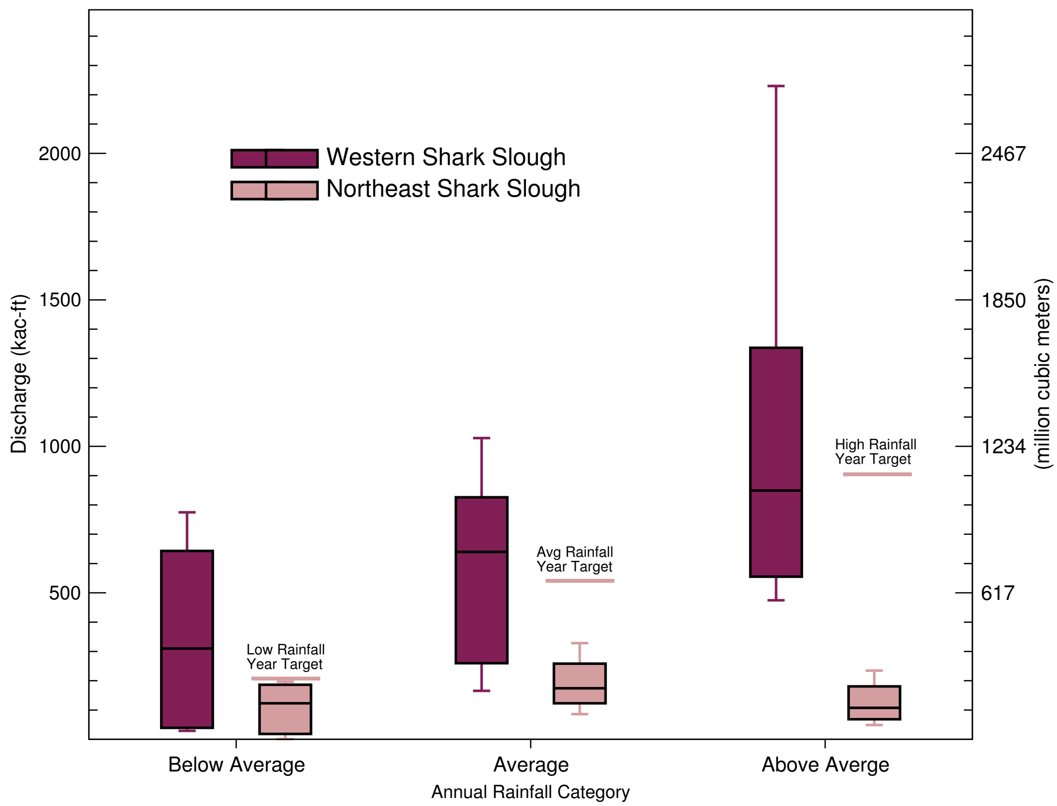



**Figure 5. Annual flow in Western Shark Slough and Northeast Shark River Slough by annual rainfall category and target.**

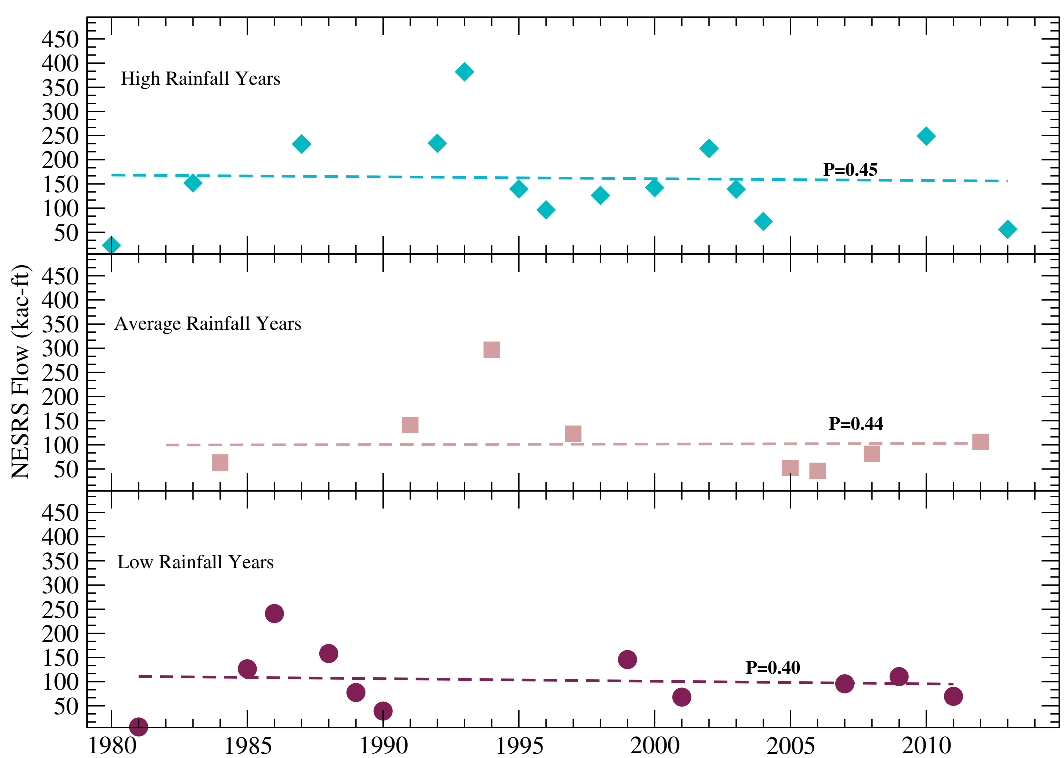



**Figure 6. Trends in flow to Northeast Shark River Slough (NESRS) by rainfall category.** The dry year target of 250 kac-ft was met once in 1986. Average and high rainfall year targets were not met during these years.

has been met twice in the last 32 years. In both instances, the target was met during a low rainfall year. The target was not met for either the average or high rainfall years. Looking at the temporal trends for each of the rainfall categories in Figure 8, it is evident that, while the regression line for each has a positive slope, the cumulative probability values, i.e., the p-values, are too high to confidently declare that there is a trend with time.

### *Highlights*

The analysis of indicators suggests that we are currently not achieving our objectives and that there is no evidence of a trend in either of the indicators. This result is not surprising given that, while some of the corrective measures necessary to meet these targets have been completed, obstacles still remain in the path of establishing a comprehensive water control

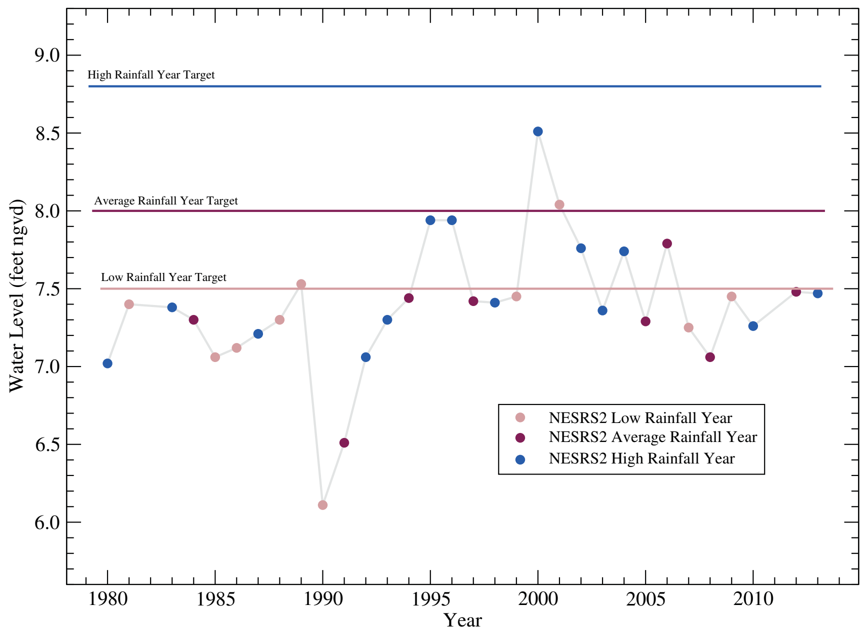



**Figure 7. Annual water levels with targets by rainfall category.**

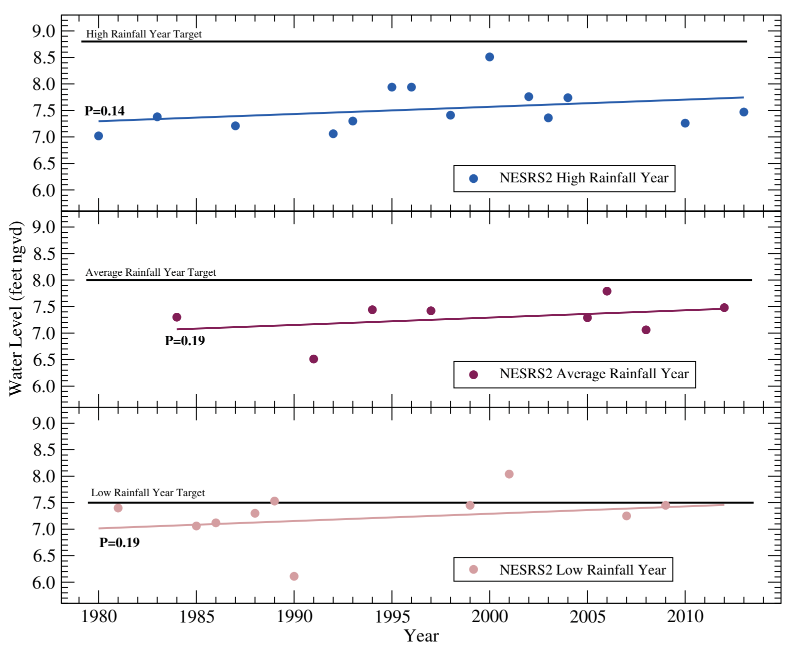



**Figure 8. Trends in annual water levels in low, average, and high rainfall years.**

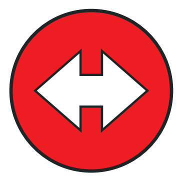
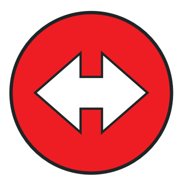
plan. Ultimately, it is the water control plan that will allow us to take advantage of the land that has been acquired and the infrastructure that has been constructed to improve the hydrology of NESRS.

The current status and trend of Indicators 1a, 1b, and 2 using the red-yellow-green stoplight designations is summarized in Table 1. Metrics used to assess the status of these indicators fell well below the established conservation targets. Based on the criteria specified above, Indicators 1a and 1b received red lights for the 1980–2013 and 2013 status period and therefore remain a significant concern. Several of the regression lines of flow magnitude and direction show a trend with a reasonable statistical significance. However, while these statistics are instructive, we feel that there is too much influence of rainfall variability and too few points to ultimately conclude that there is truly a temporal trend in these data that is a result of controllable factors (i.e., hydrologic system operations). Therefore, Indicators 1a and 1b each receive horizontal arrows representing no temporal trend.

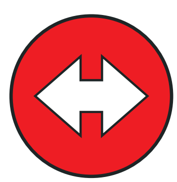
Metrics used to assess the status of Indicator 2 also fell well below the established conservation targets. For this reason, and because a water control plan is still years away from realization, Indicator 2 receives a red light and remains a significant concern, but no trend was identified in the water level record.

**Table 1. Hydrology indicator metrics.**

Indicator 1: Water volume and distribution.

| Criteria | Desired State of Conservation | Condition & Trend | Rationale |
|---|---|---|---|
| 1a. 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. |
| 1b. 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). |

## *References*

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.

# Indicator 3a: Water Quality (Total Phosphorus)

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## *Background and Importance*

Pre-drainage Everglades flora and fauna developed under oligotrophic and low mineral conditions and as such, ecosystem function is altered with minor increases in phosphorus availability (Gaiser 2009). Because of runoff from agricultural and urban development, Everglades National Park has received water enriched with nutrients for decades. Water containing elevated levels of nutrients has been associated with altered ecosystem structure and function, including conversion of sawgrass (*Cladium jamaicense* Crantz) stands to cattail (*Typha domingensis* Pers; Hagerthey et al. 2008) and periphyton community shifts and die-off (Gaiser 2009). In response to such adverse changes in the Everglades ecosystem, the federal government sued the State of Florida in 1988 for violation of water quality standards and intergovernmental agreements (Case No. 88–1886–CIV–MORENO). The lawsuit was settled in 1991, and a Consent Decree was issued in 1992 embodying the terms of the settlement. The Consent Decree established long-term total phosphorus (phosphorus) limits that eventually went into effect in December 2006 for all water discharges into the park in Shark River Slough (via water control structures S–12A, S–12B, S–12C, S–12D, and the section of Tamiami Trail between S–333 and S–334), Taylor Slough (S–332, S–332D, S–174 and S–175), and the Coastal Basins (S–18C; Fig. 1). Further, the Consent Decree required on-farm best management practices and construction of treatment wetlands to reduce phosphorus concentrations and loads prior to delivery to the Everglades. From 1993 to 2012, on-farm best management practices and constructed treatment wetlands respectively reduced phosphorus loads prior to delivery to the Everglades by 50 and 74% on average, annually.

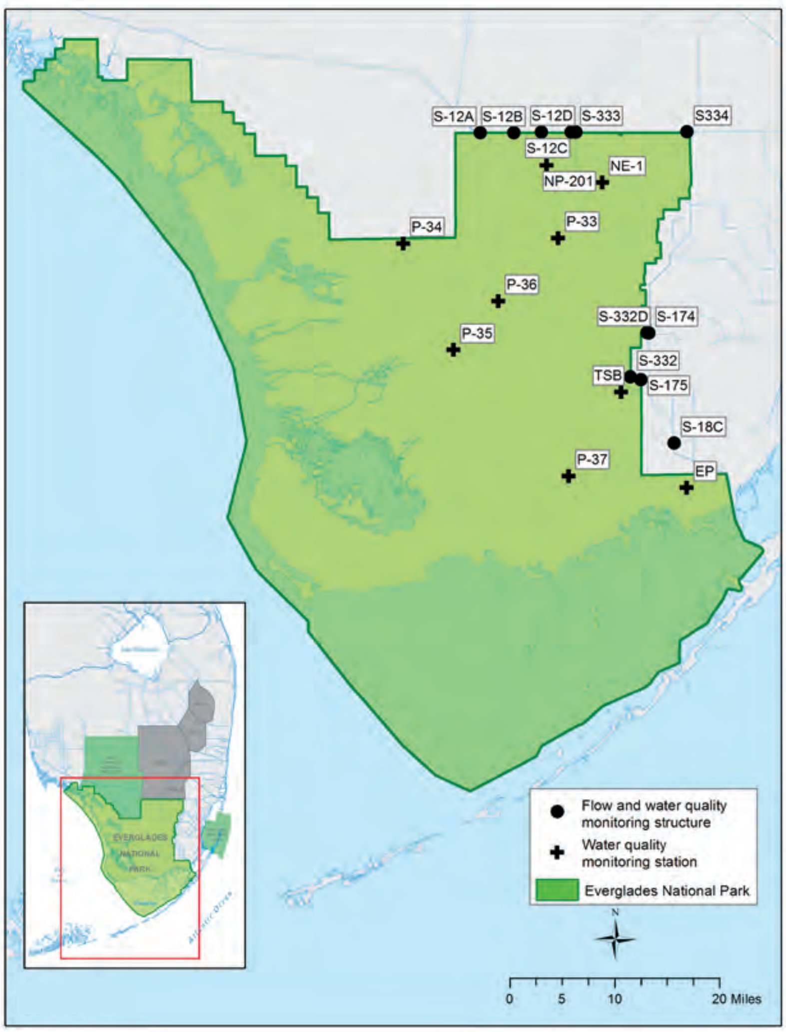



**Figure 1. Location of surface water phosphorus concentration monitoring stations.**

### *Desired State of Conservation*

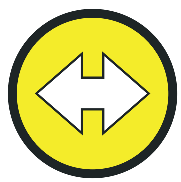
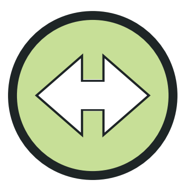
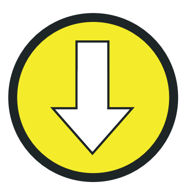
The Consent Decree established limits and targets for total phosphorus concentrations in surface water delivered to the park and in the marsh. Inflow points have both an upper limit and a desired low phosphorus target. The limit on inflow flow-weighted mean phosphorus concentrations for Shark River Slough varies seasonally depending on flow conditions, while the limit for Taylor Slough and Coastal Basins (combined) is constant at 11 µg $L^{-1}$. The Consent Decree also provided total phosphorus targets for these inflows that should result in flow-weighted mean phosphorus concentrations downstream of these inflows being at or below 8 µg $L^{-1}$ for Shark River Slough and 6 µg $L^{-1}$ for Taylor Slough and Coastal Basins. Compliance for the inflows is assessed as a 12-month rolling flow-weighted mean phosphorus concentration assessed on September 30 of each year. A 12-month rolling flow-weighted mean phosphorus concentration greater than the long-term limit is coded red in the stoplight table, between the limit and the target is coded yellow, and at or below the target is coded green (Table 1).

Interior marsh stations have only targets. We evaluated phosphorus targets in the downstream, interior marsh as the annual median phosphorus concentration assessed on September 30 each year. An annual median phosphorus concentration greater than the target is coded red, while a concentration at or below the target is coded green.

### *Description of Indicator Monitored*

Total phosphorus concentrations in surface water were monitored at water quality stations identified in Figure 1. Data at the inflow structures were collected biweekly using autosamplers or by grab samples (manual collection using clean bottles), while marsh samples were collected as grab samples on a monthly basis. Samples were collected by South Florida Water Management District (District) staff and the resulting data are stored on the District's data web portal, DBHYDRO (http://www.sfwmd.gov/dbhydroplsql). Flow data were collected by the U.S. Geological Survey or U.S. Army Corps of Engineers for each of the inflow structures and these data also are reported on the District's web portal. The water quality and flow period of record for this analysis is from October 1986 through June 2012.

**Table 1. Summary of current status and trends in phosphorus concentrations delivered to Shark River Slough as well as to Taylor Slough and Coastal Basins.**

| Criteria | Desired State of Conservation | Condition & Trend | Rationale |
|---|---|---|---|
| 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. |

### *Status of the Indicator in the Current Year and Trends over Time*

For most years since October 1992, inflow phosphorus concentrations for Shark River Slough (Fig. 2), as well as Taylor Slough and Coastal Basins (Fig. 3), were close to or lower than identified long-term limits, but generally higher than the targets. Lowest inflow phosphorus concentrations were observed from October 1995 through much of 1997 and these concentrations were below the targets for Shark River Slough, as well as Taylor Slough and Coastal Basins. Following this period, phosphorus concentrations returned to levels higher than the targets and generally coincided with the variable long-term limits at Shark River Slough, while inflow concentrations at Taylor Slough and the Coastal Basins mostly remained below the long-term limit.

Lower inflow phosphorus concentrations were coincident with relatively high annual Everglades rainfall (69 inches) and high water stages in the headwaters during the period from October 1995 through September 1996. (Daily rainfall and stage data were derived from 59 stations situated across the Everglades and represent regional conditions (South Florida Natural Resources Center DataForEVER dataset, accessed 2012). Annual Everglades rainfall during this period was 17 inches greater than mean annual Everglades rainfall. Mean annual stage in the headwater to Shark River Slough for the period from October 1995 through September 1996 was 0.5 to 1 foot higher than mean annual stage over the period of record. Marsh water, in general, tends to contain lower nutrient levels than canal water from agricultural and urban runoff. During this period, high rainfall coupled with high water stages in Shark River Slough headwater marshes likely contributed to the movement of water from the marsh into the canals, diluting nutrient concentrations delivered to the park.

Increases in phosphorus concentrations in inflows were consistent with lower annual regional rainfall and water management operations, particularly at the inflows to Shark River Slough. For example, phosphorus concentrations peaked through much of 2001 coincident with (1) drought conditions from 1998 through 2002 (Verdi et al. 2006), (2) lowering of water stages in the park headwaters beginning in 2000, and (3) management-imposed limitations on flow through the most western inflow structures (S–12A and S–12B) for a large portion of the year. Drought conditions tend to result in lowering of surface water depths, which promotes the concentration of water constituents (i.e., nutrients, minerals, etc.) in water delivered to Shark River Slough and thus within the marsh. Water stage reduction in the headwaters to the park and limitations imposed on flows through S–12A and S–12B were operational decisions intended to reduce the frequency of flooding in Cape Sable Seaside Sparrow habitat located in the western Marl Prairie (SFNRC 2005). The stage reduction in Shark River Slough headwaters promotes the concentration

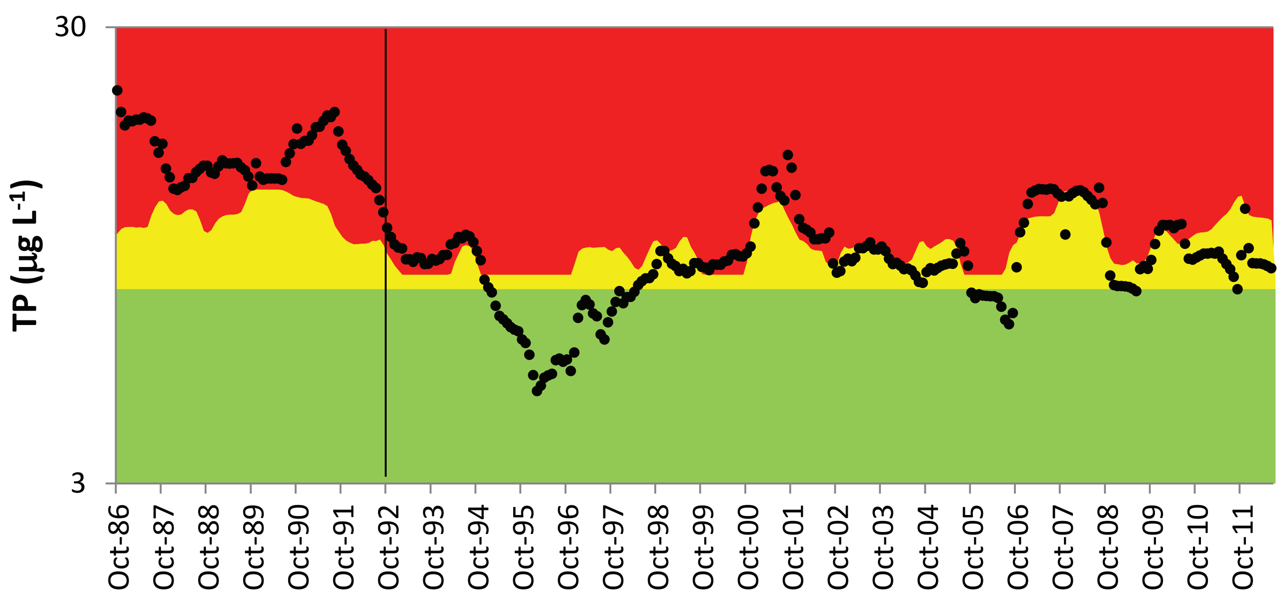



**Figure 2. Inflow total phosphorus concentrations used to assess compliance with the long-term phosphorus limits and targets for Shark River Slough.** Black dots represent 12-month flow-weighted mean phosphorus concentrations; green area represents phosphorus concentrations at or below the Consent Decree phosphorus target; yellow area represents phosphorus concentrations above the Consent Decree phosphorus target, but at or below the long-term limit; and the red area represents concentrations above the long-term limits for the park.

of surface water constituents, particularly when those stages recede below 9.5 ft. This concentration reduces the potential of marsh water to dilute nutrient concentrations in canal water prior to delivery to Shark River Slough. Limiting flows through S–12A and S–12B, where phosphorus concentrations are low because of nutrient-poor marsh water from the headwaters, forces more water to be delivered to Shark River Slough through S–12D and S–333. Of the structures delivering water to Shark River Slough, S–12D and S–333 receive the greatest influence from canal water, and these structures had the highest phosphorus concentrations and account for the greatest fraction of water delivered to Shark River Slough. Further, because the flows to Shark River Slough rely heavily on S–12D and S–333, the overall phosphorus concentration (compliance concentration) delivered to Shark River Slough does not receive the full benefit of the lower concentrations at S–12A and S–12B.

Phosphorus concentrations at some inflow structures to Shark River Slough exhibited a decreasing trend since October 1986 and have been stable since October 1992, but since October 1986 and October 1992, phosphorus concentration exhibited upward trends at the inflows to Taylor Slough and Coastal Basins (Table 2). After the initiation of on-farm best management practices in 1993, phosphorus concentrations have remained below the high levels observed during the late 1980s at the inflows to Shark River Slough. Alternatively, at the inflows to Taylor Slough and Coastal Basins, phosphorus concentrations have generally remained above concentrations observed from October 1986 through October 1994 and the pattern appears to increase when drought conditions are prevalent and decline in years of high rainfall. Following the low inflow phosphorus concentration period from October 1995 through much of 1997 for Shark River Slough, as well as Taylor Slough and Coastal Basins, phosphorus concentrations increased at several of the individual inflow structures (Figs. 2 and 3). The low phosphorus concentration period was rainfall-rich with high headwater stages. This period was followed by drought conditions and operational reductions in water stage that likely promoted concentrating of surface water constituents, ultimately increasing phosphorus concentrations. The lack of downward trends in phosphorus concentrations delivered to the park following the initiation of constructed treatment wetlands suggest that benefits from upstream phosphorus reductions may take longer to cascade down to the park, and that untreated sources of phosphorus may have an increasing influence relative to treated sources.

Currently, headwater phosphorus concentrations continue to be too high for park flora and fauna. Inflow concentrations hovering around or just below the long-term limits, but still above the target, indicate that these inflows still threaten park ecology and that additional phosphorus reduction measures need to be implemented, particularly for park water sources presently not treated.

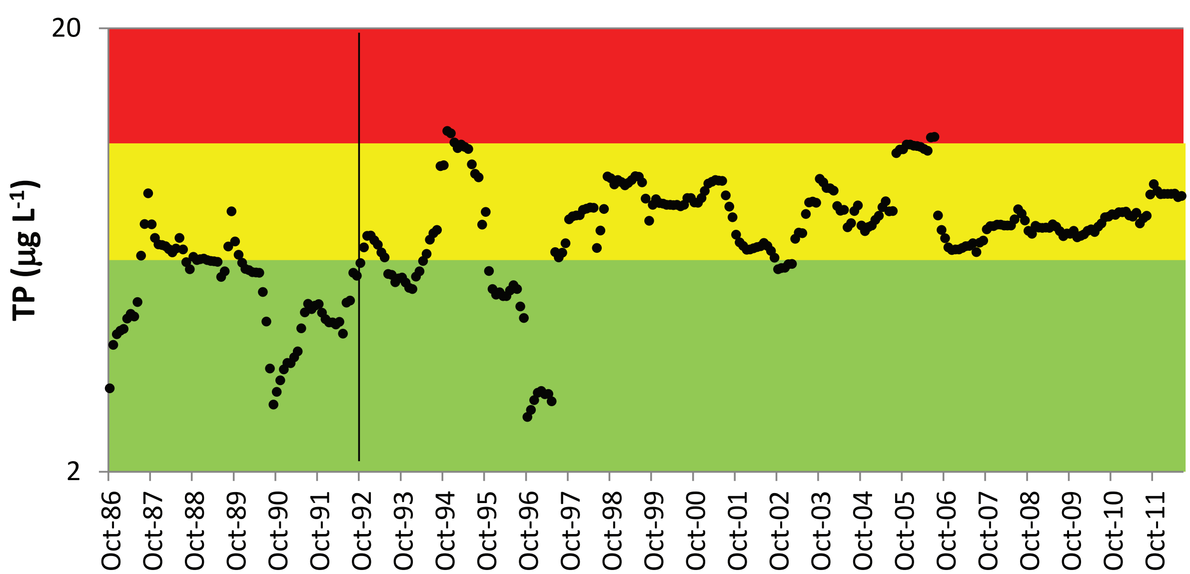



**Figure 3. Inflow total phosphorus concentrations used to assess compliance with the long-term phosphorus limits and targets for Taylor Slough and Coastal Basins.** Black dots represent 12-month flow-weighted mean phosphorus concentrations; green area represents phosphorus concentrations at or below the Consent Decree phosphorus target; yellow area represents phosphorus concentrations above the Consent Decree phosphorus target, but at or below the long-term limit; and the red area represents concentrations above the long-term limits for the park.

**Table 2. Long-term phosphorus trends for the inflows to the park and in the marsh interior.** Trend values in bold represent significant trends.

| Area | 1986–2012 | | 1992–2012 | |
|---|---|---|---|---|
| | Trend | p-value | Trend | p-value |
| Inflow: Shark River Slough | **-1.098** | 0.000 | 0.429 | 0.195 |
| Interior: Shark River Slough | -0.008 | 0.268 | -0.005 | 0.419 |
| Inflow: Taylor Slough and Coastal Basins | **0.617** | 0.002 | **0.915** | 0.009 |
| Interior: Taylor Slough and Coastal Basins | **-0.037** | 0.000 | **-0.012** | 0.000 |

Median annual interior marsh phosphorus concentrations within Shark River Slough, as well as Taylor Slough and Coastal Basins, remained below the target since October 1992 (Figs. 4 and 5), and the Taylor Slough and Coastal Basins interior marsh exhibited downward trends in phosphorus concentrations since October 1986 and October 1992 (Table 2). Since October 1992, there have been minor phosphorus concentration spikes in Shark River Slough during droughts, but even these spikes did not increase above the targets. Taylor Slough and Coastal Basins did not show this pattern except during the extreme drought of 2006 through 2007. Overall, phosphorus concentrations in surface water alone indicate that the marsh in Shark River Slough, as well as Taylor Slough and Coastal Basins, is meeting expected targets. However, nutrient loading still is occurring and impacts are evident in marsh periphyton (see Indicator 3b: Periphyton).

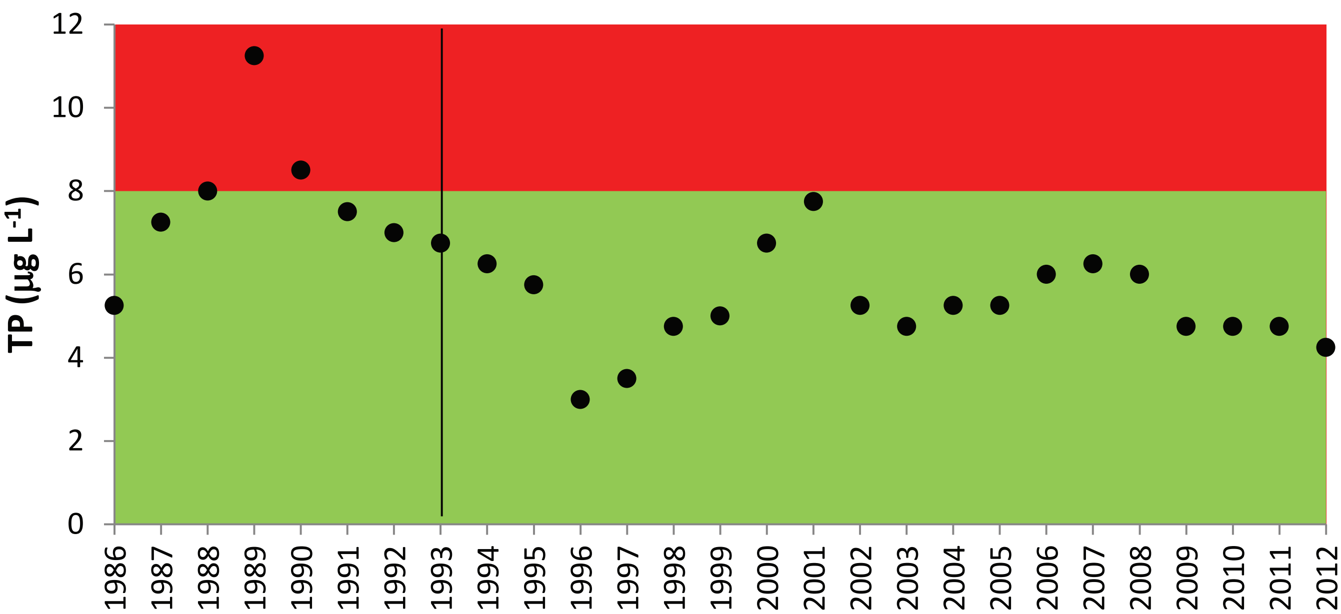



**Figure 4. Interior marsh total phosphorus concentrations used to assess targets for Shark River Slough.** Black dots represent the combined annual median phosphorus concentrations in the marsh; green area represents the Consent Decree phosphorus target; and the red area represents concentrations above acceptable levels for park ecology.

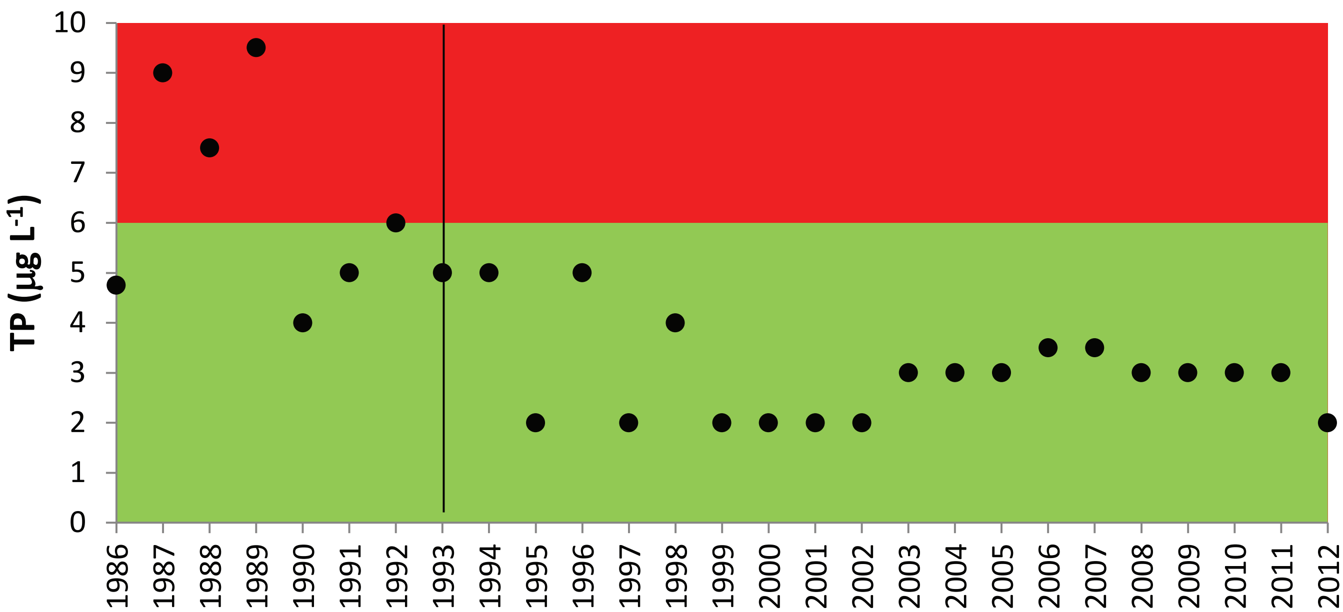



**Figure 5. Interior marsh total phosphorus concentrations used to assess targets for Taylor Slough and Coastal Basins.** Black dots represent the combined annual median phosphorus concentrations in the marsh; green area represents the Consent Decree phosphorus target; and the red area represents concentrations above acceptable levels for park ecology.

