South Florida Ecosystem Restoration Task Force

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System-wide Ecological Indicators for Everglades Restoration 2018

EvergladesRestoration.gov

Restoring America's Everglades

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EXECUTIVE SUMMARY

This report is a digest of scientific findings about eleven system-wide ecological indicators in the South Florida Ecosystem (Table 1). These eleven indicators have been carefully selected in order to focus our ability to assess the success of the Everglades restoration program from a system-wide perspective.

Table 1. System-wide Ecological Indicators
- Invasive Exotic Plants
- Lake Okeechobee Nearshore Zone Submerged Aquatic Vegetation
- Eastern Oysters
- Crocodilians (American Alligators & Crocodiles)
- Fish & Macroinvertebrates
- Periphyton
- Wading Birds (White Ibis & Wood Stork)
- Southern Coastal Systems Phytoplankton Blooms
- Florida Bay Submersed Aquatic Vegetation
- Juvenile Pink Shrimp
- Wading Birds (Roseate Spoonbill)

These indicators are key organisms that we know (through research and monitoring) respond to environmental conditions in ways that allow us to measure their responses in relation to restoration activities. Because of this, we may see similar ecological responses among indicators. This logical agreement among indicators - a collective response, if you will - can help us understand how drivers and stressors act on more than one indicator and provides a better system-wide awareness of the overall status of restoration as reflected in the ecological responses of these indicators. The more indicators that collectively respond to the drivers and stressors, the stronger the signal that the underlying problem is ubiquitous to the system and is affecting the fundamental ecological and biological nature of the Everglades ecosystem. Fixing these problems is key to fixing the Everglades.

The big picture findings below stem from these collective responses and are the findings that were common to more than one indicator, and to large, important regions of the natural system.

- **None of the indicators have shown improvement over this reporting period and none have met restoration targets.** Seven indicators are red {Lake Okeechobee nearshore zone submersed aquatic vegetation, Eastern oyster, crocodilians, fish & macroinvertebrates, wading birds (white ibis a & wood stork), southwest coastal systems phytoplankton blooms, and wading birds (roseate spoonbill}, three are yellow, (invasive exotic plants, periphyton, Florida Bay submersed aquatic vegetation and monitoring for one (pink shrimp) is no longer adequate to provide a system-wide stoplight color. Some (crocodilians, fish, and wading birds) are showing increasing consecutive years with red stoplights (well below restoration targets) despite individual years when components of the stoplights show improvement (timing of wading bird nesting was slightly earlier in Water Year 17). These results reflect that current ecological conditions are close to the tolerance for many of the indicators and emphasize the importance and urgency of restoration efforts.

- **Long-term tracking of these indicators has provided us information that can and is being used in restoration planning and we are optimistic that once implemented, restoration activities will improve conditions.** For example, restoration activities that provide additional water storage in the Lake Okeechobee, St. Lucie, and Caloosahatchee watersheds as well as storage south of the lake will help to reduce the severity of excess freshwater discharges from Lake Okeechobee, minimize huge fluctuations in salinity, enable oyster populations to thrive, and lead to increased oyster population densities. In addition, additional storage will allow Lake Okeechobee to more closely follow the timing and depths of an ecologically beneficial stage envelope and should enhance submersed aquatic vegetation coverage and density in the nearshore region.

- **Natural events provide insights into restoration.** The extreme drought in Florida Bay in 2015-16 led to the submersed aquatic vegetation (seagrass) die-off in areas of the bay that became hypersaline illustrating the consequences of not restoring freshwater flow to Florida Bay. On the other extreme, the record rainy wet season in 2017 provided the opportunity to send much needed water into Northeast Shark River Slough through the new one-mile bridge, downstream into Picayune Strand via the newly constructed Merritt Pump Station, and across the L-28 levee into Big Cypress National Preserve. Continued monitoring will allow us to assess if the anticipated positive ecosystem responses to more water in these areas are realized.

- **Invasive exotic plants and animals continue to present challenges to Everglades restoration**. While integrating herbicide treatments, fire, and the substantial increase in the number of biocontrol agents released throughout the South Florida Ecosystem is improving overall management outcomes for some invasive plant species, the geographic distribution of some species has increased and, due to a lack of maintenance control measures, populations previously under control have resurged. The greatest threats to invasive plant management success in the Everglades are 1) insufficient resources to address invasive species in critical areas and 2) the continued establishment of new invasive species. There are now 73 of the 79 Category I Invasive Plant Species (FLEPPC 2017) established in the South Florida Ecosystem. Experience gained over the last two decades confirms that containing and reducing populations of highly invasive species often requires substantial initial investment of resources as well as commitment to long-term maintenance control of the populations as restoration proceeds. Established invasive exotic animals such as Burmese pythons, Argentine black and white tegus, and non-native fish threaten native species directly through predation and indirectly through changes in foodwebs. Within Everglades National Park there is strong statistically supported evidence that a rapid increase of non-native fishes is impacting native species, decreasing both fish density and biomass. How this will ultimately affect the ability of these aquatic communities to provide critical food for iconic predators, including wading birds and alligators, remains to be learned.

- **Although concentrations have been reduced substantially, phosphorus (P) continues to be a system-wide water quality concern.** Elevated concentrations complicate water management operations and legal constraints and, as such, can constrain the ability to supply more water to the natural system. As indicated by periphyton nutrient content and biomass, water quality in the Water Conservation Areas has declined since 2014, likely resulting from increased water flows and hence additional P load. Average wet season values of quality, biomass and composition for each of the basins are highly correlated with inflowing total P concentrations, suggesting high sensitivity to loads that change with water flow. This explains why wet years on record show greater impairment in the periphyton indicator than dry years. Water flows are key to restoration of the Everglades as well as the timing and distribution of water movement through the system as those factors will influence phosphorus concentrations and loads entering the marshes. In addition, coastal systems are susceptible to the effects of increased nutrient enrichment from factors such as run-off or local sea-level rise.

- **Monitoring programs continue to have funding challenges.** Budget constraints and expanded monitoring objectives for exotic plants necessitated reductions in system-wide monitoring from a two year to five-year interval. Funding for oyster monitoring in Lake Worth Lagoon by Palm Beach County is uncertain for 2019. Funding for crocodilian monitoring covers only a subset of the areas specified when the system-wide stoplights were established. The number of sampling sites for the southern coastal system phytoplankton bloom indicator have been reduced both in space and time and there is only funding for pink shrimp monitoring in Biscayne Bay. All of these modifications to indicator monitoring have the potential to affect the ability to assess **system-wide** ecological responses to restoration.

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INTRODUCTION

What are ecological indicators and why do we need them?
"An ecological indicator is a metric that is designed to inform us easily and quickly about the conditions of an ecosystem." (Bennett 2000)

"A useful ecological indicator must produce results that are clearly understood and accepted by scientists, policy makers, and the public." (Jackson et al. 2000)

Ecological indicators are used to communicate information about ecosystems and the impact human activity has on them. Ecosystems are complex and ecological indicators can help describe them in simpler terms. For example, the total number of different fish species found in an area can be used as an indicator of biodiversity.

There are many different types of indicators. They can be used to reflect a variety of aspects of ecosystems, including biological, chemical, and physical. Due to this diversity, the development and selection of ecological indicators is a complex process.

National indicators for pollution (for example the ozone index one sees on the daily news) and the economy (for example the gross domestic product reported daily in the news as the measure of national income and output) have been used for decades to convey complex scientific and economic principles and data into easily understandable concepts.

Many ecological restoration initiatives globally and nationally are either currently using or developing ecological indicators to assist them in grading ecological conditions. A few of the larger US restoration programs that are developing and using ecological indicators include Chesapeake Bay, Maryland; San Francisco Bay Delta River System, California; Yellowstone National Park, Montana; Columbia River, Oregon; and the South Florida Ecosystem restoration program.

Indicators make understanding an ecosystem possible in terms of management, time, and costs. For example, it would be far too expensive, perhaps even impossible, to count every animal and plant in the Everglades to see if the restoration was a success. Instead, a few indicator species can be monitored in a relatively few locations to determine the success of the restoration. Indicators can be developed to evaluate very specific things or regions, or to evaluate broad system-wide aspects of an ecosystem.

This report is a digest of scientific findings about eleven system-wide ecological indicators in the South Florida Ecosystem (Table 1). These eleven indicators have been carefully selected in order to focus our ability to assess the success of the Everglades restoration program from a system-wide perspective.

These ecological indicators are organisms that integrate innumerable ecological functions in their life processes. For example, hydrology (water depth, timing, and duration) and water quality affect the types and quantities of periphyton, which affect the types and quantities and availability of fish that feed on periphyton, which affect the amount and availability of fish as food for alligators and wading birds. They're all interconnected, and indicators provide a more pragmatic means to understand those complex interconnections.

Ecological indicators are used because we cannot measure everything all the time. Scientists measure a few attributes of a few indicators precisely because they integrate many ecological and biological functions that either we cannot measure because it would be too expensive and time consuming, or simply because some things are too difficult to measure. Thus—through measuring more simple aspects of the lives of key organisms—we are able to take into account the innumerable biogeochemical and environmental processes they integrate and, through more simple and affordable research and monitoring, we can begin to understand how indicators may respond to ecosystem drivers and stressors such as rainfall, hydrology, salinity, water management, nutrients, and invasive exotic species.

Purpose

This suite of system-wide ecological indicators has been developed specifically to provide a mountaintop view of restoration for the South Florida Ecosystem Restoration Task Force (Task Force) and Congress.

The Task Force, established by section 528(f) of the Water Resources Development Act (WRDA) of 1996, consists of 14 members. There are seven federal, two tribal, and five state and local government representatives. The main duty of the Task Force is to provide a coordinating organization to help harmonize the activities of the agencies involved with Everglades restoration. The Task Force requested that the Science Coordination Group (SCG, a team of scientists and managers) develop a small set of system-wide ecological indicators that would help them understand, in the broadest terms, how the ecosystem and key components are responding to restoration and management activities via implementation of the Comprehensive Everglades Restoration Program (CERP) and other non-CERP restoration projects.

The CERP and REstoration, COordination, and VERification (RECOVER) programs were developed to monitor many additional aspects of the ecosystem, including such things as: rare and endangered species, mercury, water levels, water flows, stormwater releases, dissolved oxygen, soil accretion and loss, phosphorus concentrations in soil and water, algal blooms in Lake Okeechobee, hydrologic sheet flow, increased spatial extent of flooded areas through land purchases, percent of landscape inundated, tree islands, salinity, and many more. The set of indicators included here are a subset from those larger monitoring and assessment programs. They are intended to provide a system-wide, big-picture appraisal of restoration. Many additional indicators have been established that provide a broader array of parameters. Some of these are intended to evaluate sub-regional elements of the ecosystem (e.g., individual habitat types), and others are designed to evaluate individual CERP projects (e.g., water treatment areas). This combination of indicators affords managers information for adjusting restoration activities at both large and small scales.

Goal

Any method of communicating complex scientific issues and findings to non-scientists must: 1) be developed with consideration for the specific audience, 2) be transparent as to how the science was used to generate the summary findings, 3) be reasonably easy to follow the simplified results back through the analyses and data to see a clear and unambiguous connection to the information used to roll -up the results, 4) maintain the credibility of the scientific results without either minimizing or distorting the science, and 5) should not be, or appear to be, simply a judgment call (Norton 1998, Dale and Beyeler 2001, Niemi and McDonald 2004, Dennison et al. 2007). In reviewing the literature on communicating science to non-scientists we realized that the system of communication we developed for this suite of system-wide ecological indicators must be effective in quickly and accurately getting the point across to our audience in order for our information to be used effectively (Rowan 1991, 1992, Dunwoody 1992, Weigold 2001, Thomas et al. 2006, Dennison et al. 2007).

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The approach we used to select these indicators focused on individual indicators that integrated numerous physical, biological, and ecological properties, scales, processes, and interactions to try to capture that sweeping mountaintop view. Based on the available science, we made the underlying assumption that these indicators integrated many additional ecological and biological functions that were not or could not be measured and thus provided an assessment of innumerable ecological components that these indicators integrated in their life processes.

Having too many indicators is recognized as one of the more important problems with using and communicating them (National Research Council 2000, Parrish et al. 2003). Identifying a limited number of focal conservation targets and their key ecological attributes improves the successful use and interpretation of ecological information for managers and policy makers and enhances decision making (Schiller et al. 2001, Parrish et al. 2003, Dennison et al. 2007).

Our goal has been to develop and use a suite of indicators composed of an elegant few that would achieve a balance among: feasibility of collecting information, sufficient and suitable information to accurately assess ecological conditions, and relevance for communicating the information in an effective, credible, and persuasive manner to decision makers. For the purposes of this set of indicators, "system-wide" is characterized by both the physiographic and ecological elements that include: the boundary of the South Florida Water Management District (SFWMD) and RECOVER assessment modules (Figure 1) and the ecological links among key organisms [see Wetlands 25:4 (2005) for examples of the Conceptual Ecological Models (CEM)].

In addition, these indicators will help evaluate the ecological changes resulting from the implementation of the restoration projects and provide information and context by which to adapt and improve, add, replace, or remove indicators as new scientific information and findings become available. Indicator responses will also help determine appropriate system operations necessary to attain structural and functional goals for multiple habitat types among varying components of the Everglades system.

Using a suite of system-wide ecological indicators to present highly aggregated ecological information requires indicators that cover the spatial and temporal scales and features of the ecosystem they are intended to represent and characterize (Table 2; Figure 2). While individual indicators can help decision makers adaptively manage at the local scale or for particular restoration projects, collectively, indicators can help decision makers assess restoration at the system scale.

Table 2. List of South Florida Ecosystem Features Landscape Characteristics

Hydropatterns
- Hydroperiods
- Vegetation Pattern and Patchiness
- Productivity
- Native Biodiversity
- Oligotrophy (low in nutrients)
- Pristine-ness
- Intactness (connectivity/spatial extent)
- Trophic Balance
- Habitat Balance/Heterogeneity

Trophic Constituents and Biodiversity
- Primary Producers (autotrophs - organisms that obtain energy from light or inorganic compounds; and detritus - dead organic material) Primary Consumers (herbivores and detritivores - animals that eat plants or detritus)
- Secondary Consumers (animals that feed upon herbivores and detritivores)
- Tertiary Consumers (animals that feed upon secondary consumers)

Physical Properties
- Water Quality
- Water Management (i.e., when, where, and how much water is moved)
- Invasive Exotic Species
- Salinity
- Nutrients (e.g., Nitrogen, Phosphorus, Sulphur)
- Contaminants (e.g., pesticides, pharmaceutical chemicals, mercury)
- Soils

Ecological Regions (see Figure 1)
- Greater Everglades
- Southern Coastal System
- Northern Estuaries
- Big Cypress
- Kissimmee River Basin
- Lake Okeechobee
- Florida Keys

Temporal Scales (see Figure 2)
- Indicators that respond rapidly to environmental changes (e.g., periphyton)
- Indicators that respond more slowly to environmental changes (e.g., crocodilians)

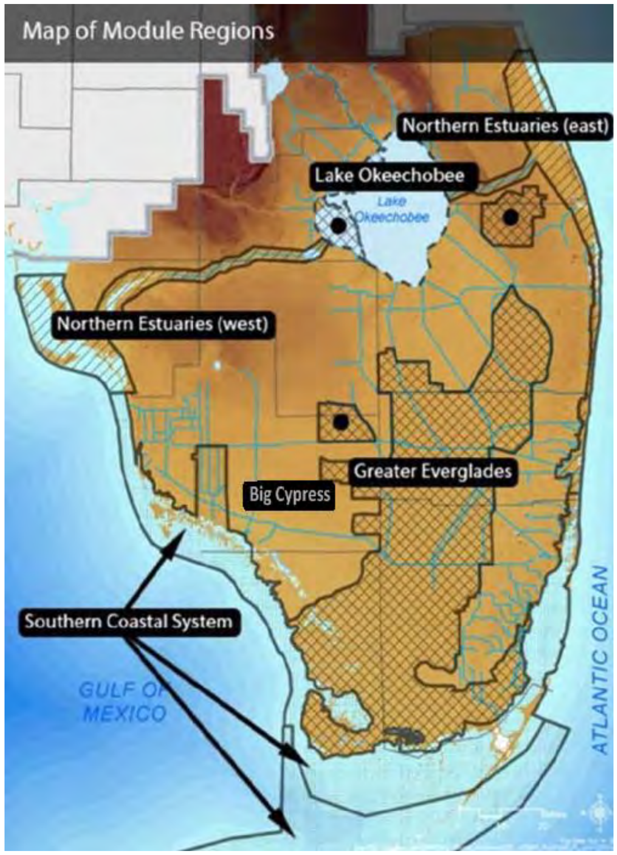

Figure 1. Map of south Florida illustrating the boundary of the SFWMD and the regional assessment modules. Figure courtesy of RECOVER's 2009 System Status Report.