## *Highlights*

In summary, inflow phosphorus concentrations to the park are at an undesirable level, while interior marsh phosphorus concentrations have stabilized at concentrations below the targets (Table 1). Any future water management plans that further reduce water levels in the headwaters to the park have a potential to increase phosphorus concentrations in runoff to the park. However, the marsh along the eastern boundary of the park appears to have benefited from increased water stages (Surratt et al. 2012) resulting from the implementation of water detention basins designed to reduce seepage from the park (SFNRC 2005, Surratt et al. 2012). Based on the performance of these basins, implementation of projects that promote longer duration of marsh inundation and higher water depths, particularly along the eastern boundary of the park, has the potential to further reduce phosphorus concentrations in the marsh and ultimately long-term impacts to the ecosystem.

## *References*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Surratt, D., D. Shinde, and N. Aumen. 2012. Recent cattail expansion and possible relationships to water management: Changes in upper Taylor Slough (Everglades National Park, Florida, USA). Environmental Management 49:720–733.

Verdi, R.J., S.A. Tomlinson, and R.L. Marella. 2006. The drought of 1998–2002: Impacts on Florida's hydrology and landscape. U.S. Geological Survey Circular 1295, 35 pp. Available at http://pubs.usgs.gov/circ/2006/1295/ (accessed December 7, 2012).

## Indicator 3b: Water Quality (Periphyton)

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### *Background and Importance*

Water managers for Everglades National Park have identified periphyton biomass, tissue total phosphorus (phosphorus) content, and community composition as early indicators of nutrient enrichment. Periphyton is an important feature of the Everglades ecosystem and contributes a large portion of net primary productivity. Phosphorus in this oligotrophic ecosystem is quickly assimilated by periphyton and cycled through macrophytes and ultimately into the soil via plant litter (Gaiser 2009). Periphyton responds to changes in environmental conditions at both small and large spatial scales in a matter of days to a few weeks. Therefore, periphyton has the potential to 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 (Gaiser 2009).

### *Desired State of Conservation*

The desired state of conservation for the periphyton indicator is the restoration of periphyton biomass, tissue phosphorus content, and composition to conditions that support stable aquatic fauna communities. Stoplight coding methods for periphyton biomass, tissue phosphorus content, and periphyton community composition in Shark River Slough and the Taylor Slough areas are from Gaiser (2009) and are based on mean and one standard error of the mean for unimpacted marsh areas (areas with soil phosphorus concentrations lower than 500 mg $kg^{-1}$). If a monitoring station has a periphyton biomass, tissue phosphorus content, or composition within one standard error of the mean, the station is coded green; between one and two standard errors of the mean, the station is coded yellow; and if the station is greater than two standard errors, the station is coded red (Gaiser 2009). When fewer than 25% of the stations in an area (i.e., Shark River Slough and Taylor Slough) are coded yellow or red, the area is coded green, but if more than 25% are coded yellow or red, then the area is coded yellow. When more than 50% of the stations in an area are coded red, the area is coded red. Areas coded green are in acceptable condition, areas coded yellow are experiencing low-level nutrient enrichment, and areas coded red are nutrient-enriched and considered degraded.

### *Description of Indicator Monitored*

Periphyton biomass, tissue phosphorus content, and composition were monitored throughout the park at the suite of stations identified in Figure 1. Data were collected annually by Florida International University as part of a cooperative agreement with the park. Data are maintained by the university and delivered to the park annually. The periphyton period of record spans from 2006 through 2012.

### *Status of the Indicator in the Current Year and Trends over Time*

In the park marsh, periphyton biomass, tissue phosphorus content, and composition suggest the park is experiencing low-level nutrient enrichment. Since 2006, periphyton biomass status in Shark River Slough has been categorized as re-

**Periphyton is an important component of the Everglades ecosystem.** NPS photo.

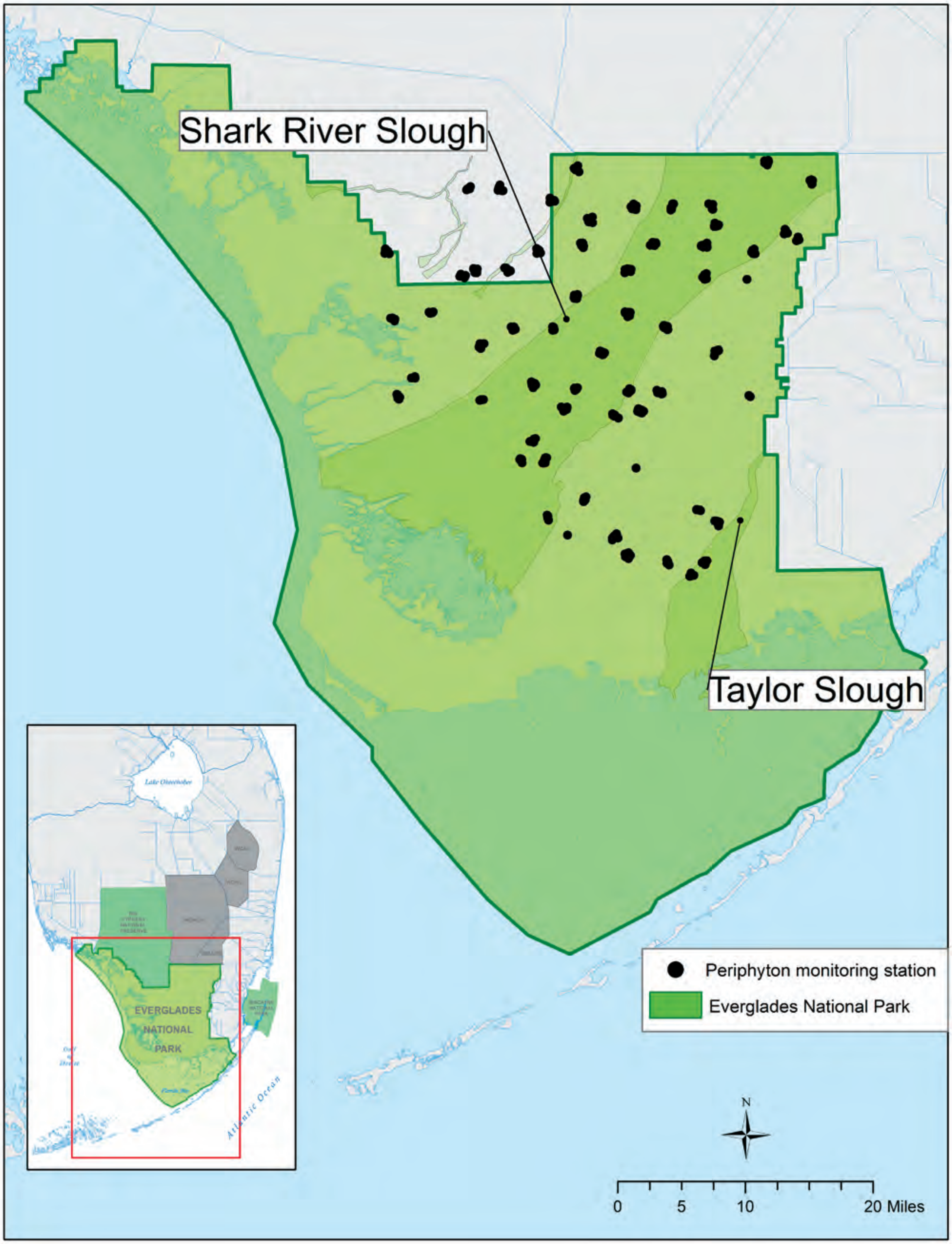



**Figure 1. Location of periphyton sampling stations in Everglades National Park.**

ceiving low-level nutrient enrichment and is coded as yellow (Table 1). This pattern also was observed in periphyton tissue phosphorus content, except in 2010 when Shark River Slough shifted from a category of low-level enrichment to an acceptable condition, that is, from yellow to green. Periphyton composition was in acceptable condition (coded green) during 2007 and 2010, but the remaining years since 2006 indicated a low level of enrichment, coded yellow (no data were collected in 2012). Overall, the current status of Shark River Slough is one of low-level enrichment, coded yellow (Table 2). Periphyton biomass, tissue phosphorus content, and composition are projected to remain at a low level of enrichment over the next 2 years as increased flows are forecast for Shark River Slough with no expected reductions in phosphorus concentrations over this period.

Since 2006, Taylor Slough periphyton has generally been in acceptable condition (Table 1) with respect to phosphorus enrichment. The biomass indicator suggests the Taylor Slough area was experiencing low-level enrichment (coded yellow) in 2008, while the remaining years all indicated acceptable conditions (coded green). Tissue phosphorus content in Taylor Slough was categorized as experiencing low-level enrichment (coded yellow) in 2007, but the area was in acceptable condition (coded green) until 2012, when the condition reversed to indicate low-level enrichment again (coded yellow). Periphyton composition was acceptable for the area from 2007 through 2009, declining back to low-level enrichment (coded yellow) thereafter (no data were collected in 2012). The periphyton biomass indicator is projected to remain acceptable (coded green) over the next 2 years, but if nutrient enrichment increases, or hydroperiod or water depth decrease, along the eastern park boundary, the periphyton tissue phosphorus content and composition may increase and the area could decline to a status of low-level enrichment (coded yellow).

### *Highlights*

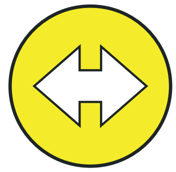
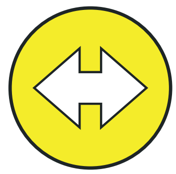
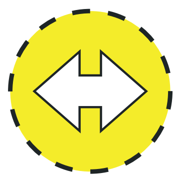
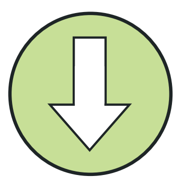
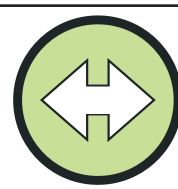
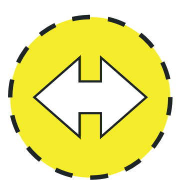
In summary, the 2-year prospects for Shark River Slough and Taylor Slough are consistent with upstream inflows, and pending water management operations have the potential to increase nutrient enrichment. Shark River Slough receives water from a series of flow structures located at the northern boundary of the park, and these inflow structures have a phosphorus concentration between the long-term limit and the phosphorus target (coded yellow) (see Indicator 3a: Phosphorus), consistent with the Shark River Slough 2-year prospect. Any future water management plans that further reduce water levels in the headwaters to Shark River Slough have a potential to increase phosphorus concentrations in runoff to Shark River Slough. Alternatively, the Taylor Slough area receives water from inflow structures located on the eastern park boundary and these inflows have a low-level nutrient status (coded yellow) (Table 2), consistent with the Taylor Slough 2-year prospect (Table 1). The marsh along the eastern boundary of the park appears to have benefited from increased water stages (Surratt et al. 2012) resulting from the implementation of water detention basins designed to reduce seepage from the park (SFNRC 2005, Surratt et al. 2012).

**Table 1. Current (2012) status and patterns (2006 through 2012) in periphyton tissue phosphorus content, biomass, and composition. Black symbols indicate no samples were collected.**

| Performance measure | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2-yr | Current status and 2-yr prospect |
|---|---|---|---|---|---|---|---|---|---|
| **Shark River Slough** | | | | | | | | | |
| Tissue phosphorus content | Yellow | Yellow | Yellow | Yellow | Green | Yellow | Yellow | Yellow | *Current status*: Inflow phosphorus is resulting in low-level nutrient enrichment and degrading periphyton. *2-Yr Prospects*: Increased flows under lower headwater stages may further degrade periphyton. |
| Biomass | Yellow | Yellow | Yellow | Yellow | Yellow | Yellow | Yellow | Yellow | |
| Composition | Yellow | Green | Yellow | Green | Yellow | Yellow | Black | Yellow | |
| **Taylor Slough** | | | | | | | | | |
| Tissue phosphorus content | Green | Yellow | Green | Green | Green | Green | Yellow | Yellow | *Current status*: Inflow phosphorus is resulting in low-level nutrient enrichment and degrading composition. *2-Yr Prospects*: Periphyton may be degraded if hydroperiods or water depths decline. |
| Biomass | Green | Green | Yellow | Green | Green | Green | Green | Green | |
| Composition | Yellow | Green | Green | Green | Yellow | Yellow | Black | Yellow | |

Based on the performance of these basins, implementation of projects that promote longer duration of marsh inundation and higher water depths, particularly along the eastern boundary of the park, has the potential to further reduce phosphorus concentrations in the marsh and, ultimately, long-term impacts to the ecosystem.

**Table 2. Periphyton conditions assessment for Shark River Slough as well as Taylor Slough.**

| Criteria | Desired State of Conservation | Condition & Trend | Rationale |
|---|---|---|---|
| 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. |

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Surratt, D., D. Shinde, and N. Aumen. 2012. Recent cattail expansion and possible relationships to water management: Changes in upper Taylor Slough (Everglades National Park, Florida, USA). Environmental Management 49:720–733.

# SECTION 2: THE FRESHWATER ENVIRONMENT: RIDGE, SLOUGH, AND MARL PRAIRIES

NPS photo

## Indicator 4: Freshwater Fish and Aquatic Invertebrates

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### *Background and Importance*

Fish and aquatic invertebrate assemblages play an important role in Everglades food webs and can be used as indicators of ecosystem health. Although wading birds, alligators, and other visible species garner much public support, they are highly dependent upon prey availability for reproductive success. Factors that influence fish and aquatic invertebrate populations may cascade up the food web and affect the more charismatic species. An increase in the abundance of native fish and aquatic invertebrates from present conditions to those that approximate pre-drainage conditions is necessary to achieve the desired state of conservation for removal of Everglades National Park (ENP) from the World Heritage Sites in Danger list. Knowing exactly what the abundance of the native fish and aquatic invertebrate assemblages were during pre-drainage conditions is impossible because we lack historical data. However, the goal of a measurable positive trend can be verified by monitoring in situ conditions and using models developed to predict population densities of freshwater fish and invertebrates relative to target hydrologic conditions (Trexler et al. 2003). In order to develop these relationships, both the aquatic community and hydrologic parameters are monitored.

Everglades National Park has a history of freshwater fish and invertebrate monitoring efforts dating back to the 1960s. One of the main projects, the Freshwater Aquatics Long-term Monitoring Project, began in the late 1970s. This project tracks trends over time and has proven invaluable for understanding the relationship between freshwater fish and large aquatic invertebrates and hydrologic conditions. This project has been used to develop targets for restoration in the absence of historical data (Trexler et al. 2003) and to assess changes in hydrologic management (Trexler et al. 2005). Additional monitoring in support of the Modified Waters Deliveries project has expanded monitoring efforts and, together with the long-term monitoring project, has been used to develop restoration assessment protocols (Trexler and Goss 2009).

### *Desired State of Conservation*

The desired state of conservation is to maximize densities of small-sized freshwater fishes and aquatic invertebrates through ecological processes consistent with contemporary knowledge of the pre-drainage Everglades ecosystem, hydrologic control of metacommunity dynamics in an oligotrophic wetland.

### *Description of Indicator Monitored*

The long-term monitoring efforts in ENP focus on six sites located within Shark River Slough (SRS) and three sites within Taylor Slough (TS) sampled by staff of Florida International University (FIU) and ENP (Fig. 1). The three northern SRS sites were sampled using current methods since 1985. Sampling at the southern SRS and the TS sites began in 1996, allowing assessments during 1996–2012. Each site consists of

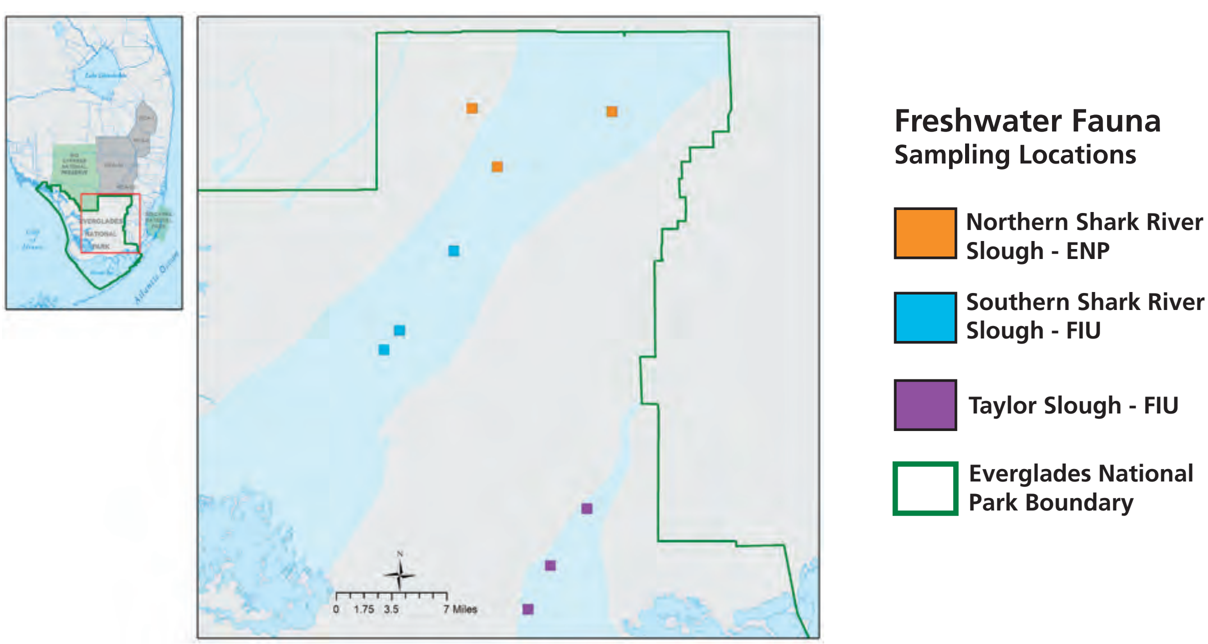



**Figure 1. Map of freshwater fauna monitoring locations in Shark River and Taylor sloughs.**

three to five separate plots of either 45 by 75 meters or 100 by 100 meters, depending on local vegetation patterns. A 1-$m^2$ throw trap was used to collect seven randomly placed samples from each plot, five times per year (July, October, December, February, and April). Fishes and invertebrates were collected from each 1-$m^2$ sample, collated, and averaged to estimate a density of individuals at each site. Water depths for each site were estimated using a relationship between depths measured in each sample and data collected at nearby hydrologic monitoring stations.

Statistical relationships between total fish abundance and the abundance of indicator taxa and days since a site was last dry (DSD) have been used to develop performance measures, evaluate observed conditions relative to target conditions, and assess restoration projects (Trexler et al. 2003, Trexler et al. 2005, Trexler and Goss 2009). Trexler and Goss (2009) used a variety of indicators for restoration assessment. These indicators consist of species that are drought intolerant (rare after a site dries and abundance increases the longer a site is flooded; e.g., bluefin killifish (*Lucania goodei*); Fig. 2), species that are drought tolerant (are most abundant soon after dry conditions; e.g., flagfish (*Jordanella floridae*), species that are weakly related to time since a drying event (e.g., mosquitofish (*Gambusia holbrooki*)), species whose abundance is related to depth rather than hydroperiod (e.g., the Everglades crayfish (*Procambarus alleni*)), and total fish abundance. This suite of indicators covers a broad range of the existing Everglades aquatic fauna. The indicators are calculated individually and are also used in summary protocols to describe the status of the aquatic faunal community in the two major slough systems of ENP: Shark River Slough and Taylor Slough.

The application of these indicators to evaluate Everglades restoration was developed by Trexler and Goss (2009) and is used in the Freshwater Fish and Macroinvertebrate section of the System-wide Ecological Indicators for Everglades Restoration (SEIER) series of reports (Doren et al. 2008, Brandt et al. 2012). The SEIER uses the 1993–1999 time period as a target hydrologic condition to develop forecasting statistical models linking rainfall and depth at monitoring sites and that is used to predict the DSD at each site from 2000 through 2012. Statistical relationships between the predicted DSD and fish abundance (Trexler et al. 2003, Trexler et al.

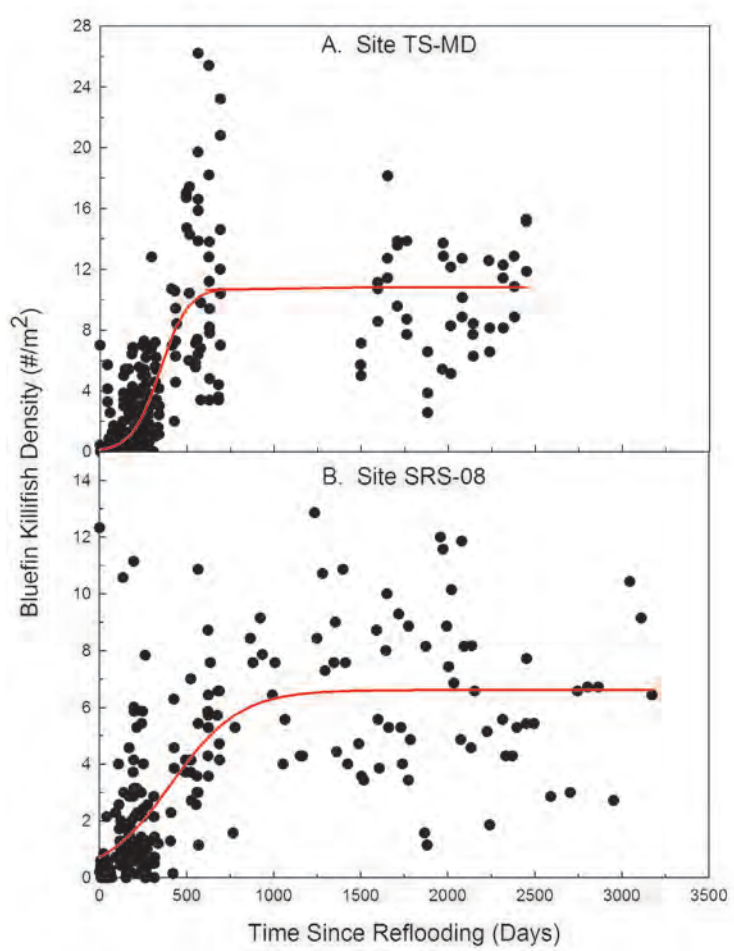



**Figure 2. Example relationships between bluefin killifish density (#/$m^2$) and time since reflooding (days) at a site in Taylor Slough (panel A) and a site in Shark River Slough (panel B) used for performance measure development.**

2005) are used to establish the target interval for fish abundance (mean ±2 SE). These target intervals were compared to the observed catches using criteria developed by Trexler and Goss (2009). An impact was defined by the magnitude of difference between the observed mean and SE limits and the target interval; a simple system of stoplight indicators is used to summarize results for a general audience. Red stoplight ratings are assigned to note significant concern because the measured annual target interval is above or below the mean ±3 SE, or when in two out of three consecutive years the target interval is above or below the mean ±2 SE, or when in four out of five consecutive years the target interval is above or below the observed mean ±1.5 SE (Trexler and Goss 2009). Yellow stoplights corresponded to years where the target was outside of the mean ±1.5 SE and indicate conditions that warrant further attention. Green lights correspond to years where the observed mean ±1.5 SE falls within the target region and indicates good condition (Trexler and Goss 2009), approximating the desired state of conservation. The most recent report includes trends over the 2000–2012 water years, with detailed analysis of the 2012 water year (2012 = May 2011 through April 2012). The results presented here are a summary of the results prepared by Dr. Joel Trexler (Florida International University) for the Brandt et al. 2012 report.

The target years of 1993–1999 are used because that time period contains wet season flood conditions during 1995–1996 that are considered similar to what may have been expected under natural conditions. A water management change in 2000 also separates the time period and allows assessment of the influence of water management change on the indicators. Doren et al. (2008) notes that alternative baseline models (e.g., Natural System Model) could be used that would likely predict longer hydroperiod conditions and more frequent impacts than the 1993–1999 model used.

### *Status of the Indicator in the Current Year and Trends over Time*

Over the period of 1993–2012, fish abundance, as measured by density of all species collected, in SRS and TS decreased from multi-year highs observed in the late 1990s to lower numbers recorded into the mid-2000s and appear to have a slightly increasing trend since 2005 (Fig. 3). Bluefin killifish abundance (a drought intolerant species) was commonly greater than 4/m$^2$ prior to 2000 but has become more variable since 2000, with abundance often below 4/m$^2$ (Fig. 4). Bluefin killifish were at or below target levels of abundance that were set based on rainfall (Fig. 5). In contrast, the Everglades crayfish, a drought tolerant invertebrate, was collected at low densities (at or near 0/m$^2$ in SRS prior to 2000), but has spiked in abundance several times since 2000 (Fig. 6); Everglades crayfish were generally at or above target level during this period (Fig. 7). Lower abundance of drought intolerant species and higher abundance of drought tolerant species indicate dry conditions after 2000 in SRS and TS relative to expectations based on rainfall.

In 2012, restoration targets were generally not met because of drier marsh conditions than expected based on rainfall. Total fish abundance and bluefin killifish (a drought intoler-

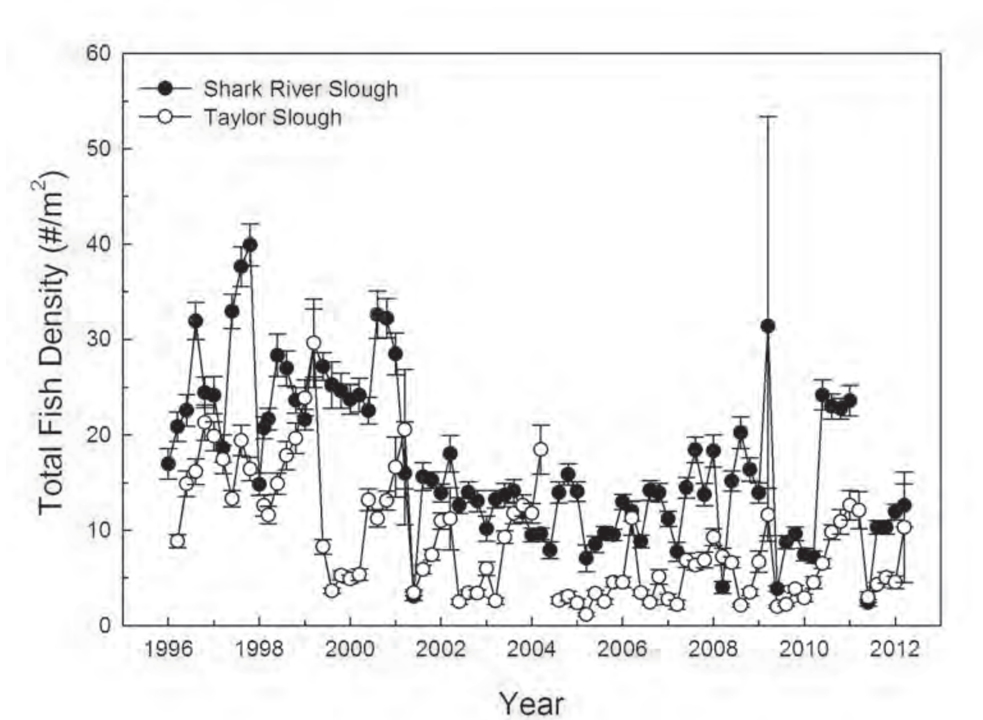



**Figure 3. Total fish density (#/m$^2$) in Shark River and Taylor sloughs during 1996–2012.**

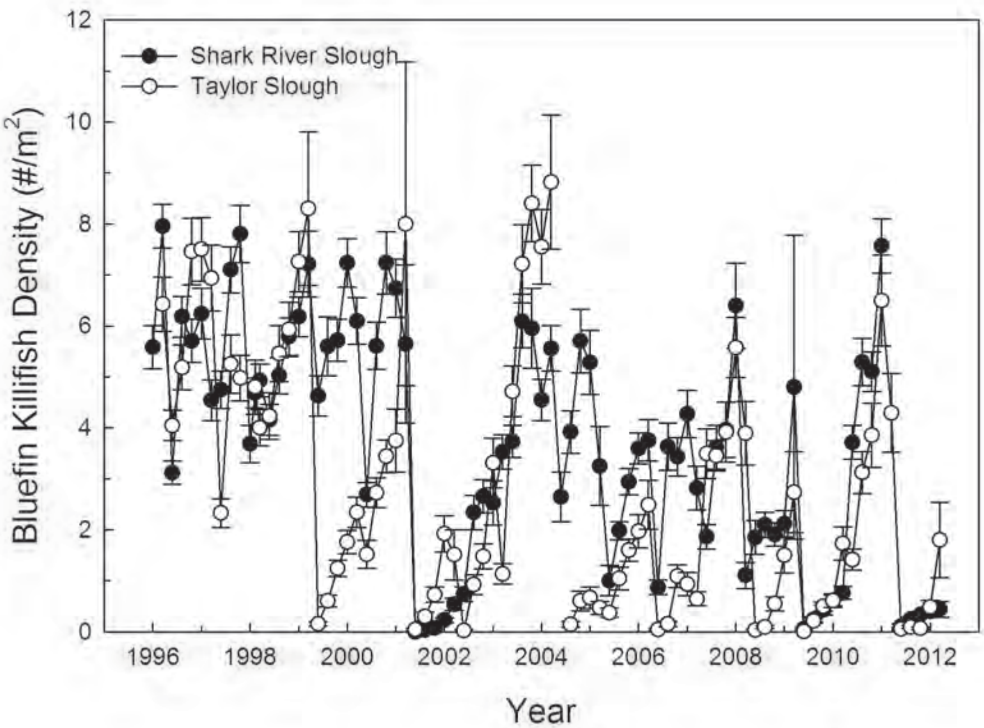



**Figure 4. Bluefin killifish density (#/m²) in Shark River and Taylor sloughs during 1996–2012.**

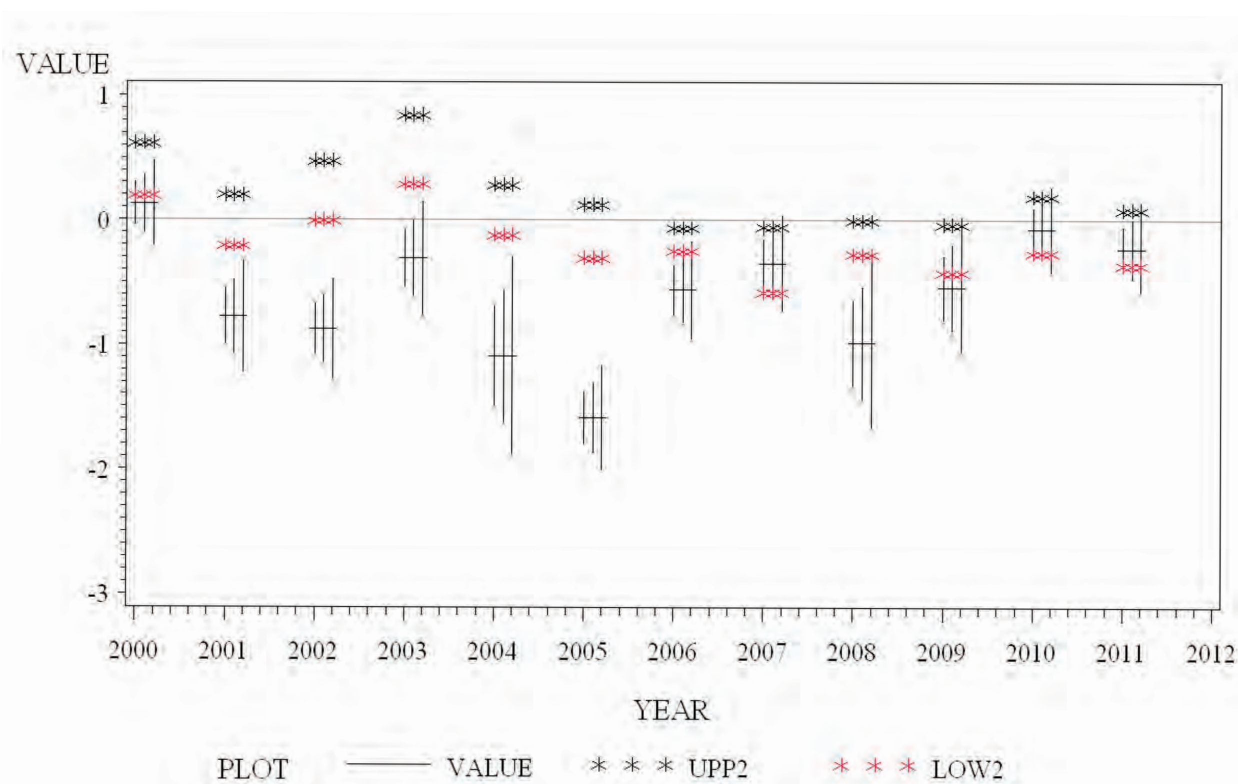



**Figure 5. An example of the bluefin killifish assessment from one site in Taylor Slough, 2000–2011.** The average observed density (value ±1, 2, and 3 SE) and target density is plotted with upper and lower intervals. Stoplight assessments are based on the average of all sites in the region.

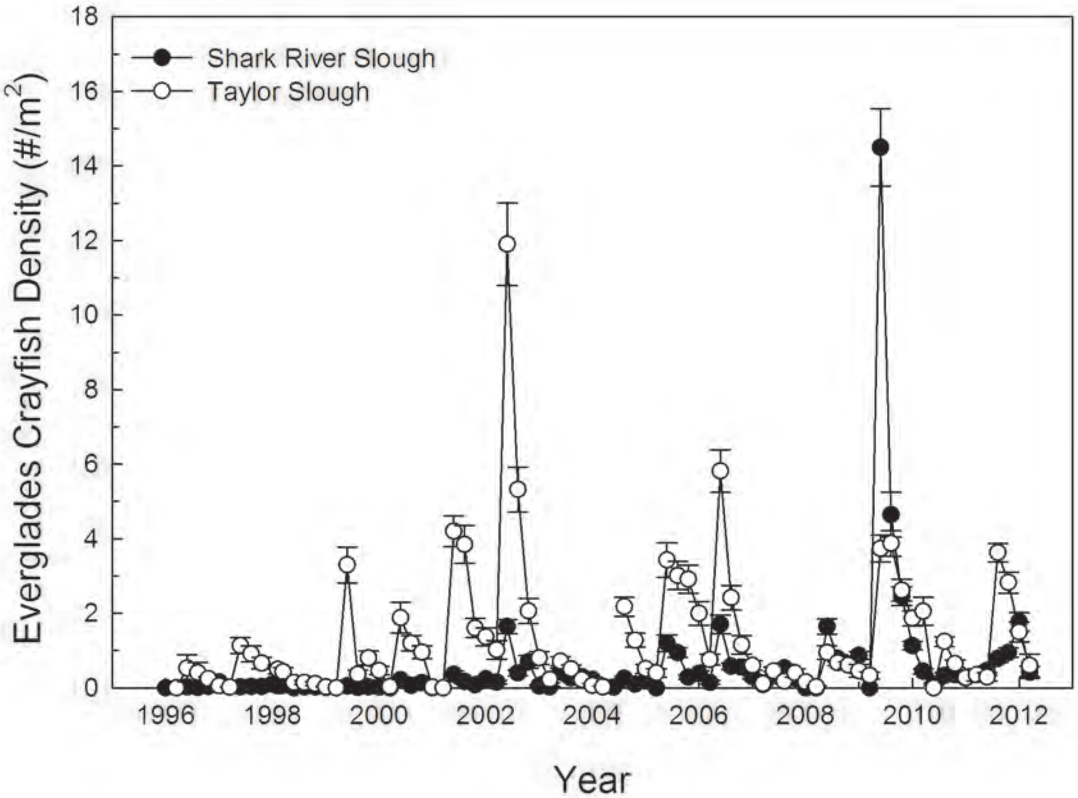



**Figure 6. Everglades crayfish density (#/m²) in Shark River and Taylor sloughs from 1996–2012.**

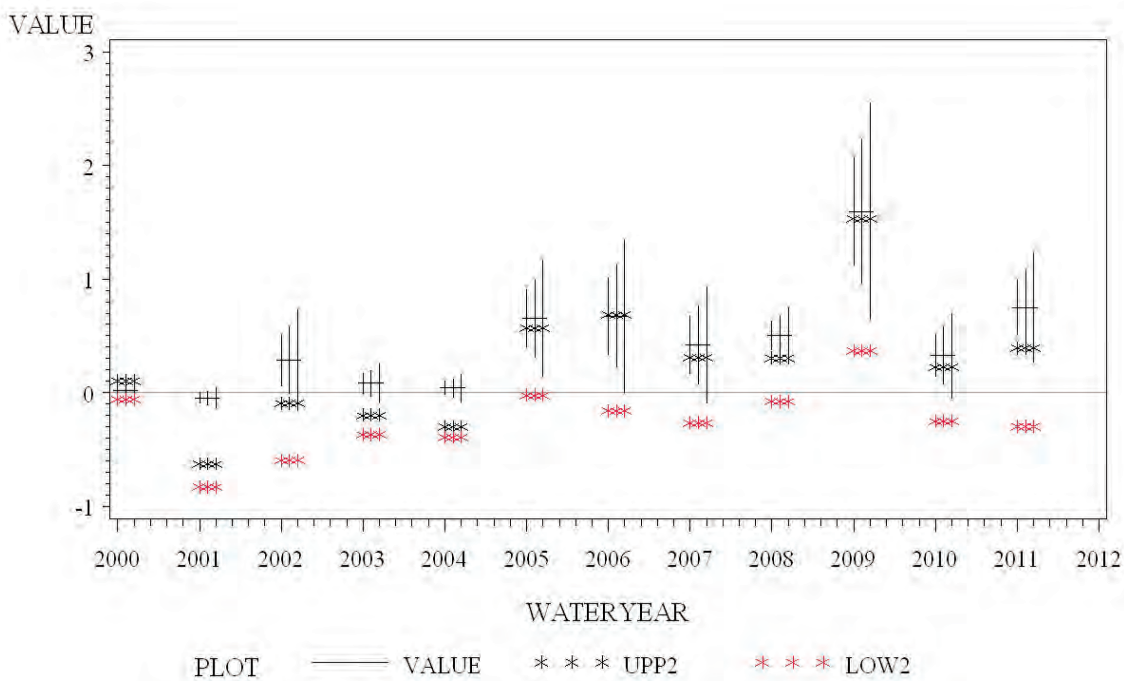



**Figure 7. An example of the Everglades crayfish assessment from one site in Shark River Slough, 2000–2011.** The average observed density (value ±1, 2, and 3 SE) and target density (with upper and lower intervals) are plotted. Stoplight assessments are based on the average of all sites in the region.

ant indicator) abundance were lower than expected, while drought tolerant species (flagfish and Everglades crayfish) were generally at or more abundant than target conditions in SRS (Table 1). These results indicate that drier than expected conditions were present in SRS based on what was predicted from observed rainfall and 1993–1999 baseline conditions; based on rainfall, we predicted more drought-intolerant and fewer drought-tolerant aquatic animals than were present. These findings warranted a red stoplight indicating significant concern for the conditions in SRS overall. Total fish abundance and bluefin killifish abundance were also lower than expected in TS, while abundance of drought tolerant species (flagfish and Everglades crayfish) was at or higher than expected, though with standard errors overlapping the target range. These results indicated drier than expected conditions in TS and warranted a moderate concern (yellow) stoplight rating for the conditions in TS overall (Table 2).

**Table 1. Summary aquatic fauna condition assessment for Shark River Slough, 2011–2012 (modified from Brandt et al. 2012).**

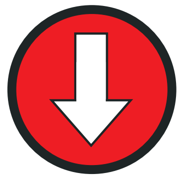
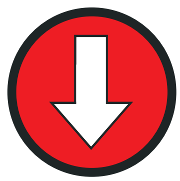
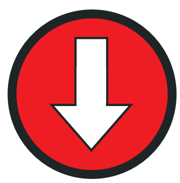
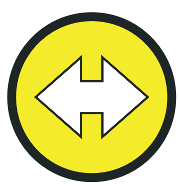
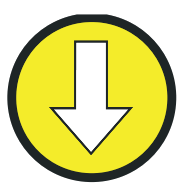
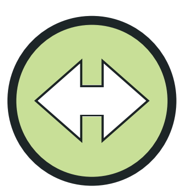
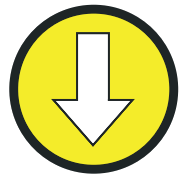
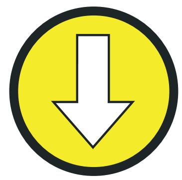
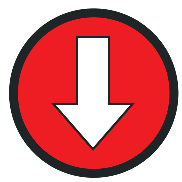
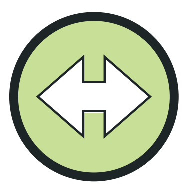
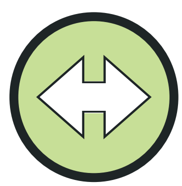
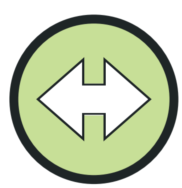
| Criteria | Desired State of Conservation | Condition & Trend | Rationale |
|---|---|---|---|
| Shark River Slough overall | Abundance is maximized in a manner that reflects pre-drainage conditions. |  | Fewer fish were present than expected based on rainfall conditions and drought-tolerant species were abundant. Represents a decline in condition from previous years. |
| Total fish abundance | Abundance is maximized in a manner that reflects pre-drainage conditions. |  | Drier than expected conditions resulted in fewer fish than expected and fewer than previous years. |
| Bluefin killifish abundance | Drought intolerant species. Abundance is maximized in a manner that reflects pre-drainage conditions. |  | Drier than expected conditions resulted in lower abundance than expected and fewer than previous years. |
| Flagfish abundance | Drought tolerant species. Abundance is maximized in a manner that reflects pre-drainage conditions. |  | Drier than expected conditions resulted in moderately higher than expected abundance and similar to previous years. |
| Mosquitofish abundance | Abundance is maximized in a manner that reflects pre-drainage conditions. |  | Drier than expected conditions resulted in moderately lower abundance than expected and fewer than previous years. |
| Everglades crayfish abundance | Drought tolerant species. Abundance is maximized in a manner that reflects pre-drainage conditions. |  | Drier conditions resulted in expected abundance that was similar to previous years. |

**Table 2. Summary aquatic fauna condition assessment for Taylor Slough, 2011–2012 (modified from Brandt et al. 2012).**

| Criteria | Desired State of Conservation | Condition & Trend | Rationale |
|---|---|---|---|
| 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. |
| Total fish abundance | Abundance is maximized in a manner that reflects pre-drainage conditions. |  | Drier than expected conditions resulted in moderately lower fish abundance than expected and fewer than previous years. |
| Bluefin killifish abundance | Drought intolerant species. Abundance maximized in a manner that reflects pre-drainage conditions. |  | Drier than expected conditions resulted in lower abundance than expected and fewer than previous years. |
| Flagfish abundance | Drought tolerant species. Abundance is maximized in a manner that reflects pre-drainage conditions. |  | Drier conditions resulted in expected abundance that was similar to previous years. |
| Mosquitofish abundance | Abundance is maximized in a manner that reflects pre-drainage conditions. |  | Drier conditions resulted in at or slightly below expected abundance that was similar to previous years. |
| Everglades crayfish abundance | Drought tolerant species. Abundance is maximized in a manner that reflects pre-drainage conditions. |  | Drier conditions resulted in expected abundance that was similar to preceding years. |

## *Highlights*

In the past water year, the overall conditions in Shark River Slough warranted significant concern (red stoplight) due to lower total fish abundance, lower abundance of drought intolerant species, and higher abundance of drought tolerant species than expected (Table 1). Taylor Slough experienced moderately lower total fish abundance and a lower abundance of drought intolerant species than expected, but also had an abundance of drought tolerant species similar to expected targets. The difference between target and observed conditions warranted a moderate concern stoplight indication overall (yellow stoplight, Table 2). In addition, conditions have declined from previous years in both Shark River and Taylor sloughs.

We believe that the hydrologic targets used are conservative compared to others that are often discussed, particularly from various versions of the Natural System Model. It is likely that use of the Natural System Model would result in longer hydroperiod targets than those derived from the 1993–1999 observed data (Doren et al. 2008). A longer hydroperiod target derived from the Natural System Model would highlight even more impacts than are reported here.

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## Indicator 5: American Alligator

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### *Background and Importance*

The American alligator (*Alligator mississippiensis*) 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, they are closely associated with and responsive to hydrologic change; these characteristics make them ideal candidates for inclusion in long-term ecology studies related to assessing effectiveness of restoration efforts.

Relationships between dry season refugia, aquatic fauna, wading birds, and alligators are not well understood and have been identified as areas of key scientific uncertainty in the 2000 Comprehensive Everglades Restoration Plan (U.S. Army Corps of Engineers 1999). In addition to National Park Service (NPS) long-term (1985–present) monitoring of aspects of alligator reproduction, in 2001 the multi-agency Alligator Survey Network Monitoring Program created routes within the park to gather data on alligator abundance in an effort to address these uncertainties.

Ugarte (2006), analyzing two decades of alligator nesting data, noted a negative relationship between nesting effort and water extremes (either high or low) during the period of courtship, mating, and nest construction. Extreme hydrologic conditions (wet or dry) typically depress nesting effort; extremely dry conditions concentrate nesting around central sloughs. Greater spatial distribution across diverse hydroperiod habitats decreases potential for large scale nest failure due to flooding. Spatial distribution has become a more important indicator of conditions than simply percent of nests flooded, and is a critical component of the change we hope to observe as restoration progresses.

### *Desired State of Conservation*

Positive trends in nesting effort/success, nest distribution, and abundance of the American alligator, to a level consistent with a restored Everglades wetland ecosystem, are identified as key targets for the removal of Everglades National Park from the World Heritage Sites in Danger list.

### *Description of Indicator Monitored*

Park staff monitor on an annual basis alligator nesting effort (Indicator 5A), nest success (Indicator 5B), and spatial distribution of nests (Indicator 5C) in different hydrologic basins. Abundance of alligators (Indicator 5D) is monitored by university cooperators. Nesting effort is an annual count of the minimum number of nests built and observed within standardized survey transects. Nest success involves determining, for each nest monitored, whether it was successful (at least one egg hatched) or failed (no eggs hatched) and includes documentation of known causes of failure for each nest monitored. NPS monitoring is conducted through systematic reconnaissance flights (SRF) and subsequent monitoring of nests identified during SRF. All freshwater basins expected to support the majority of alligator nesting activity within Everglades National Park (ENP) are flown by helicopter along established transects. Locations of alligator nests are recorded using a global positioning system (GPS). Survey transects cover the vast majority of primary nesting habitat, the areas expected to experience the most change with restoration, and areas most impacted by upstream hydrologic change, as opposed to tidal or other influences. A subset of the total observed nests is chosen at random, then periodically visited throughout incubation until such time as individual fate can be determined for each nest. Nesting surveys have been completed for 2012, but data analysis is not complete, and this document presents results through 2011.

**Research staff counting and checking eggs for fertilization and development (banding).** NPS photo by Lori Oberhofer.

Abundance of alligators is monitored using spotlight surveys conducted along established transects. The spotlight survey has been ongoing for less than 10 years and is limited in terms of spatial coverage within the park. Survey routes are primarily restricted to Shark River Slough and may not reflect trends in other areas or account for possible dispersal from Shark Slough as conditions improve in peripheral marshes. Abundance is estimated by size class based on a two-stage hierarchical model of survey results. Spotlight surveys were not conducted in 2012, and estimates of alligator abundance are only available through 2008.

### *Status of Indicator in the Current Year and Trends over Time*

Alligator reproduction monitoring transects and associated hydrologic basins are depicted in Figure 1. Alligator nesting effort and distribution have overall exhibited an increasing trend within ENP since monitoring began in 1985. The most consistent nesting effort of any 5-year period within the 27-year study occurred during 2005–2009 (Fig. 2). Unexpectedly, and despite drought conditions, nesting effort/success in 2009 was only slightly lower than the prior 4-year average and distribution was fairly widespread (Fig. 3). The relative stability of water levels during the previous 5 years may have created conditions more favorable for maintenance and continuous occupation of alligator holes and other dry season refugia beyond the central sloughs, an important goal of restoration efforts. The 2009–2010 dry season was wet and water levels park-wide remained high during courtship and mating: there was not a large change in stage from dry to wet season or from onset of nest construction to hatching. As previously described, these conditions are typically favorable for alligator reproduction, and 2010 nesting effort was the greatest on record with moderate hatching success and spatial distribution (Figs. 2, 3, and 4).

Severe drought conditions experienced in the Everglades during the 2010–2011 dry season persisted well into the courtship, mating, and nest building period. Much of ENP typically supporting alligator nesting had little to no surface water during this period, with the exception of only the deepest solution or alligator holes. Given conditions, nesting effort was expected to be low in 2011 and ultimately only 32 nests were found in transect surveys (Fig. 2). Considering the severe drought conditions that extended even into central sloughs, nests were fairly well distributed in 2011, yet conspicuously absent from the driest areas of ENP.

In contrast to observed increasing trends in alligator reproduction, researchers, using a two-stage hierarchical model to estimate abundance from recent spotlight survey data, report an apparent decreasing population trend in all size-classes of alligators within ENP during 2003–2008. This trend is most pronounced for small to medium size-classes

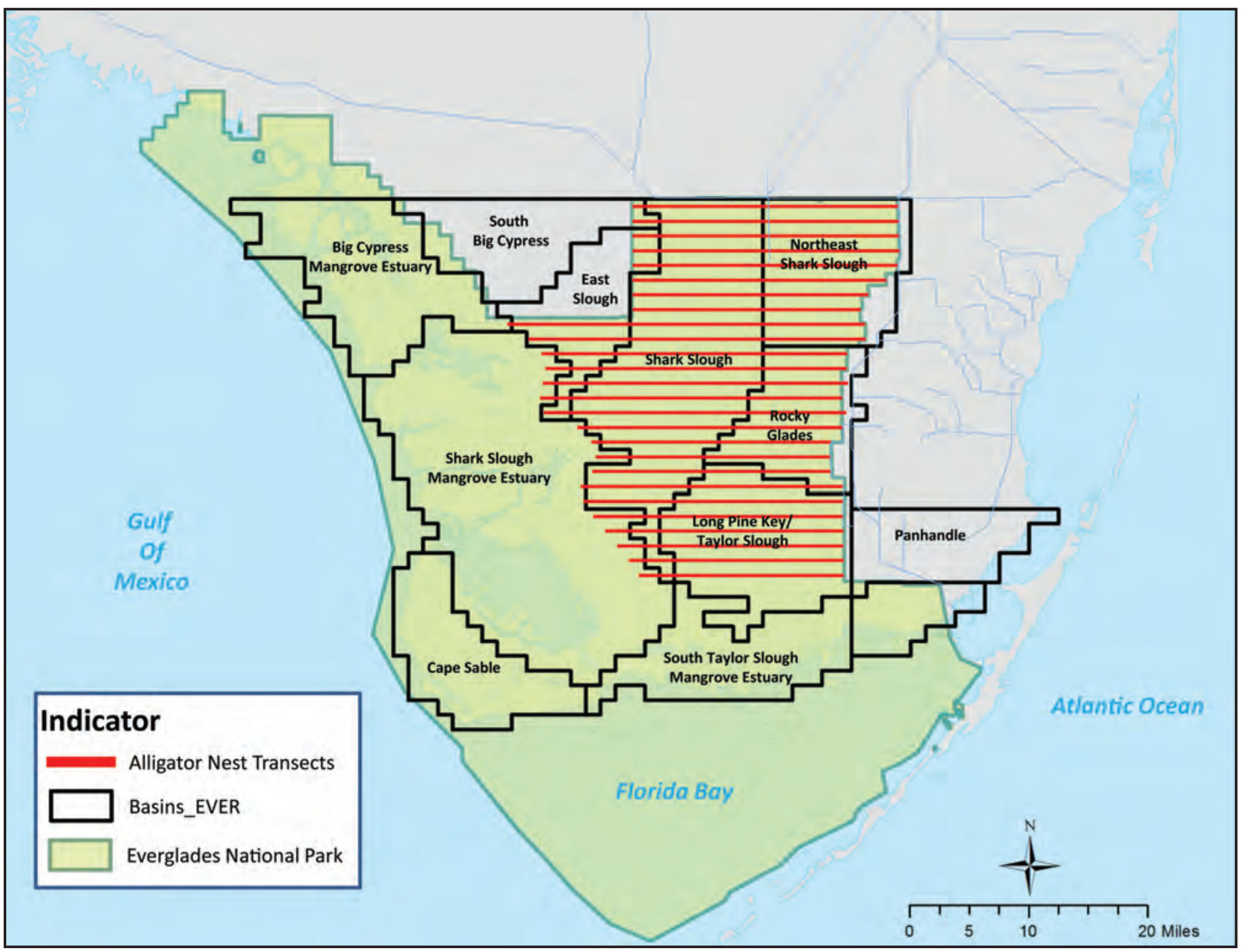



**Figure 1. Location of alligator reproduction monitoring transects and associated hydrologic basins.**

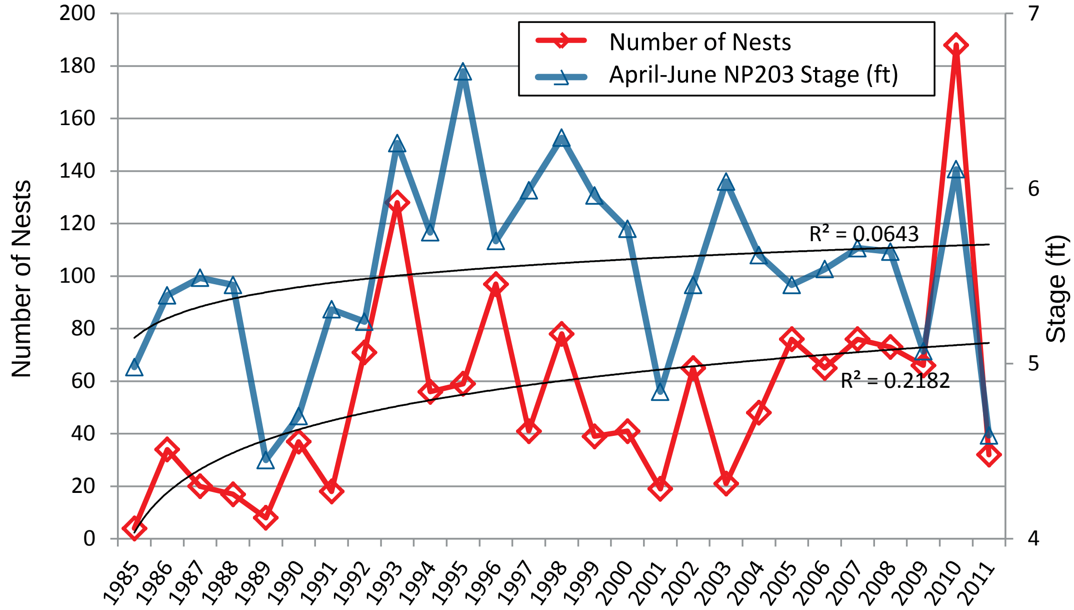



**Figure 2. Indicator 5A. Alligator nests observed within 500-m transect boundaries during Systematic Reconnaissance Flights (1985–2011) and number monitored to determine egg numbers, condition, and fate.** Nests observed outside transect boundaries were monitored during some years. Only Shark Slough and Northeast Shark Slough were surveyed during 1985–1991.

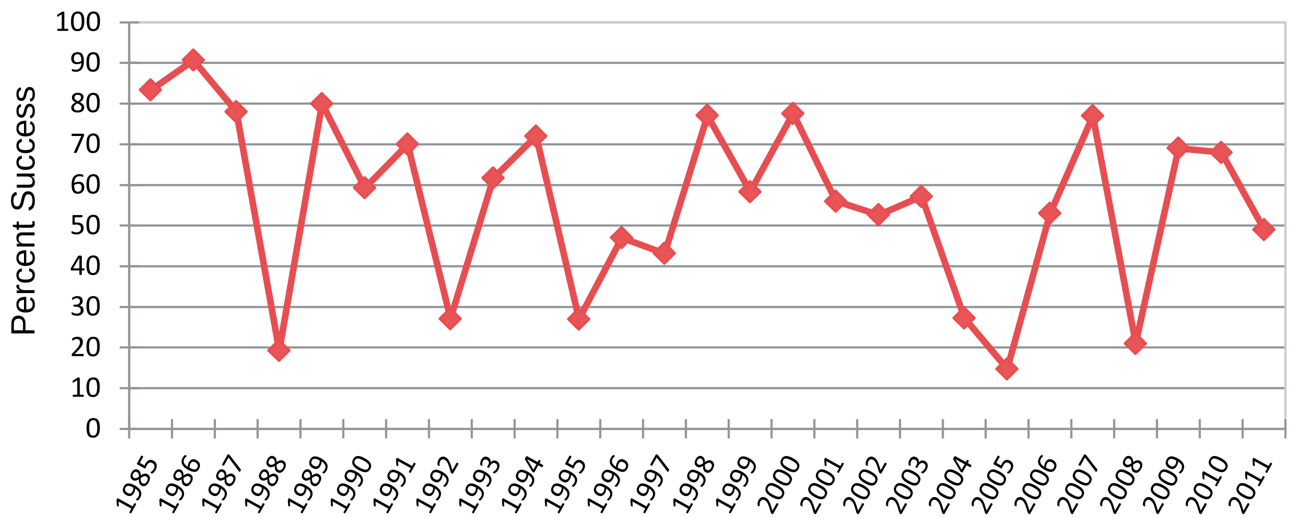



**Figure 3. Indicator 5B. Alligator nest percent hatching success for all monitored nests within ENP, 1985–2011.**

(Fig. 5) and, should reproductive effort and success increase without subsequent recruitment to the adult population, alligator populations within the park may experience future adverse effects. Fujisaki et al. (2011) recognize that the observed pattern may reflect a natural population cycle but also theorize that it may be due to extremely low water depths occurring more frequently in recent years than they have historically (see Indicator 4: Freshwater Fish and Aquatic Invertebrates). Conditions of low water depth are generally poor for alligators yet more suitable for survival of adults than juveniles. These early results do show a potential negative trend that demonstrates the need for continued monitoring, including expansion of the project into peripheral marshes. Though spotlight surveys and the associated captures were

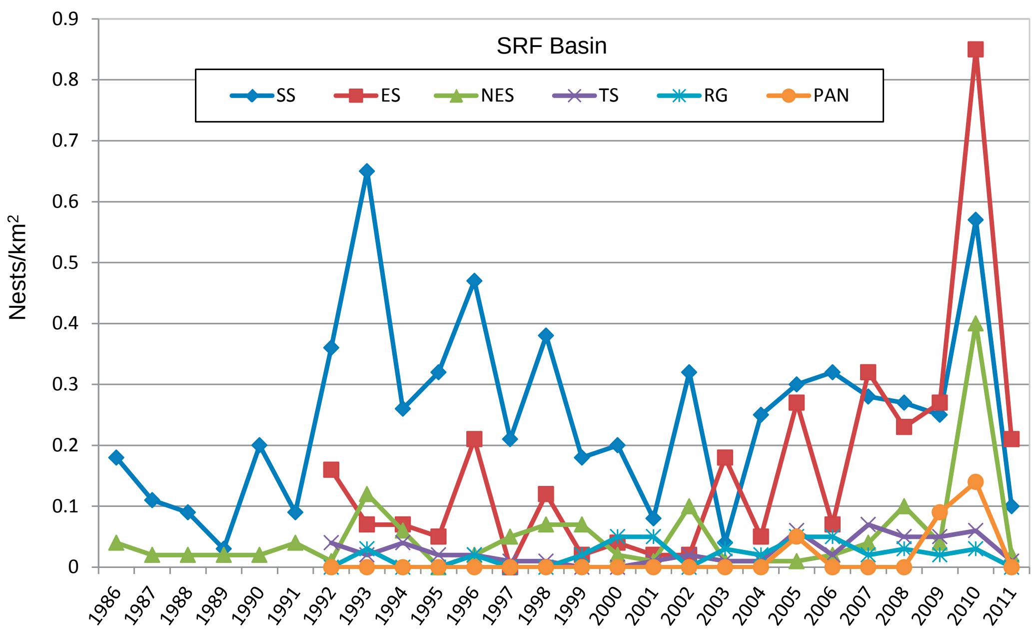



**Figure 4 . Indicator 5C. Observed annual nest density by hydrologic basin, 1985–2011.**

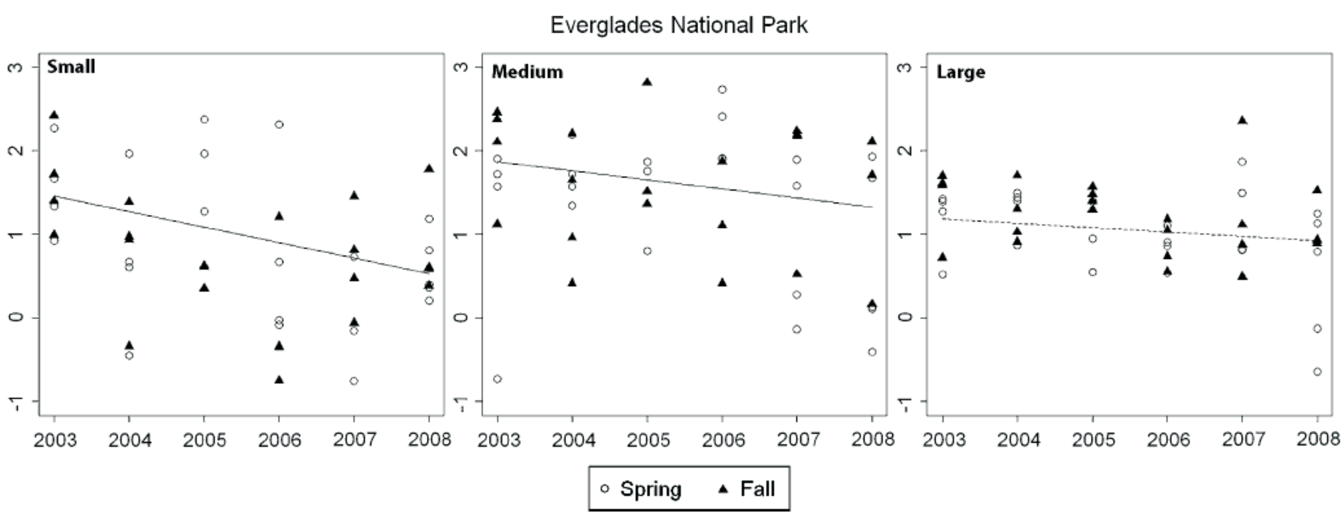


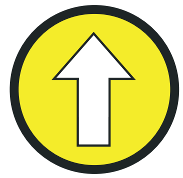
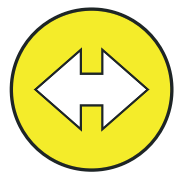
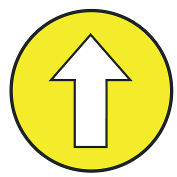
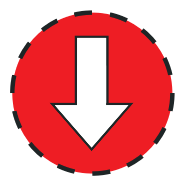

**Figure 5 . Indicator 5D. Estimated slope of abundance trend by size class from American alligators in Everglades National Park.** Solid line indicates that 95% confidence interval of the slope does not contain zero while dashed line indicates it does contain zero. Points (open circle for spring and filled triangle for fall) are mean log count/km by size class, route, and season rescaled by estimated detection probability. (Reproduced from Fujisaki et al. 2011).

intended to detect long-term trends in the park, funding has been cut and future ability to conduct this work remains uncertain at best. Elimination of this research reduces the ability of scientists and managers to detect the effects of landscape-level changes to Everglades hydrology on alligator populations.

### *Highlights*

The desired state of conservation and the current conditions and trends for aspects of American alligator nesting, distribution, and abundance described in the summary above are summarized in Table 1.

**Table 1. American alligator stoplight summary.**

| 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. |

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## Indicator 6: Wading Birds

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### *Background and Importance*

Wading birds are a defining and visible component of the Everglades ecosystem. The decline of wading bird populations was cited as one of the primary reasons for the need to create Everglades National Park (ENP). Since the establishment of ENP in 1947, human development and urbanization of south Florida have put great stress on the area's water resources. Control features such as levies and canals have been constructed to divert and manage water for urban and agricultural development. Many wildlife species have been affected by the resultant changes in the historic hydrologic pattern throughout the Greater Everglades, including ENP, but perhaps the most visible change has been a drastic decrease in the historically large numbers of breeding wading birds.

During a visit to south Florida in the 1830s, the well-known naturalist and artist John James Audubon wrote, "We observed great flocks of wading birds flying overhead toward their evening roosts .... They appeared in such numbers to actually block out the light from the sun for some time." It is estimated that there has been a 70 percent reduction in total number of nesting wading birds between the historical (e.g., pre-drainage) Everglades system and the Everglades as it exists today. Breeding bird records from the 1930s show that as many as 245,000 birds once nested in the Greater Everglades (Ogden 1994).

A decline in numbers of nesting birds is not the only change that has taken place over the years. Shifts have been observed in the timing of nest initiation, species composition of colonies, and abandonment of traditional nesting colony locations. A number of key species, most notably the endangered wood stork (*Mycteria americana*), have experienced a change in the timing of nesting initiation. Nesting now begins several months later in the dry season than in pre-drainage times. With nesting occurring later in the year, the arrival of the wet season rainfall can disperse prey before birds have finished nesting, leading to poor foraging conditions and starvation of chicks that are not yet fledged.

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. Aquatic prey, in turn, are dependent on a variety of environmental factors including the quantity, distribution, and timing of water flows. To date, many of the proposed restoration projects, planned to reestablish a more natural timing and pattern of hydrology to the area, have not yet been fully implemented.

**Fledgling wood stork chicks, Paurotis Pond, ENP.** NPS photo by Lori Oberhofer.

Monitoring of nesting wading birds is planned in conjunction with restoration efforts. Reestablishment of healthy wading bird populations is required if ENP is to be removed from the list of World Heritage Sites in Danger.

### *Desired State of Conservation*

The desired state of conservation for wading birds includes metrics identified by Frederick et al. (2009) and the Comprehensive Everglades Restoration Program (CERP) (RECOVER 2004, 2006a, 2006b) for the recovery of wading bird populations in south Florida:

Indicator 6A: The total number of pairs of nesting wading birds in south Florida should increase.

Indicator 6B: Timing of nest initiation should change toward the earlier initiation dates that occurred in pre-drainage times.

Indicator 6C: The proportion of wading bird nests that occur in the coastal/headwaters ecotone areas of ENP should increase. The target is for 70% of the combined nests within the Greater Everglades to be located in ENP.

Indicator 6D: The frequency of occurrence of exceptional nesting events (increase in overall nesting effort, especially by white ibis (*Eudocimus albus*), in the Greater Everglades should increase.

Indicator 6E: Species composition of nesting colonies should shift from those mostly composed of sight feeding species (egrets and herons) to those that are tactile-foragers (white ibis and wood storks).

### *Description of Indicator Monitored*

Information about wading bird nesting effort, timing of nesting, and location and number of colonies is collected by ENP biologists during monthly colony nesting surveys. ENP biologists conduct aerial surveys of known colony sites beginning in October and continuing until nesting is finished (usually in May or June). A systematic survey throughout ENP for wading bird nesting is conducted once during the nesting season when colonies are most active in order to detect new and/or smaller transient colonies that might be missed during the monthly site checks (Fig. 1). Colony surveys have been conducted consistently since the early 1990s. Prior to this time, aerial surveys and ground monitoring of accessible colonies occurred on a less scheduled basis.