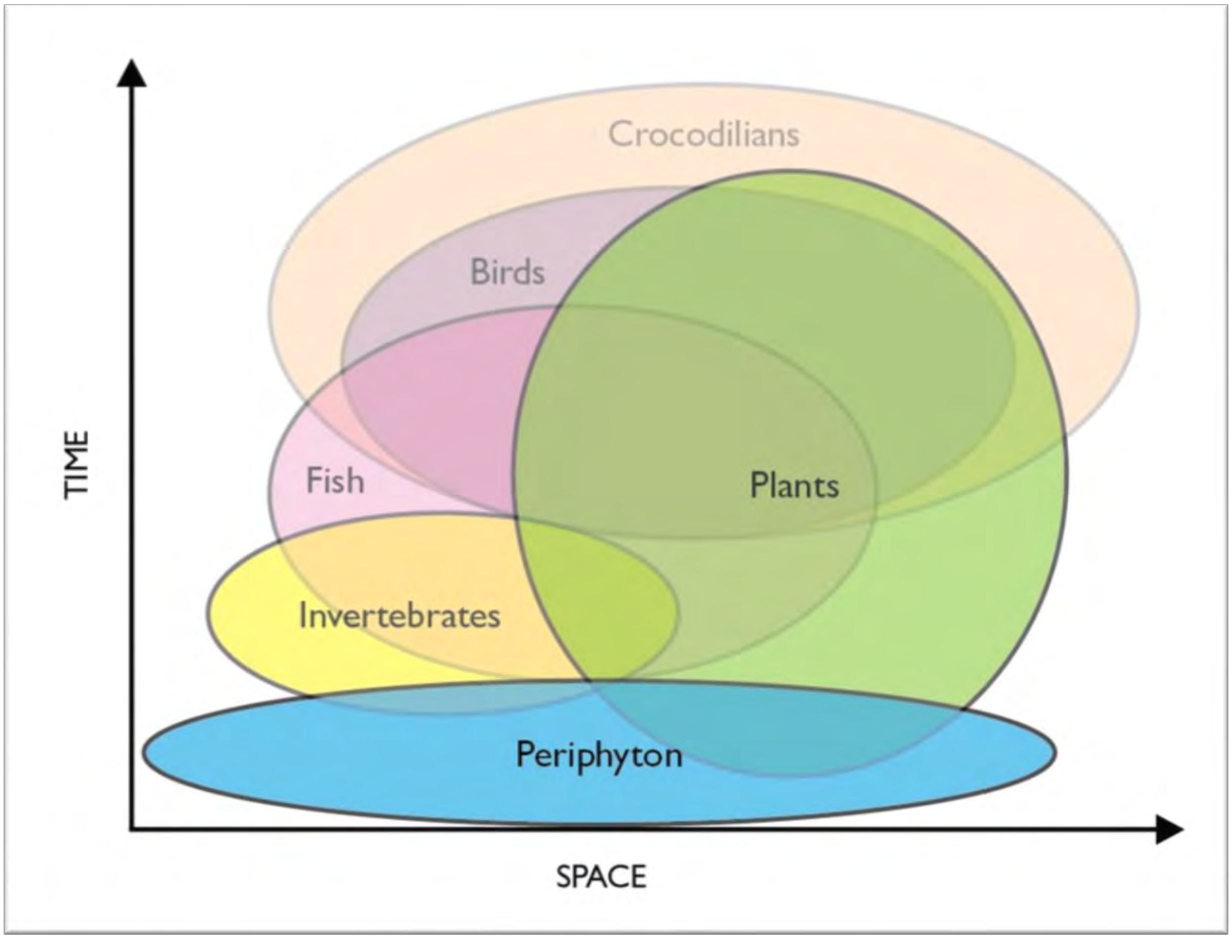

Figure 2. Graphical representation of how the individual indicators (only 6 indicators are shown interrelate with the temporal and spatial aspects of the ecosystem. The suite of system-wide ecological indicators was chosen based upon their collective ability to comprehensively reflect ecosystem response in terms of space and time. For example, periphyton responds to change very rapidly at both small and large spatial scales while crocodilians respond more slowly to change at small to large spatial scales. As indicators, they "cover" different aspects of the ecosystem. The system-wide ecological indicators collectively "cover" the ecosystem in terms of response to change over space and time. This figure is an illustration of how individual indicators may interrelate and respond to restoration in terms of space and time. This figure uses six indicators as an example and is not meant to precisely represent the exact spatial and temporal interactions of the system-wide ecological indicators.

Introduction

We chose stoplights to depict indicator status. There are many different methods that are being used to communicate scientific information in easier-to-understand formats. We evaluated numerous methods and ideas on organizing and communicating complex science and found many helpful ideas. We also noted that most methods were, in the end, still quite complex, and it took more information and explanation to understand the method than we felt made sense if the goal was to make things easier to understand. Therefore, we chose to use one of the most clear-cut and universally understood symbols—the stoplight—with a simple and straightforward findings page to provide a reasonable context for the stoplights.

Details of how stoplight colors are assigned for each indicator are available in a special issue of Ecological Indicators (2009, V9 Supplement 6). In this 2018 report, additional information on indicator calculations is provided to reflect information learned and changes in sampling.

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Hydrologic Context for the System-wide Ecological Indicators: Water Years 2017–2018

Hydrology is a major driver of Everglades ecology. In this section we provide an overview of the south Florida water cycle and a basic description of conditions during the reporting period: Water Years (WY) 2017 (May 1, 2016 to April 30, 2017) and 2018 (May 1, 2017 to April 30, 2018).

The Everglades has a hydrologic cycle, also called a water cycle, uniquely its own. Throughout most of the continental United States to the north, water levels generally rise and fall in tune with the four seasons. There, water levels typically peak during the spring as snow melts and front-driven storms move through, and ebb in the fall at the end of the hot summer stretch. The water cycle of subtropical south Florida and the Everglades, however, is fueled by only two seasons, wet and dry, leading to a reversal of its seasonal high and low water marks. In contrast with conditions to the north, water levels in the Everglades peak in the fall, coinciding with the end of the wet season, and ebb in the spring, coinciding with the end of the dry season when large expanses of wetlands dry out (Figure 3).

Although south Florida is generally considered a wet region (with an average annual rainfall of approximately 52 inches), serious droughts are common because of both longer-term climate variations and the seasonal pattern of rainfall. On average, approximately 77% (or 40 inches) of the total annual rainfall occurs in the May through October wet season, while approximately 23% (or 12 inches) occurs in the November through April dry season (Figure 4).

Historically, prolonged drought cycles are broken by periods of increased tropical cyclone activity (tropical depressions, tropical storms, and hurricanes). In addition, large-scale climate drivers also have a significant impact on south Florida hydrology. The hydrologic conditions during WY 2016 was highly influenced by the El Niño-Southern Oscillation (ENSO), a climatic phenomenon caused by warming sea surface temperatures in the eastern Pacific, which strongly influences dry season rainfall variability in south Florida.

El Niño years have warmer Pacific sea surface temperatures, which translates into above average rainfall and surface water flows during the south Florida dry season. By contrast, La Niña years are associated with cooling Pacific sea surface temperatures, and conversely, dry season rainfall and water flows tend to be below average. WY 2016 was strongly influenced by El Niño as can be seen in the higher than average dry season rainfall (Figure 5).

Summer Wet Season

The wet season begins in late spring, usually around Memorial Day. It is characterized by consistently hot and humid weather, the daily buildup of spectacular cumulonimbus cloud formations, and resultant heavy thunderstorms that are often local and short-term in nature. Other larger systems—including early season storms enhanced by lingering spring-time instability in the upper atmosphere, mid-latitude cyclones, and tropical storms—periodically spike the Everglades with regionally expansive rains.

In response to these meteorological inputs, the Everglades become flooded with an ankle- to waist-deep, slow-moving pool of water through summer and fall, leaving only the high-ground tree islands and hardwood hammocks above water.

The term sheet flow is used to describe this shallow and spatially expansive wetland plain that, unlike a lake or bog, flows like a stream, only much more slowly, almost imperceptibly slowly to the human eye. Spanning from horizon to horizon, this sheet of water flows south through a maze of tree-island-dotted ridges and sinuous low-lying sloughs, giving rise to the name River of Grass coined by Marjory Stoneman Douglas in 1947.

Winter Dry Season

The weather turns mild during the winter half of the year, marking an end to the regular buildup of afternoon thundershowers and tropical storms and thus initiating the dry season, an approximate 6- to 7-month period dominated by a slow shallowing of standing water. As the dry season ensues, more and more land emerges. Water first recedes from the highest perched pinelands and other tree islands. Drainage of the marl prairies follows next, leading to an eventual retreat of water into the lowest-lying sloughs and marshes. The rate of recession may be slowed or even temporarily reversed by sporadic winter rains that are typically brought on by the descent of cold continental air masses from the north. Lower winter evaporation rates also hinder the rate of recession, though it rapidly picks up again in the spring as daylight hours and air temperatures increase evaporation.

Although south Florida is generally considered a wet area by merit of its abundant average annual rain total of 52 inches (with a 70/30 percent wet/dry season split) and its often flooded wetland views, drought and wildfire play vital roles in maintaining the region's unique assemblage of flora and fauna. The ecological health of the Everglades is intimately tied to seasonal and inter-annual fluctuations of the water cycle and is impacted by a combination of:

- Natural processes
    - Rainfall
    - Evaporation
    - Overland flow
    - Groundwater infiltration
- Climatic oscillations
    - El Niño/La Niña
    - Climate change
- Water management manipulation associated with operation of the Central and Southern Florida (C&SF) project and other drainage works for the purpose of:
    - Flood protection
    - Urban and agricultural water supply
    - Environmental protection

Each water year is different in the Everglades, and the hydrologic cycle is characterized by large inter-annual variation – in other words, seldom do we experience average years. The previous two water years illustrate this variation well and are summarized next.

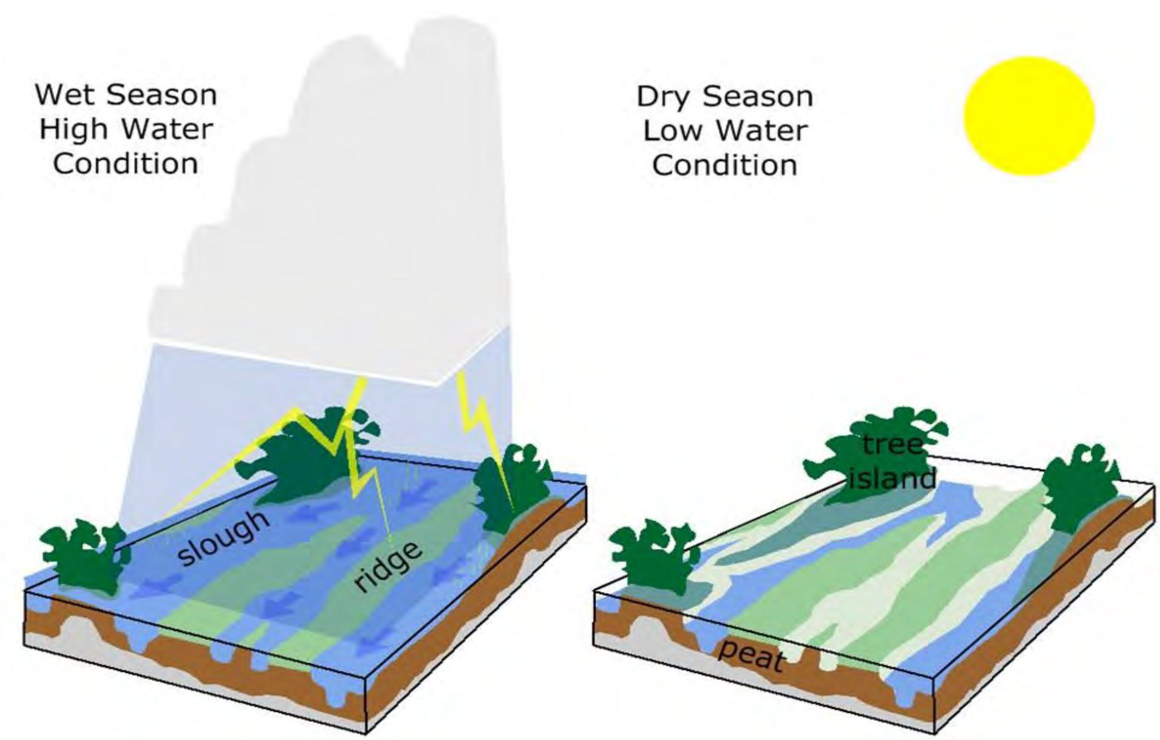

Figure 3. Artistic representations of the Everglades during fall high water and spring low water conditions. During the summer/fall rainy season, a shallow and slow-moving sheet of water inundates the entire ridge and slough landscape (except for the tree islands that usually remain dry). During the winter/spring dry season, water levels drop to the point that only the sloughs usually hold water.

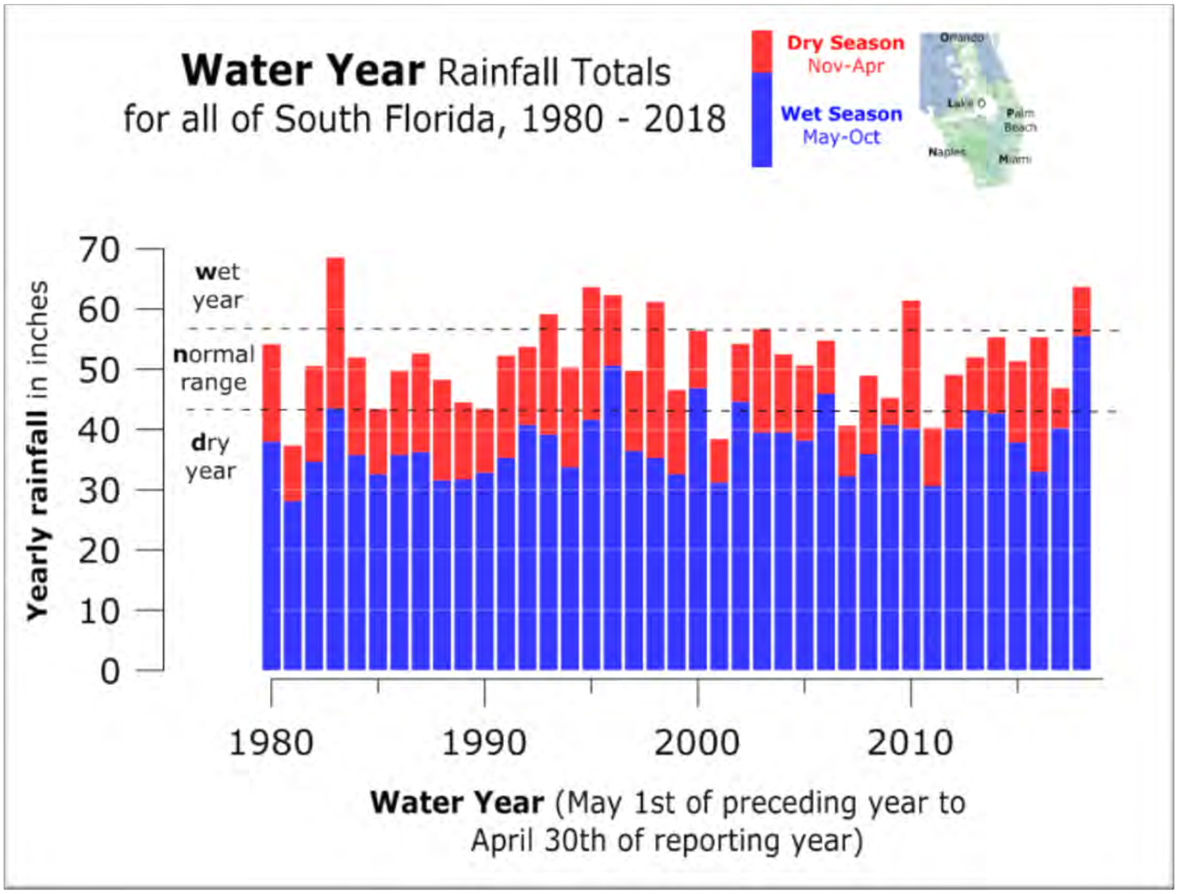

Figure 4. Yearly rainfall (inches) throughout the SFWMD. This graph was produced using daily rainfall data provided by the SFWMD. District meteorologists compute a daily rainfall value for the fourteen major basins and district-wide from rain gauge measurements. See www.Gohydrology.org for more information.