In areas outside of ENP, both aerial and ground surveys are conducted by biologists working for federal, state, university, and non-governmental organizations. Together, they provide coverage of wading bird colonies found in the Water Conservation Areas, including Arthur R. Marshall Loxahatchee National Wildlife Refuge, as well as other sites within south Florida.

### *Status of the Indicator in the Current Year and Trends over Time*

Indicator 6A: Numbers of nesting wading birds declined sharply between the historical pre-drainage years of the 1930s and the post-drainage years of the 1970s (Ogden 1994; Cro-

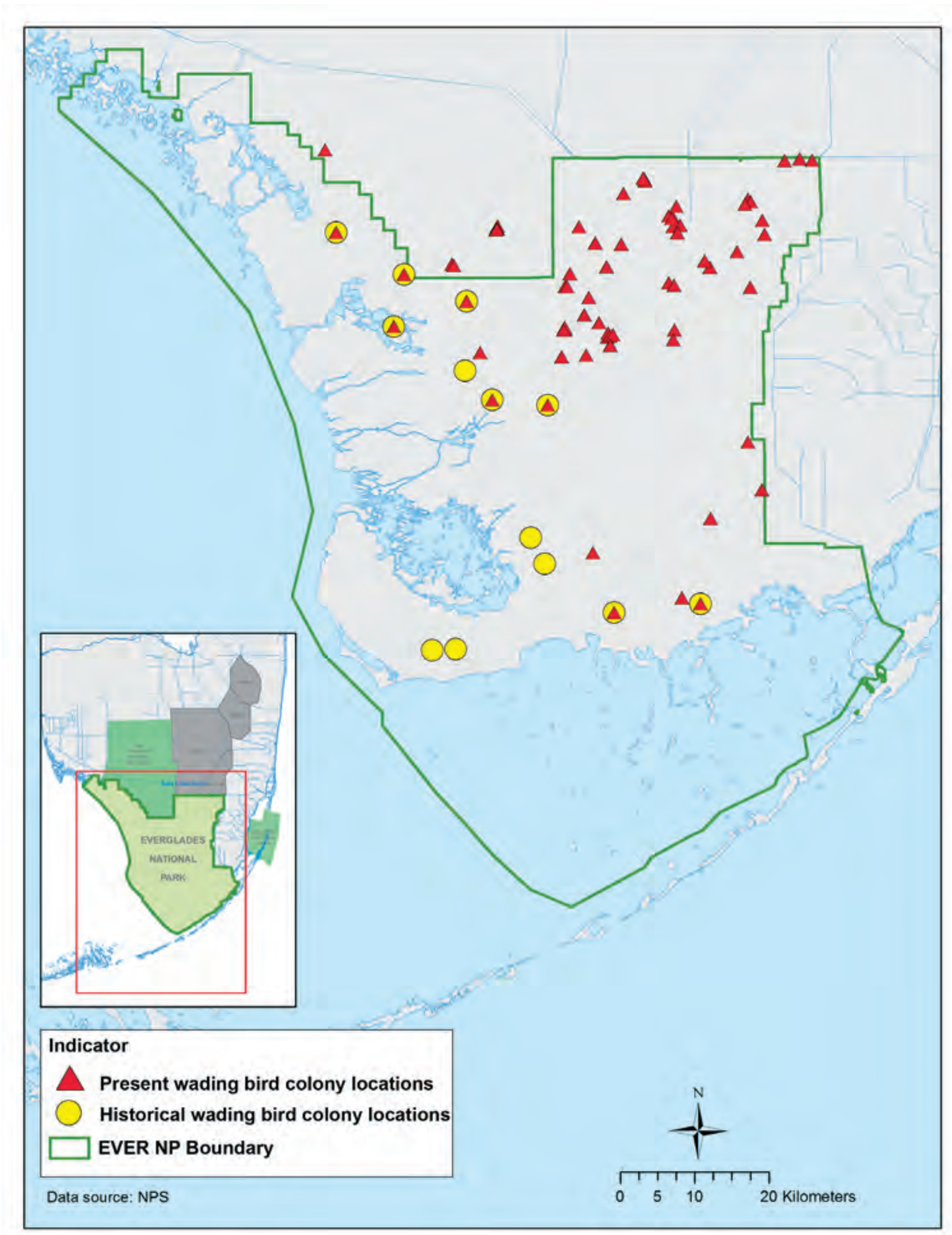



**Figure 1. Location of present and historical wading bird colony locations.**

zier and Gawlik 2003). The performance measures set forth by CERP (RECOVER 2004, 2006a, 2006b) seek to increase and maintain a minimum of 4,000 pairs of great egrets, 10,000 to 20,000 combined pairs of snowy egrets and tricolored herons, 10,000 to 25,000 pairs of white ibises, and 1,500 to 3,000 pairs of wood storks. Some of these population targets have currently been met and trends are positive for all species with the exception of snowy egrets and tricolored herons (Fig. 2).

Indicator 6B: A return to the natural timing of wood stork nesting beginning in December/January is needed to ensure nesting success for storks. Wood stork chicks require approximately 105 to 130 days for fledging from nests. The loss of early dry season foraging habitats has reduced numbers of prey fish sufficient to trigger wood stork nesting. If storks continue to initiate nesting late, then chicks have a much greater chance of still being in nests when summer rains begin in late May or June. When water levels rise, prey concentrations and density decline and chicks starve. This indicator has not improved over time as storks continue to initiate nesting in February or March at all colonies within the park.

Indicator 6C: While the majority of nesting birds throughout south Florida are still nesting in the Water Conservation

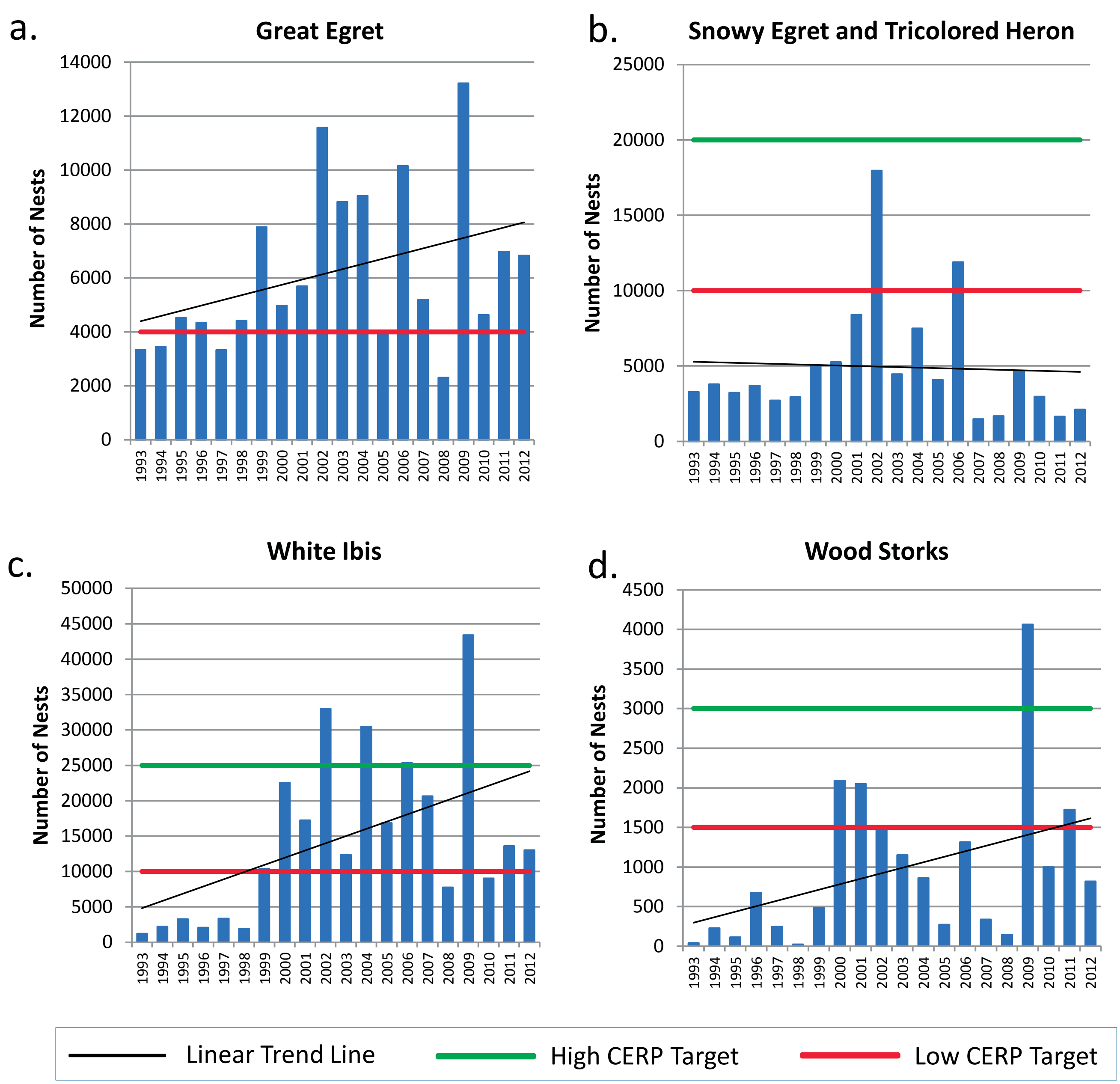



**Figure 2 . Number of (a) great egret, (b) snowy egret and tricolored heron, (c) white ibis, and (d) wood stork nests in relation to CERP target populations, 1993–2012 (Frederick et al. 2008).**

**Wading bird colony, Broad River, ENP.** NPS photo by Lori Oberhofer.

Areas and other areas to the north of ENP, more birds have chosen in recent years to return to historic nesting sites in the coastal/headwaters ecotone areas inside the park. These sites include the headwaters regions of the Shark, Broad, and Lostmans rivers, Alligator and Cabbage bay areas, and southern mainland areas north of Florida Bay. If hydrologic conditions continue to improve, we should expect to see greater numbers of birds nesting in these areas as well as a return to other former (but currently empty) nesting areas such as Gator Lake, Mud Lake, East River, and Lane River. Currently this target has not been met (Fig. 3 ).

Indicator 6D: In pre-drainage times, large white ibis nesting events occurred approximately every 1 or 2 years immediately following a severe drought (Frederick et al. 2008). The numbers and interval of nesting events recorded in recent years have met the target (Fig. 4).

Indicator 6E: Egrets and herons feed by sight and do not require as high a prey density as tactile feeders such as ibis and storks. The change in composition of colonies from historic levels of tactile feeders to mostly sight-feeding birds suggests a decrease in prey density within the Everglades habitat (Gawlik 2002). The historic ratio of wood stork and white ibis nests to great egret nests was determined to be 30:1. Current conditions do not reflect this ratio and would suggest that the habitat is becoming less favorable to tactile feeders, which need to build energy reserves for nesting. This metric is not being met and has appeared to stabilize well below the desired target (Brandt et al. 2012).

### *Highlights*

The status of wading birds within Everglades National Park is summarized in Table 1 for each of five metrics. While the condition and trend of some metrics, such as the total number of pairs nesting, have shown considerable improvement over time, there remains significant concern for other metrics, such as the timing of wood stork nest initiation.

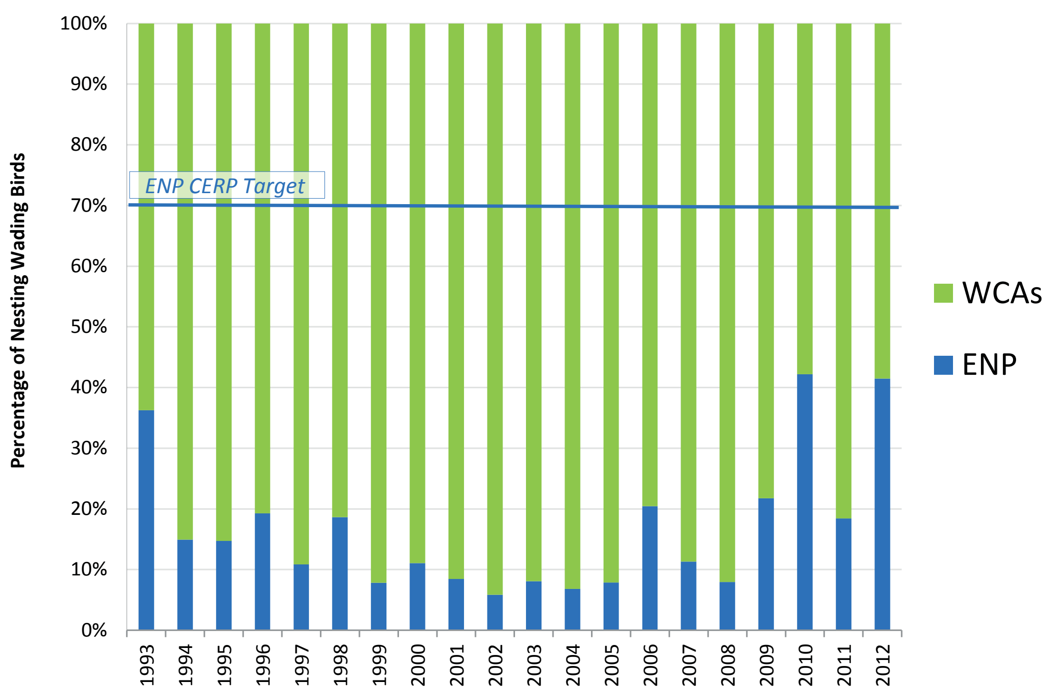



**Figure 3. Percentage of wading birds nesting in Water Conservation Areas (WCAs) and in Everglades National Park (ENP) in relation to the CERP target, 1993–2012.**

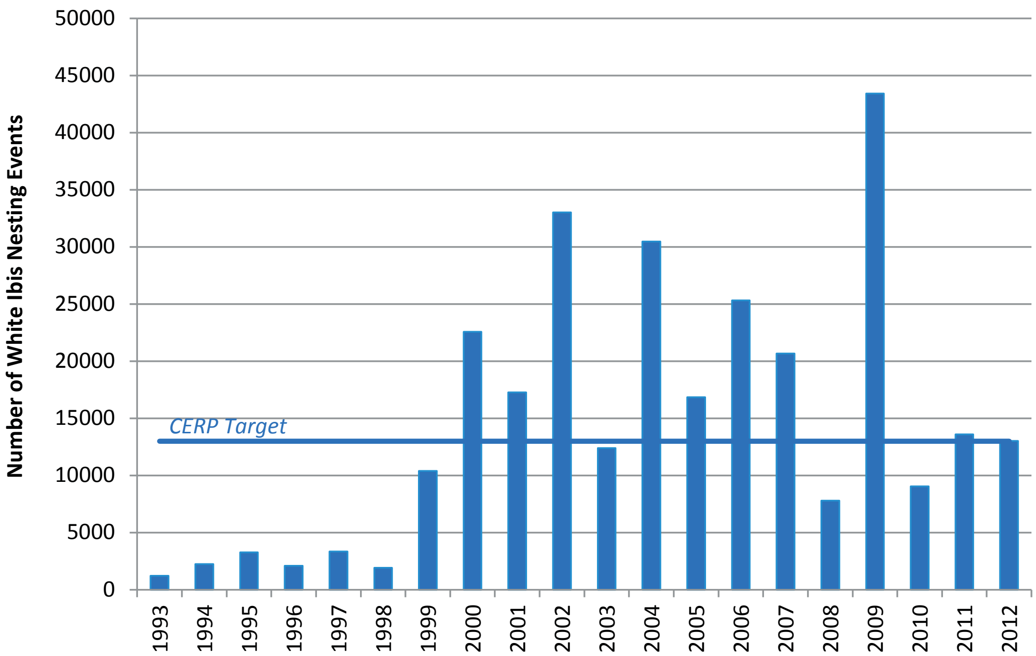



**Figure 4. Number of white ibis nesting events in relation to the CERP target, 1993–2012.**

**Table 1. Wading bird indicator metrics as identified by the Comprehensive Everglades Restoration Program (RECOVER 2004, 2006a, 2006b), Frederick et al. (2008), and Brandt et al. (2012) for the recovery of wading bird populations in south Florida.**

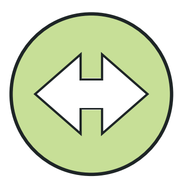
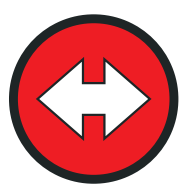
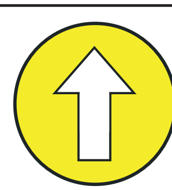
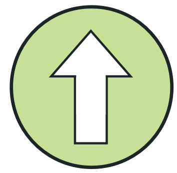
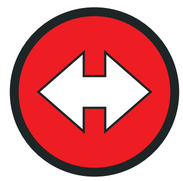
| Criteria | Desired State of Conservation | Condition & Trend | Rationale |
|---|---|---|---|
| Increase the total number of pairs of nesting birds in south Florida. | Maintain or increase current total numbers of nesting birds in ENP mainland colonies to a level consistent with a restored Everglades 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. |

**Table 1 continued. Wading bird indicator metrics as identified by the Comprehensive Everglades Restoration Program (RECOVER 2004, 2006a, 2006b), Frederick et al. 2008, and Brandt et al. 2012 for the recovery of wading bird populations in south Florida.**

| Criteria | Desired State of Conservation | Condition & Trend | Rationale |
|---|---|---|---|
| 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). |

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# SECTION 3: THE COASTAL AND ESTUARINE ENVIRONMENT: FLORIDA BAY

NPS photo by Bill Perry.

## Indicator 7: Salinity Patterns in Florida Bay

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### *Background and Importance*

Salinity is a defining feature of the ecosystem in coastal estuarine regions, including Florida Bay. Since 1990, Everglades National Park (ENP) and its federal and state partners have been involved in an extensive monitoring program with the overarching goal of understanding conditions affecting salinity within Florida Bay and in the coastal estuaries. Salinity within Florida Bay is primarily affected by four factors: evaporation, precipitation, freshwater inflows, and exchange with the coastal ocean. Evaporation is relatively constant year-to-year and regionally across Florida Bay and is driven primarily by temperature, humidity, and wind. Precipitation over the period of record has shown a consistent bias toward higher quantities in the coastal and eastern zones (Fig. 1). Freshwater flows off the southern coastline of ENP and into the bay. This flow is driven by precipitation and water management activities, occurs seasonally, and represents the primary component of the water budget that is manageable. These inflows are biased toward relatively greater quantities into the eastern zone of Florida Bay; flow into the coastal zone is limited by topography. In contrast, exchange with the open ocean is greatest in the western zone of the bay, with shallow banks increasingly limiting the transfer of water into the interior of Florida Bay. The result of this freshwater distribution and ocean exchange tends to produce salinity conditions that range from estuarine during the wet season to hypersaline during the dry season. Measures of historical conditions indicate that Florida Bay

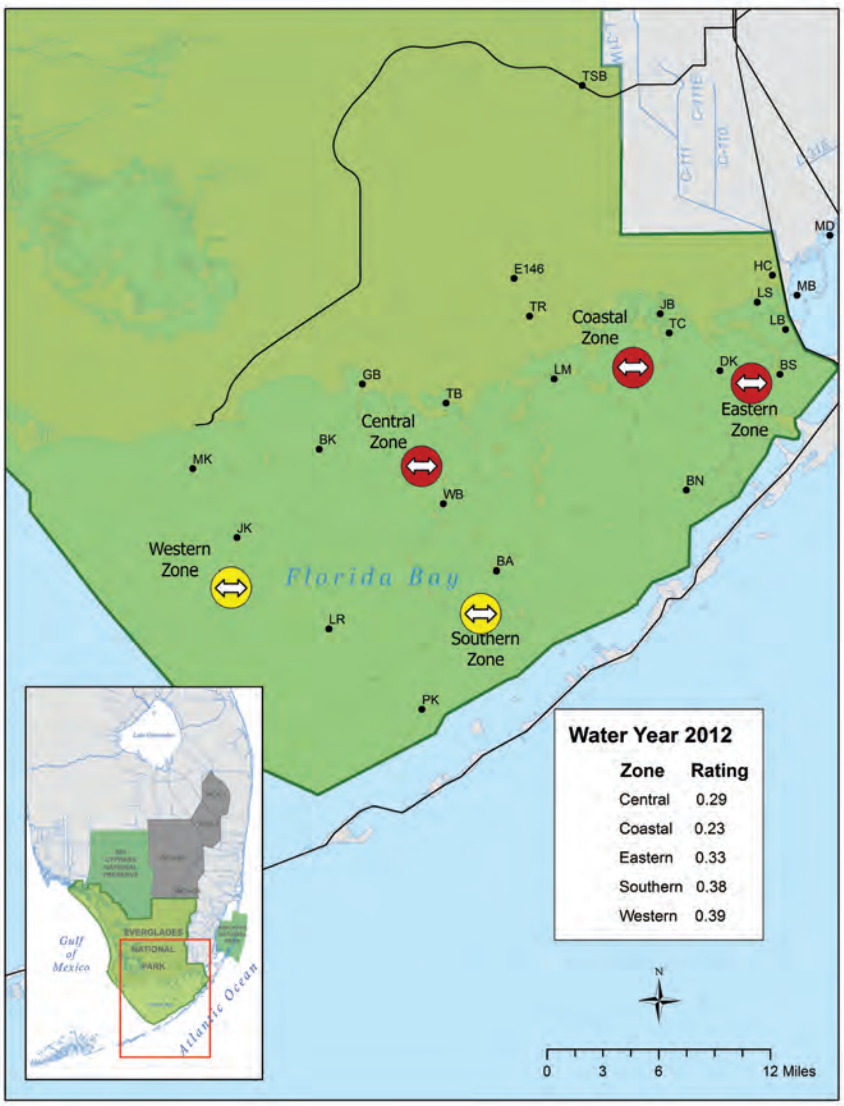



**Figure 1. Location of monitoring stations and ecological zones in Florida Bay and the neighboring freshwater slough.** Ecological indicator ratings and trends are included in the figure and inset table.

was substantially fresher in the past than it is today, suggesting that substantially more freshwater entered the bay prior to the advent of water management activities in south Florida. These fresher conditions supported a dynamic abundance of estuarine-dependent species and associated estuarine benthic conditions.

### *Desired State of Conservation*

In June 2012, the South Florida Ecosystem Restoration Task Force agreed on a salinity performance measure to be used to track conditions and evaluate the effect of restoration activities on Florida Bay (CERP 2012). This performance measure was developed based on the output of a 36-year run of the South Florida Water Management District's Natural Systems Model (NSM) version 4.6.2 (SFWMD 2005). This model was designed to represent the depth and flow conditions of the pre-drainage Everglades. Output from this model was then adjusted to agree with paleographic information, derived from analysis of faunal assemblages in sediment cores collected in the bay, to produce a reasonable estimate of the historic salinity regime (Marshall et al. 2009, Marshall and Wingard 2012). The following restoration goals represent the desired state of conservation:

- Restore oligohaline to mesohaline salinity patterns in the nearshore environment
- Lower the average salinity in the bay
- Reduce the frequency, duration, magnitude, and spatial extent of hypersaline conditions throughout the bay, and
- Restore seasonal deliveries of freshwater more typical of the natural system, e.g., extension of water deliveries into the dry season.

### *Description of Indicator Monitored*

For this report, the desired state of conservation is evaluated by comparing observed salinity to the paleo-adjusted NSM targets using the methods described in the Restoration Coordination and Verification Program's (RECOVER) salinity performance measure for Florida Bay (CERP 2012). The indicator is evaluated by calculating metrics that quantify the 1) overlap, 2) mean offset, and 3) relative occurrence of high salinity events between observed and desired conditions. The overlap metric is defined as the number of days that the interquartile range of salinity observations overlaps with the interquartile range of the salinity target. The mean offset metric is a measure of the difference between the means of the observed and target conditions on a monthly, seasonal, and annual basis. The high salinity metric is defined as the ratio of the number of high salinity days under desired conditions to the number of observed high salinity days. High salinity is defined as the 90th percentile of the target salinity.

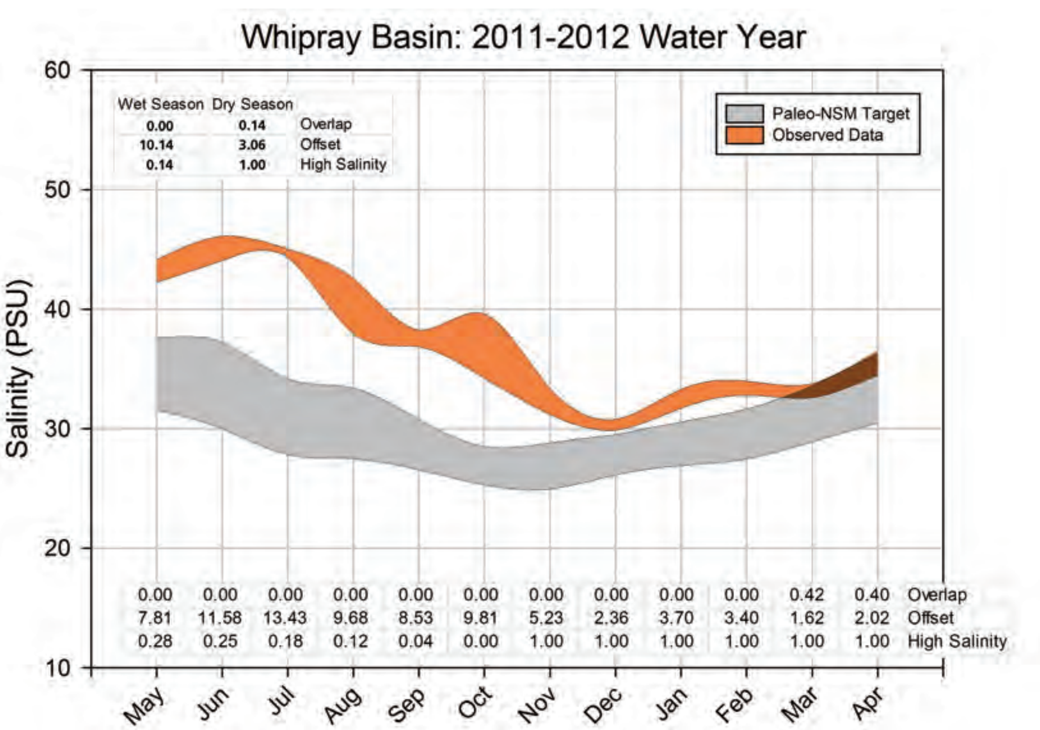



**Figure 2. Overlap, mean offset, and high salinity performance metrics for Whipray Basin salinity presented as a plot with overlaid monthly and seasonal tables.** The data describes the behavior of the observed salinity data relative to the paleo-NSM salinity target.

### *Status of the Indicator in the Current Year and Trends over Time*

All three performance metrics are displayed in Figure 2, which shows the interquartile range for the salinity target along with the interquartile range of observed values from an individual year for salinity from the Whipray Bay hydrologic station (WB) in the central zone. This product was developed for each station in Florida Bay for each year in the period of record, 1991–2012, to evaluate the trend of the indicator. The performance metrics are provided for each month in a table along the x-axis, while seasonal values are tabulated separately on the upper left hand corner of the plot. Generally, salinity values within Whipray Basin are higher than the target range but overlap during March and April. With respect to seasonal timing, the lowest observed salinity period is later in the year in relation to the target, indicating that the observed salinity lags behind the target. The difference in salinity between the observed and the target is quantified on a monthly basis via the mean offset metric. In particular, the largest mean offset occurs in July, at the start of the wet season, where the target shows a month-to-month decrease in salinity while the observed data are relatively stable. The high salinity metric shows decreasing values, indicating poorer conditions, from May through October as the target decreases more rapidly than the observed salinity. Scores for all three metrics are generally higher during the dry season, with the greatest difference occurring in the high salinity metric.

The salinity performance metrics were also determined for the period of 1991–2012 for each station in Florida Bay, and a summary of the annual statistics is provided in Table 1. The salinity conditions are variable but show no year-to-year trend. Annual variability in the performance metric is related to precipitation, with relatively wetter years resulting in lower salinity and better conditions baywide than relatively dryer years. For 2012, all three metrics rated low enough to be a cause for concern (Table 2). The overlap, mean offset, and high salinity metrics all reflect the same problem: salinity for

**Table 1. Annual performance metric composite scores by ecological zone for 1991–2012.** Values in red were estimated by linear interpolation between neighboring years.

| Water Year | Western | Southern | Central | Coastal | Eastern |
|---|---|---|---|---|---|
| 2012 | 0.39 | 0.38 | 0.29 | 0.23 | 0.33 |
| 2011 | 0.38 | 0.47 | 0.42 | 0.36 | 0.46 |
| 2010 | 0.41 | 0.38 | 0.38 | 0.28 | 0.34 |
| 2009 | 0.39 | 0.31 | 0.28 | 0.19 | 0.23 |
| 2008 | 0.35 | 0.45 | 0.47 | 0.41 | 0.44 |
| 2007 | 0.56 | 0.41 | 0.44 | 0.29 | 0.30 |
| 2006 | 0.29 | 0.43 | 0.43 | 0.44 | 0.47 |
| 2005 | 0.20 | 0.21 | 0.22 | 0.34 | 0.18 |
| 2004 | 0.51 | 0.55 | 0.57 | 0.54 | 0.53 |
| 2003 | 0.37 | 0.49 | 0.48 | 0.52 | 0.55 |
| 2002 | 0.51 | 0.48 | 0.54 | 0.45 | 0.43 |
| 2001 | 0.34 | 0.34 | 0.27 | 0.45 | 0.50 |
| 2000 | 0.49 | 0.49 | 0.56 | 0.54 | 0.54 |
| 1999 | 0.29 | 0.45 | 0.52 | 0.59 | 0.49 |
| 1998 | 0.59 | 0.61 | 0.60 | 0.64 | 0.61 |
| 1997 | 0.57 | 0.67 | 0.56 | 0.54 | 0.61 |
| 1996 | 0.64 | 0.60 | 0.60 | 0.73 | 0.67 |
| 1995 | 0.47 | 0.46 | 0.51 | 0.58 | 0.48 |
| 1994 | 0.51 | 0.37 | 0.26 | 0.46 | 0.43 |
| 1993 | 0.56 | 0.50 | 0.58 | 0.35 | 0.56 |
| 1992 | 0.24 | 0.25 | 0.25 | 0.25 | 0.34 |
| 1991 | NULL | 0.11 | 0.31 | NULL | 0.09 |
| **Average** | **0.43** | **0.44** | **0.44** | **0.44** | **0.45** |
| **Std. dev.** | **0.12** | **0.11** | **0.13** | **0.14** | **0.13** |

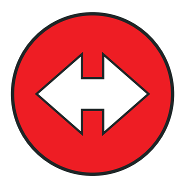
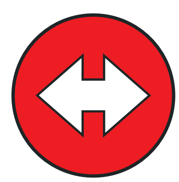
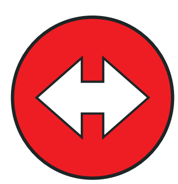
Florida Bay is higher than the targets and there is no trend toward the targets at this time. On a positive note, while salinity conditions vary there are no obvious downward trends in the performance measure.

Differences in connectivity and mixing between basins result in differences in salinity conditions across the bay. To simplify the analysis of spatial variability between zones, the performance measures were normalized and averaged to create a single metric for each zone. Results indicated that conditions during the 2011–2012 water year were closer to the target along the western and southern zones of Florida Bay relative to the central, eastern, and coastal zones (Fig. 1). This distribution was expected since the western and southern zones exchange water more freely with the Gulf of Mexico. In the coastal zone, where managed changes in freshwater delivery have their greatest effect, the average of the three performance metrics was 0.23, the lowest metric in the bay for the study year. The central and eastern zones scored slightly better at 0.29 and 0.33 respectively. The resultant metrics for 2012 showed lower values than the previous year but were within the year-to-year variability for the period of record for salinity observations.

### *Highlights*

In summary, salinity in Florida Bay is not meeting the targets that have been developed for the system (Table 2). The range of salinities observed coincide with the desired conditions only 2 months out of the year while the mean salinity is above the target condition throughout the year. Additionally, the occurrence of extreme high salinity events is more frequent than desired. It is recognized that there is currently no discernible trend toward the desired salinity conditions for the bay and that improvement in these conditions hinges on successful implementation of restoration efforts ranging from the Central Everglades Planning Project (CEPP) to the C–111 South Dade project.

**Table 2. Summary condition and trend in salinity performance metrics for 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. |

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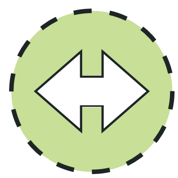
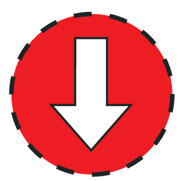
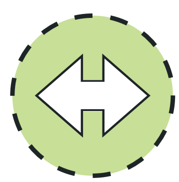
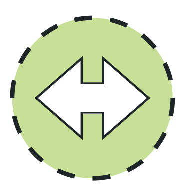
## Indicator 8: Algal Blooms in Florida Bay

**David Rudnick**, Everglades National Park, South Florida Natural Resources Center; David_Rudnick@nps.gov

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 (Table 1). A more detailed description of this indicator, reflecting advances in methodologies, analytical methods, and trends in data, will be provided in future State of Conservation reports.

**Table 1. 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. |

# Indicator 9: Seagrasses in Florida Bay

**Tracy Ziegler**, Everglades National Park, South Florida Natural Resources Center; Tracy_Ziegler@nps.gov

## *Background and Importance*

Submerged aquatic vegetation (SAV) communities composed of seagrasses and macroalgae form the basis for the keystone community of the Florida Bay ecosystem (Fourqurean et al. 2002). SAV communities are an important indicator of ecosystem health because they provide key ecological services, including sediment stabilization, nutrient cycling, and food resources for upper trophic levels, and they provide habitat structure that enhances local biodiversity (Orth et al. 2006). These plants are not just the base for a highly productive food web; they also provide essential habitat for invertebrates and juvenile, adult, and spawning fish in upper trophic levels, including many economically important species. Seagrasses also provide a large nutrient sink, which restricts nutrient availability to phytoplankton, thereby ameliorating potential algal blooms (Madden et al. 2009).

Because SAV communities reside at the land and sea interface, they are subject to physical disturbances and water quality changes associated with anthropogenic influences. SAV species composition, abundance, and spatial distribution are affected by spatial and temporal salinity patterns and nutrient and light levels. Freshwater inflow quantity, timing, and distribution affect salinity, nutrient, and light levels. Seagrasses are useful reflections of the health of an ecosystem because they respond to highly variable and not easily detectable aspects of the system, including pulses of nutrients and changes in sediment conditions (Madden et al. 2009). Thus, seagrasses are considered one of the best indicators of change in Florida Bay (Fourqurean et al. 2002).

*Thalassia testudium* (turtle grass) is the dominant seagrass and is considered the climax species in the Florida Bay ecosystem. *Halodule wrightii* (shoal grass) and *Syringodium filiforme* (manatee grass) are found to be mixed with turtle grass, although manatee grass is typically found in deeper marine areas in the western part of the bay. *Ruppia maritima* (widgeon grass) occurs in the northern areas of the bay. *Halophila engelmannii* (star grass) and *Halophila decipinens* (paddle grass) are two rare species found in various regions of the bay. Along with macroalgae, these species form the SAV community of Florida Bay.

The seagrass community underwent a widespread mortality event in 1987, which began with observations of "potholes" in seagrass beds in the north-central part of Florida Bay. Extensive areas of *Thalassia* began dying rapidly in the central and western basins, resulting in a 30% loss of the community by 1990 (Madden et al. 2009). These mortality events led to a cascade of ecological effects, such as increased turbidity, frequent algal blooms, and negative impacts to the sponge community, spiny lobsters, pink shrimp, and game fish landings. Years of hypersaline conditions most likely triggered these mortality events, creating favorable conditions for *Thalassia* to exceed its carrying capacity and consequently crash (Fourqurean et al. 2002). In order to improve conditions for the seagrass community and the Florida Bay ecosystem, restoration goals are focused on an improved salinity regime and increased freshwater inputs.

## *Desired State of Conservation of the Indicator*

The Desired State of Conservation for SAV community composition is an increase in species that are currently less dominant in the bay's overall seagrass community. In Florida Bay, the desired condition would include the recovery of seagrass beds over most of the bay bottom, extending west along the Gulf of Mexico coastal shelf, as well as to restore a diverse mosaic of *Thalassia*, *Halodule*, *Ruppia*, and *Syringodium* seagrass communities.

The seagrass indicators are created from a set of metrics that reflect the attributes of the SAV community. These metrics include spatial extent, abundance, species dominance, and presence of target species. All four metrics are combined to produce a single Abundance Index that reflects the status and health of the community. For the Abundance Index metric, the desired state of conservation would demonstrate a long-term positive trend in community composition (abundance and extent) of SAV in the Florida Bay ecosystem.

The Target Species Index is a metric 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, resulting in improved habitat quality (Madden et al. 2009). Indicator targets vary spatially and are zone-specific (see next section for description). For the Target Species Index, the desired state of conservation would see a long-term positive trend in target species of SAV in the Florida Bay ecosystem.

## *Description of Indicator Monitored*

SAV assessment indicator data are collected under a multi-agency monitoring program. Data for Florida Bay in Everglades National Park are being collected primarily through two programs: 1) SAV monitoring in northeastern Florida Bay by the Miami-Dade Department of Environmental Resource Management (Miami-Dade DERM) and 2) in northern and central Florida Bay by the South Florida Fisheries Habitat Assessment Program (FHAP). Monitoring for SAV in Florida Bay has been in progress since the early 1990s.

DERM monitors SAV within basins of two regions in northeastern Florida Bay (Fig. 1). The Northern Transition Zone includes Highway Creek, Long Sound, Joe Bay, Alligator Bay in Eagle Key basin, Davis Cove and Trout Cove in Deer Key basin, Little Madeira Bay, and an area south of Little

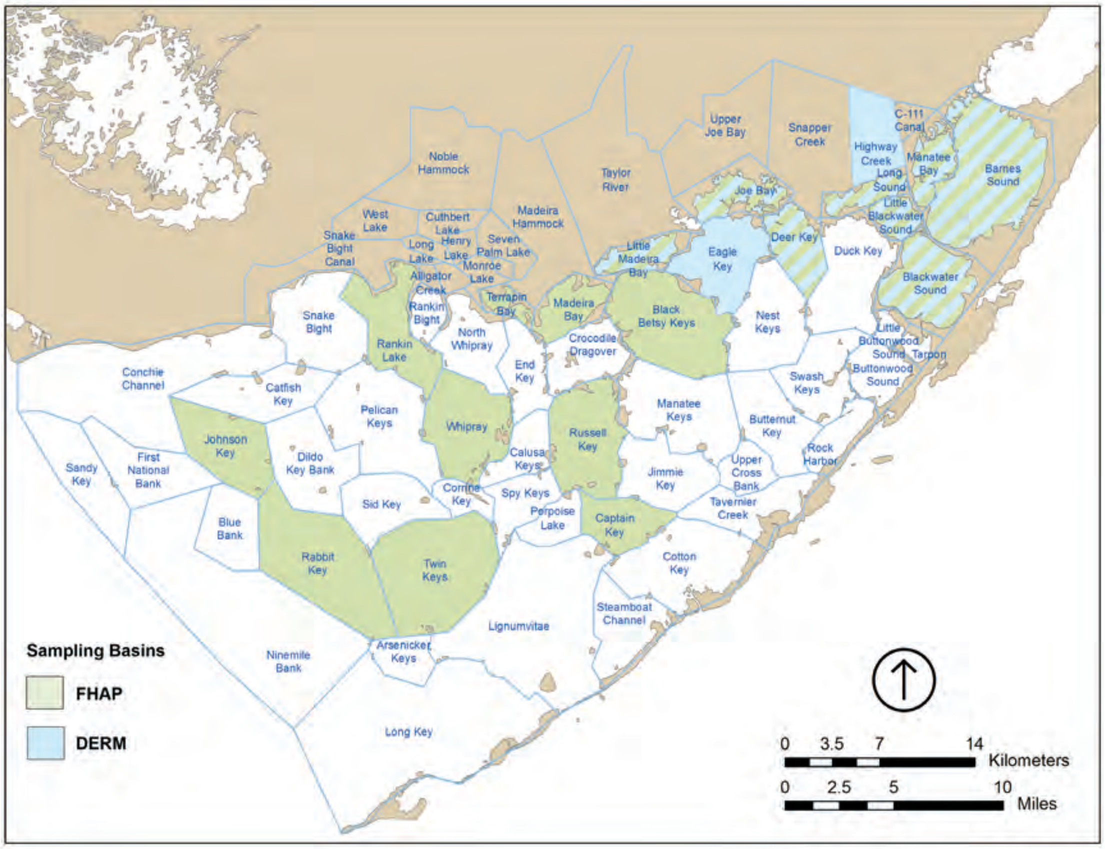



**Figure 1. Location of submerged aquatic vegetation (SAV) areas that are monitored in Florida Bay by Miami-Dade DERM and FHAP.**

Madeira Bay near Eagle Key Basin. The Northeastern Zone includes Manatee Bay, Barnes Sound, Little Blackwater Sound, and Blackwater Sound. These basins were selected to detect potential effects of managed water releases into Taylor Slough and the C-111 canal system.

FHAP provides spatially explicit data on the distribution, abundance, and species composition of Florida Bay SAV. South Florida FHAP annual sampling is at the end of the dry season (May–June) when salinity stress on seagrasses is typically highest. SAV is visually quantified at 30 randomly selected sites within 20 basins of Florida Bay (Fig. 1). Intensive sampling efforts are conducted twice annually (May–June at the end of the dry season, and October–November at the end of the wet season) at 15 permanent transects in Florida Bay.

### *Status of the Indicator in the Current Year and Trends over Time*

Abundance Index data collected during 1995–2011 suggest that *Thalassia* cover has declined in western Florida Bay basins where density was highest in 1995 (i.e., Rabbit Key and Twin Key basins; Fig. 2). However, *Thalassia* cover has increased substantially in the basins most heavily affected by the die-off (i.e., Rankin Lake, Whipray Basin, and Johnson Key Basin). *Halodule* and *Syringodium* densities have increased in all these basins (Fig. 2); thus, the seagrass communities of western and central Florida Bay (i.e., Rankin Lake, Whipray Basin, Johnson Key Basin, Rabbit Key Basin, and Twin Key Basin) were generally more diverse in 2011 than they were in 1995. Changes in seagrass species abundance in western Florida Bay during 1995–2011 appear to be driven primarily by secondary succession following the turtle grass die-off and subsequent phytoplankton blooms. These patterns of succession also reflect increasing light availability (and less turbidity) during that time period, especially from 1995 through 2001.

### *Highlights*

Although the SAV indicators show a positive trend in some areas (Table 1), this assessment should be interpreted cautiously because the system is still vulnerable. Seagrass communities are not yet near the desired condition. These communities are threatened and will remain threatened until improvements in upland water management are in effect. Thus, restoration efforts to improve freshwater delivery into the system need to continue.

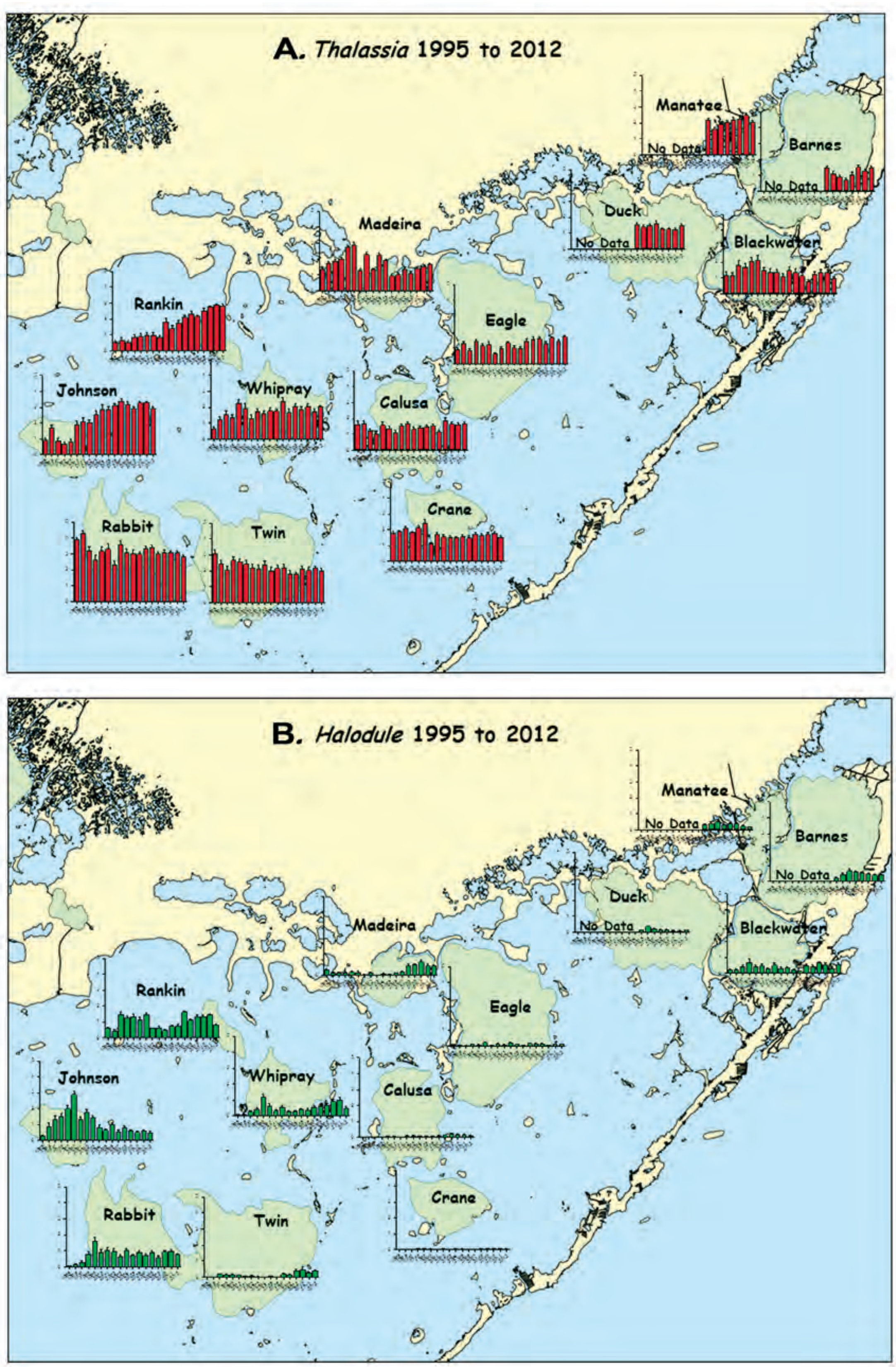



**Figure 2. Mean density (± standard error) of seagrass species A) *Thalassia*, and B) *Halodule* in monitored regions of Florida Bay from 1995 to 2011.** Used with permission from Hall and Durako (2012).

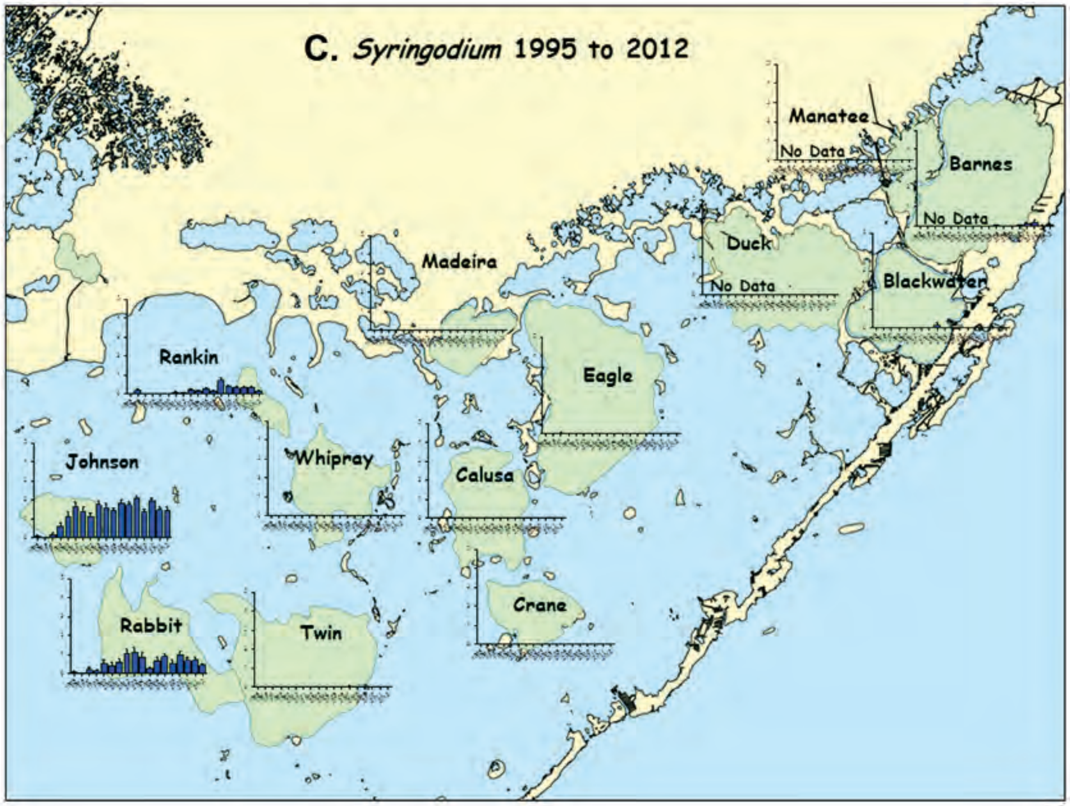



**Figure 2 continued. Mean density (± standard error) of seagrass species C) *Syringodium* in monitored regions of Florida Bay from 1995 to 2011.** Used with permission from Hall and Durako (2012).

**Table 1. Status of seagrasses in various zones within Florida Bay, Everglades National Park.**

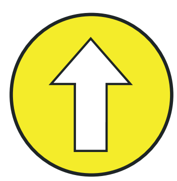
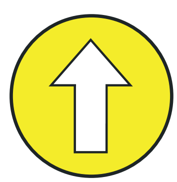
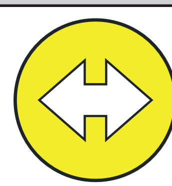
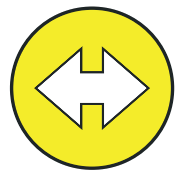
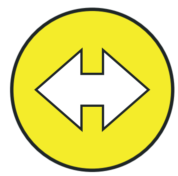
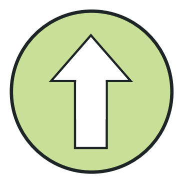
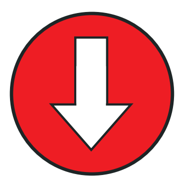
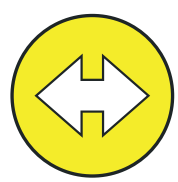
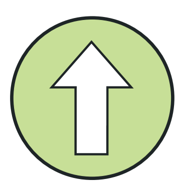
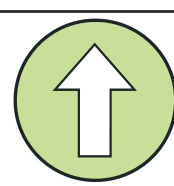
| Criteria | Desired State of Conservation | Condition & Trend | Rationale |
|---|---|---|---|
| **NORTHEASTERN ZONE** | | | |
| Seagrass abundance | Abundance of seagrass consistent with a restored Everglades ecosystem. |  | Aggregate Abundance Index is in the good range, with signs of recovery from 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. |

**Table 1 continued. Status of seagrasses in various zones within Florida Bay, Everglades National Park.**

| Criteria | Desired State of Conservation | Condition & Trend | Rationale |
|---|---|---|---|
| **TRANSITION ZONE continued** | | | |
| 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. |
| **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. |

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# Indicator 10: Estuarine Fish (Sport Fish) and Invertebrates

**Jason Osborne**, Everglades National Park, South Florida Natural Resources Center; Jason_Osborne@nps.gov

## *Background and Importance*

The salt and brackish waters of Everglades National Park (ENP) contain world-class fishing opportunities for recreational anglers. A prohibition on commercial fisheries within ENP since 1985 has helped to sustain these high-quality recreational fisheries. The coastal areas of the park support rich and diverse flora and fauna that depend on the condition and quality of the marine and estuarine communities in the region as a whole. Nursery habitat and fish and invertebrate communities are of great importance to coastal food webs and form the basis of regional commercial and recreational fisheries. Many sport fish species are high trophic-level predators and their populations rely on invertebrate populations, including the commercially valuable pink shrimp (*Farfantepenaeus duorarum*), and a variety of fish species for their prey base. The abundance and availability of these high trophic-level native species reflect the condition of nearshore marine and estuarine communities because they rely on this region for their entire lifecycle.

The information presented in this indicator assessment is based on the following data-collection methods. Recreational sport fishing anglers were interviewed every weekend to glean information about their fishing trips. Additionally, park-permitted professional fishing guides submitted similar daily charter fishing logbook reports, as outlined in the requirements of their permit. These records of angler effort and success help biologists determine the relative abundance, distribution, and trends in species fished for throughout the period of record (POR). Angler interview data have been collected in ENP nearly continuously since 1958; however, data for this report were limited to the past 19 years (1993–2011), the period when data were collected most consistently.

As an important commercial and ecological species, pink shrimp serves as one of several biological indicators for assessing the response of south Florida's southern estuaries to upstream changes in hydrology related to the restoration of the greater Everglades (Browder and Robblee 2009).

## *Desired State of Conservation*

The desired state of conservation for nearshore faunal communities is for the fishery to maintain or increase current abundance of high trophic-level predators, as well as their required prey base. Fluctuations in species abundances are expected, but a generally stable or increasing trend would indicate favorable conditions, and populations should rebound quickly following any declines. Ultimately, the system can be deemed healthy if it supports a resilient and sustainable fishery with enough fish and invertebrates remaining in the population to reproduce and contribute to the next year's recruitment. We expect this resilient and sustainable fishery to be supported by a diversity of suitable habitats distributed throughout the park's coastal waters and estuaries. For example, habitat in the Gulf Coast region should be sufficient to support resilient eastern oyster (*Crassostrea virginica*) beds and populations of red drum (*Sciaenops ocellata*), blue crabs (*Callinectes sapidus*), and stone crabs (*Menippe mercenaria*). Florida Bay seagrass (*Halodule, Ruppia*, *Thalassia*) beds (see Indicator 9) should support substantial populations of pink shrimp, spotted seatrout (*Cynoscion nebulosus*), and gray snapper (*Lutjanus griseus*).

## *Description of Indicator Monitored*

The relative abundance and distribution of four species of sport fish were monitored within the park by park staff to determine the status of the fisheries in ENP. The species evaluated were snook (*Centropomus undecimalis*), red drum, spotted seatrout, and gray snapper. Pink shrimp density was evaluated by researchers from the U.S. Geological Survey and the National Oceanic and Atmospheric Administration through a project called the South Florida Fish and Invertebrate Assessment Network (FIAN), an element of the Monitoring and Assessment Plan under the auspices of the Comprehensive Everglades Restoration Plan.

### Sport Fish

Information collected by ENP personnel from anglers and guides includes the number of fish caught (including kept and released) by species, the number of hours fished, the number of people fishing, species preference, and the area(s) where the majority of the fish were caught. The metric used in this analysis is called the catch per unit effort (CPUE), also known as catch rate, and is an index of relative abundance. The amount of catch is the total number of fish of a given species that were kept and released during a given fishing trip. Effort is defined as the number of people fishing on the boat multiplied by the number of hours spent fishing that day. The CPUE for each interview can be calculated by dividing the fishing party's catch (keeping track of each species separately) by their effort expended while fishing. CPUEs for this analysis were calculated using interviews where the species analyzed was either preferred and/or caught.

Monitoring involves interaction with the general public as well as acquisition of information from permitted fishing guides. Face-to-face interviews (also known as creel surveys) are conducted as fishing groups arrive at points of contact (Flamingo and Everglades City/Chokoloskee). Permitted fishing guides send in their logbook reports via mail or email submission. Anglers arriving at the points of contact are selected on a random basis for interviews; thereby, information is acquired from throughout the park's saltwater fishing areas. These areas are defined as six zones on the basis of ecological differences, location, and habitats as follows: northern Florida Bay (Area 1) is characterized as directly influenced by mainland freshwater runoff from Taylor Slough; southern Florida Bay (Area 2) typically has higher salinities because it is enveloped by the Florida Keys on the eastern side and the Gulf of Mexico on the western side; western Florida Bay and Cape Sable (Area 3) are characterized by expansive saltwater mud banks and saltwater tidal creeks; Whitewater Bay (Area 4) is characterized by its brackish, tannin-colored waters and freshwater runoff from Shark River Slough; Shark River area from Little Shark River to Broad River (Area 5) is influenced by freshwater runoff from Shark River Slough and variable salinities that are affected by saltwater intrusions in much of this area; and Lower Ten Thousand Islands from Lostmans River to Chokoloskee (Area 6) is characterized by inshore bays and oyster beds near the park's west coast (Fig. 1). These six zones represent different ecological areas of the park's marine waters.

## Pink Shrimp

This report summarizes results of the FIAN program (Robblee et al. 2012). A 1-m$^2$ throw trap (Robblee et al. 1991), the basic sampling tool of FIAN, collects discrete, quantitative samples of epibenthic fish and invertebrates that are associated with benthic vegetation or that seek shelter in benthic vegetation when disturbed. Throw trapping is conducted at 19 sites throughout south Florida estuaries, with 12 occurring within ENP (Fig. 2). At each site, 30 throw trap samples are collected, and the density of pink shrimp is measured. At present, the annual assessment consists of comparison of spring and fall mean shrimp density in relation to available reference data for each area.

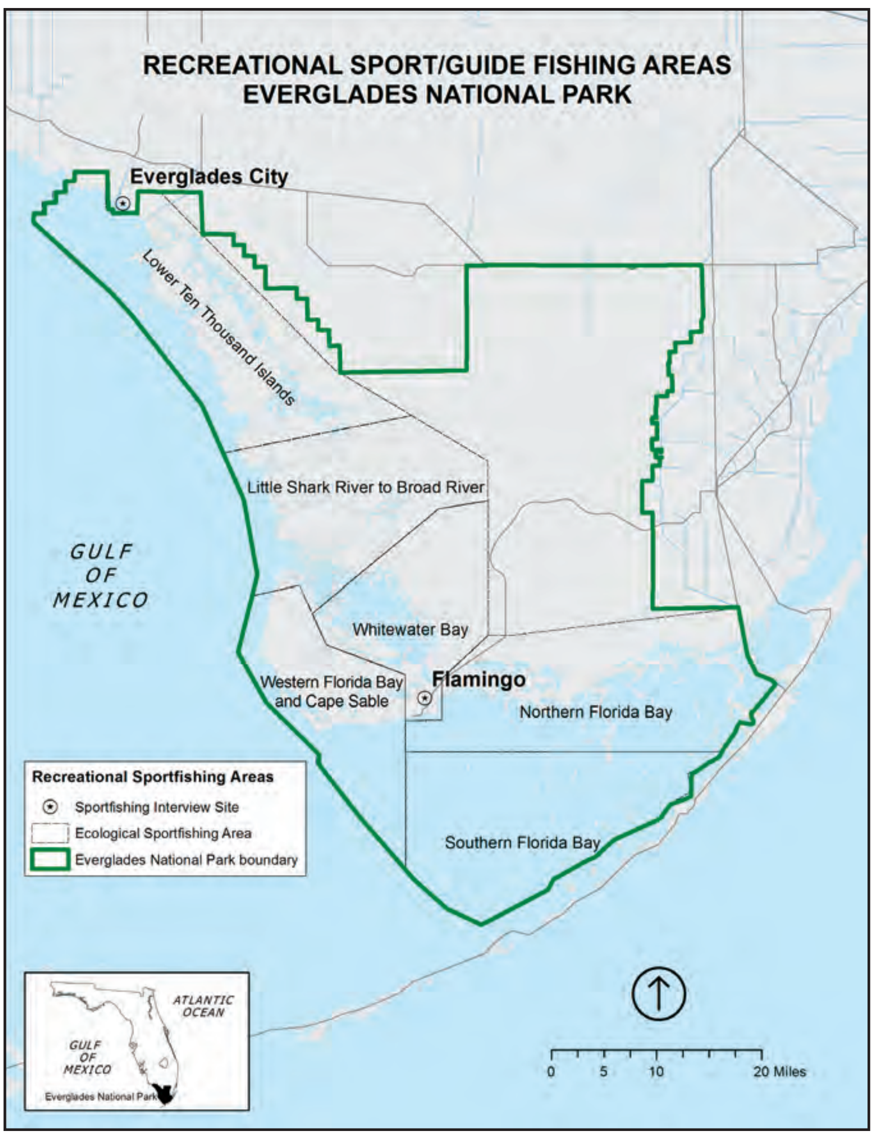



**Figure 1. Location of recreational sport/guide fishing areas, Everglades National Park.**

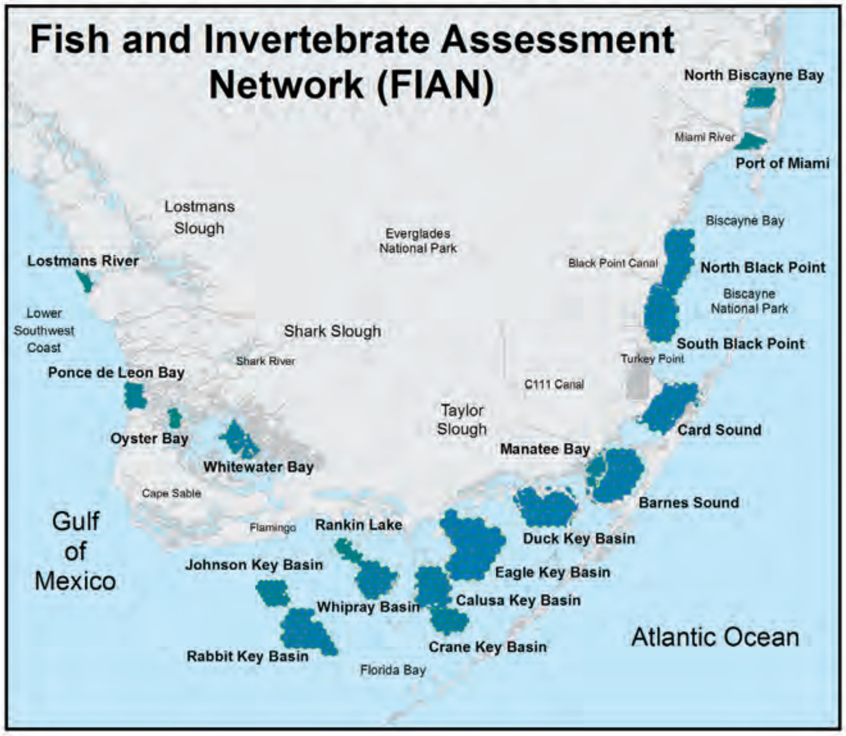



**Figure 2. Fish and invertebrate assessment network.** Used with permission from Robblee et al. (2012).

The pink shrimp ecological indicator assesses the status of the pink shrimp in southern Florida estuaries by comparing shrimp density in the current year (for this report, 2010 and 2011) to a reference data set that represents a pre-restoration pink shrimp density, based on FIAN measurements for 2005–2009 (Robblee et al. 2012). Pink shrimp densities that are less than the 1st quartile are scored as 0 (poor performance), values greater than or equal to the 1st and less than or equal to the 3rd quartile are scored as 0.5 (neutral performance), and values greater than the 3rd quartile are scored as 1 (positive performance). Stoplight indicator colors (red, yellow, green) are assigned to summarize poor, neutral, and positive performance, respectively.

### *Status of the Indicator in the Current Year and Trends over Time*

#### Sport Fish

Trends in catch rates for the four focal sport fish species monitored throughout the POR are shown in Figures 3–6. The relative abundance (CPUE) for each of the sport fish species maintained a generally stable trend over the POR. Each species of sport fish was distributed throughout the park for the POR, and regional differences in CPUE likely reflect differences in habitat suitability in different ecological zones (Fig. 7).

The generally positive long-term trend in snook catch rates from the mid-1990s through 2009 (Fig. 3) was largely due to the active involvement of the Florida Fish and Wildlife Conservation Commission (FWC) in successfully managing for that sport fishery through regulation changes. Low catch rates in 2010 were the result of a significant cold weather fish kill that occurred in January of that year. Water temperatures of 12–14° C are known to be lethal for most snook (Shafland and Foote 1983) and 9–10° C for larger snook (Howells et al. 1990). Nighttime water temperatures were below 14° C for 14 consecutive days and were below 9° C for 6 of those nights. As a result, there was extensive mortality of snook (along with other sport fish species) throughout the park. An estimated 214,000 snook succumbed during this event (Hallac and Ziegler 2010). In 2011, the relative abundance of snook in the park stabilized (Fig. 3), and an increasing trend in snook catch rates is expected in 2012. Snook were well-distributed throughout the park over the POR, with the lowest numbers in southern Florida Bay and the highest in the Lower Ten Thousand Islands area (Fig. 7).

Catch rates for red drum in 2011 were the highest they have been for the POR (Fig. 4). Catch rates have been stable, except for the significant increase in CPUEs in 2010 and 2011 (Fig. 4). Similar to the snook fishery, an increasing trend in red drum catch rates is expected in 2012. Red drum were well-distributed throughout the park during the POR, with the lowest numbers in Whitewater Bay and the Shark River areas and the highest in all of Florida Bay (northern, southern, and western), Cape Sable, and the Lower Ten Thousand Islands area (Fig. 7).

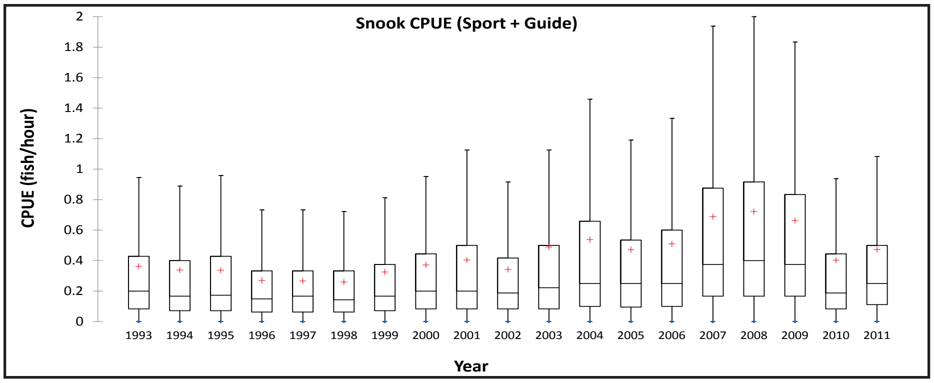



**Figure 3. Annual catch rates for recreational (sport) and guided anglers for common snook in Everglades National Park, 1993–2011.** Note: The "boxes" contain 75% of the data. The horizontal line inside the box represents the median. The upper and lower "whiskers" represent 95% of the data. Outliers in the data, representing both the upper and lower 2.5%, are not portrayed in this "box and whisker" plot. The red plus signs represent the mean (average).

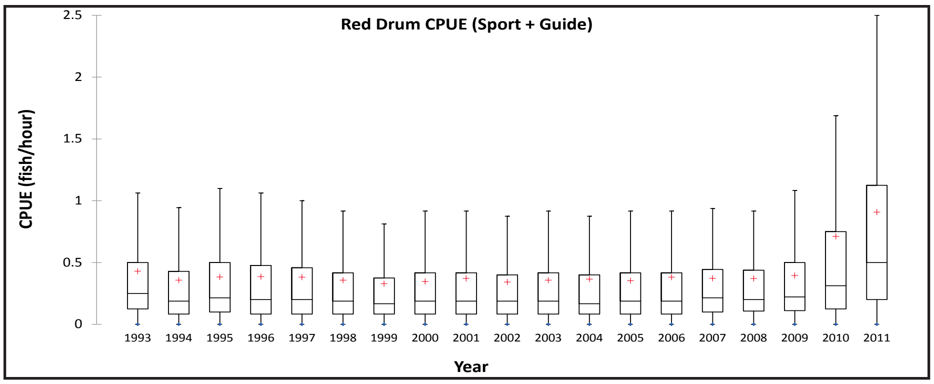



**Figure 4. Annual catch rates for recreational (sport) and guided anglers for Red Drum in Everglades National Park, 1993–2011.** Note: The "boxes" contain 75% of the data. The horizontal line inside the box represents the median. The upper and lower "whiskers" represent 95% of the data. Outliers in the data, representing both the upper and lower 2.5%, are not portrayed in this "box and whisker" plot. The red plus signs represent the mean (average).