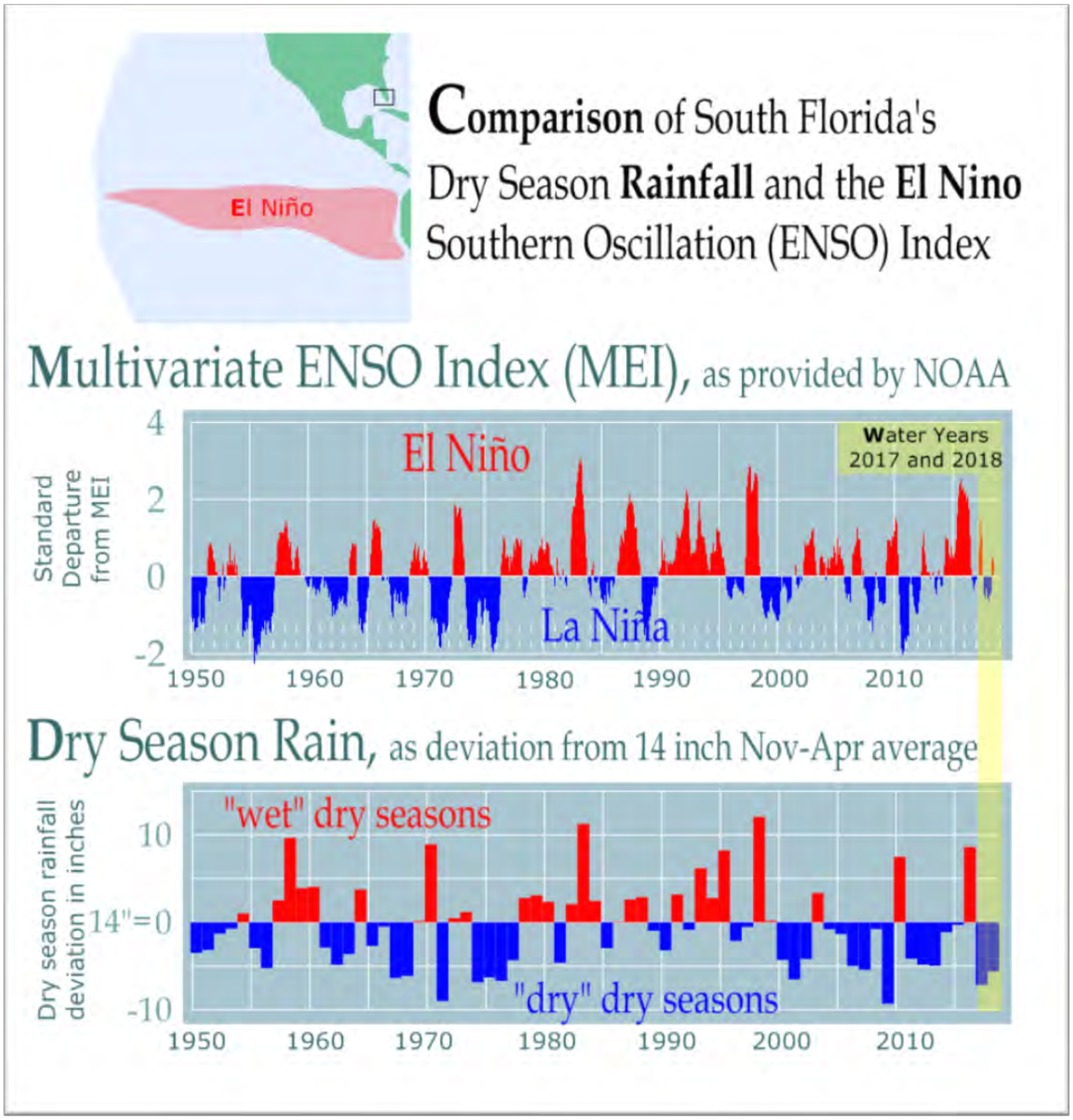

Figure 5. Correlation between the Multivariate ENSO Index (MEI) and winter dry season rain totals for south Florida. The top graph displays the standard departure of the MEI from 1950 to present. The bottom graph shows dry season rainfall for south Florida expressed as a departure (in inches) from the 14-inch November through April long-term average. In general, dry season rain totals are amplified during El Niño events and diminished during La Niña events.

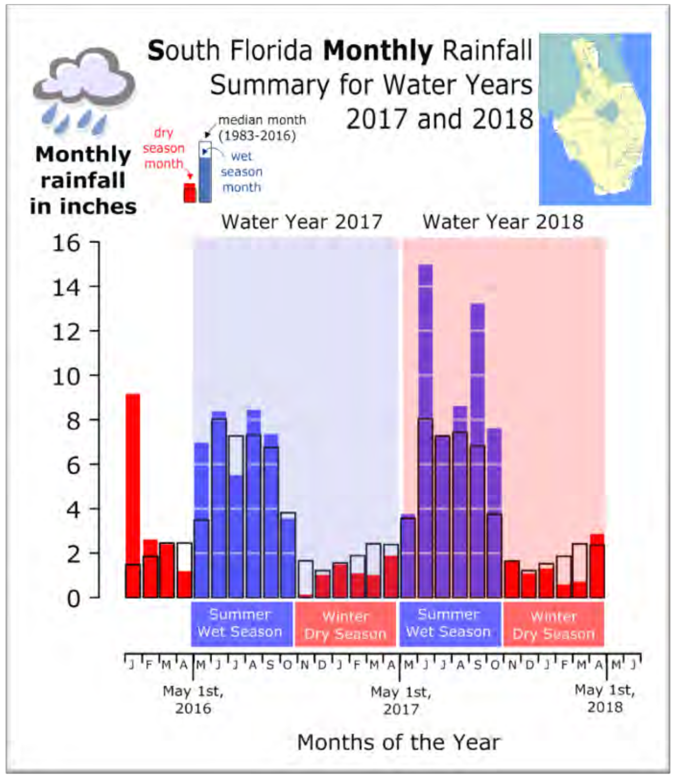

Figure 6. Summary of monthly rainfall in Water Years 2017 and 2018 throughout the South Florida Ecosystem. The graph was produced using daily rainfall data provided by the SFWMD. SFWMD meteorologists compute a daily rainfall value for the fourteen major basins and district-wide from rain gauge measurements. See http://www.gohydrology.org/p/about.html for more information.

Water Year Summaries

Water Year 2017 (May 1, 2016 to April 30, 2017)

Water Year 2017 featured a "normal" wet season and "below average" dry season 40 inches of rain fell across south Florida during the six-month (May through October) summer wet season with 7 inches falling in the six-month (November through April) dry season that followed, for an annual total of 47 inches.

Accordingly, wetlands and waterways of the Everglades filled up through the summer wet season and reliably receded during the winter dry season months. The biggest boost of rain came in August [and in particular in Water Conservation Areas (WCAs) 1 and 2 where 12 inches were recorded for the month] causing slough water depths to crest at a 2-foot depth through much of the Everglades by early October, more or less coinciding with the vast wetland's normal annual peak — but one that, too, was also short-lived.

Continuing a decade-long trend of anomalously low tropical storm activity, October (a month which historically accounts for a quarter of Florida's hurricane-strength storms) had little rain to offer, thus ushering in an early start to a winter recession of water, and one that would last particularly long. Of note and continuing a two-decade trend, the spring dry down was especially pronounced in the Big Cypress Swamp as evidenced by Corkscrew Swamp's central marsh drying out and the outbreak of a large wildfire in Big Cypress National Preserve.

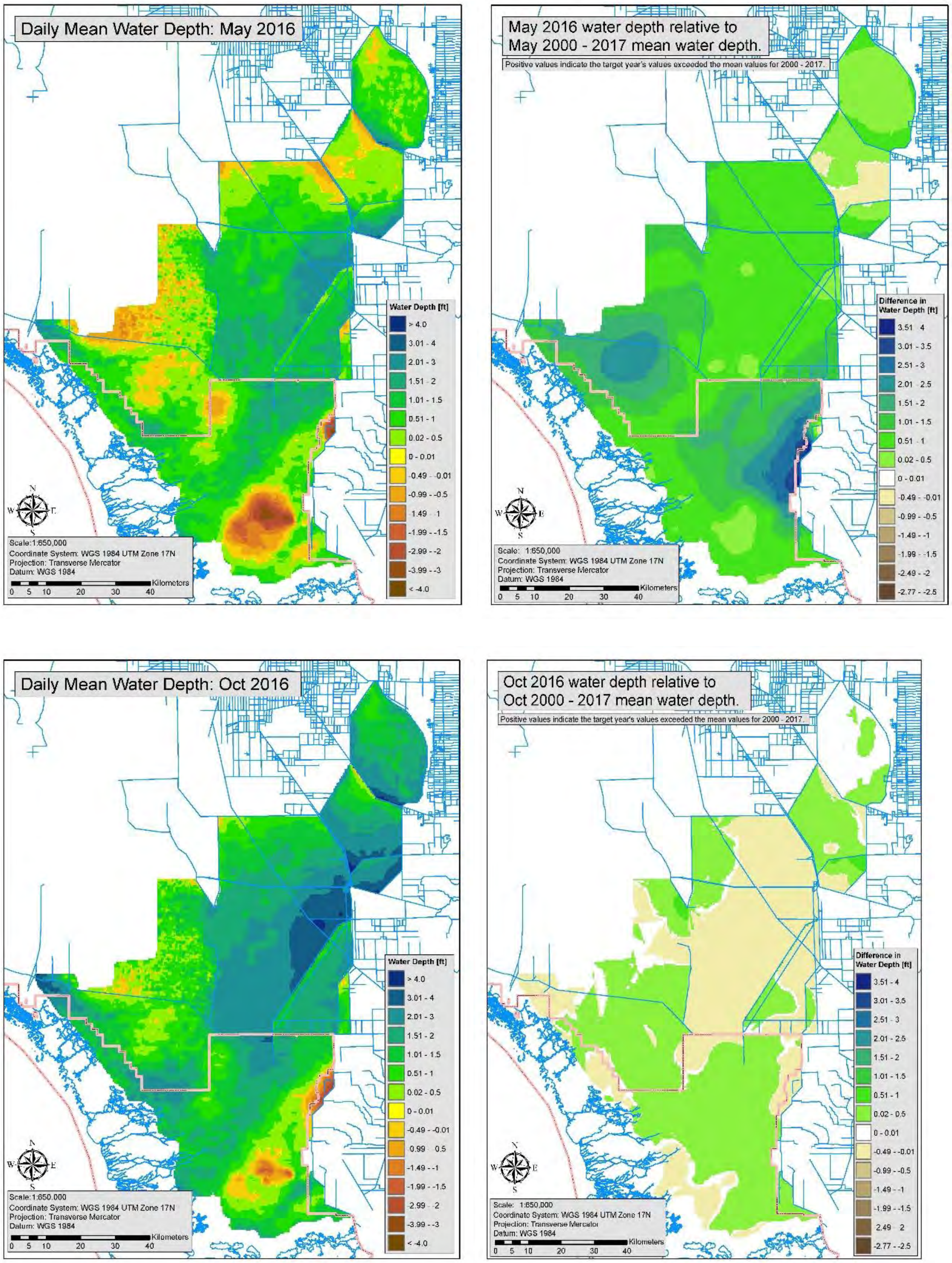

Figure 7. Water depth at the beginning of the 2017 water year (end of dry season) (top left) and wet season (bottom left) and difference from the average water depth at the same time from 2000-2017 (right panels).

Water Year 2018 (May 1, 2017 to April 30, 2018)

Water Year 2018 was a year of wet and dry extremes featuring a “record rainy” summer wet season and, in a repeat of the previous year, a “below average” dry season as follows: a whopping 55 inches of rain fell across south Florida during the six-month (May through October) summer wet season (the long-term average is 38 inches) and 8 inches fell in the six-month (November through April) winter dry season that followed, for an annual total of 64 inches.

Despite the bountiful summer rains, a sweltering May actually started WY 2018 off on a rather dry note with a continuation and deepening of the drought from the previous water year. Reminiscent of the saying “all droughts end in flood,” an epic three-day onslaught of rain in early June ushered in an “instant” wet season across all of south Florida and set the stage for the record-rainy wet season to come. Abundant tropical moisture and regular afternoon storms combined with the exclamation points of Tropical Storm Emily, Hurricane Irma, and Tropical Storm Philippe to produce a wet season that went down in the history books with rarely seen events, including water sheet-flowing over a few miles of Turner River and Wagonwheel roads after the June deluge and a brief overtopping of Tamiami Trail between Forty and Fifty Mile Bend in the days following Irma for the first time since 1995.

The “instant” wet season stayed well above average for most areas of the ecosystem from June into January, peaking for much of the summer 1-2 feet above normal levels, causing even high-ground tree islands in the WCAs and pine flatwoods of the Big Cypress to submerge for multiple months.

A series of emergency measures were taken to alleviate the unusual bounty of summer water, some of which had negative connotations — such as mandatory releases from Lake Okeechobee to the Caloosahatchee and St. Lucie estuaries to protect the integrity of the lakes perimeter levee as it is being repaired — whereas other were pursued on a positive Everglades Restoration note. Most notable in that regard were three efforts focused on spreading the water out: (1) to the East, water managers sent water through the new one mile bridge into Everglades National Park’s (ENPs) Northeast Shark River Slough at an unprecedented scale, (2) to the West, the newly-constructed Merritt Pump Station went into action to spread water into downstream Picayune Strand, and (3) in the center, a series of pumps was utilized for a second straight year to send water west across the L-28 levee into Big Cypress National Preserve.

The meteorologic pendulum swung to the dry side of the spectrum for the winter, producing both good and bad results. On the positive side, the paucity of winter rains (combined with a high summer climb) set the stage for a remarkably fast, if also steady and prolonged, water recession that sparked a frenzy of foraging and nesting activity among wading birds across the Everglades. Super colonies of wading birds were observed for the first time in ENP in decades. Wood stork rookeries were reported in Big Cypress National Preserve for the first time since the 1990s. On the negative side, the Big Cypress half of the ecosystem was plagued by an unusually long wildfire season as a result of the lack of timely winter rains. Fires in the Picayune Strand and Big Cypress National Preserve generated plume clouds of smoke across the region throughout March, April, and into May.

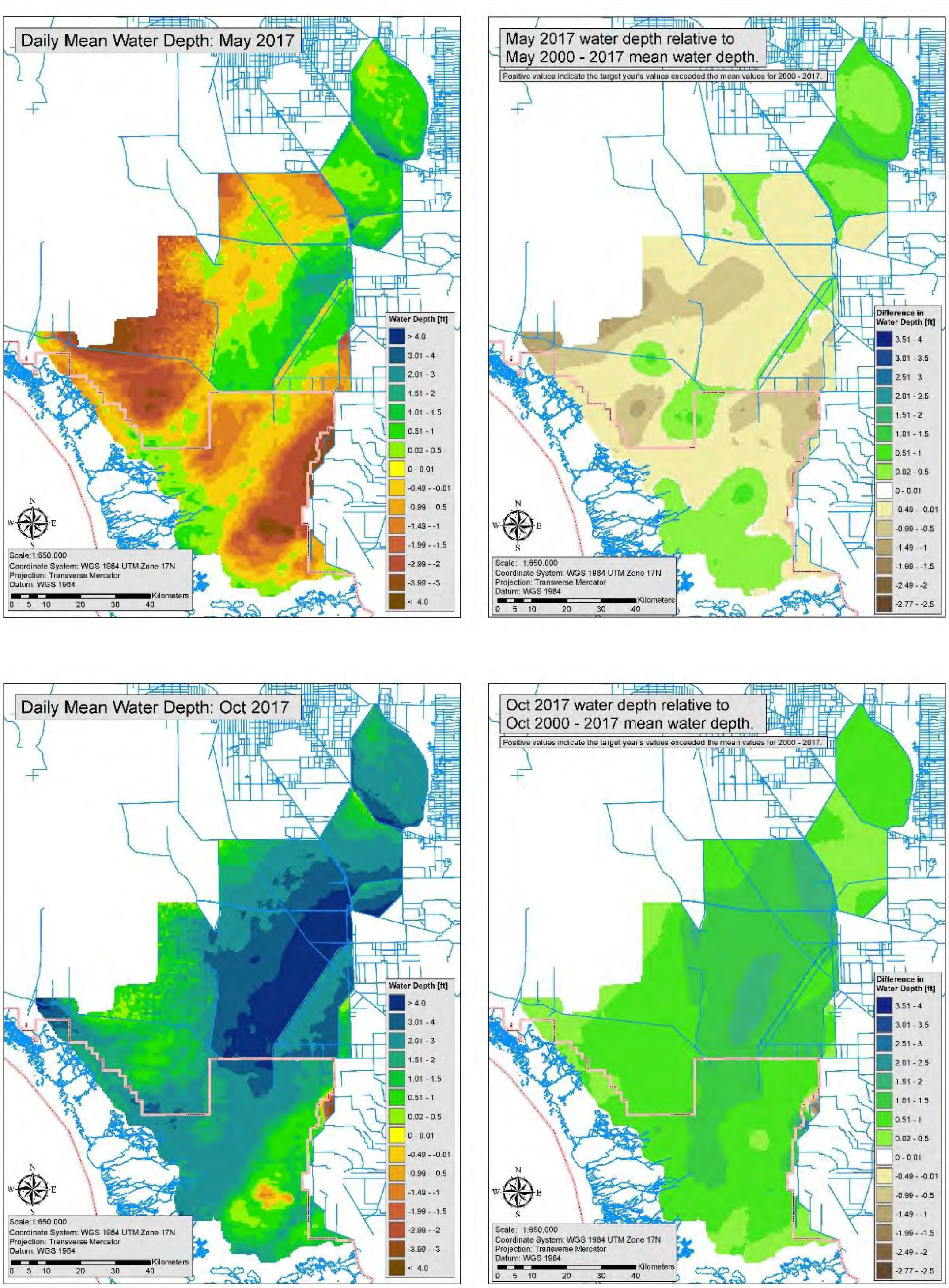

Figure 8. Water depth at the beginning of the 2018 WY (end of dry season top left), and the WY 2018 wet season (bottom left). Right panels show differences from the average water depth at the same time from 2000-2017.

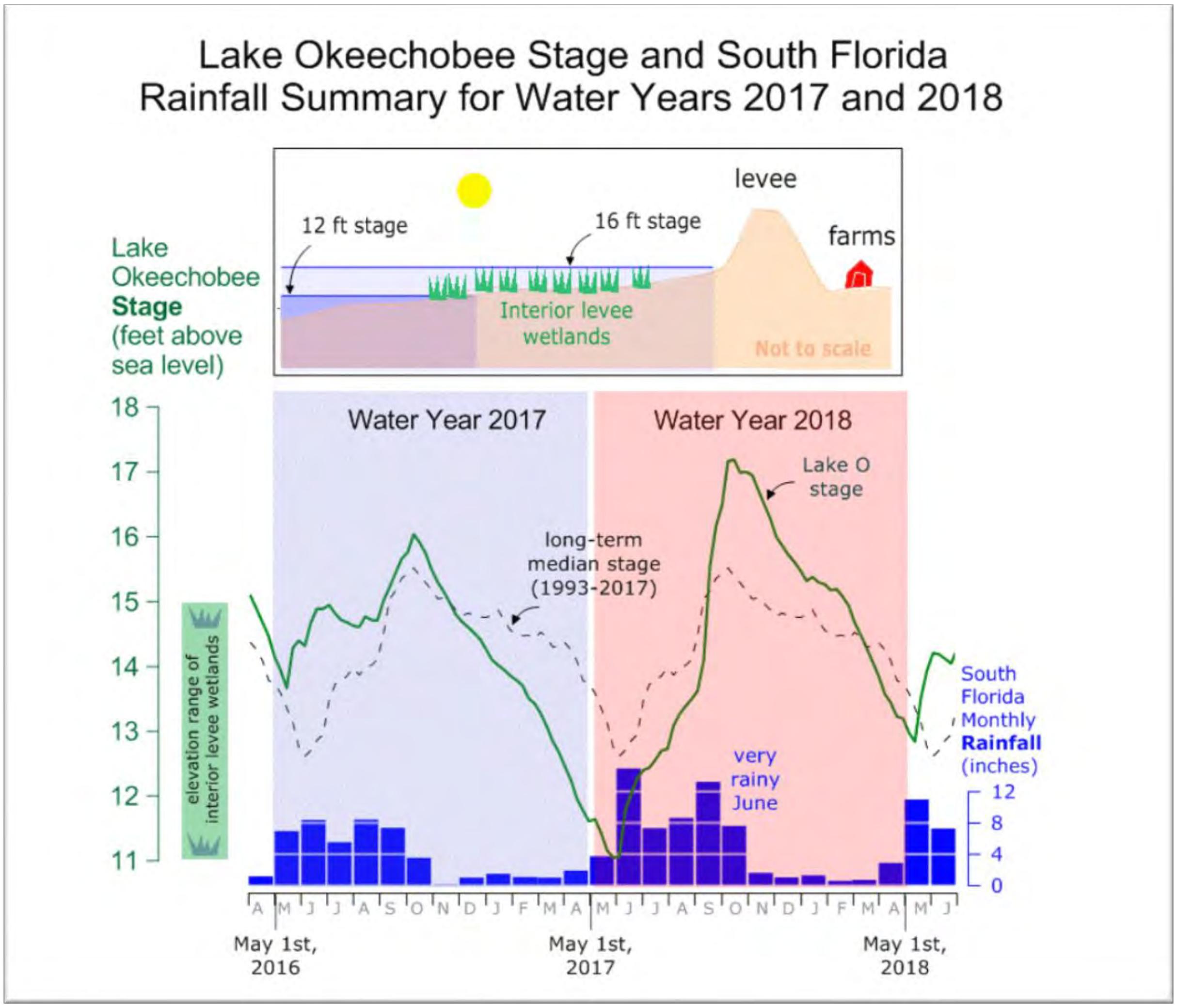

Figure 9. Lake Okeechobee stage and summary of monthly rainfall in the SFWMD in water years 2017 and 2018. Daily rainfall data provided by the SFWMD. District meteorologists compute a daily rainfall value for the fourteen major basins and district wide from rain gauge measurements. See GoHydrology.com for more information.

STOPLIGHT FORMAT

Our integrated summary uses colored traffic light symbols that have a message that is instantly recognizable, easy to comprehend, and is universally understood. We used this stoplight restoration report card communication system as a common format for all eleven indicators to provide a uniform and harmonious method of rolling-up the science into an uncomplicated synthesis. This report card effectively evaluates and presents indicator data to managers, policy makers, and the public in a format that is easily understood, provides information-rich visual elements, and is uniform to help standardize assessments among the indicators in order to provide more of an apples-to-apples comparison that managers and policy makers seem to prefer (Schiller et al. 2001, Dennison et al. 2007).

Research and monitoring data are used to develop a set of metrics for each indicator that can be used as performance measures (for example, the number of alligators per kilometer) for the indicator and to develop targets (for example, 1.7 alligators per kilometer) that can be used to link indicator performance to restoration goals. These metrics and targets are different for each indicator. The stoplight colors are determined for each indicator using three steps.

First, the ecological status of the indicator is determined by analysis of quantifiable data collected for each performance measure for each indicator (for example, the data might show that on average there are 0.75 alligators per kilometer). The status of each performance measure is then compared to the restoration targets for the indicators (for example, our target for restoration might be 1.7 alligators per kilometer). The level of performance is then compared to the thresholds for success or failure in meeting the targets and a stoplight color is assigned (for example, 0.75 alligators per kilometer indicates a low number of alligators compared to the target of 1.7 per kilometer and might result in a red stoplight being assigned for this performance measure). These numbers are used for example purposes only.

All of the stoplights were developed directly from the scientific data and the colors of the stoplights—red, yellow, or green—were determined using clear criteria from the results of the data (see 2009 special issue of Ecological Indicators Vol. 9, Supplement 6). Because the report is purposely short and succinct, it was not possible to provide information on the approaches used for each indicator in determining thresholds for the individual colors. However, the assessments clearly show how the scientific findings relate directly to the color of the stoplights, providing a transparency from empirical field data to summary data and graphics and then to the stoplight color.

This 2018 report includes a stoplight/key summary status report for each indicator. For more detailed information on these indicators please refer to references listed in each indicator section (if applicable), the Special Issue of Ecological Indicators: Indicators for Everglades Restoration (2009), the System-wide Ecological Indicators for Everglades Restoration 2016 Report, the 2018 South Florida Environmental Report, and the RECOVER 2019 System Status Report (SSR) that addresses the overall status of the ecosystem relative to system-level hypotheses, performance measures, and restoration goals.

Stoplight Format

The 2012 and 2014 SSRs provide an integrated assessment of RECOVER's Monitoring and Assessment Plan (MAP) and non-MAP data, span multiple spatial scales, and in some cases assess decades worth of information. Because of broad inter- governmental coordination, the SSR incorporates elements of this stoplight indicator update and provides the detailed underlying data, theory, and analyses used in this report. The 2012 and 2014 SSRs are available on an interactive web page that allows managers, stakeholders, and scientists with varying interests and degrees of technical expertise to easily find the information they need. This combination of indicator reports will provide managers with information they need to adjust restoration activities at both large and small scales.

Here we provide a short summary of why these organisms are important as ecological indicators for system-wide assessment of restoration, and what the stoplights represent [see Ecological Indicators Special Issue (Vol. 9, Supplement 6 November 2009) for more details].

Invasive Exotic Plants

- Exotic plants are an indicator of the status of the spread of invasive exotic plants and an indicator of progress in their control and management.
- Exotic plant distribution is used as an assessment of the integrity of the natural system and native vegetation.
- Exotic plants can cause ecological changes; therefore, prevention, control, and management are key to restoration of the ecosystem.

Lake Okeechobee Nearshore Zone Submerged Aquatic Vegetation (SAV)

- The lake's SAV community provides habitat for fish and wildlife, offers stability for sediments, and improves water quality.
- A healthy SAV community directly corresponds to healthy lake conditions.
- The SAV community is directly influenced by hydroperiod, nutrients, and water quality.
- Stoplight colors for the Lake Okeechobee nearshore SAV indicators consist of a revised performance measure with total area of summer SAV coverage (target of >50,000 acres) and the interim goal during restoration activities (35,000 acres). These data are derived from the annual summer nearshore SAV mapping project.

Eastern Oysters

- Oysters provide essential habitat for many other estuarine species.
- Oysters improve water quality by filtering particles from the water.
- Water quality, particularly salinity, is directly correlated to the physical health, density, and distribution of oysters in the estuaries.
- Hydrological restoration in the estuaries should improve the overall distribution and health of oyster reefs.

Crocodilians (American Alligators & Crocodiles)

- Crocodilians are top predators in the food web affecting prey populations.
- Alligators are a keystone species and ecosystem engineers.
- Crocodilians integrate the effects of hydrology in all their life stages.
- Growth and survival rates of crocodilians are directly correlated with hydrology.
- Stoplight colors for both the alligator and crocodile indicators incorporate current values, average values, and trends of performance measures over the last 3 or 5 years. For alligators, the performance measures are relative density (#/km), body condition, and occupancy of alligator holes in ENP measured over the last 5, 3, and 3 years, respectively. (Occupancy of alligator holes is not currently included in the calculation since sampling for that performance measure has not been conducted since 2012.) For crocodiles the performance measures are juvenile growth and survival measured over the last 3 and 5 years, respectively.

Fish & Macroinvertebrates

- Fish and macroinvertebrates are critical as a food for predators such as wading birds and alligators.
- Fish and macroinvertebrates density and community composition are correlated with hydrology.
- Fish and macroinvertebrates integrate the effects of hydrology in all their life stages.

- The positive or negative trends of Fish & Macroinvertebrates relative to hydrological changes permit an assessment of positive or negative trends in restoration.

Periphyton

- Periphyton is comprised of microbes that form the base of the food web.
- Periphyton is an abundant and ubiquitous Everglades feature that controls water quality and soil formation.
- The abundance and composition of periphyton is directly tied to water quality and quantity.
- The nutrient concentration of periphyton is a direct indication of upstream nutrient supply.
- Periphyton responds very quickly (days) and predictably to changes in environmental conditions and serves as an "early-warning-indicator."
- Stoplight colors for periphyton are based on deviation from expected values for abundance, nutrient (phosphorus) concentration, and abundance of weedy diatom algae species. For each parameter, yellow and red are indicated for values more than one and two standard deviations from mean expected values, respectively. For each wetland basin, yellow is indicated if greater than 25% of sample sites are yellow or red, and red is indicated if greater than 50% of sites are red. Expected values are calculated from the long-term average values from least disturbed sites in each wetland basin.

Wading Birds (White Ibis & Wood Stork)

- Large numbers of wading birds were a defining characteristic of the Everglades.
- Their different foraging strategies indicate that large spatial extent and seasonal hydrology made it possible for the historic Everglades to support vast numbers of wading birds.
- Timing of wading bird nesting is directly correlated with water levels and timing of the availability of prey.
- Nesting success of wading birds is directly correlated with water levels and prey density.
- Restoration goals for White Ibis and Wood Storks include recovering spatial and temporal variability to support large numbers of wading birds, restored timing of nesting, and restored nesting success

Southern Coastal Systems Phytoplankton Blooms

- The Southern Coastal Systems Phytoplankton Blooms indicator reflects the overall water quality condition within south Florida estuaries and coastal waters from the Ten Thousand Islands to Florida Bay to Biscayne Bay.
- Improved freshwater flows and healthy SAV are expected to significantly reduce the number, scale, and time-span of algal blooms and provide an important indicator of the overall health of the bays.
- Thresholds for this indicator's stoplight colors were developed from long term chlorophyll a concentrations (CHLA) data (1989-present) collected monthly at a large spatial scale. Chlorophyll a concentrations reflect algal biomass. The median and quartiles of CHLA were calculated to quantify the reference conditions for the ten subregions of the southern estuaries. These reference conditions were then used to establish criteria from which the status of CHLA and thus water quality in each of the subregions can be evaluated on an annual basis. If the annual median CHLA concentration is greater than the reference median, but lower than the 75th percentile, the subregion is marked yellow and if the annual median concentration is greater than the 75th percentile of the reference, the subregion is marked red.