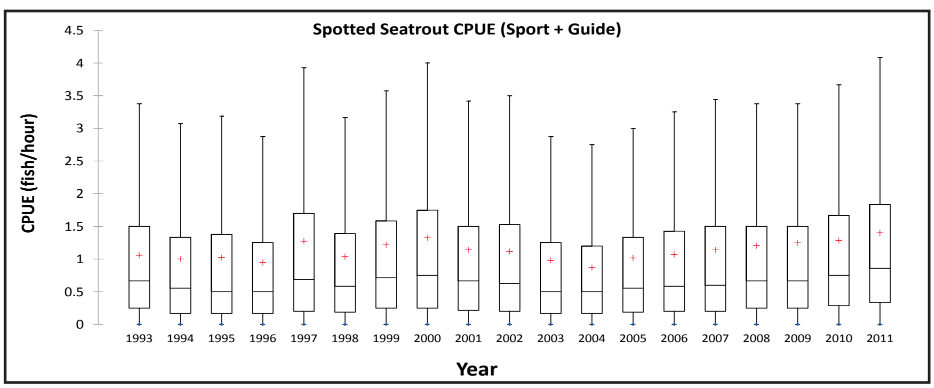



**Figure 5. Annual catch rates for recreational (sport) and guided anglers for Spotted Seatrout in Everglades National Park, 1993–2011.** Note: The "boxes" contain 75% of the data. The horizontal line inside the box represents the median. The upper and lower "whiskers" represent 95% of the data. Outliers in the data, representing both the upper and lower 2.5%, are not portrayed in this "box and whisker" plot. The red plus signs represent the mean (average).

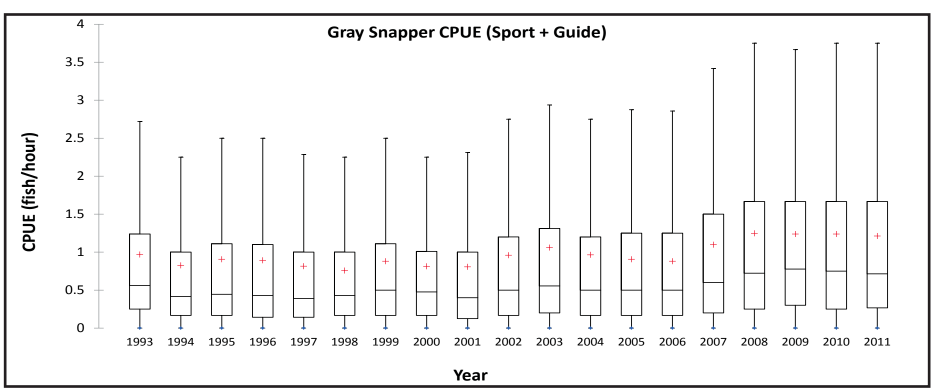



**Figure 6. Annual catch rates for recreational (sport) and guided anglers for Gray Snapper in Everglades National Park, 1993–2011.** Note: The "boxes" contain 75% of the data. The horizontal line inside the box represents the median. The upper and lower "whiskers" represent 95% of the data. Outliers in the data, representing both the upper and lower 2.5%, are not portrayed in this "box and whisker" plot. The red plus signs represent the mean (average).

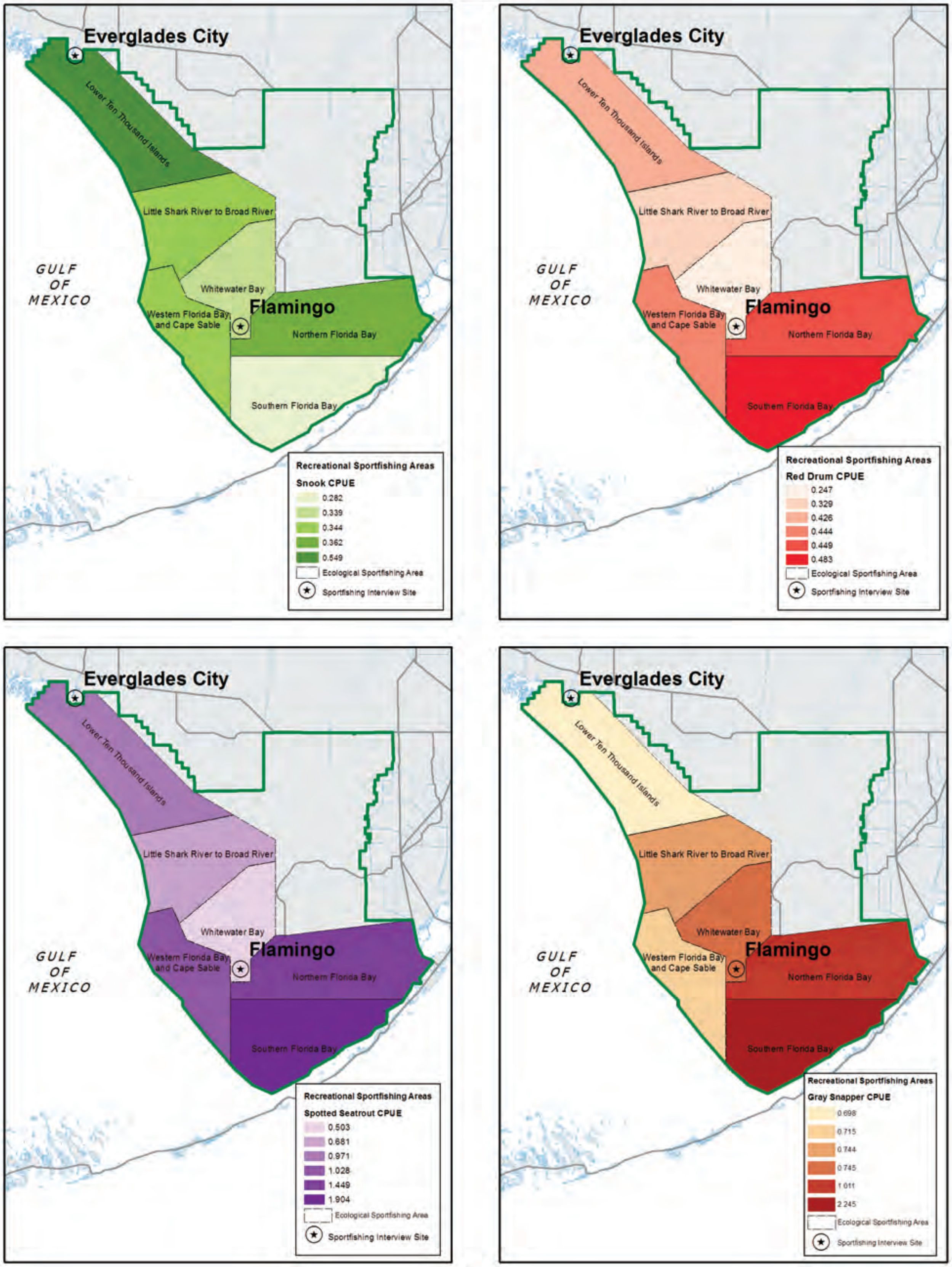



**Figure 7. Distribution of four focal sportfish species in Everglades National Park, 1993-2011.** Each species' CPUE for the 19-year POR is displayed for each sportfishing area to show how each species is distributed throughout the park, based on its "catchability." The higher the CPUE for any given area, the more likely it would be to catch that species.

Generally, catch rates have been stable for spotted seatrout throughout the POR (Fig. 5), though some variation was recorded. There has been a slight increasing trend in spotted seatrout catch rates since 2004 (Fig. 5). This species did not seem to be affected by the cold weather fish kill in 2010. Spotted seatrout were well-distributed throughout the park during the POR, with the lowest numbers in Whitewater Bay and the Shark River areas, and the highest in northern and southern Florida Bay (Fig. 7).

Catch rates for gray snapper (Fig. 6) have been relatively high for the last five years (2007–2011). Generally, catch rates have been stable throughout the POR (Fig. 6). Gray snapper were affected by the cold weather fish kill in 2010, though to a lesser degree than snook. An estimated 18,000 gray snapper succumbed during this event (Hallac and Ziegler 2010). Gray snapper were well-distributed throughout the park during the POR, with the lowest numbers in western Florida Bay/Cape Sable, Whitewater Bay, Shark River areas, and the Lower Ten Thousand Islands area, and by far the highest in southern Florida Bay (Fig. 7).

## Pink Shrimp

A comparison of the distribution of pink shrimp performance at monitoring locations in the spring and fall of 2010 and 2011, using the stoplight indicator colors, is provided in Figure 8. In addition, the distribution of pink shrimp in south Florida during the wet and dry seasons, averaging the FIAN data collected over a 7-year period (2005–2011), is shown in Figure 9.

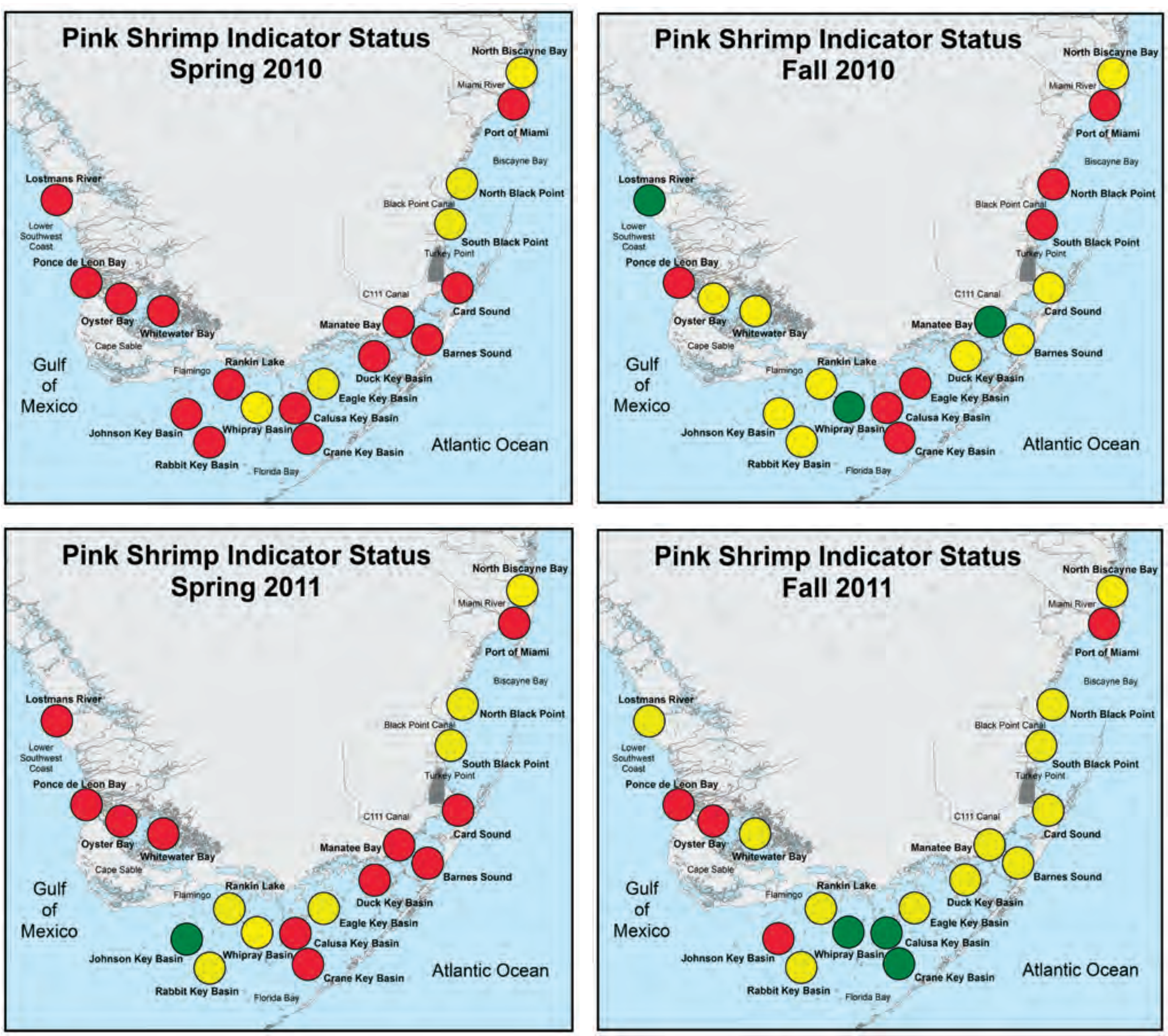



**Figure 8. Comparison of the distribution of pink shrimp performance in the spring and fall of 2010 and 2011.** The stoplight colors are used to summarize pink shrimp performance; red (< 1st quartile, poor performance), yellow (≥ 1st and ≤ 3rd quartile, neutral performance) and green (> 3rd quartile, good performance). Used with permission from Robblee et al. (2012).

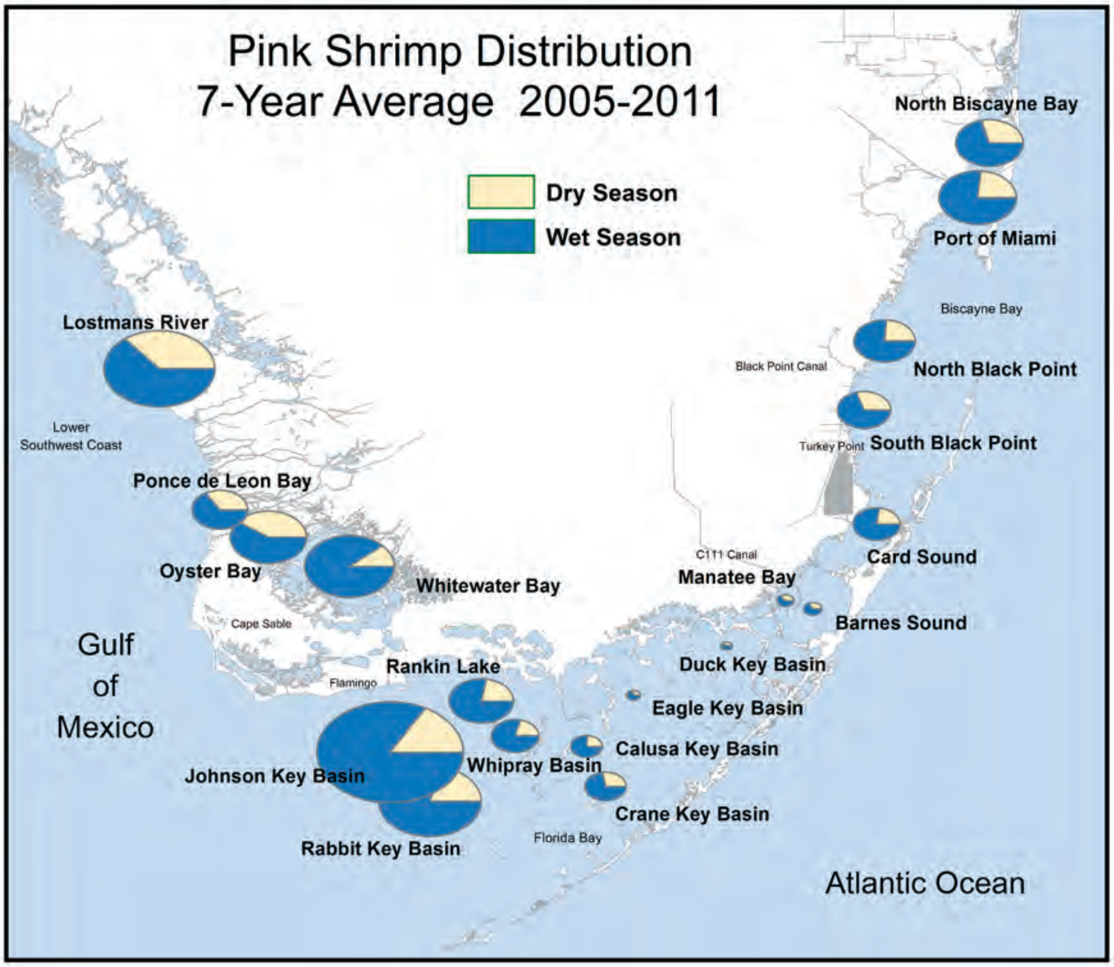



**Figure 9. Pink shrimp (*Farfantepenaeus duorarum*) distribution in south Florida averaged over the 7 years of FIAN, 2005-2011.** The size of each pie diagram equals the sum of average dry and wet season density scaled from a maximum of 6.17±7.66/m$^2$ (±1sd) in Johnson Key Basin to a minimum of 0.04±0.27/m$^2$ in Duck Key Basin. Spring and fall densities observed in Johnson Key Basin, 1.92±2.05/m$^2$ and 10.42±8.78/m$^2$, and in Duck Key Basin, 0.04±0.33/m$^2$ and 0.03±0.21/m$^2$, respectively. Used with permission from Robblee et al. (2012).

Pink shrimp status was classified as poor to neutral in the regions encompassed by FIAN within EVER in both 2010 and 2011 (Tables 1 and 2); patterns in pink shrimp performance among monitoring locations were not consistent between spring and fall or between the two years (Fig. 8). Johnson Key Basin was the sole monitoring location to perform well (achieve positive status) in the spring of 2011 (Table 2). Five of twelve locations performed well in the fall (Fig. 8). Whipray Basin was the only monitoring location to achieve a positive status in the fall of both 2010 and 2011 (Tables 1 and 2). The central area of Florida Bay performed well in the fall of 2011 achieving a positive status at Whipray Basin, Calusa Key Basin, and Crane Key Basin (Table 2). The lower mangrove coast region achieved poor status at all monitoring locations in spring of both years (Tables 1 and 2). Lostmans River was one of two locations to achieve a positive status in fall 2010, but had a neutral status in fall 2011 (Tables 1 and 2).

### *Highlights*

Four of the five indicators monitored show a stable or increasing trend in abundance in the park (Table 3). The relative abundance of all four sport fish species was consistent with the desired state of conservation for the indicator, although snook remains in a cautionary status due to lingering effects of the 2010 cold event. Only pink shrimp densities were below baseline levels at the majority of the sampling sites in Florida Bay and along the southwest coast of the park. The declining state of pink shrimp densities is a concern for the sport fish populations since shrimp are an important component of the prey base for sport fish.

**Table 1. Spring and fall 2010 pink shrimp performance in EVER relative to the FIAN 5-year baseline.** The 1st and 3rd quartiles of the base condition are indicated as Q1 and Q3, spring and fall, respectively. The stoplight colors are used to summarize pink shrimp performance; red (< 1st quartile, poor performance), yellow (≥ 1st and ≤ 3rd quartile, neutral performance) and green (> 3rd quartile, good performance). Trend in pink shrimp delta-density over the 6-year period-of-record (2005-2010) is provided with arrows indicating direction; open arrows = non-significant trend, blue closed arrows = significant trend at $p < 0.05$. Used with permission from Robblee et al. (2012).

**Florida Bay Region**

| | Q1 | Q3 | Spring | Trend | Q1 | Q3 | Fall | Trend |
|---|---|---|---|---|---|---|---|---|
| Duck Key Basin | 0.03 | 0.07 | Yellow | ⇧ | 0.00 | 0.03 | Yellow | ⇩ |
| Eagle Key Basin | 0.00 | 0.07 | Yellow | ⇩ | 0.07 | 0.11 | Red | ⇩ |
| Calusa Key Basin | 0.14 | 0.17 | Yellow | ⇩ | 0.28 | 0.56 | Red | ⇩ |
| Crane Key Basin | 0.17 | 0.53 | Yellow | ⇩ | 0.53 | 0.80 | Red | ⬇ (green) |
| Rankin Lake | 0.43 | 0.90 | Red | ⬇ (blue) | 0.66 | 2.30 | Yellow | ⇩ |
| Whipray Basin | 0.03 | 0.56 | Yellow | ⇩ | 0.53 | 0.73 | Green | ⇩ |
| Johnson Key Basin | 1.94 | 2.29 | Red | ⬇ (blue) | 5.81 | 15.63 | Yellow | ⇩ |
| Rabbit Key Basin | 0.84 | 1.57 | Red | ⬇ (blue) | 2.42 | 7.89 | Yellow | ⇩ |
| Regional Summary | 0.50 | 0.71 | Red | ⬇ (blue) | 1.36 | 4.07 | Yellow | ⇩ |

**Lower Southwest Mangrove Coast**

| | Q1 | Q3 | Spring | Trend | Q1 | Q3 | Fall | Trend |
|---|---|---|---|---|---|---|---|---|
| Lostmans River | 1.22 | 7.11 | Red | ⇧ | 1.74 | 5.57 | Green | ⇧ |
| Ponce de Leon Bay | 0.72 | 0.91 | Red | ⇧ | 0.95 | 1.55 | Red | ⇩ |
| Oyster Bay | 0.63 | 1.47 | Red | ⇧ | 1.14 | 3.57 | Yellow | ⬇ (blue) |
| Whitewater Bay | 0.43 | 0.50 | Red | ⇧ | 1.53 | 6.70 | Yellow | ⇩ |
| Regional Summary | 1.36 | 2.66 | Red | ⇧ | 1.93 | 4.21 | Yellow | ⇩ |

**Table 2. Spring and fall 2011 pink shrimp performance in EVER relative to the FIAN 5-year baseline.** The 1st and 3rd quartiles of the base condition are indicated as Q1 and Q3, spring and fall, respectively. The stoplight colors are used to summarize pink shrimp performance; red (< 1st quartile, poor performance), yellow (≥ 1st and ≤ 3rd quartile, neutral performance) and green (> 3rd quartile, good performance). Trend in pink shrimp delta-density over the 7-year period-of-record (2005-2011) is provided with arrows indicating direction; open arrows = non-significant trend, blue closed arrows = significant trend at $p < 0.05$. Used with permission from Robblee et al. (2012).

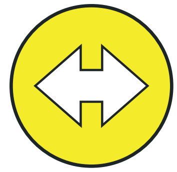
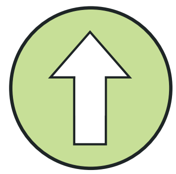
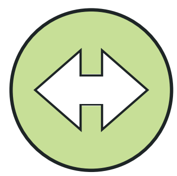
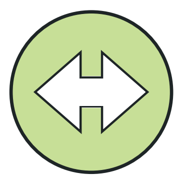
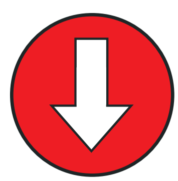
**Florida Bay Region**

| | Q1 | Q3 | Spring | Trend | Q1 | Q3 | Fall | Trend |
|---|---|---|---|---|---|---|---|---|
| Duck Key Basin | 0.03 | 0.07 | Red | ⇧ | 0.00 | 0.03 | Yellow | ⇩ |
| Eagle Key Basin | 0.00 | 0.07 | Yellow | ⇩ | 0.07 | 0.11 | Yellow | ⇩ |
| Calusa Key Basin | 0.14 | 0.17 | Red | ⇩ | 0.28 | 0.56 | Green | ⇩ |
| Crane Key Basin | 0.17 | 0.53 | Red | ⇩ | 0.53 | 0.80 | Green | ⇩ |
| Rankin Lake | 0.43 | 0.90 | Red | ⬇ (blue) | 0.66 | 2.30 | Yellow | ⇩ |
| Whipray Basin | 0.03 | 0.56 | Yellow | ⬇ (green) | 0.53 | 0.73 | Green | ⇩ |
| Johnson Key Basin | 1.94 | 2.29 | Green | ⇩ | 5.81 | 15.63 | Red | ⇩ |
| Rabbit Key Basin | 0.84 | 1.57 | Yellow | ⬇ (blue) | 2.42 | 7.89 | Yellow | ⇩ |
| Regional Summary | 0.50 | 0.71 | Red | ⬇ (blue) | 1.36 | 4.07 | Yellow | ⬇ (green) |

**Lower Southwest Mangrove Coast**

| | Q1 | Q3 | Spring | Trend | Q1 | Q3 | Fall | Trend |
|---|---|---|---|---|---|---|---|---|
| Lostmans River | 1.22 | 7.11 | Red | ⇧ | 1.74 | 5.57 | Yellow | ⇧ |
| Ponce de Leon Bay | 0.72 | 0.91 | Red | ⇩ | 0.95 | 1.55 | Red | ⇩ |
| Oyster Bay | 0.63 | 1.47 | Red | ⇧ | 1.14 | 3.57 | Red | ⬇ (blue) |
| Whitewater Bay | 0.43 | 0.50 | Red | ⇧ | 1.53 | 6.70 | Yellow | ⇩ |
| Regional Summary | 0.80 | 2.66 | Red | ⇧ | 1.93 | 4.21 | Yellow | ⇩ |

**Table 3. Status of 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. |

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# Indicator 11: American Crocodile

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## *Background and Importance*

American crocodiles (*Crocodylus acutus)* were federally listed as endangered by the U.S. Fish and Wildlife Service (USFWS) in 1975. The species decline was largely due to extensive habitat degradation (including nesting sites) and overhunting. 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 of the species to threatened status in 2007. This ecological indicator summary provides an assessment of the species status trend from 1993 to 2011 and describes the methods used for verification. The University of Florida Fort Lauderdale Research and Education Center (UF–FLREC) provided all data presented here.

The American crocodile is a flagship species of the Everglades that functions as an ecosystem indicator because its lifecycle is closely responsive to patterns of freshwater inputs to the estuaries and resultant nearshore salinity patterns. The majority of the crocodile population in south Florida exists within or adjacent to Everglades National Park (ENP), where brackish marshes close to Florida Bay serve as important nursery habitat for juveniles and as foraging and breeding habitat for adults. Though currently greatly reduced due to lack of funding, intensive monitoring of the crocodile population and associated ecological research has been ongoing since the mid-1970s. These efforts have produced detailed information on the life history of the species and the relationship between the American crocodile and the health of the Everglades system.

The most critical and measurable metrics believed to directly relate crocodiles to hydrologic restoration include nest distribution and nesting effort, and differential growth and survival from hatchling to late juvenile stages. Hatchling and juvenile survival is critical to species recovery and strongly influenced by salinity, growth rate, and the dispersal distance required to reach suitable nursery habitat (Mazzotti 1983 and 1999, Green et al. 2001, Mazzotti et al. 2009). Mortality is naturally high in young crocodiles yet decreases significantly and proportionately at relatively distinct growth stages, these stages being most rapidly attained under low salinity conditions (Mazzotti 1983, Moler 1991). Hatchlings experience the greatest mortality rate and least tolerance to high salinity (>20 ppt) prior to reaching approximately 200 g (or 40–45cm total length), typically 3–4 months post-hatching under fair conditions (Mazzotti and Dunson 1984, Kushlan and Mazzotti 1989, Moler 1991). Mazzotti et al. (2007a) estimated first-year survival of crocodiles within ENP to be only 1.5%, the lowest reported in Florida. Moler (1991) reported nearly 20% higher first-year survival when hatchlings grew rapidly enough to obtain this size prior to exposure to higher salinities, less abundant food, and more numerous predators characteristic of the dry season. Newly recruited juveniles (>200 g) continue to grow most rapidly in lower salinity, while becoming increasingly more tolerant of seawater and less susceptible to predation. A second survival milestone is reached at approximately 75 cm total length and typically occurs between 15 and 20 months of age in ENP. Juveniles larger than this face very low predation risk and by 4 to 5 years of age, survival is not influenced by salinity, predation risk nears zero, and annual survival likely approaches 100% (Kushlan and Mazzotti 1989, Moler 1991).

Female crocodiles generally select elevated nest sites in close proximity to suitable nesting habitat (Fig. 1). Historically (from anecdotal records in the 1950s and 1960s), most known crocodile nests in ENP were located on shorelines and islands in northeastern Florida Bay. This region received large volumes of freshwater input originating from Taylor Slough and effects of these inputs on salinity persevered well into the dry season. Upstream land-use modifications have severely reduced the quantity, quality, timing, and distribution of flow into northeastern Florida Bay, resulting in higher than natural salinities. As for many other native species, in order for Everglades restoration to be truly successful for crocodiles, freshwater inputs to south Florida estuaries, especially those in northeastern Florida Bay, must be restored to approximate natural conditions. Unnaturally hypersaline conditions, in particular, must be reduced in frequency, magnitude, and duration. Hydrologic restoration will create better habitat quality leading to increased prey base, growth and survival of hatchlings, reproductive effort, and ultimately, increased crocodile population density.

In the Cape Sable region of ENP, a system of canals was excavated in the 1920s in an effort to drain the interior marsh, resulting in increased salinities (sometimes hypersaline) well into the interior and reduced fitness as crocodile habitat. Canals were plugged circa 1960, failed circa 1990, and were plugged again in 1997. By 2002, the dams were again failing and canals widening, decreasing habitat suitability and allowing continued marine intrusion which occurred faster than ever following 80 years of intermittent canal erosion. In 2007, the Cape Sable Canal Mitigation Project was undertaken to again address these problems; new dams were completed in 2010 and designed with the expectation that they last for 50 years. This expensive and high profile project is expected to substantially restore habitat quality for many species of flora and fauna and is particularly promising for the continued recovery of crocodiles throughout the park.

## *Desired State of Conservation*

A positive trend in recovery of the American crocodile (*C. acutus*), to a level consistent with a restored Everglades eco-

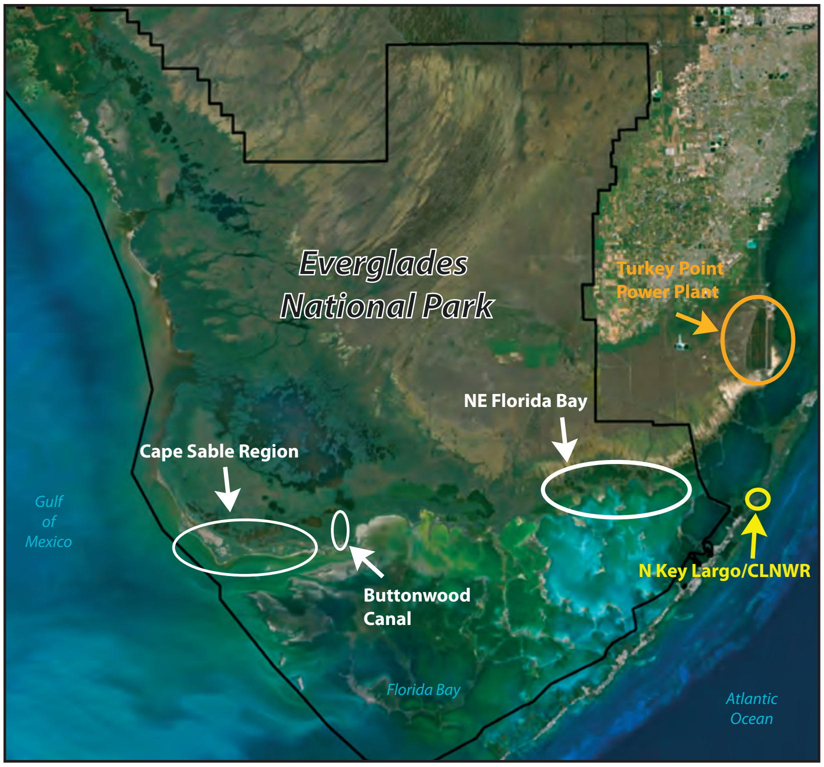



**Figure 1. Primary crocodile nesting locales within Everglades National Park and adjacent primary nesting sites in south Florida.**

system, is identified as a key target for ENP's removal from the World Heritage Sites in Danger list. Key components of recovery include increased species relative abundance and spatial distribution, increasing trend in nesting effort, and increased hatchling-juvenile growth and survival.

## *Description of Indicator Monitored*

UF–FLREC and National Park Service personnel, in conjunction with other agencies, collectively monitor the total annual number of nests in ENP and adjacent primary nesting sites (Fig. 1), including northern Key Largo/Crocodile Lake National Wildlife Refuge (CLNWR) and Turkey Point Power Plant. Relative abundance, demographic structure, and survival of crocodiles throughout ENP are monitored by UF–FLREC cooperators.

## *Status of the Indicator in the Current Year and Trends over Time*

Results of spotlight surveys, combined with mark-recapture events, indicate that the relative abundance of *C. acutus* has increased throughout the species range in southern Florida (Fig. 2). Hatchling and juvenile growth and survival within ENP continue to be low compared to adjacent nesting sites and likely differ among locales within the park (Table 1). Survival estimates within ENP may be artificially low due to the substantially greater difficulty of recapturing young crocodiles in ENPs' expansive habitat relative to the more accessible habitats of adjacent nursery sites. Additional research efforts must be conducted to differentiate between growth and survival at different locales within ENP and this is a primary focus of current park-funded research efforts.

Although nighttime spotlight surveys, combined with mark and recapture data, are the primary means of assessing population dynamics beyond reproductive effort in ENP, the best directly detectable metrics of successful recovery for crocodiles are sustained increases of nesting effort, distribution, and success. Nest monitoring is performed annually by air, water, and on foot during nest construction and hatching. The primary criterion considered for federal reclassification from endangered to threatened status (2007) was the existence of 60 or more documented nests annually over 3 consecutive years. While the overall number of nests has been rising for more than three decades following effective protection, there was a definitive change point within ENP circa 2002–2003 that is not replicated elsewhere in Florida (Fig. 3). Nesting has increased elsewhere, yet overall observed rapid increase in nesting of Florida's American crocodile population, spanning the period 2003 to 2011, is almost entirely comprised of nests that lie within the Cape Sable region of the park.