Florida Bay Submersed Aquatic Vegetation (SAV)

- Florida Bay has one of the largest seagrass beds in the world, covering 90% of the 180,000 hectares of the bay.
- SAV serves many critical functions within estuarine and coastal ecosystems, such as habitat, food, and water quality.
- The SAV community is correlated to upstream hydrology and water quality.
- Florida Bay SAV condition is an important indicator for ecosystem restoration because the bay is located at the bottom of the South Florida Ecosystem's hydrological system.

Juvenile Pink Shrimp

- Pink shrimp are an important and characteristic component of the estuarine fauna of the Everglades.
- Pink shrimp abundance is correlated to freshwater flow from the Everglades.
- Growth and survival of juvenile pink shrimp are influenced by salinity and are good indicators of hydrological restoration for the estuaries.
- Pink shrimp were found to be more closely correlated with salinity and seagrass (SAV) conditions than 29 other estuarine species evaluated.

Wading Birds (Roseate Spoonbill)

- Roseate Spoonbill responses are directly correlated to hydrology and prey availability.
- Spoonbills time their nesting to water levels that result in concentrated prey.
- Availability of Roseate Spoonbill prey is directly correlated with hydrology.
- Positive or negative trends of the Roseate Spoonbill relative to hydrological changes permit an assessment of positive or negative trends in restoration.

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This is a snapshot of the status of each indicator system-wide for the last five years. Results shown here are consistent with previous assessments done by the National Research Council (2012), reflecting the continued patterns of severely altered hydrology throughout the ecosystem.

Because of funding limitations, five of eleven of the indicators have experienced reductions in sampling. Results in this report reflect those reductions and stoplight colors for previous years have been recalculated using comparable data to the reduced effort to allow for comparisons over time. Although we can still present stoplight colors over time, what is reported may be for different geographic areas than was originally designed to capture system-wide responses.

	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018
Invasive Exotic Plants	Y	Y	Y	Y	Y
Lake Okeechobee Nearshore Zone Submersed Aquatic Vegetation	R	R	R	R	R
Eastern Oysters- **Modified (Northern Estuaries only)**	R	R	R	R	R
Crocodilians (American Alligators & Crocodiles)- **Modified (DOI Lands Only)**	R	R	R	R	R
Fish & Macroinvertebrates (WCA3 and ENP only)	R	R	R	R	R
Periphyton- **Modified (no species composition)**	Y	Y	Y	Y	Y
Wading Birds (White Ibis & Wood Stork)	R	R	R	R	R
Southern Coastal Systems Phytoplankton Blooms	Y	Y	Y	Y	R
Florida Bay Submersed Aquatic Vegetation	Y	Y	Y	Y	Y
Juvenile Pink Shrimp- **Modified (no sampling)**	B	B	B	B	B
Wading Birds (Roseate Spoonbill)	R	R	R	R	R

Stoplight Legend

Red (R) Substantial deviations from restoration targets creating severe negative condition that merits action. ***Well below restoration target.***

Yellow (Y) Current situation does not meet restoration targets and may require additional restoration action. ***Below restoration target.***

Green (G) Situation is within the range expected for a healthy ecosystem within the natural variability of rainfall. Continuation of management and monitoring effort is essential to maintain and be able to assess “green” status. ***Meets restoration target.***

Black (B) No data or an inadequate amount of data were collected due to lack of funding.

About the Indicator Sections

Scientists responsible for each indicator were given an outline and asked to provide information for their indicator for each section that was relevant to them (see below). For the time series of stoplights they were asked to provide information for the last five years. Time series from earlier years can be found in the 2014 and 2016 System-wide Ecological Indicators for Everglades Restoration report.

- Summary/Key Findings
- Time series of stoplights
- Map of WY 2018 stoplight colors
- Updates on calculation of indicator
- Description of how have these data been used
- New insights relevant to future restoration decisions
- Literature cited, reports and publications for more information

Summary/Key Findings

The status of the invasive exotic plant indicator (Doren et al. 2009) remains below the restoration target (yellow stoplight) at the end of WY 2018. Continued positive results for several priority invasive plant species in some ecological systems are offset by negative results in other systems. Region-wide interagency efforts to manage the highly invasive melaleuca tree, remains on track and much of the system is under regular treatment rotations. While no system-wide assessments were conducted in the reporting period, melaleuca abundance within all regions has decreased since 1995 (Rodgers and Pernas, 2015). However, the overall geographic distribution of the species has increased and, due to a lack of maintenance control measures, localized melaleuca populations previously under control have resurged.

Old World climbing fern continues to present significant challenges to restoration. Long-term data confirm continued increases in abundance and geographic range throughout the region. Substantial impacts to forested wetland ecosystems are attributed to the colonization of this vining fern, which displaces native plant species, degrades wildlife habitat, and promotes destructive wildfires. Expansion of Old World climbing fern is particularly severe in the floodplain swamps of the Kissimmee River basin (Rodgers et al. 2017), Everglades tree islands of Arthur R. Marshall (A.R.M.) Loxahatchee National Wildlife Refuge (NWR), and cordgrass marshes of ENP. Current conditions in these areas do not meet restoration criteria. The SFWMD, U.S. Fish and Wildlife Service, and Florida Fish and Wildlife Conservation Commission have intensified control efforts for Old World climbing fern and melaleuca in the A.R.M Loxahatchee NWR. An aggressive five-year plan to complete initial treatments of these two species across the entire refuge is now being implemented.

Given the diversity of south Florida's invasive species, their varied impacts, and limited resources, managers must prioritize responses. Science-based assessments help inform managers of predicted impacts of invasive species and associated impediments to restoration success. Management approaches that combine a variety of treatment and control techniques as a means of mitigating invasion impacts are proving useful. For example, integrating herbicide treatments, fire, and biological controls though the CERP Biological Control Implementation Project (also known as the Melaleuca Eradication and Other Exotic Plants Project) is improving overall management outcomes for some invasive species. Continued improvements in invasive species management through coordinated planning, construction, and operation and maintenance phases of restoration efforts (see CERP Guidance Memorandum 062.00, 2012) are needed to promote more cost-effective management strategies.

The greatest threats to invasive plant management success in the Everglades are 1) insufficient resources to address invasive species in critical areas and 2) the continued establishment of new invasive species. Experience gained over the last two decades confirms that containing and reducing populations of highly invasive species often requires substantial initial investment of resources as well as commitment to long-term maintenance control of the populations as restoration proceeds.

The invasive plant indicator remains below the restoration target.

Table 1. Stoplight Table for Invasive Exotic Plants for Water Years 2012 - 2018

Invasive Plant Species	WY 2012	WY 2013	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018
System-Wide	Y	Y	Y	Y	Y	Y	Y
Kissimmee River Basin	Y	Y	Y	R	R	R	R
Lake Okeechobee	Y	Y	Y	Y	Y	Y	Y
Northern Estuaries – East Coast	Y	Y	Y	Y	Y	Y	Y
Northern Estuaries – West Coast	Y	Y	Y	Y	Y	Y	Y
Greater Everglades	Y	Y	Y	Y	Y	Y	Y
A.R.M. Loxahatchee National Wildlife Refuge	R	R	R	R	R	R	R
Water Conservation Area 2A/B	Y	Y	Y	Y	Y	Y	G
Water Conservation Area 3A	Y	Y	Y	Y	Y	Y	Y
Water Conservation Area 3B	Y	Y	Y	Y	Y	Y	Y
Everglades National Park	Y	Y	Y	Y	Y	Y	Y
Biscayne Bay Complex	Y	Y	Y	Y	Y	Y	Y
Southern Estuaries	Y	Y	Y	B	B	B	B
Florida Keys	G	G	G	B	B	B	B

Data and Calculations

Updates on calculation of indicator
No changes were made for the calculation of the WY 2017 and WY 2018 scores; however, limited monitoring data results are available for the reporting period. Rodgers et al. 2018 describes a multi-scale invasive monitoring strategy for the Everglades ecosystem. Budget constraints and expanded monitoring objectives necessitate reductions in system-wide monitoring from a two-year to five-year interval. The next round of system-wide monitoring will occur in 2019. Between the system-wide assessments, monitoring has transitioned to address early detection and small-scale mapping to assist land managers with near term treatment activities. As such, the indicator assessments for this reporting period are based on 2015 monitoring data and assessment questions described in Doren et al. 2009.

How have these data been used?
Data were used to update the RECOVER system-wide science chapter sections on invasive species in the Systems Status Report. The System Status Report covers many drivers and stressors affecting changes in the South Florida Ecosystem. Invasive species are a driver of change that has significant implications for several MAP ecosystem indicators. Data provided in the report is utilized to elucidate how invasive species, as ecosystem engineers, may alter restoration outcomes as CERP progresses. These data are also used to report on the status of invasive species and progress towards their management in the South Florida Environmental Report to meet mandated reporting requirements pursuant to Chapter 2005-36, Laws of Florida, and Section 373.036(7), Florida Statutes (F.S.).

New insights relevant to future restoration decisions
Most of the modules continue to have serious invasive exotic plant problems, which are affecting natural areas and altering habitats and ecosystem processes. Control of invasive plants is successful for a few species in some areas. WCA 2A/B scored green for the first time. This area was once heavily infested with melaleuca and had localized populations of Australian pine and Brazilian pepper. During the reporting period, this management area had no new invasive species invasions, all priority species are well controlled at very low densities and subject to routine follow up herbicide treatments, and the management area is regularly monitored for invasive plants at multiple spatial scales.

There are now 73 of the 79 Category I Invasive Plant Species (FLEPPC 2017) established in the CERP footprint. These species are known to alter native plant communities by displacing native species, changing community structure or ecological function, or hybridizing with natives. Early detection monitoring resulted in the detection of several new invasive species introductions during the reporting period. For example, the recent discovery of mission grass—a federal noxious weed—in Palm Beach County has triggered a rapid response effort to eradicate this plant from the region.

Three biological control agents for melaleuca are well-established and melaleuca reduction is documented (Tipping et al. 2008). Two agents for Old World climbing fern are established. One of these, the brown lygodium moth, is now widespread and exerting localized pressure on the invasive fern. The recent expansion of the lygodium gall mite from introduction sites is an encouraging development and the pest has shown some localized damage to Old World climbing fern, particularly following fire events. New biological control agents have been released for several other serious invasive plants, and other agents are in development. Recent progress identifying additional agents for Old World climbing fern and, for the first time, Brazilian pepper are promising developments. The CERP Biological Control Implementation Project has substantially increased the number of biocontrol agent releases throughout the CERP footprint.

Monitoring that would identify new invasive species or new distributions for existing species covers the Greater Everglades module (Rodgers et al 2018) and portions of the Kissimmee River, Lake Okeechobee, and Big Cypress modules. These efforts are providing insight into landscape-scale distribution and abundance changes for some species, but the ability to identify where and when new species establish is limited. In many cases, invasive plant populations are not being systematically monitored. Overall, the picture remains mixed for invasive plants. Although progress has been made on a number of species, we are still unable to control many species faster than they are invading and spreading. To control species faster than they are invading and spreading, prevention, monitoring, and control programs must be expanded.

Literature cited, reports, and publications for more information

Doren, R. F., J. C. Volin, J. H. Richards. 2009. Invasive exotic plant indicators for ecosystem restoration: An example from the Everglades restoration program. Ecological Indicators 9S:S29-36.

FLEPPC 2015. Florida Exotic Pest Plant Council's 2015 List of Invasive Plant Species.

Rodgers, L. and T. Pernas. 2015. Long-term changes in distribution and abundance of invasive plants in the Florida Everglades. Florida Exotic Pest Plan Council Symposium, 10 March 2015.

Rodgers, L., C. Mason, M. Bodle, R. Brown, E. Allen, P. Tipping, M. Rochford, F. Mazzotti, A. Peters, M. Renda, C. Beeler, J. Ketterlin-Eckles, F. Laroche, C. Segura, and K. Serbesoff-King. 2017. Status of Nonindigenous Species in South Florida Environmental Report, pg.7:1-58.

Rodgers, L. T. Pernas, J. Redwine, B. Shamblin. 2018. Multiscale Invasive Plant Monitoring: Experiences from the Greater Everglades Restoration Area. Weed Technology 32:11-19.

Lake Okeechobee Nearshore Zone Submersed Aquatic Vegetation Indicator

Summary/Key Findings

The status of the Lake Okeechobee Nearshore submersed aquatic vegetation (SAV) indicator has been well below the restoration target and interim goal (red stoplight) since WY 2014. Although the WY 2014 summer coverage was close to the interim goal, there has been a decrease in summer coverage for the five WYs since WY 2014. The total number of acres covered by SAV in the summer of WY 2018 did increase compared to WY 2017, but preliminary data suggest Hurricane Irma eliminated any recovery after hitting south central Florida in the fall of WY 2018.

Even under the 2008 Lake Okeechobee Regulation Schedule (LORS), the lake stage has exceeded the higher end or above the ecological stage envelope (12.5 to 15.5 ft above sea level) every water year since WY 2013 and has twice been roughly one foot or more above the dry season low stage target of 12.5 feet above sea level. While the spring of WY 2017 and most of the WY 2018 summer had lake stage below or at the lower end of the ecological stage envelope, Hurricane Irma passed over the lake and its watershed in the fall of WY 2018, pushing lake stage to a max of 17.2-ft, the highest stage since October 2004. Lake stage remained above 16 ft for nearly 2.5 months and stayed above the ecological stage envelope for nearly 3.5 months. Most of the quarterly SAV transect sites sampled in November 2017 and February 2018 showed continued losses of SAV after Hurricane Irma's passing.

On the basis of annual SAV coverage data collected since WY 2001, maintaining lake stage within the ecologically beneficial stage envelope, both in terms of water depth and temporal ascension and recession rates, provides the best conditions to maximize nearshore SAV coverage. When lake stages have been significantly above or below the ecologically beneficial stage envelope, SAV coverage has declined. Restoration activities that provide a significant increase in water storage in the Lake Okeechobee watershed, thereby allowing the lake to more closely follow the timing and depths of an ecologically beneficial stage envelope, should enhance SAV coverage and density in the nearshore region. However, even with better control of lake stage, periodic events such as tropical storms and droughts will continue to influence nearshore SAV coverage. The damage caused by Hurricane Irma significantly decreased coverage, likely to the lowest levels since multiple hurricanes impacted the lake in WY 2005-2006, when it took several years for the SAV to recover. The SAV coverage was already low prior to Hurricane Irma after a string of years with relatively high lake stages, possibly reducing the resilience of this community prior to this event. Prolonged lower lake stages at or below the bottom of the ecological stage envelope will be required to expedite recovery of the SAV community following Hurricane Irma's impacts.

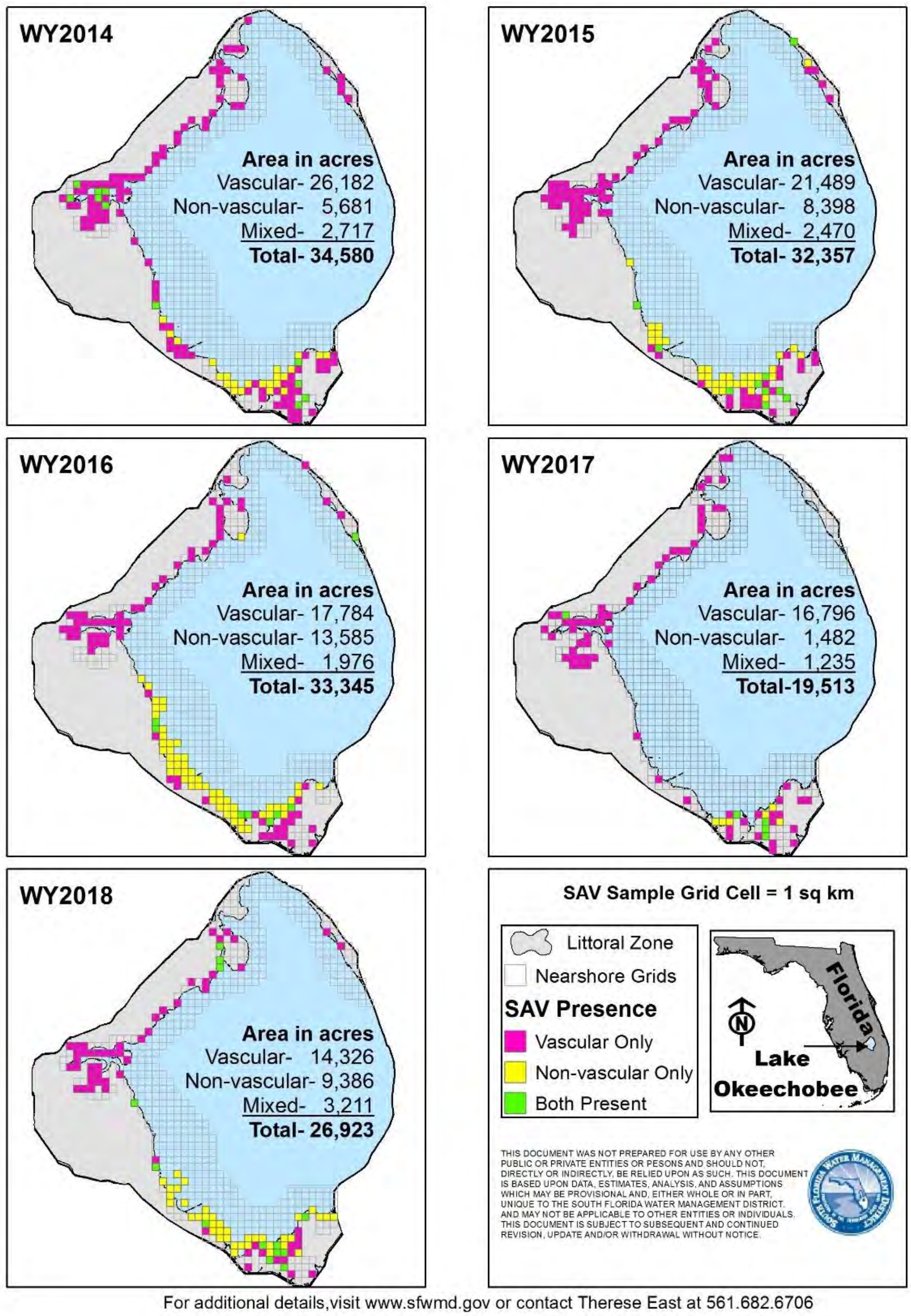


Figure 1. Distribution of SAV in Lake Okeechobee from 2014-2018.

Table 1. Stoplight table for Lake Okeechobee Nearshore Zone Submersed Aquatic Vegetation for Water Years 2014-2018.
Stoplight colors presented here reflect updated calculation of the indicator (see updates on calculation of indicator section).

	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018
≥50,000 target SAV acres	R	R	R	R	R
35,000 SAV acres intermediate goal	R	R	R	R	R

Data and Calculations

Updates on calculation of indicator

In 2016 the Lake Okeechobee Nearshore Zone Submersed Aquatic Vegetation Indicator was revised and approved by RECOVER as a performance measure. The new calculation has only one parameter, annual summer (July/August) peak coverage of SAV, while the previous version also included percent of vascular species. The performance measure includes an interim goal of at least 35,000 acres annual areal coverage of SAV. Anything less than 35,000 acres receives a red stoplight. Values between 35,000 and 49,999 receive a yellow stoplight and values ≥50,000 meet the target and receive a green stoplight.

Inner marsh grid cells had been added to the annual mapping project in WY 2011 to consider higher elevation SAV communities but were removed in WY 2017 since lake stages were only high enough for those sites to be sampled twice (Figure 2). They were not included in any of the results cited above, or in the development of nearshore SAV targets.

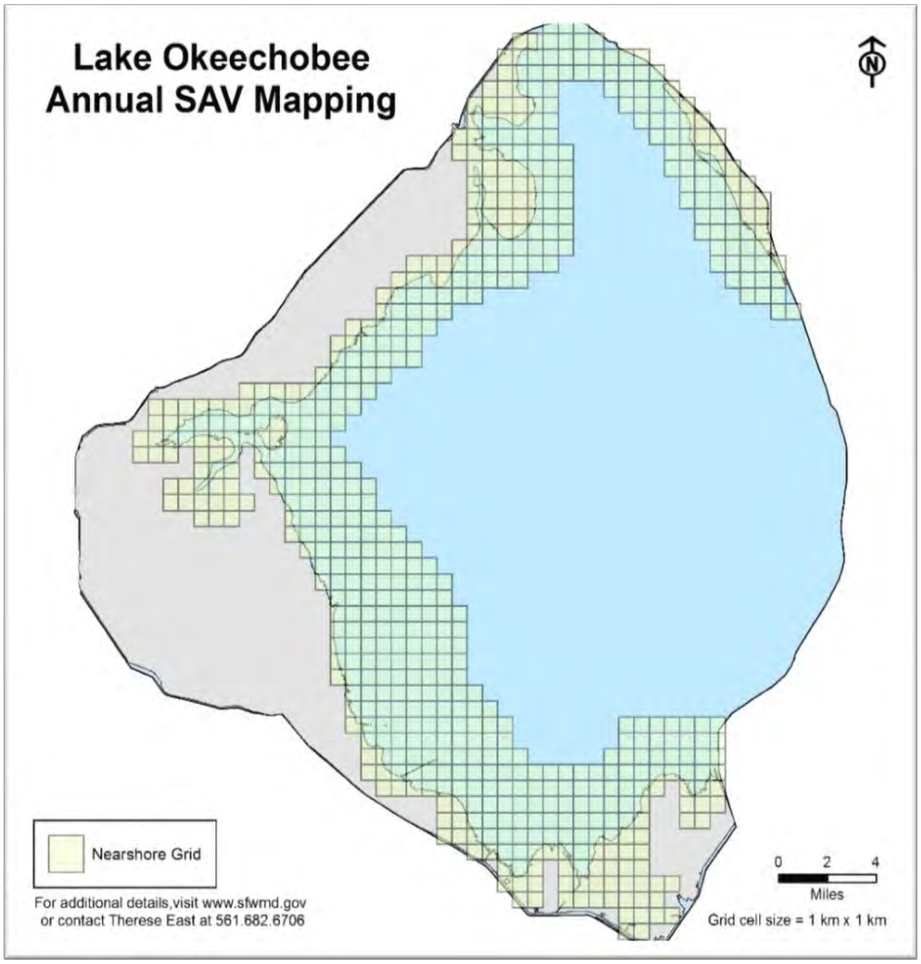


Figure 2. Updated map showing only the nearshore mapping grid cells which have been sampled since WY 2001.

How these data are being used

Lake Okeechobee SAV is reported in the South Florida Environmental Report and the RECOVER Systems Status Report. The data are being used to help determine the amount of habitat for nearshore fish and wildlife and changes in water quality.

Summary/Key Findings

The status of the eastern oyster was well below the restoration target (red stoplight) at the end of WY 2016 and remains well below the restoration target at the end of WY 2018. This summary reports on the status of the eastern oyster in the Northern Estuaries: the St. Lucie Estuary (SLE), Loxahatchee River Estuary (LRE), Lake Worth Lagoon (LWL) and Caloosahatchee River Estuary(CRE). Oyster monitoring in the SLE, LRE, and CRE is funded by the SFWMD and oyster monitoring in the LWL is funded by Palm Beach County through 2018. Monitoring in the LWL could be impacted by a lack of consistent funding. Efforts to continue have succeeded thus far on an ad hoc basis, but a long-term source of funding for this effort is needed.

Restoration activities that provide additional water storage in the Lake Okeechobee, St. Lucie and Caloosahatchee watersheds, as well as storage south of the lake, will help reduce the severity of excess freshwater discharges from Lake Okeechobee, minimize large fluctuations in salinity, enable oyster populations to thrive, and lead to increased oyster population densities. Too much fresh water impacts reproduction, larval recruitment, survival, and growth, while too little fresh water impacts the survival of oysters due to predation and higher prevalence and intensity of the *Perkinsus marinus (P. marinus)* pathogen.

Oysters in the SLE and CRE were adversely affected by too much freshwater in the winter and summer months of 2016. Although there was not a major oyster die-off related to the low salinities in 2016, reproductive development was delayed and recruitment rates remained low throughout the year. Oysters were also severely impacted in WY 2018 following Hurricane Irma when low salinities led to large-scale oyster die-offs at upstream CRE locations and throughout the SLE. Oysters in the LRE and LWL were consistently impacted by high salinities that resulted in high disease and predation rates.

The oyster indicator remains well below the restoration target.

Table 1. Stoplight Table for Eastern Oysters Indicator (Northern Estuaries Only) for Water Years 2014 - 2018. Stoplight colors presented here reflect updated calculation of the indicator (see updates on calculation of indicator section).

Eastern Oyster	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018
Northern Estuaries	Red	Red	Red	Red	Red
St. Lucie Estuary	Red	Red	Red	Red	Red
Loxahatchee River Estuary	Red	Red	Red	Red	Red
Lake Worth Lagoon	Red	Red	Red	Red	Red
Caloosahatchee River Estuary	Red	Red	Red	Yellow	Red

Data and Calculations

Updates on calculation of the indicator

For the SLE, LRE, LWL, and CRE, oyster density, spat recruitment (larval settlement rates), and prevalence of infections by the parasitic protozoan *P. marinus* (dermo) were used to calculate scores for each estuary.

This year, the Northern Estuaries group of RECOVER had a lengthy discussion about what parameters to include in calculating scores to be used for the System Status Report (SSR) and this report. It was decided that three key parameters should be the focus: living oyster density, spat recruitment, and prevalence of *P. marinus*. This differs from what was presented in the 2009 Ecological Indicators special issue in that condition index, gonadal condition, juvenile growth, infection intensity of *P. marinus*, and trend are not included. Gonadal index was not included since it seems to be more tied to seasonality and slower to reflect changes in water quality (unless water quality declines enough to kill the oysters, but then there are no oysters to sample for gonadal index). Infection intensity of *P. marinus* was not included because it is generally low at all Northern Estuary sites and thus also not as reflective of local water quality conditions. In contrast, infection prevalence of *P. marinus* tends to reflect changes in salinity fairly rapidly. For example, average infection rates can decrease from ~80% in a high salinity month to 20% or less if salinities decrease abruptly in the following month. For that reason, prevalence of *P. marinus* was included in this year's calculations.

Scores and stoplight colors are as follows:

<u>Oyster Density</u>
St. Lucie North and South Forks:
<20 red, 20<yellow<100, >100 green

St. Lucie Middle Estuary, Loxahatchee River Estuary, and Lake Worth Lagoon:
<100 red, 100<yellow<500, >500 green

Caloosahatchee River Estuary:
<500 red, 500<yellow<1000, >1000 green

<u>Larval Recruitment (only including data from May-October of each year)</u>
All Sites:
<1 red, 1<yellow<5, >5 green

<u>Dermo Prevalence</u>
All Sites:
<20 green, 20<yellow<60, >60 red

How these data are being

Oysters continue to serve as one of the principal performance metrics for the Northern Estuaries region of CERP. Data is used for evaluation in the System Status Report and oysters are a key component of baseline monitoring prior to construction projects and will be increasingly valuable in assessing how implemented projects affect conditions in the Northern Estuaries.

Insights relevant to future restoration decisions

Freshwater inflows into the Northern Estuaries have been altered from a natural state to one in which inflows are more variable and extreme. This altered salinity regime has adversely affected oyster populations by exposing them to high freshwater inflows during the wet season, which leads to acute declines in oyster abundances, and by allowing too little freshwater inflow during the dry season or drought periods, which leads to gradual increases in predation, disease, and mortality rates. While there may be occasional dry years, or years when conditions are wet during the dry season, there is generally too much freshwater inflow into the SLE and CRE in the summer months and too little freshwater inflow in the winter months. In the LRE and LWL, there is too little freshwater inflow throughout the year.

Oyster responses and population abundances in the Northern Estuaries are below targets and are frequently experiencing declines under the current variable salinity conditions. Recovery rates of oyster abundances suggest that oyster index scores could be expected to increase if natural hydrological conditions are restored.

Restoration of natural hydrologic freshwater inflow patterns along with substrate enhancement (addition of cultch) is essential for improving the health and abundance of oysters in the Northern Estuaries.

Current conditions do not meet restoration criteria, signifying that the Northern Estuaries need further attention.

If hydrological conditions remain the same, there will not be an improvement in oyster abundances or responses in the Northern Estuaries.

Continued monitoring of oysters in the Northern Estuaries will provide an indication of ecological responses to ecosystem restoration and allow for differentiation between responses to restoration efforts and natural variations. Monitoring of LWL is no longer funded as part of the CERP process and continued funding is not guaranteed.

Estuary Specific

St. Lucie Estuary

Increased rainfall associated with the 2015/2016 El Niño event led to prolonged freshwater releases into the SLE in 2016. Although there was not a major associated die-off in the estuary, oyster densities were somewhat depressed during the spring 2016 survey. Oyster densities stabilized, and even increased in the middle estuary, in WY 2017 despite a prolonged period of above optimal salinities during the last half of the water year. Salinities were generally within the optimal range early in WY 2018 but decreased abruptly in September following the extremely powerful and intense Hurricane Irma, which caused a large-scale oyster die-off in the SLE. Although it is evident that the magnitude of freshwater inputs into the SLE following Hurricane Irma was large enough to decimate the oyster population, it is also worth noting that the timing and duration of the freshwater event likely exacerbated the effects and prolonged the recovery period by suppressing reproduction and larval recruitment. A total of two live oysters were found in the SLE during the survey conducted in March 2018.

Peak reproductive development and spawning activity typically occurs between April and September and is usually greater in the months during or after a period with moderate or higher salinities. Peak larval recruitment rates generally occurred in May of each year; however, there was a smaller magnitude fall peak in WY 2016. Little to no recruitment was detected in during periods when salinities were below the optimal range (WY 2017 and WY 2018). Analysis of reproductive development in adult oysters showed that most completed gametogenesis and spawned. This suggests that the newly spawned larvae either did not survive in the low salinity environment or were physically flushed downstream and out of the estuary.

Disease prevalence from the parasitic protozoan *P. marinus* (Dermo) was low to moderate, ranging from 0% to 67%. More oysters were infected with the parasite during periods with moderate to high salinities such as those that occurred in WY 2016. The lowest infection rates occurred in WY 2017 following the extended period of reduced salinities associated with the 2015/2016 El Niño event. No live oysters were present in the SLE for disease analyses from September 2017 to April 2018 due to die-offs associated with low salinities following Hurricane Irma.

Oyster populations in the SLE continue to be negatively affected by the highly variable freshwater inflows that are a result of the altered local hydrology. Extended periods of high salinities result in gradual increases in disease infection rates that lead to compromised oyster health and survivorship. Periods of extremely low salinities, as occurred in WY 2018, result in acute damage to oyster populations. The rapid transitions between high and low salinity regimes compound the effects of the salinity extremes by reducing the opportunity for acclimatization to new conditions. The timing and duration of extreme low salinity events also greatly affect the severity of the damage to oyster populations. In WY 2017, the low salinity event began early in the year, when temperatures were lower, and concluded by November thus allowing a small number of larvae to settle in the estuary before the end of the spawning season. In WY 2018, salinities remained below optimal levels from September through December therefore delaying potential recovery until the initiation of the spawning season in spring 2018.