Increased nesting in the Cape Sable region may be linked to restoration efforts undertaken to correct unnatural saltwater intrusion into the formerly freshwater interior marsh,

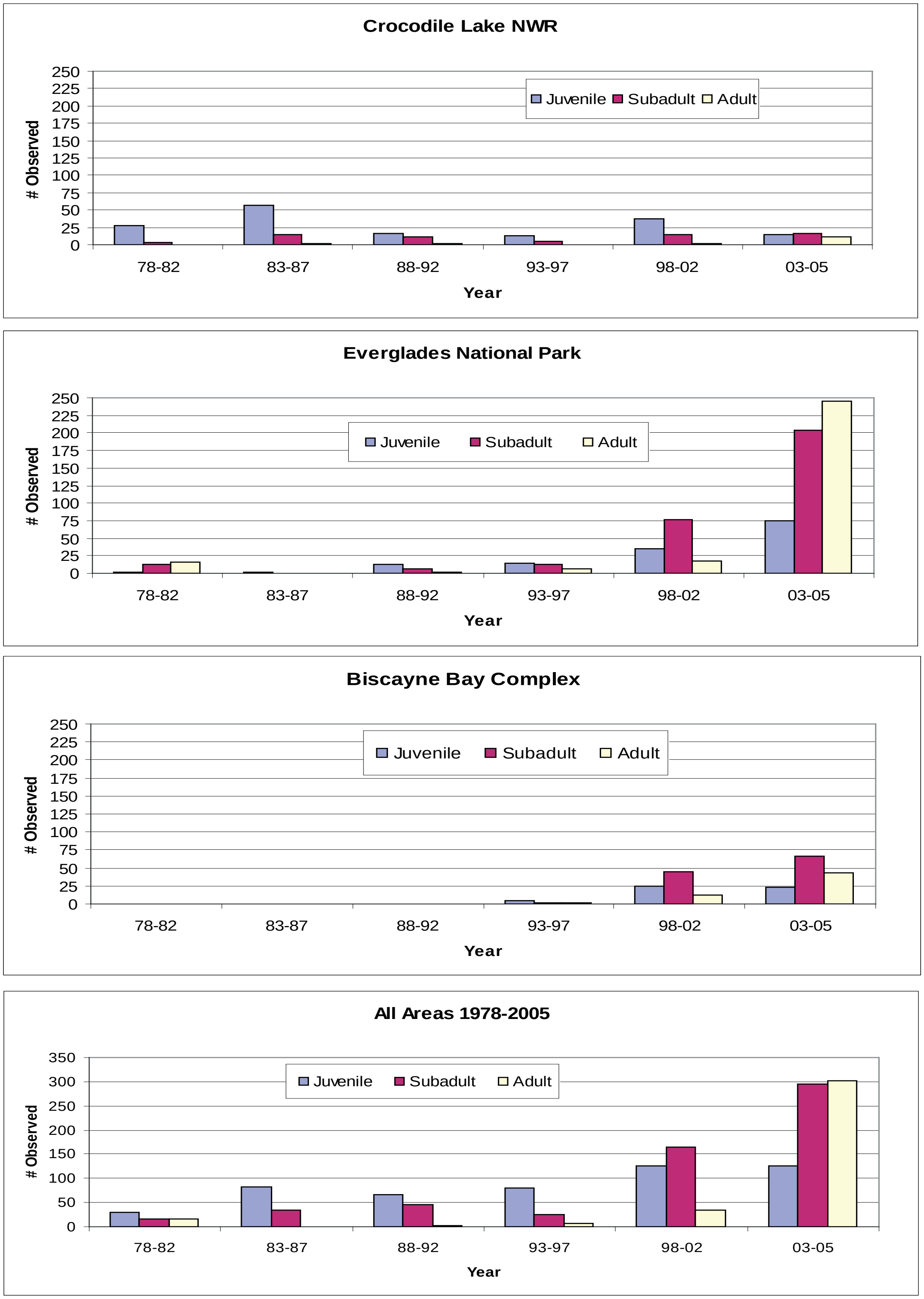



**Figure 2. Summary of crocodile spotlight observations by size class distribution over time and between locations in south Florida.** The Turkey Point Power Plant is included in “All Areas.” Reproduced and modified from Mazzotti and Cherkiss (2007).

**Table 1. Growth, survival (proportion of hatchling crocodiles that survived for at least 12 months), and dispersal (proportion of hatchling crocodiles that survived and dispersed out of their natal area) in south Florida.** Growth was different among the three nesting areas (ANOVA, $F_{2\ 541} = 3.91$; $p = 0.02$; LSD T-test, $\alpha = 0.05$). More hatchlings survived than expected by chance at CLNWR ($X^2 = 423.9$; $p \leq 0.001$), whereas more hatchlings dispersed from the Turkey Point site ($X^2 = 7.4$; $p \leq 0.025$). Different superscripts indicate significant differences among growth rates. Reproduced with modifications from Mazzotti et al. (2007b).

| Location | Juvenile Growth cm/day Mean (Range) | Minimum | |
|---|---|---|---|
| | | # (%) Survived for >12 months | # (%) Dispersed from natal area |
| Turkey Point Period of Record: 1978–2004 | 0.11 (-0.8 to 1.30)[a] (N = 205) | 59 (1.71 %) ($N_1$ = 3452) | 17 (29.0 %) ($N_2$ = 59) |
| Crocodile Lake NWR Period of Record: 1978–1999 | 0.10 (0.000 to 0.42)[a] (N = 246) | 94 (17.97 %) ($N_1$ = 523) | 14 (15.0 %) ($N_2$ = 94) |
| Everglades National Park Period of Record: 1978–2004 | 0.07 (-0.057 to 0.16)[b] (N = 93) | 28 (1.50 %) ($N_1$ = 1,871) | 2 (7.0 %) ($N_2$ = 28) |

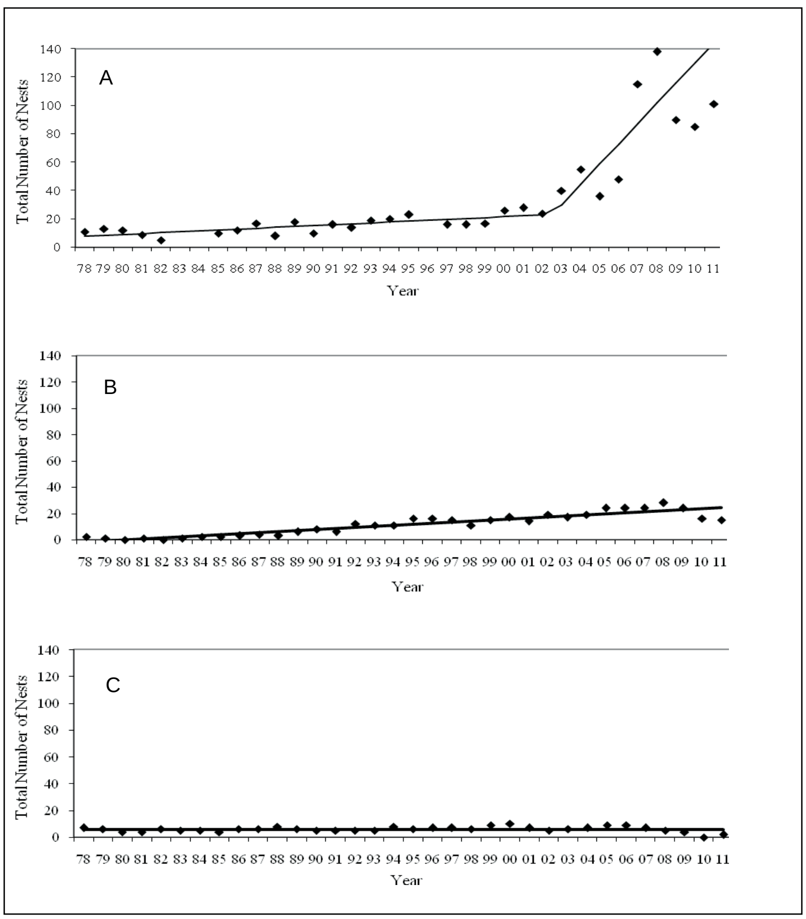



**Figure 3. Linear regression for total number of American crocodile nests found between 1978 and 2011 in the three primary nesting areas (A) Everglades National Park ($R^2 = 0.5801$; $p = 0.0001$; nests = 1052), (B) Turkey Point Power Plant ($R^2 = 0.8563$; $p = 0.0001$; nests = 387) and (C) Crocodile Lake National Wildlife Refuge ($R^2 = 0.0$; $p = 0.9762$; nests = 201).** Reproduced from Mazzotti and Cherkiss (2011).

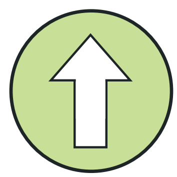
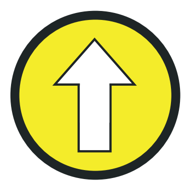
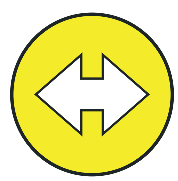
thereby reversing the associated habitat degradation. In addition to an overall more numerous crocodile population, increased nesting beginning circa 2002 may be partially a result of crocodiles responding to improved salinity regimes after implementation of plugging in 1997, and offspring from the few prior nests in the area reaching maturity (typically at 7–9 years of age).

Contrary to the nesting trends observed at Cape Sable and despite increasing occurrence of crocodiles since 1975, there has not been a large increase of nesting effort in other monitored areas within ENP. Additionally, nesting sites have shifted away from islands and beaches of Florida Bay toward mainland water sources, which have very little terrain at an elevation suitable for successful nesting. These observations support the dire need for further restoration of flows into northeastern Florida Bay and confirm the indicator status assigned to crocodiles and the suitability of crocodile monitoring as a cost-efficient method for determining the success of Everglades restoration objectives.

## *Highlights*

Table 2 presents the desired state of conservation and the current conditions and trends for all aspects of the American crocodile population described in the summary above.

**Table 2. American crocodile stoplight summary.**

| 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 NE 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. |

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# SECTION 4: INVASIVE EXOTIC SPECIES

NPS photo by Nicole Fratto

## Indicator 12: Invasive Exotic Plants

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### *Background and Importance*

Approximately 1,000 plant species currently are recorded in Everglades National Park (ENP) and, of these, approximately 250 are non-native (exotic) plants. Exotic plants have the capacity to drastically alter the natural environment (Doren et al. 2009, Mack et al. 2000). Consequently, several laws, general directives and polices, including but not limited to the National Park Service (NPS) Organic Act of 1916, NPS Management Polices 2006 (4.4.4.1–.2) and the enabling legislation for ENP, require management of exotic plants.

Limited funding and time make it infeasible to treat all the exotic plants of management concern. Whiteaker and Doren (1989) prioritized the management of exotic plants in ENP based on five categories defined by distribution and potential to invade. Today, the four exotic plant species that are of highest management concern and affect the largest proportion of ENP by area are melaleuca (*Melaleuca quinquenervia*), Australian pine (*Casuarina equisetifolia*), Old World climbing fern (*Lygodium microphyllum*), and Brazilian pepper (*Schinus terebinthifolius*). Surveys and mapping indicate that these four species are distributed across approximately 30% of the land mass of ENP. The remaining approximately 246 exotic plant species vary in the degree of their potential to invade and their distribution pattern. The distribution and percent cover of these other species are difficult to estimate since monitoring of these species is limited.

### *Desired State of Conservation*

Many of the descriptions of invasive exotic plant management in NPS documents lack measurable goals and provide only general language about control being feasible, with the intent that distribution and abundance would be limited to the maximum extent practicable with available resources (National Park Service 2006). In this report, quantifiable objectives for the desired state of the four exotic plants of highest management priority (melaleuca, Australian pine, Old World climbing fern, and Brazilian pepper) in ENP are described. Quantifiable objectives are also described for the category of the remaining exotic plants found within ENP.

The desired management state for melaleuca and Australian pine in ENP is defined as less than 1% cover per $km^2$ in the areas now or historically containing these species, and prevention of the expansion of these species to new areas. If greater than 1% cover per $km^2$ or a greater than 5% increase in infestation area is detected within a 2-year period, then greater resources should be dedicated to the control of melaleuca and Australian pine.

The desired management state for Old World climbing fern and Brazilian pepper is set as less than 5% cover per $km^2$ in areas currently containing these species, and prevention of the expansion of these species to new areas. If greater than 5% cover per $km^2$ or a greater than 5% increase in infestation area is detected within a 2-year period, then greater resources should be dedicated to control of Old World climbing fern.

The desired management state of the remaining exotic plant species is defined as less than 1% cover per species per $km^2$ in areas currently containing these species, and prevention of the expansion of these species to new areas. The desired management state would also include monitoring and control of newly detected species. If greater than 1% cover per $km^2$ or a greater than 5% increase in infestation area is detected within a 2-year period, then greater resources should be dedicated to the control of these species.

### *Description of Indicator Monitored*

A number of monitoring efforts are in place to track the status of exotic plant species in ENP and surrounding areas. Currently melaleuca, Australian pine, Old World climbing fern, and Brazilian pepper are monitored using the Digital Aerial Sketch Mapping (DASM) method (Fig. 1). This method consists of conducting systematic aerial survey transects in small aircraft flying at low altitude, with observers visually identifying, estimating percent cover, and mapping species occurrence across the landscape (Rodgers et al. In press). The South Florida Water Management District, NPS, and U.S. Fish and Wildlife Service conduct this survey every 2 years.

In addition to the interagency DASM monitoring project, the NPS also has independent monitoring projects. The Corridors of Invasiveness project is conducted by the NPS South Florida/Caribbean Network. The monitoring goal of the Corridors of Invasiveness project is to detect newly emerging invasive plant species in or near the NPS park units of south Florida, including Everglades National Park, Biscayne National Park, and Big Cypress National Preserve. This survey is conducted every 5 years. The NPS Exotic Plant Management Team (EPMT) also conducts efficacy plot monitoring on NPS lands. This monitoring effort has established permanent plots within areas of known invasive exotic infestation and monitors the plots pre- and post-treatment. Chance observations are also reported and recorded from reliable sources through EDDMapS (Early Detection and Distribution Mapping System), an on-line invasive species distribution mapping system (www.eddmaps.org).

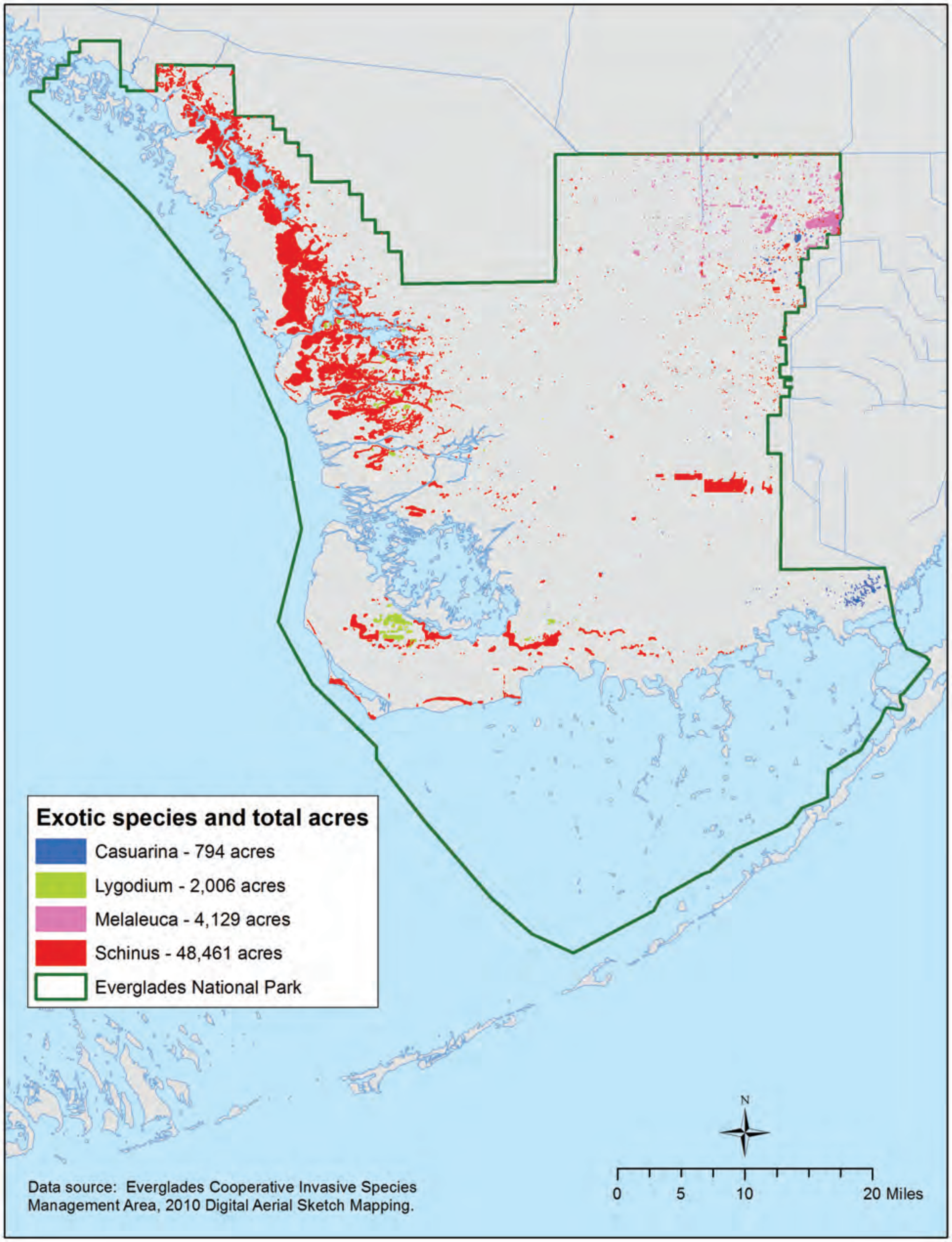



**Figure 1. The 2010 distribution of the four invasive exotic plant species monitored with the DASM technique for Everglades National Park.**

### *Status of the Indicator in the Current Year and Trends over Time*

The 2010 DASM data are the most current data available for estimating the cover and density of the four priority exotic species described above. At the time of this report, approximately 99% of the melaleuca in ENP has been initially treated (treated once). However, more than 4,000 acres of melaleuca still remain, of which 1,600 acres still need initial treatment. The 1,600 acres consist of dense (greater than 50% cover) to very dense (greater than 75% cover) melaleuca in the northeastern part of ENP. The majority of Australian pine within ENP has received initial treatment; however, about 800 acres of low (0.1–25%) to moderate (26–50% cover) Australian pine infestation remain in the southeastern part of ENP and are still in need of initial treatment.

Old World climbing fern was first reported in ENP in 1999, growing in the remote, sparsely wooded coastal marshes along the western part of ENP. At the time Old World climbing fern was reported, it was estimated to cover less than 300 acres. Due to a combination of the plants' biology, inaccessibility of infested sites, limited treatment options, and limitations on funding, Old World climbing fern is expanding its range. Today, Old World climbing fern has established in approximately 2,000 acres of the coastal marshes at densities ranging from >5 to 75% cover and, to a lesser extent, has invaded other habitats across ENP.

Brazilian pepper is the most widespread invasive plant in ENP, is estimated to cover more than 48,000 acres, and is expanding in range. Brazilian pepper is particularly abundant along the fringes of the mangroves at densities ranging from >5 to 75%. In some instances, individual stands of Brazilian pepper cover 4,000 to 6,000 acres. Due to a combination of the plants' biology, inaccessibility of infested sites, and limitations on funding, a cost-effective strategy for systematically removing Brazilian pepper from the park—without reducing treatment of melaleuca, Australian pine, or Old World climbing fern—has not been identified. Rather, treatment of this plant is done sporadically as a part of broader exotics projects and in discreet areas that have been identified as resource management priorities, such as areas of high visitor use or areas where exotic vegetation could have negative impacts on threatened and endangered species.

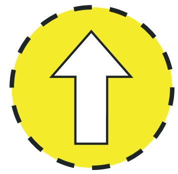
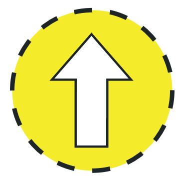
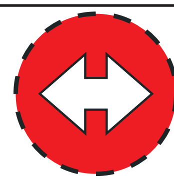
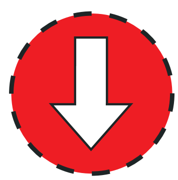
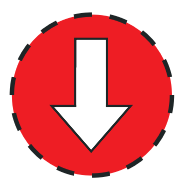
The other 246 exotic plant species currently within ENP have varying invasion potentials and distributions. According to the Florida Exotic Pest Plant Council's (FLEPPC) 2011 list of invasive plant species, 36 of the 246 exotic species in ENP are considered capable of altering native plant communities by displacing native species, changing community structures or ecological functions, or hybridizing with natives. Furthermore, new exotic plant species have established immediately outside ENP boundaries and some have characteristics that indicate they would pose a threat to ENP's natural environment. Insufficient resources limits ENP's ability to contain those species that are restricted in distribution but pose a potential threat to natural areas and to prevent new exotic species from entering ENP.

### *Highlights*

Available funding, current treatment technologies, and the biology, distribution, and accessibility of the particular exotic species, amongst other considerations, influence how park management prioritizes which species are treated. The ENP exotic plant program directs limited resources to the treatment of those exotic species where management actions have the greatest feasibility of achieving the desired state. Melaleuca and Australian pine fall into this category. This prioritization of resources explains why melaleuca and Australian pine show the most positive forecasted trends (Table 1). A second tier of resource prioritization is required within the work on melaleuca and Australian pine, where decisions must be made between maintaining vast areas of melaleuca and Australian pine at or near the desired state versus bringing additional areas of melaleuca and Australian pine under control. Given the management priority of melaleuca and Australian pine, the forecasted trend for all remaining exotic plant species, even those of high management concern, is not positive (Table 1).

**Treated and untreated *Melaleuca quinquenervia*, Everglades National Park.** NPS photo by Hillary Cooley.

**Table 1. Summary of the status of the four invasive plant species of top management concern and the collective group of additional invasive plant species in Everglades National Park.**

| 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. |

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## Indicator 13a: Invasive Exotic Freshwater Fish

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### *Background and Importance*

The invasion of exotic fishes and aquatic invertebrates continues to be a major challenge facing natural resource managers in south Florida. Established in 1947, Everglades National Park (ENP) is mandated to preserve the flora and fauna in a natural state (1934 Everglades Establishment Act) and to "maintain natural abundance, diversity, and ecological integrity of native plants and animals" (1989 Everglades National Park Protection and Expansion Act). The establishment of exotic species in the park ecosystem conflicts directly with these mandates.

Crisscrossed by large and small drainage canals, the landscape of present day south Florida contains deep-water habitats that were uncommon prior to development (Gunderson and Loftus 1993). As of 2007, 34 exotic freshwater fish species have established reproducing populations within Florida (Shafland et al. 2008). When released by pet owners or escaped from culture facilities, exotic fishes find refuge in deep water canals from the seasonal drying and cool winter temperatures that allow species of tropical origin, vulnerable to cold temperatures, to persist (Shafland and Pestrak 1982) and spread over large areas (Courtenay and Robins 1973, Courtenay and Miley 1975, Loftus and Kushlan 1987, Loftus 1988). The first non-native fishes were found in ENP in the late 1960s to early 1970s (Loftus 1988). By 2000, nine non-native species had been observed in ENP and several species were known from the canal system nearby ENP but not yet found within park boundaries (Loftus 2000). As of 2012, 17 non-native fishes have been found in ENP and 14 of these appear to have established reproductive populations (Kline et al. 2013). These exotic species represent a significant addition to the naturally species-poor native fish assemblage found in the freshwaters of ENP (32 species; Loftus 2000). Periodic increases in the number of new exotic species observed appear to correspond with changes in connectivity of ENP marshes with canals resulting from modifications in the water management system (Kline et al. 2013). Preventing future introductions may be the most effective means to manage exotic fishes because effective control or elimination of exotic fishes is difficult and may be impractical within the extensive wetlands of the Everglades (Loftus 1988).

### *Desired State of Conservation*

The rate of new introductions and relative abundance of exotic fish are relevant indicators by which to assess the desired state of conservation of ENP. Few technologies are feasible to control or eliminate exotic fishes in open wetlands (Loftus 1988). Therefore, a decrease in the rate of new introductions is a desired state of conservation of ENP. A freshwater fish assemblage composed entirely of native species is an additional desired state of conservation. A relative abundance of exotic fish >2% indicates a condition warranting significant concern, between 0% and 2% indicates a marginally degraded but potentially ecologically sustainable condition, and 0% indicates the optimal condition. These criteria were developed by Dr. Joel Trexler, Florida International University, for Shark River and Taylor sloughs in the Freshwater Fish and Macroinvertebrate section of the System-wide Ecological Indicators for Everglades Restoration (SEIER) reports (Doren et al. 2008).

### *Description of Indicator Monitored*

Monitoring efforts are in place to detect new exotic species and track their distribution within ENP marshes. All fish monitoring projects within ENP offer the potential to collect exotic species, and visual observations verified by ENP staff can provide important records of new exotic species occurring in the park. Previous studies provide a baseline condition against which to assess the current exotic species condition. Loftus (1988) documented the early history of invasions by exotic fishes into ENP. Trexler et al. (2000) summarized the relative abundance of exotic fishes from monitoring efforts in ENP from before 2000. Kline et al. (2013) revisited the history of invasions into ENP associated with major water management changes, presented a summary of freshwater monitoring efforts after 2000, and provided accounts of exotic species introduced after 2000. The history of introductions reported by these studies was used to calculate a rate of new introductions of exotic fishes to ENP (number of new species per year) starting in the time period 1947–1949 and continuing on a decadal basis (e.g., 1950–1959, 1960–1969, etc.) to 2010–2012. The decadal time scale was used to reduce the influence that subjectively selected time scales could have on the calculation of rate of introductions.

Everglades National Park's long-term monitoring effort has used a 1-$m^2$ throw trap to quantitatively sample the small-fish (<80 mm standard length) assemblage in northern Shark River Slough (Fig. 1) since the 1978 water year (ending April 1978). These data are used to assess the relative abundance of exotic fish within wet prairie and slough habitats based on water years (e.g., the 2000 water year is May 1999 to April 2000). The relative abundance of exotic fish is also assessed with throw traps at three sites in southern Shark River Slough and three sites in Taylor Slough (Fig. 1) under a cooperative agreement between ENP and Dr. Joel Trexler (Florida International University), combined with data collected in northern Shark River Slough, and reported in the SEIER reports (Doren et al. 2008).

A park-wide sample by ENP, taken with the goal of tracking the spread of exotic species throughout the freshwater marshes, has been conducted in October annually from 2004

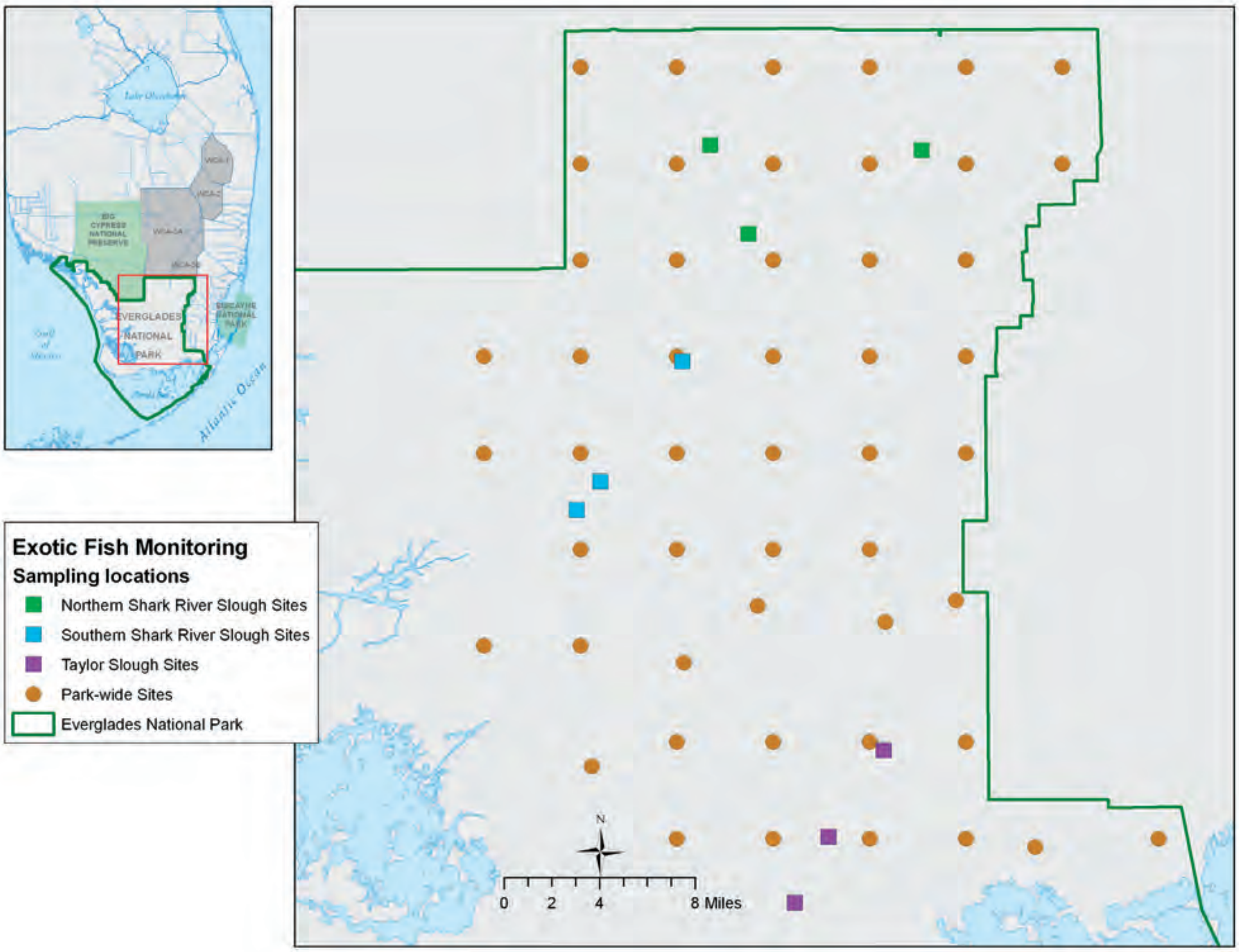



**Figure 1. Map of monitoring locations for exotic fish indicators.**

to 2011. Samples are collected from 50 sites throughout the freshwater area of ENP including slough, Rocky Glades, marl prairie, and mangrove fringe habitats (Fig. 1). Six minnow traps are set at each site for 24 hours. This method is known to collect a wide variety of species, including exotic species, and generally characterizes the small-fish assemblage at a site. This project also estimates the frequency of occurrence of exotic fishes (percentage of sites where at least one fish of any exotic species was collected), which can be used as an indication of spatial distribution of non-native fishes.

### *Status of the Indicator in the Current Year and Trends over Time*

When ENP was established in 1947, there were no known exotic fishes inside park waters. The exact dates the first exotic fishes (black acara, *Cichlasoma bimaculatum*, and walking catfish, *Clarias batrachus*) were found in ENP is unknown but is presumed to be in the late 1960s to early 1970s (Loftus 1988; Fig. 2). Between the late 1960s and 1979, three exotic species were observed in ENP. Between 1980 and 1992, six new exotic fishes were observed in ENP bringing the total to nine (Fig. 2). No new species were observed between 1993 and 1999. Between 2000 and 2012, eight additional exotic fishes were observed in ENP (Fig. 2). For an assessment of the rate of introductions of new species on a decadal basis, we chose to split the first observation of black acara into the 1960s and the walking catfish into the 1970s because exact dates are unknown. As a result, 0.1 new species per year were recorded in the 1960s and 0.2 new species per year were recorded in the 1970s. In the 1980s, the rate of introductions increased to 0.5 species/yr shortly after the construction and operation of the South Dade Conveyance System was completed and operations began routing additional water to the eastern side of ENP from canals (Kline et al. 2013, Kotun and Renshaw 2013). In the 1990s, only one new species was observed (0.1 species/yr) during a time when water management was relatively consistent after an increase in pump station capacity in 1992 (Kline et al. 2013, Kotun and Renshaw 2013). In the 2000s, there was an increase in the rate of new exotic species to 0.7 species/yr coincident with major water management changes, including the Interim Structural and Operational Plan and the Interim Operational Plans (ISOP/IOP), which routed additional wa-

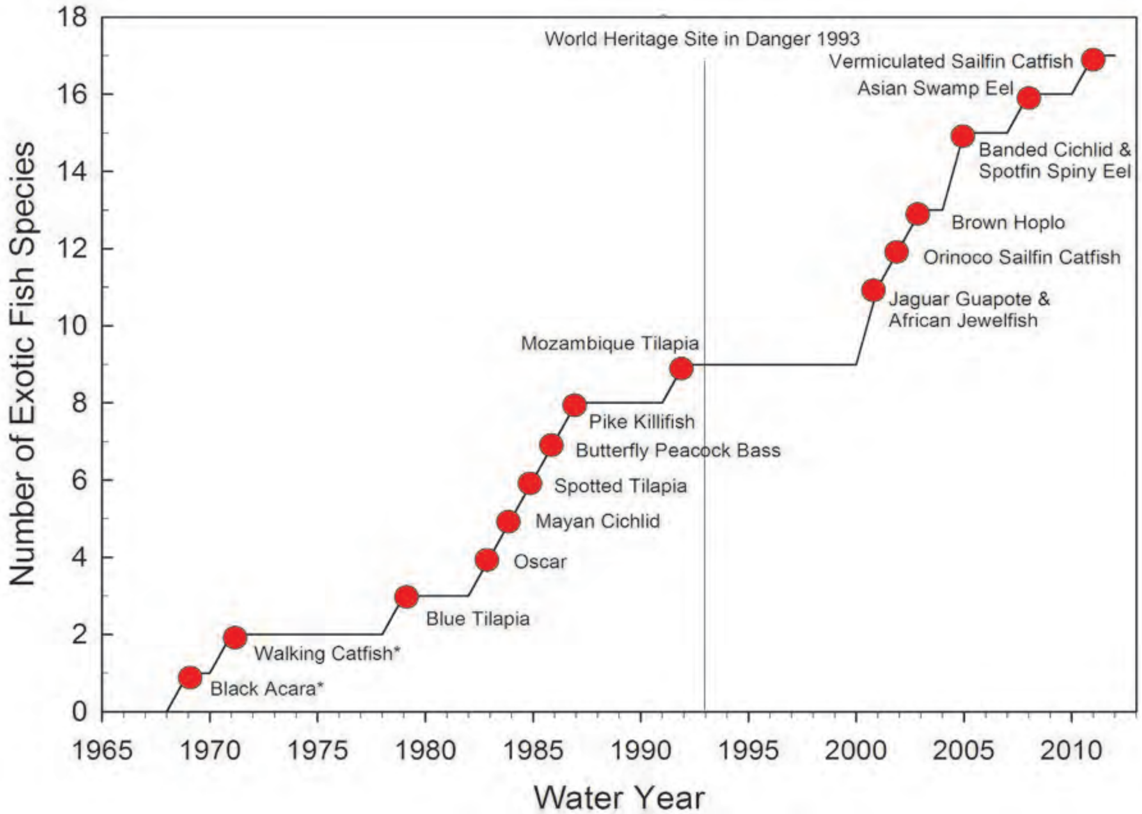



**Figure 2. Timeline of the introduction of exotic fish species into ENP.** * denotes an approximate date.

**Exotic fish in bucket. Clockwise from one o'clock: brown hoplo, African jewelfish, Mayan cichlid, black acara, jaguar guapote, and black acara again.** Photo by Jeff Kline, ENP.

ter to the eastern side of ENP, raised canal water levels, and increased connectivity of canals to ENP marshes (Kline et al. 2013, Kotun and Renshaw 2013). This increase in species and the increased rate of introductions since 2000 represents a degradation of the aquatic fauna assemblage in ENP, though no new species were collected after 2010. At present, 17 species of exotic fish have been observed in ENP, and of these, 10 species are in the family Cichlidae.