Loxahatchee River Estuary

The density of live oysters was higher in the Northwest Fork than in the Southwest Fork of the LRE during WY 2016 to WY 2018. No substantial low salinity events occurred in the LRE, but there were more suboptimal salinity days in the Northwest Fork. Those lower salinities likely reduced predation and disease pressures on resident Northwest Fork oysters thus allowing them to survive and thrive, ultimately resulting in the greater densities mentioned above. Despite the predominance of above optimal salinities in the Southwest Fork, densities of live oysters remained relatively stable from WY 2016 to WY 2018.

The timing of reproductive development and larval recruitment in the LRE is similar among oysters in the two forks. Reproductive development and spawning activity generally occurred between May and October. Peak spring larval recruitment rates typically occurred in May of each year while peak fall rates occurred most commonly in October; however, there were moderate peaks in August of WY 2016 and WY 2018. One exception worth noting is the absence of a fall peak in September or October during WY 2018. This period coincided with the occurrence of suboptimal salinities following Hurricane Irma. A likely explanation is that the newly spawned larvae either did not survive in the low salinity environment or were physically flushed downstream and out of the estuary.

Disease prevalence from the parasitic protozoan *P. marinus* (Dermo) was moderate to high, ranging from 30% to 97% in LRE oysters. These are substantially higher infection rates than seen in oysters from the SLE. The lowest infection rates (WY means near 60%) in oysters from the LRE were measured in WY 2018 during or following months with reduced salinities. In other water years, mean infection prevalence ranged from 63% to 81%. These high infection rates indicate that freshwater inflows into the estuary have generally not been of sufficient magnitude or duration to provide relief from disease pressure.

Oyster populations in the LRE have been negatively impacted by the variable freshwater inflows that are a result of the altered local hydrology. Extended periods of high salinities result in gradual increases in disease infection rates that lead to compromised oyster health and survivorship. If salinities rapidly decrease to suboptimal levels, as occurred in WY 2018, the opportunity for acclimatization to new conditions is reduced or eliminated and the local oysters become more susceptible to predation and disease. High salinities are a persistent problem in the LRE but there is evidence that brief excursions to optimal salinities, or even suboptimal salinities, can substantially reduce disease rates and increase reproductive capacity. However, the timing of these low salinity events determines if there will be a positive or negative outcome. In WY 2018, the low salinity events occurred just prior to and during the spawning season leading to substantially reduced larval recruitment rates.

Lake Worth Lagoon

The density of live oysters was moderate in the LWL during WY 2016 – WY 2018. No substantial low salinity events occurred in the LWL, but there were more suboptimal salinity days in WY 2018 following Hurricane Irma. Those lower salinities likely reduced predation and disease pressures on resident LWL oysters thus allowing them to better survive and thrive. Despite the predominance of above optimal salinities in the LWL, densities of live oysters remained relatively stable from WY 2016 to WY 2018.

Reproductive development and spawning activity generally occurred between May and December. Peak larval recruitment rates typically occurred in September or October of each year; however, there was a moderate peak in May of WY 2016. Recruitment patterns differed substantially in WY 2018, when peak rates were measured in June and July and much lower recruitment rates were detected in the fall. This missing fall recruitment peak was most likely due to the occurrence of suboptimal salinities following Hurricane Irma.

Disease prevalence from the parasitic protozoan *P. marinus* (Dermo) was high and ranged from 47% to 100% in LWL oysters. These are substantially higher infection rates than seen in oysters from the SLE. The lowest infection rates (WY mean near 65%) in oysters from LWL were measured in WY 2018 during or following months with reduced salinities. These high infection rates indicate that freshwater inflows into the estuary have generally not been of sufficient magnitude or duration to provide relief from disease pressure.

Oyster populations in LWL have been negatively impacted by the variable freshwater inflows that are a result of the altered local hydrology. Extended periods of high salinities result in gradual increases in disease infection rates that lead to compromised oyster health and survivorship. High salinities are a persistent problem in LWL but there is evidence that brief excursions to optimal salinities, or even suboptimal salinities, can substantially reduce disease rates and increase reproductive capacity.

Caloosahatchee River Estuary

The density of live oysters at sampled stations in the CRE is highly variable and greatly influenced by freshwater inflows and the resultant salinity fluctuations along the upstream to downstream gradient. During most density surveys, oyster numbers were greatest at one of the upstream stations while the lowest densities of live oysters were found at the most downstream station. During WY 2017 and WY 2018, when freshwater inflows were high and salinities were near zero, oysters at the upstream stations disappeared or were present only at very low densities.

Reproductive development and spawning activity generally occurred between April and November in the CRE. Peak larval recruitment rates typically occurred in August or September of each year; however, there was an earlier peak in April at the end of WY 2016. Despite extended periods of suboptimal salinities in WY 2016/2017 and WY 2018, larval recruitment in the CRE continued, oftentimes at moderate to high rates.

Disease prevalence from the parasitic protozoan *P. marinus* (Dermo) was moderate to high ranging from 15% to 67% in CRE oysters. These are much higher infection rates than seen in SLE or LRE oysters. The lowest infection rates (WY means of 55% and 34%) occurred in WY 2017 following the extended period of reduced salinities associated with the 2015/2016 El Niño event and in WY 2018 after Hurricane Irma. No live oysters were present for disease analyses at the upstream stations in the CRE from September 2017 to April 2018 due to die-offs associated with low salinities following Hurricane Irma.

Oyster populations in the CRE continue to be negatively affected by the highly variable freshwater inflows that are a result of the altered local hydrology. Extended periods of high salinities result in gradual increases in disease infection rates that lead to compromised oyster health and survivorship. Periods of extremely low salinities, as occurred in WY 2016/2017 and WY 2018, result in acute damage to upstream oyster populations. The rapid transitions between high and low salinity regimes compound the effects of the salinity extremes by reducing the opportunity for acclimatization to new conditions. The timing and duration of extreme low salinity events also greatly affect the severity of the damage to oyster populations. Extended periods of above optimal or below optimal salinities are a persistent problem in the CRE but there is evidence that even brief periods of more moderate salinities can greatly enhance oyster density and reproductive output as well as reduce disease infection rates.

CROCODILIANS (AMERICAN ALLIGATORS & CROCODILES) INDICATOR—MODIFIED (DOI LANDS ONLY)

SUMMARY/KEY FINDINGS

A full system-wide status assessment for crocodilians for WY 2016–WY 2018 cannot be provided because some survey routes do not have adequate sampling since funding was suspended in WY 2012. However, surveys have continued on Department of Interior (DOI) lands (A.R.M. Loxahatchee NWR, Big Cypress National Preserve, Crocodile Lake NWR, Biscayne National Park, and ENP). Sampling in WCA3A and WCA3B was resumed in WY 2017 and we are able to report on yearly values here (Table 1). If funding continues we will be able to report on full stoplight values in WY 2021. A part of the full stoplight calculation is a trend over 3 or 5 years for body condition and relative density, respectively. Surveys in Big Cypress National Preserve are not funded and no spring surveys were conducted in WY 2018 so that stoplight is based only on fall data. If sampling does not resume we will not be able to report stoplight values for Big Cypress National Preserve.

The status of the crocodilian indicator on DOI lands has remained well below the restoration target (red stoplight) since WY 2014 and remains well below the restoration target at the end of WY 2018 (Figure 1). The overall score for DOI lands has remained well below the restoration target for six years in a row (Figure 2). While the score for A.R.M. Loxahatchee NWR has remained yellow, Big Cypress National Preserve (alligators), the Biscayne Bay Complex (crocodiles), and ENP (both alligators and crocodiles) have fluctuated between yellow and red. Overall this result reflects low relative densities of alligators (Figure 3), variable alligator body condition (Figure 4), and low crocodile growth and survival.

Table 1. Average of the two surveys for spring relative density and the lower of the average spring or fall body condition values for alligators in WCAs 3A and 3B in WY 2017 and WY 2018.

	Relative density Alligators/km		Body condition Fulton's K	
Route	WY 2017	WY 2018	WY 2017	WY 2018
WCA3A Tower				
WCA3A Holiday				
WCA3A N41				
WCA3B				

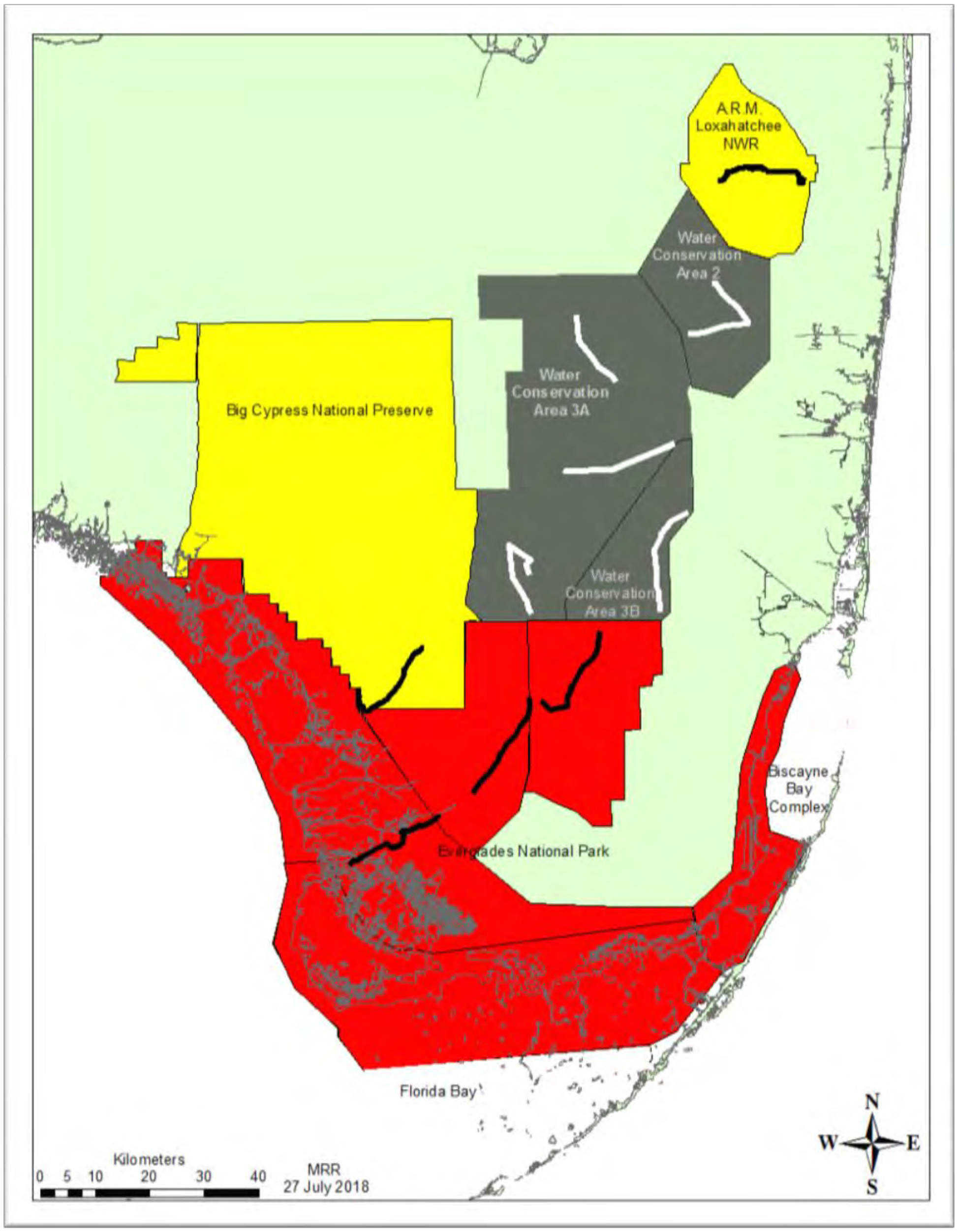


Figure 1. Stoplight colors for crocodilian indicator by management unit for WY 2018.

Figure 2. Stoplight table for Crocodilians (American Alligator & Crocodiles) Indicator – Modified (DOI Lands Only) WY 2014 – WY 2018

American Alligators and Crocodile	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018
System-wide					
DOI Lands					

	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018
American Alligator					
A.R.M. Loxahatchee National Wildlife Refuge					
Water Conservation Area 2A					
Water Conservation Area 3A					
Water Conservation Area 3B					
Everglades National Park					
Big Cypress National Preserve					
American Crocodile					
Everglades National Park					
Biscayne Bay Complex					

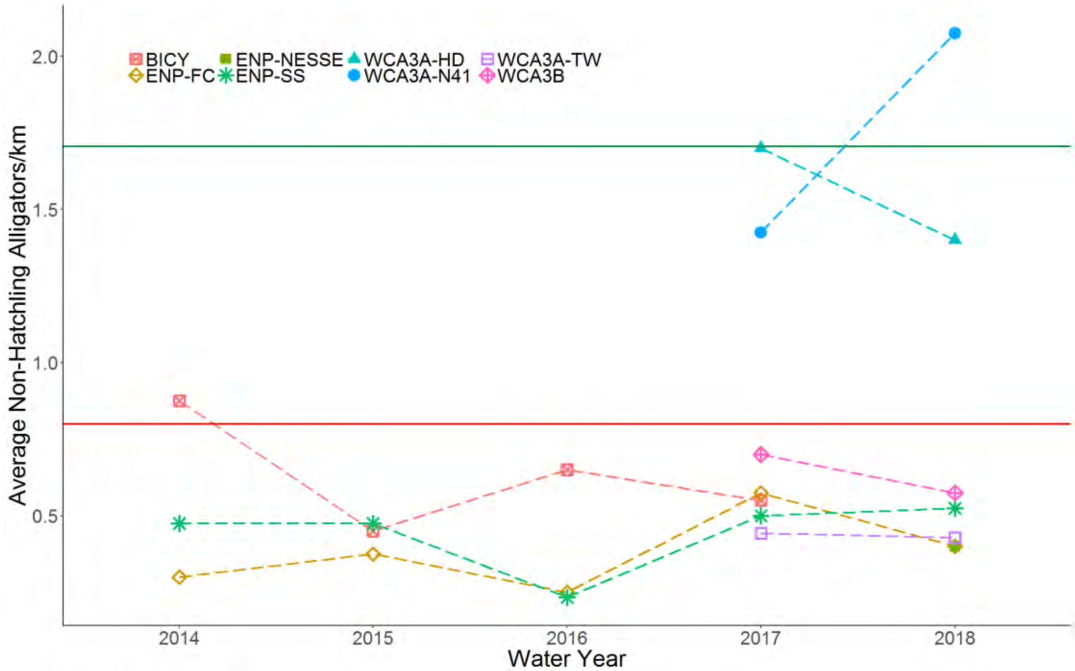


Figure 3. Average non-hatchling alligators/km of two spring surveys by water year for WY 2014-WY 2018 in areas where alligators are monitored. Top green line indicates restoration target. Bottom red line indicates conditions well below the restoration target. A.R.M. Loxahatchee NWR is not included on the graph because densities are much higher than the other areas (ranging from yearly averages of 3.18-4.45 alligators/km). WCA3A and WCA3B were not sampled during WY 2012-2016 due to lack of funding.