No exotic fishes were collected at the long-term monitoring sites within northern Shark River Slough from the start of the project in 1978 through the 1984 water year. The first exotic fish (a black acara) was collected in the 1985 water year, but no other individuals were collected until 1991 (Fig. 3A). In the 1993 water year, the relative abundance of exotic fish peaked at 2.5% of the total catch. Since then, the relative abundance of exotic fish was consistently less than 2% and no exotic fishes were collected in the 2011 water year (Fig. 3A). The cumulative number of exotic species reached three species by 1993 and then increased to four species in 1995 (Fig. 3B). No new species were collected until the 2004 water year. Between 2004 and 2008, four additional exotic species were collected (Fig. 3B). The relative abundance in both Shark River and Taylor sloughs was <2% in 2012, similar to that reported in the 2009 SEIER. However, exotic species were present at the throw-trap sites in the slough habitats indicating a moderately degraded, but stable status.

Exotic fish were collected at a high relative abundance and frequency of occurrence in the parkwide samples collected from 2004 to 2009; however, catches were lower in 2010 and 2011. Between 2004 and 2009, an average of 2 to 8 exotic fish were caught per site (Fig. 4A) and the relative abundance of exotic fish was between 8 and 18% of the total catch, warranting a negative condition (Fig. 4B). At least one exotic fish was collected at 56–78% (28–39 sites) of the 50 sites between 2004 and 2009 (Fig. 4C). The relative abundance and frequency of occurrence of exotic fish dropped following a cold weather event in January 2010 (Fig. 4B and C). In 2010 and 2011, the mean catch dropped below an average of one exotic fish per site and the relative abundance of exotic fish dropped below 2%, warranting a cautious condition and positive trend as-

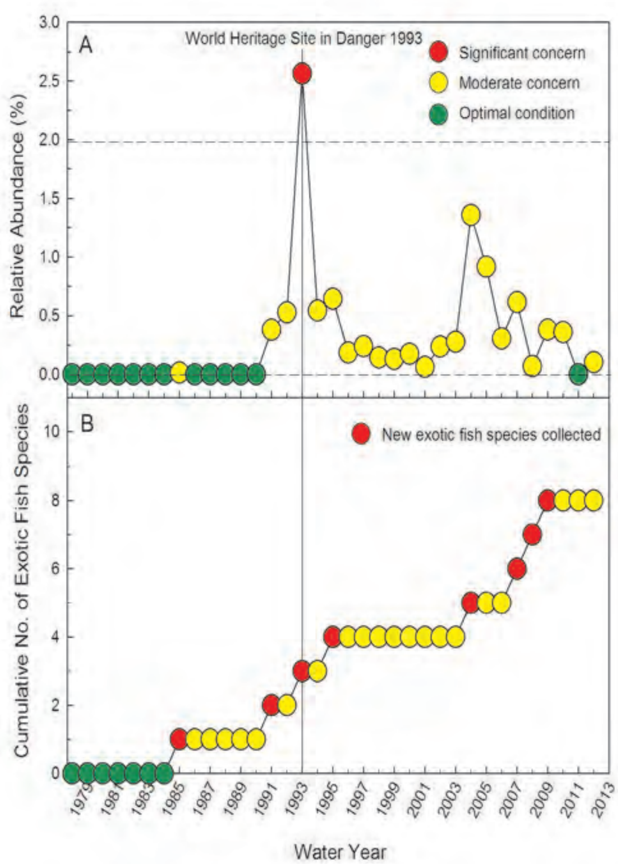



**Figure 3. The A) relative abundance and, B) cumulative number of exotic fish species collected with throw traps in northern Shark River Slough from 1978 to May 2012.**

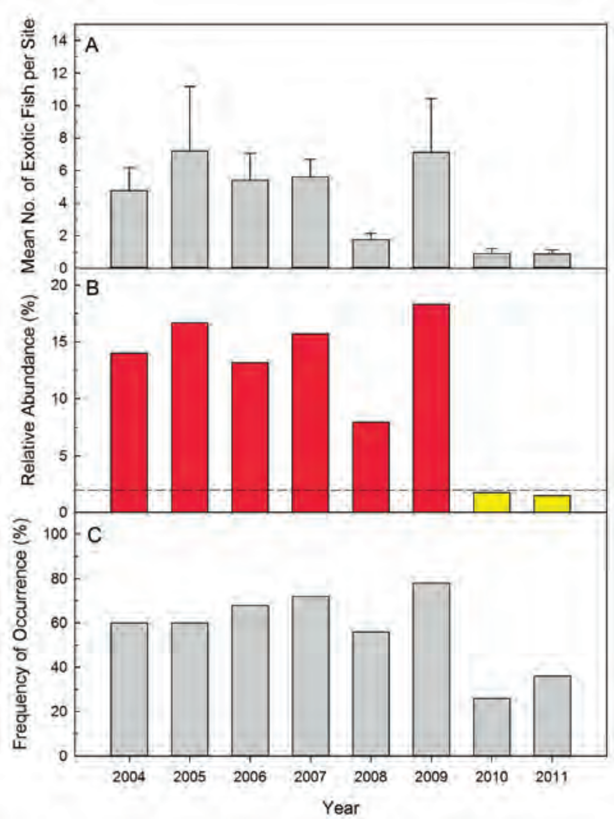



**Figure 4. The A) mean number per site, B) relative abundance (%), and C) frequency of occurrence of exotic fish at 50 sites sampled in October of each year during 2004–2011 throughout the freshwaters of ENP.** A relative abundance of >2% is the threshold for significant concern (red) and >0 and <2% indicates a moderate concern rating (yellow).

sessment (Fig. 4B). In 2010, exotic fish were only collected at 13 sites (26%). In 2011, exotic fish were collected at 18 of 50 sites (36%; Fig. 4C) and were at a relative abundance >2% at 14 sites (Fig. 5), an indication the exotic fish populations were expanding.

## *Highlights*

The rate of new introductions has increased since 2000, a significant concern and a negative trend (Table 1). Seventeen species of exotic fishes have been observed in ENP, which represents a significant change in the composition of freshwater fishes. The 10 species of Cichlidae, of which there are no native species in Florida, make it now the largest family of freshwater fishes found in ENP. Increases in the number of exotic introductions appeared to follow changes in water management that altered the connectivity of canals to ENP marshes (Kline et al. 2013). Incorporating invasive species control into the adaptive management process of hydrologic restoration may help reduce the spread of exotic fishes into natural areas and limit degradation.

In the slough habitats exotic fishes tended to be <2% of the total catch, but across the greater freshwater area, exotic fishes were >2% of the total catch between 2004 and 2009, a significant concern. However, since the 2010 cold weather event, the relative abundance of exotics dropped below 2%, but exotics were caught in more locations in 2012 than in 2011, suggesting caution with an undesirable trend toward a higher relative abundance (Table 1). The vulnerability of tropically derived exotic species to periodic cold winter temperatures may be a key to their management. Schofield et al. (2009) suggest restoring or modifying unnatural deep-water habitats such as canals, borrow ponds, and ditches to allow natural winter cooling, which could help control exotic fish populations.

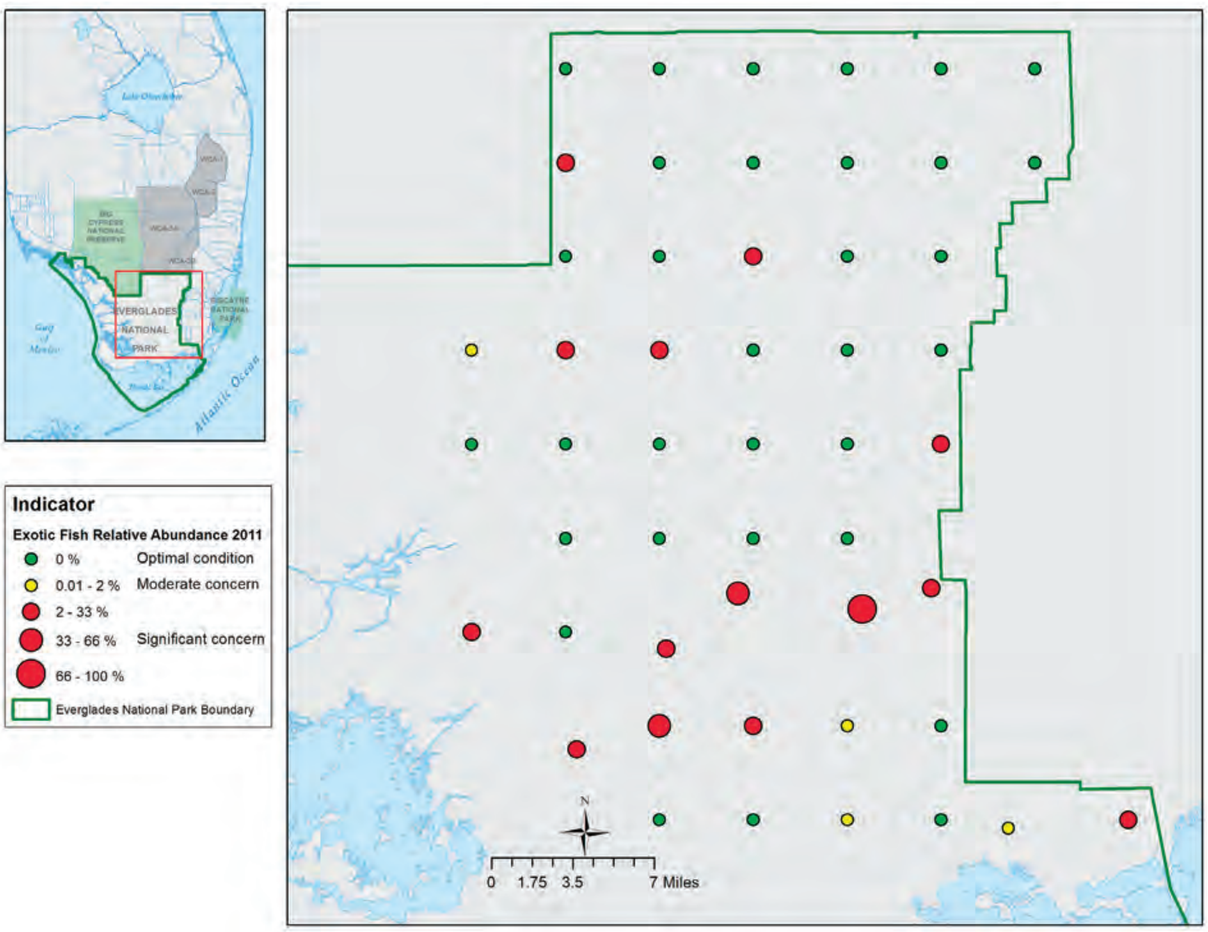
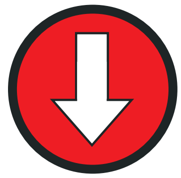
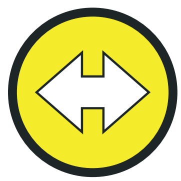
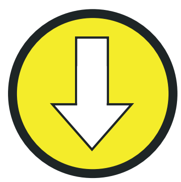



**Figure 5. Relative abundance of exotic fish at 50 sites sampled in October 2011.**

**Table 1. Invasive exotic freshwater fish.**

| Criteria | Desired State of Conservation | Condition & Trend | Rationale |
|---|---|---|---|
| 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. |

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## Indicator 13b: Invasive Exotic Herpetofauna

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### *Background and Importance*

The prolonged invasion of south Florida by myriad nonnative reptile and amphibian species is well documented. The region enjoys a subtropical climate, is a major gateway of global trade in live animals, and supports a heavily populated, culturally diverse metropolis of high relative wealth—all circumstances that aid the introduction, establishment, and spread of invasive species (Chiron et al. 2010, Pyšek et al. 2010, Engeman et al. 2011). Once established, these species rarely prove manageable. Rather, their ability to persist and flourish presents the potential to negatively impact native wildlife populations, change ecosystem structure and function, become a nuisance to human communities, and/or alter the historic character of the invaded area.

Recent studies reveal that the invasion of Florida by herpetological species is particularly severe. As of 2011, 56 reptile and amphibian species were established in the state, a number unmatched anywhere in the world (Krysko et al. 2011). The vast majority of these species are found in southern Florida, persisting around and—in some cases—within the Everglades ecosystem (Meshaka 2011). For more than a century, repeated inventories of reptiles and amphibians have documented an accelerated rate of new introductions (King and Krakauer 1966, Wilson and Porras 1983, Meshaka et al. 2004, Meshaka 2011). Nonnative invaders now account for more than one-fourth of the herpetological species presently found in Florida (Meshaka and Ashton 2005).

Given limited resources, competing management priorities, and a paucity of effective control tools, it is impractical to attempt management of all nonnative reptile and amphibian species currently established in and around Everglades National Park (ENP). National Park Service policies stipulate that species that present the greatest potential for impact and/or the greatest promise for control are afforded top priority (National Park Service 2006). In accordance, three species of considerable concern have been targeted for management: the northern African python (*Python sebae*), the Argentine tegu (*Tupinambis merianae*), and the Burmese python (*Python molurus bivittatus*).

The northern African python appears to be established over a relatively small area of central Miami-Dade County that immediately borders the northeastern corner of ENP. The Argentine tegu—an omnivorous, terrestrial lizard of considerable size—is well established in southern Miami-Dade County, and multiple individuals have been intercepted along the ENP border. At present, there is no evidence to suggest that northern African pythons or Argentine tegus are reproducing within park boundaries. The Burmese python, however, is presently well established across a very large swath of south Florida, including all terrestrial ecosystems of ENP.

Collectively, these three species all show potential to spread beyond their current range, negatively impact native wildlife through competition and direct predation, and adapt to new environments. Each of these species, however, exists within a distinct state of invasion relative to the park and—consequently—each serves as a benchmark for the park's larger efforts against nonnative herpetofauna.

**Ongoing surveys can provide one method for monitoring the status of Burmese pythons and other invasive herpetofauna.** Photo by Michiko Squires, University of Florida.

### *Desired State of Conservation*

The desired state of conservation for this indicator would entail a notable decline in the number of nonnative herpetofaunal species found in the greater Everglades ecosystem, a decrease in the spatial extent of their occurrence, and a reduction of impacts on park resources from their presence.

Efforts to manage invasive herpetofauna are hampered by the continued introduction of new reptile and amphibian species. Each new arrival demands attention that diminishes the availability of finite resources at the park's disposal. Thus a necessary precursor to attaining our desired state of conservation for established species is to substantially slow the rate of additional introductions with the eventual goal of eliminating new arrivals altogether.

As the park's most effective and least costly management option, prevention remains the preferred conservation scenario. Eradication—through the application of early detection and rapid response protocols—is desired where new introductions do occur, particularly when they threaten resources within ENP. And for well-established species that present little hope for eradication, a desirable long-term management strategy would be achieved when efforts toward containment and resource protection demonstrate success.

More specifically, the following four goals define our desired state of conservation:

**Goal 1:** The rate of new herpetofaunal introductions in and around ENP decreases over time

**Goal 2:** Known invasive species adjacent to ENP are detected and eliminated prior to establishment in the park

**Goal 3:** Recent introductions to the park are effectively addressed and populations of incipient invasive species are eliminated

**Goal 4:** Established populations are contained, decreases in the health/abundance of established populations are achieved, and the effects of these species on resources within ENP are reduced

## *Description of Indicator Monitored*

A series of herpetological inventories has been published for ENP, providing historical snapshots of the reptile and amphibian assemblage in the park (Dalrymple 1988, Meshaka et al. 2000, Rice et al. 2004). Coupled with periodic inventories regularly published for the larger region, these studies also provide a measure of the rate of new introductions experienced over time.

Several ongoing early detection, monitoring, and suppression efforts help inform the status of nonnative reptile and amphibian species in south Florida. Much of this work is performed under the auspices of the multi-agency Everglades Cooperative Invasive Species Management Area (ECISMA), a coalition of partners and cooperators that address invasive species issues across jurisdictions within the region. The ECISMA was first organized through a Memorandum of Understanding in 2008, to which ENP was a formal signatory.

ECIMSA partners continually aggregate and verify observations of nonnative species through telephone, online, and mobile reporting avenues. Rapid response efforts are regularly organized through the ECISMA to assess new arrivals of management concern and attempt the eradication of incipient populations. These include ongoing surveys to assess the status of northern African pythons and ongoing efforts to trap and remove Argentine tegus.

ECISMA partners also work collaboratively on several long-term monitoring and containment efforts. The Everglades Invasive Reptile and Amphibian Monitoring Program (EIRAMP)—spearheaded by the University of Florida—utilizes systematic, periodic surveys along standardized routes to help document the presence and distribution of invasive species within the region. Working on behalf of federal and state authorities, permittees and authorized agents help detect and remove invasive reptiles within their respective jurisdictional boundaries. ECISMA partners also solicit involvement from the public through online and in-person training opportunities that encourage and facilitate the reporting and/or removal of invasive reptiles.

Finally, ENP and other partner agencies fund and/or facilitate key research projects that help document the occurrence, life history, impact, and potential for control of invasive herpetofaunal species.

The results of these various efforts have informed our current assessment and will inform subsequent assessments of relevant status and trends.

## *Status of the Indicator in the Current Year and Trends over Time*

### Goal 1: The rate of new herpetofaunal introductions in and around ENP decreases over time

At present, it appears the rate of new introductions in Florida continues to escalate, particularly in the Everglades region. This is evidenced not only by the establishment of new taxa (Krysko et al. 2013, Rochford et al. 2013), but also by the discovery of new satellite populations of species previously established elsewhere in the state (Florida Fish and Wildlife Conservation Commission 2014). If this trend continues unabated, it will become increasingly difficult to prevent new species from colonizing ENP and to manage those species already present.

Nearly 84% of Florida's nonnative herpetofauna has been introduced through the pet trade (Krysko et al. 2011). Although trade is regulated for a handful of exotic reptiles and amphibians through state and federal statute, the vast majority of herpetological species remain available for import and personal ownership. Given the known shortcomings of present authorities, there is little promise that regulation will curb the influx of new introductions in the near future.

**The Oustalet's chameleon (*Furcifer oustaleti*) has recently become established in close proximity to the eastern boundary of ENP.** Photo by Emma Hanslowe.

### Goal 2: Known invasives adjacent to ENP are detected and eliminated prior to establishment in the park

In 2010, researchers offered compelling evidence that the northern African python was established in Florida, following several years of encounters within a limited geographic range in central Miami-Dade County (Reed et al. 2010). These recoveries included individuals of various size classes, gravid females, and exceptionally large specimens (Reed et al. 2011). Although this population presently exists within close proximity of the northeastern boundary of ENP, best available evidence suggests the species has not yet made incursions into the park.

Coordinated, multi-agency surveys for the northern African python have occurred annually since 2009. Surveys are conducted on select days during winter months, when weather conditions are most amenable for detection and capture. Occasional searches conducted by state-permitted hunters augment detection efforts throughout the year, as do opportunistic road patrols by ECISMA partners. An ongoing public information campaign also encourages residents of nearby communities to report all sightings of large constrictors.

Five northern African pythons were removed from the area during 2013, and more than 30 have been seen or captured in the area to date. Population estimates remain elusive, due largely to presumably poor rates of detectability and the inherent difficulties of surveying a largely inaccessible landscape. Still, the species does not appear to have spread beyond a roughly 10-km$^2$ area of infestation over the past decade.

Given their limited distribution and relatively low rate of occurrence, considerable optimism exists that northern African pythons might still be eradicated. This hope is further buoyed by the high level of interagency cooperation involved in the effort. At least one recent case study suggests that an aggressive, multi-agency approach can lead to the successful eradication of an established invasive reptile. However, this typically requires prolonged support and engagement from all partners. The invaded range of the northern African python encompasses a patchwork of differing jurisdictions. It is important to note that not all landowners presently permit survey and removal on their lands—a reality that could compromise the efficacy of future efforts.

### Goal 3: Recent introductions to the park are effectively addressed and populations of incipient invasives are eliminated

A seemingly robust population of Argentine tegus continues to thrive in southern Miami-Dade County in close proximity to the eastern boundary of ENP (Pernas et al. 2012). An omnivorous species, the Argentine tegu can ingest a wide variety of live prey, consume eggs of nesting birds and reptiles, and possibly compete with native species for available resources. Similar impacts have been observed from other areas where this species has become an invasive pest (Enge 2007).

Two complementary programs currently exist to address the Argentine tegu. In 2013, ECISMA partners established an extensive trap line within—and along the periphery of—the core area of infestation in an effort to contain the existing

**Despite its considerable size, the cryptic habits and coloration of the northern African python make detection difficult.** NPS photo by Lori Oberhofer.

population and monitor for spread. That same year, the U.S. Geological Survey (USGS) established a second network of traps along the eastern boundary of ENP nearest the area of infestation, attempting to intercept individuals moving westward toward the park along known dispersal corridors. Both networks—which include both live animal traps and motion-activated cameras—are tended through late October, after which tegus enter a prolonged period of dormancy until the following February. Telemetry work has also been conducted to better understand patterns of nesting and dormancy in south Florida, and several private trappers have been working under state permit to aid in the removal of tegus.

**Argentine tegus are routinely trapped along the eastern boundary of ENP.** Photo by Emma Hanslowe.

Collectively, all efforts resulted in the removal of 182 tegus of various size classes in 2013 (Eckles 2013). Of these, 11 were intercepted by the USGS along the eastern boundary of ENP. Because trapping and interdiction efforts against Argentine tegus are relatively new, little can be inferred at present regarding the relative size and health of the target population. Nonetheless, results from the initial years of effort indicate that the population is firmly established and that individuals are utilizing dispersal corridors to invade new locations. The ability to continue containment and interdiction programs against tegus remains questionable, as these programs are labor intensive and generally lack necessary funding and personnel.

**Goal 4: Established populations are contained, decreases in the health/abundance of established populations are achieved, and the effects of these species on resources within ENP are reduced**

The Burmese python is now well established in the Everglades region. Because they share many characteristics with northern African pythons, assessing the relative size and health of the population is similarly difficult for Burmese pythons. Nonetheless, observations and captures confirm that pythons are likely present throughout all terrestrial habitats of ENP and now range considerably farther north and west

**Burmese pythons are now regularly encountered along roads and levees that traverse the vast Everglades landscape.** Photo by Michiko Squires, University of Florida.

of park boundaries (Florida Fish and Wildlife Conservation Commission 2014).

Recent studies on the ecology of the Burmese python in Florida shed some light on the cost of establishment. Direct predation on a wide variety of native, warm-blooded wildlife is well documented (Snow et al. 2007, Dove et al. 2011). For some taxa, the results have been severe. The presence of Burmese pythons has been linked to a precipitous decline in the number of small and medium-sized mammals observed in the park (Dorcas et al. 2012). Among this group, foxes and marsh rabbits seem particularly impacted, as sightings in the park have become exceedingly rare.

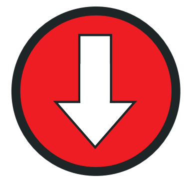
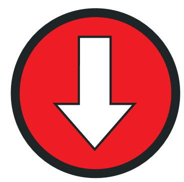
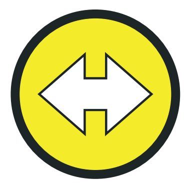
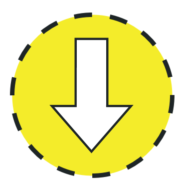
Current control techniques provide virtually no hope for eradication of Burmese pythons (Reed and Rodda 2009). Applied experience also reveals that these techniques offer limited value in suppressing the current population across the vast wilderness of ENP. Furthermore, recent research continues to color the Burmese python as a surprisingly adaptable species whose influence, perhaps, has not yet been fully felt (Mazzotti et al. 2007, Dove et al. 2012, Hart et al. 2012).

### *Highlights*

Invasive species issues have sometimes taken a back seat to landscape-scale Everglades restoration efforts. This has perhaps partially contributed the current condition and trends detailed above and summarized in Table 1 below.

More recently, however, the South Florida Ecosystem Restoration Task Force (SFERT)—representing senior policy advisors from federal, state, local, and tribal interests—has increasingly prioritized action against harmful nonnative species. In cooperation with the ECISMA, the SFERT began drafting a strategic action framework in 2013 that, when fully developed, aims to orchestrate existing efforts against invasive species and could provide opportunities to better meet the desired state of conservation described herein.

**Table 1. Summary of the herpetofauna indicator criteria of significance in Everglades National Park.**

| Criteria | Desired State of Conservation | Condition & Trend | Rationale |
|---|---|---|---|
| **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. |

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# Indicator 13c: Invasive Exotic Marine Species

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## *Background and Importance*

Biological invasions can negatively affect the distribution and abundance of native species through predation, competition, and habitat alteration. Invasive species are a major contributor to local and global extinctions (Vitousek et al. 1997, Mack et al. 2000).

Several marine invasive species have been reported in south Florida, including several acorn barnacle species (*Balanus* spp.), the Asian green mussel (*Perna viridis*), the Pacific Ocean jellyfish (*Phyllorhiza punctata*), and lionfish (*Pterois volitans* and *P. miles*; Baker et al. 2004). However, the primary marine invasive in Everglades National Park (ENP) is lionfish. Introduced predators such as lionfish, with novel characteristics and behaviors, exploit the naïveté of local prey; thus, invasive predators often have stronger effects on native prey than native predators (Salo et al. 2007).

Lionfish are native to the Indo-Pacific and were first introduced to Florida waters during the mid- to late 1980s (Hamner et al. 2007). Self-sustaining breeding populations are now widespread, making lionfish the first truly invasive marine fish in the Atlantic (Albins and Hixon 2011). Lionfish possess a broad range of traits that make them successful invaders: venomous spines, cryptic form, habitat generality, high competitive ability, efficient predation, rapid growth, high reproductive rates, and resistance to parasites (Albins and Hixon 2011). In addition, there is serious concern that lionfish could act synergistically with existing stressors of marine systems, such as overfishing, hypersalinity, and ocean warming, resulting in severe negative consequences for the local ecosystems, and consequently negatively affecting valuable fisheries (Albins and Hixon 2011).

Lionfish are generalist predators that feed on at least 25 families of native fishes, along with a variety of invertebrates including shrimp and crabs (Albins and Hixon 2008, Côté et al. 2013). They prey on economically and ecologically important species such as groupers, snappers, and parrotfishes (Côté et al. 2013). Although anecdotal information suggests that Atlantic grouper occasionally consume lionfish (Maljkovid et al. 2008), these predators have been systematically overfished throughout the region (Ault et al. 2005). The apparent paucity of predators may be due in part to venomous dorsal, anal, and pelvic fins on lionfish (Albins and Hixon 2011). Densities of lionfish in Atlantic waters often exceed those of the most common native mesopredators (Whitfield et al. 2007) and far exceed lionfish densities in their native range (Green and Côté 2009, Darling et al. 2011). In addition, lionfish in invaded regions reach larger maximum sizes and higher abundances than they do in their native range (Darling et al. 2011).

**Figure 1. Lionfish (*Pterois volitans*).** Photo by James Morris Jr., NOAA.

Lionfish occupy a wide range of habitats including coral reef, seagrass, mangrove, estuary, and man-made structures (Barbour et al. 2010). Lionfish have a wide salinity tolerance and are capable of surviving at lower salinities (Jud et al. 2011); hence, lionfish can potentially invade any habitat type within Florida Bay. Because seagrass beds and mangrove areas are known to be important nursery areas for juvenile fish and invertebrates (Hunt and Nuttle 2007), the impact of the lionfish invasion into Florida Bay is a serious concern.

In the Turks and Caicos Islands, preliminary catch-per-unit-effort (CPUE) of lionfish was about two times higher in seagrass beds, and about four times higher in mangrove areas, than on reef of similar depth (Claydon et al. 2010). Similarly, CPUE for lionfish in the Bahamas was also higher in mangroves than on reefs (Barbour et al. 2010). In addition, prey diversity was higher in mangroves than on reefs (Barbour et al. 2010). Since lionfish that reside in mangrove habitats are of smaller average size than lionfish that reside on reefs of equal depth, an ontological shift may be taking place with mangroves serving as lionfish nurseries (Barbour et al. 2010, Claydon et al. 2010).

Seagrasses are the dominant biological community in Florida Bay and have historically covered more than 90% of the bay; about 7% of the bay is mangrove habitat (Hunt and Nuttle 2007). With higher lionfish CPUE reported elsewhere for these habitats than on reefs (Barbour et al. 2010, Claydon et al. 2010), the importance of seagrass in Florida Bay as a habitat for lionfish should not be underestimated.

Prey diet also differs among lionfish that reside in reef, mangrove, or seagrass habitats. Lionfish diets in estuaries, seagrass meadows, and mangrove habitats are typically dominated by small shrimp (Jud et al. 2011). This may have far-reaching effects since Florida Bay serves as one of the principal nurseries for the offshore Tortugas pink shrimp fishery (Hunt and Nuttle 2007). Florida Bay also provides important spawning habitat for spotted seatrout (Powell 2002), as well as other commercially important species (Powell et al. 1989) that lionfish may impact.

Lionfish are slow-swimming fish that are easily captured or speared. Tagging studies suggest that the majority of lionfish have high site fidelity, even after weeks or months at liberty (Jud and Layman 2012). Their high site fidelity and small ranges may make localized population control feasible since lionfish removed from a given habitat would be replaced largely through larval recruitment rather than migration (Jud and Layman 2012).

Lionfish are less likely to be observed and reported in Florida Bay than on coral reefs since there are far fewer visitors in the water making observations. Thus, it is possible that invasions in locations like ENP may go undetected for considerable periods of time. To date, only nineteen lionfish have been sighted in ENP. The low number of reports is likely due to the absence of a monitoring program rather than the absence of lionfish, as lionfish are present throughout the surrounding region. Early detection and control of lionfish in these areas may be crucial to offsetting their long-term ecological impacts in these critical ecosystems. Since the Everglades provide critical habitat for numerous commercially, recreationally, and ecologically important species, establishment of lionfish is of particular concern.

### *Desired State of Conservation*

Lionfish densities will likely increase until resources become limiting, either by exceeding the carrying capacity of the local environment or through competition with native species; thus, the potential for predation pressure on the forage fish community, and ultimately the competition with economically important species, is of grave concern. The desired state of conservation is to eliminate the presence of lionfish, or realistically, to minimize the number of introduced lionfish in ENP to an acceptable level through periodic and repeated monitoring and removal efforts. Since adult lionfish have few (if any) predators in their introduced habitats, the potential for introduced lionfish to displace native predators would remain high. Furthermore, in a situation of increasing lionfish abundance, it is possible that lionfish will begin preying upon other economically important native predators whose populations may already be threatened due to overfishing, habitat degradation, and other factors. Thus, the predation impact of lionfish also should be measured to track the effect of their invasion on the native community. In addition, the spatial distribution of lionfish within ENP should be documented throughout the invasion.

### *Description of Indicator Monitored*

ENP currently has no established lionfish monitoring program. Nineteen lionfish have been reported from opportunistic sightings from either park staff or visitors. Five of the lionfish were found in hardbottom habitat, while one sighting was from a seagrass bed. All of the lionfish reported were under 27 cm total length.

ENP should establish a monitoring program to measure the effect of lionfish on the Florida Bay ecosystem. Monitoring the effectiveness of lionfish removals and setting removal frequency targets are critically important to measuring the extent of the invasion. To manage the lionfish invasion, ENP would focus on controlling the size of local lionfish populations because the number of lionfish in an area largely dictates the severity of their impact.

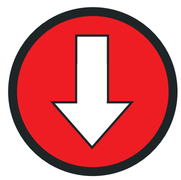
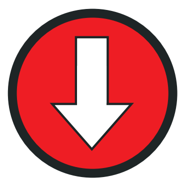
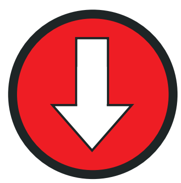
To assess lionfish predation impacts, ENP should monitor trends in the diversity and biomass of prey-sized invertebrates and fish in relation to lionfish density and biomass. The maximum size of prey that lionfish can consume is largely determined by their gape size (i.e., mouth-opening size). Lionfish have been documented to consume prey greater than 40% of their total length. As a result, the vulnerability of native species to lionfish predation depends on the size of the lionfish in the area. Lionfish are capable of growing to well over 40 cm total length in their introduced range; therefore, fishes and crustaceans up to 15 cm length could be consumed. Lionfish of this size can be easily enumerated during visual surveys at predetermined locations within the marine areas of ENP.

Lionfish have been reported from all major marine seafloor and substrate types within the Atlantic and are capable of establishing themselves in all habitat types found in Florida Bay. All lionfish reports will be documented and the spatial location, habitat type, and depth of the lionfish sighting will be recorded.

### *Status of the Indicator in the Current Year and Trends over Time*

Lionfish were first reported in ENP in 2010. Due to the absence of monitoring and the short time period since introduction, no trend can be established at this time. However, the potential for lionfish recruitment into Florida Bay is very high. Lionfish have been reported in large numbers right outside the park boundary along the Intracoastal Waterway by the Florida Fish and Wildlife Conservation Commission and other research entities. We expect that the number of lionfish sightings within ENP will continue to increase over time (Table 1).

**Table 1. Summary of the lionfish indicator criteria of significance in Everglades National Park.**

| Criteria | Desired State of Conservation | Condition & Trend | Rationale |
|---|---|---|---|
| **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. |

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