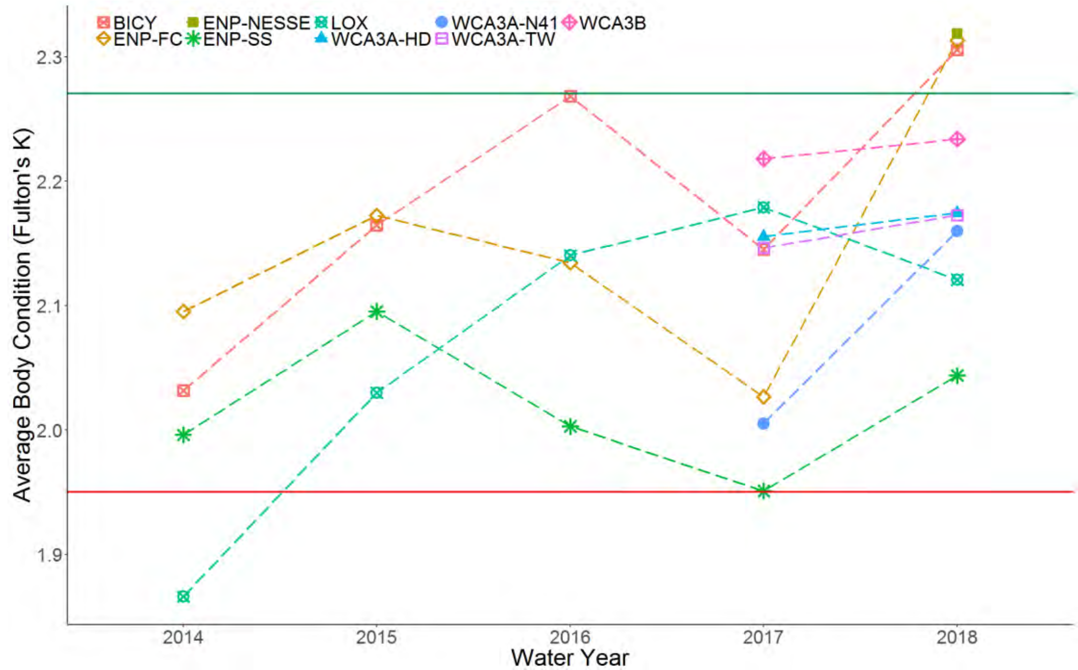


Figure 4. Average alligator body condition (Fulton's K) in areas where alligators are monitored WY 2014-WY 2018. Sampling occurs in Spring and Fall. Top green line indicates restoration target. Bottom red line indicates conditions well below the restoration target. The four sites in WCA3A and WCA3B were not sampled WY 2012-2016 due to lack of funding.

Data and Calculations

Updates on calculation of indicator

No changes were made for the calculation of the WY 2017 and WY 2018 scores; however, sampling in WCA3A and WCA3B has resumed so we should be able to add that area back into the calculations in WY 2021. In addition, we are working on an updated way to calculate the relative density component of the alligator index using a hierarchical modeling approach that incorporates detection.

How these data are being used

Data collected as a part of this project were used in the RECOVER Report Card and 2019 Systems Status Report (which covers through WY 2017. Crocodile data are being used in the Species Status Assessment (SSA) being completed by the US Fish and Wildlife Service (USFWS). The SSA is an analytical approach developed by the USFWS to deliver foundational science for informing Endangered Species Act decisions.

New insights relevant to future restoration decisions
In Fall 2017 we established a new survey route for alligators in Northeastern Shark River Slough. We now have two routes in that area (Frog City and NESSE) that will allow us to assess the effects of the Modified Water Deliveries to ENP and Tamiami Trail bridging project.

From 12 years of crocodile spotlight surveys in ENP (2004 to 2015), results of a hierarchical model estimated relative density to be 2.9 individuals/km (95% CI: 2.0 – 4.2, Mazzotti et al. in prep.), with a decreasing trend over time (Figure 5, From Mazzotti et al. in prep). Routes in the Flamingo/Cape Sable area had greater crocodile relative density than routes in the West Lake/Cuthbert Lake area and NE Florida Bay areas. Relative density was estimated to decrease with increases in salinity. These results are consistent with the hypothesis that restored flow and lower salinities may result in an increase in crocodile population size and provide support for the ecosystem management recommendations for crocodiles, which currently are to restore more natural patterns of freshwater flow to Florida Bay.

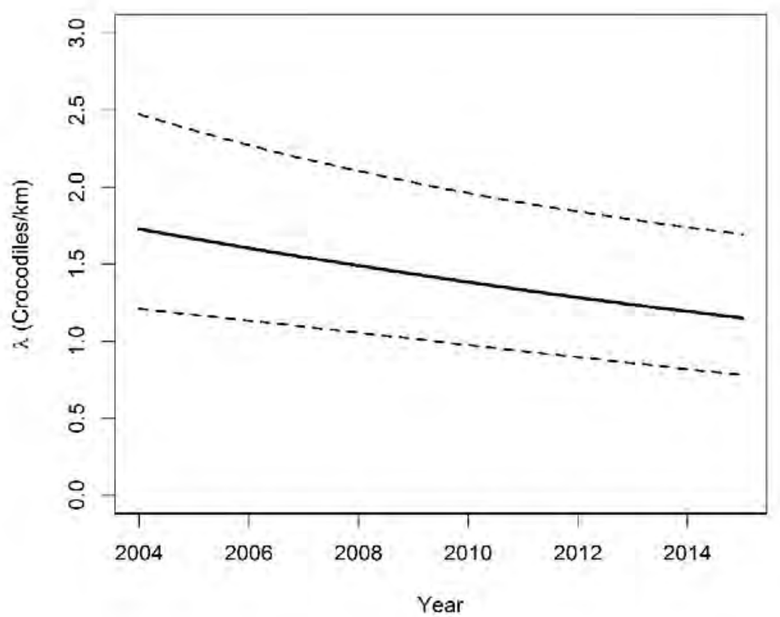


Figure 5. Relative density of crocodiles in ENP (2004 - 2015) decreased over time. Dashed lines are 95% confidence intervals. From Mazzotti et al. in prep.

Our long-term mark-recapture data from 1978 to 2015 resulted in a capture of 10,040 crocodiles, with more than 90% of captures being hatchlings. More crocodiles (67%) have been caught in the Flamingo/Cape Sable and West Lake areas relative to NE Florida Bay (25%), the Biscayne Bay Complex (3%), and Crocodile Lake NWR area (5%). We estimated overall hatchling survival at 25% (Figure 6, From Briggs et al. in prep).

Younger crocodiles were found in lowest body condition but had the fastest growth rate. Salinity affected body condition and growth. Crocodiles captured in NE Florida Bay were in lowest body condition and had reduced growth rates relative to western Florida Bay (i.e., Flamingo/Cape Sable and West Lakes area) and Biscayne Bay (Briggs et al. in prep). Our long-term monitoring efforts provide an opportunity to evaluate crocodilian response over time and to restoration efforts in areas where hydrologic conditions have been most altered.

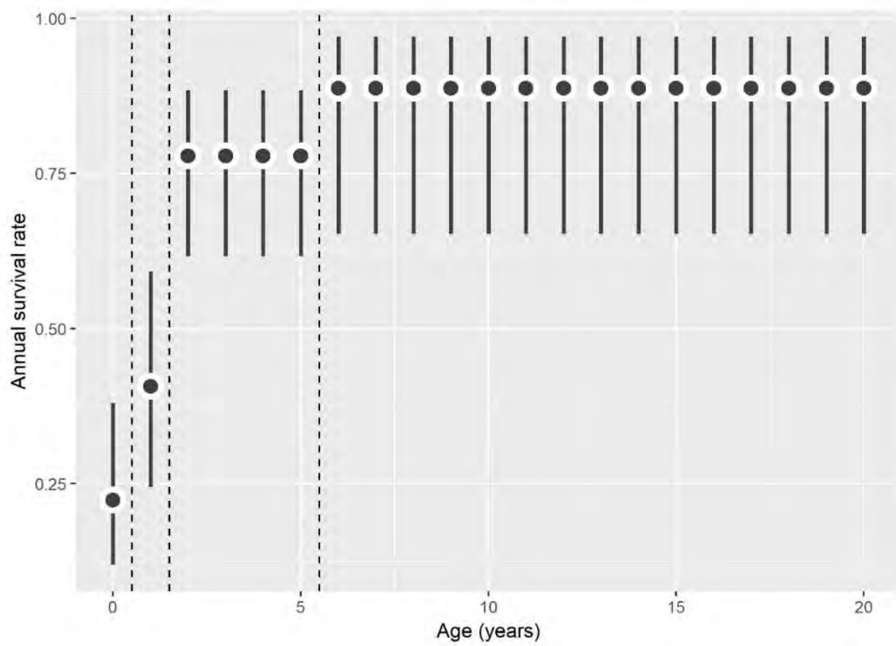


Figure 6. Annual survival rate of crocodiles captured in south Florida by age. Dots represent mean values and lines indicate 95% confidence intervals. Dashed lines are crocodiles grouped by age that demonstrate similar survival rates (0-1 yr old, 1-2 yr old, 3-6 yr old, 7-22 yr old). From Briggs et al. in prep.

From satellite tracking data from 15 adult female crocodiles in ENP home ranges spanned from 30.0 – 141.9 km^2 and core areas (50% use) ranged from 4.7 – 27.4 km^2 (Beauchamp et al. 2018). We identified patterns in home range and core area overlap, seasonally shifting patterns in core area use, and the Fox Lake complex (part of the East Cape area) as an important crocodile high-use area (Figure 7). As the population of American crocodiles continues to grow and expand into new areas it is important to consider crocodile habitat-use patterns and spatial resource requirements.

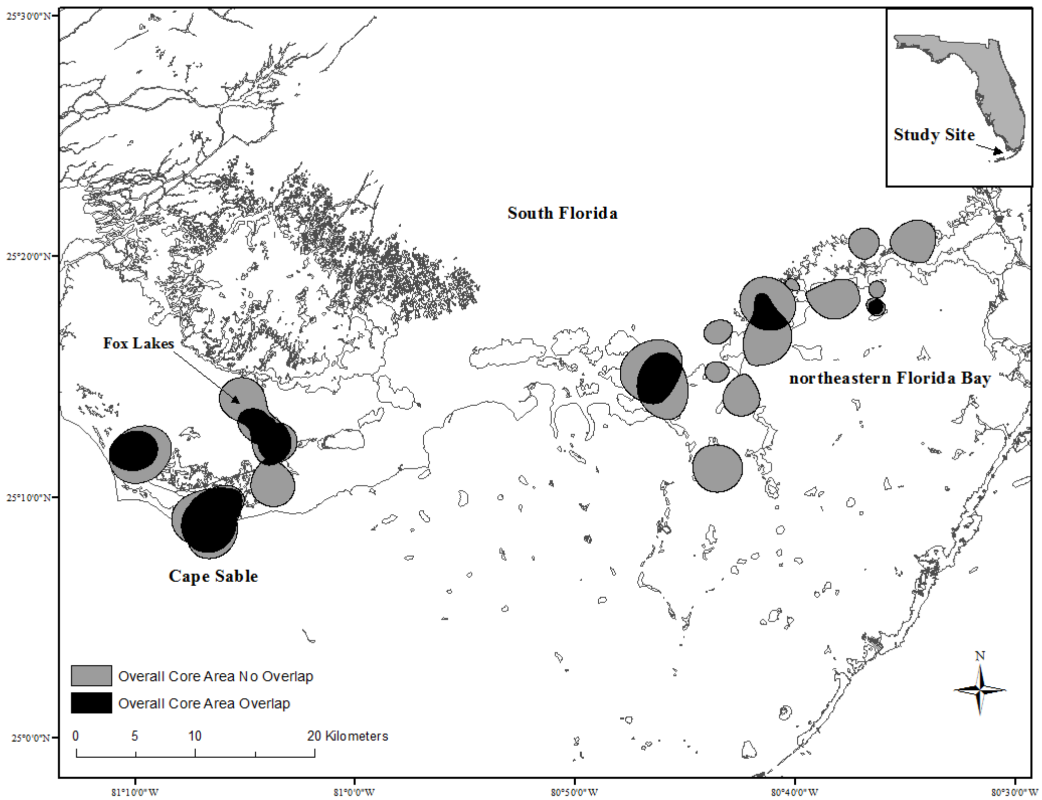


Figure 7. Overall core area (50% use) of adult female crocodiles in ENP. Dark areas represent core area overlap and grey areas are locations where crocodile's core areas did not overlap. From Beauchamp et al. 2018.

Literature cited, reports, and publications for more information

Beauchamp, J.S., K.M. Hart, M. Cherkiss, and F.J. Mazzotti. 2018. Variation in home range size and patterns in adult female American crocodiles *Crocodylus acutus*. Endangered Species Research 36:161-171.

Briggs-Gonzalez, V.S., M. Basille, C. Bonenfant, M.C. Cherkiss, M. Squires, and F.J. Mazzotti. In prep. The American Crocodile (*Crocodylus acutus*): an indicator of ecosystem health in south Florida.

Mazzotti, F.J., B.J. Smith, M. Squires, M.S. Cherkiss, S.C. Farris, C. Hackett K. Hart, V. Briggs-Gonzalez, and L.A. Brandt. In prep. Relative Density of American Crocodiles (*Crocodylus acutus*) in Everglades National Park.

Summary/ Key Findings

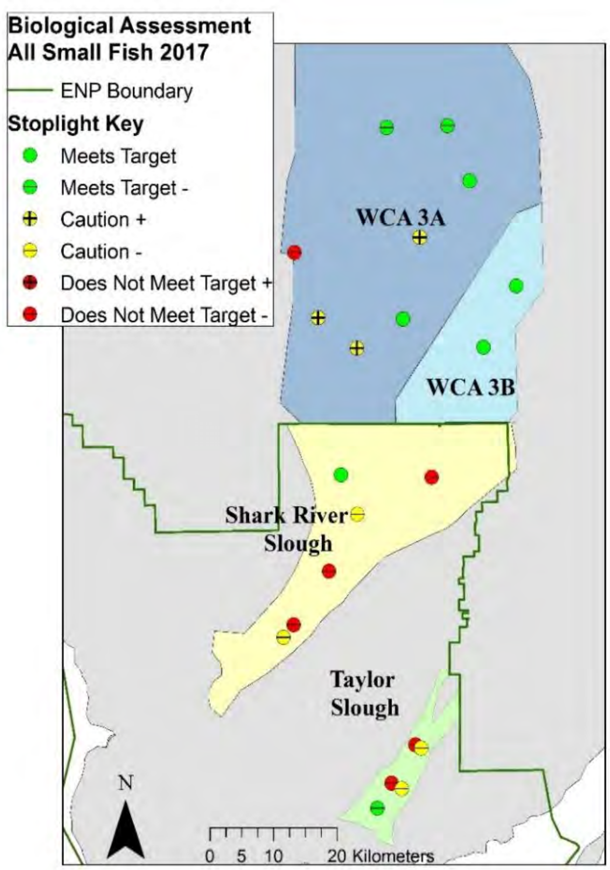
The status of the fish and macroinvertebrates indicator assessed in ENP (Shark and Taylor sloughs) and WCA 3A and WCA 3B was well below the restoration target (red stoplight) in both WY 2017 and WY 2018, which ended in April 2018. This indicator contains multiple components and those in Shark and Taylor sloughs in ENP that are sensitive to hydrological drying have been below rainfall-based expectations at most long-term monitoring sites extending back to WY 2013. This contrasts with the same indicators in WCA 3A and 3B, where they have been within or above expectations based on rainfall. There is continued evidence that Shark River Slough and Taylor Slough dried more frequently and/or longer than required to meet our rainfall-based restoration targets.

In this reporting period, the regional relative abundance of non-native fish exceeded 2% for Shark River Slough in WY 2015-2017, but dropped below that level in WY 2018. This indicator exceeded the 2% relative abundance cutoff in Taylor Sloughs from 2016 through 2018. Non-native fishes continue to be present in field samples from WCA 3A and 3B, but in frequency below the 2% relative abundance cutoff. The last biennial report was the first time that the relative abundance of non-native fish (African Jewelfish, Mayan Cichlids, Asian Swamp eels, and Spotfin Spiny Eels) exceeded our restoration targets since reporting began in WY 2002. In WY 2015-2017, we obtained strong statistical evidence that non-native fish were causing decreases in both density and biomass of native species in Shark River Slough. Those impacts were not observed in the WY 2018 data, suggesting resilience in native fish communities in these areas. How this will ultimately affect the ability of these aquatic communities to provide critical food for iconic predators, including wading birds and alligators, remains to be learned.

The Fish & Macroinvertebrates indicator remains well below the restoration target.

The density of prey-base fishes in Shark and Taylor sloughs was below rainfall-based expectations at most long-term monitoring sites over the current evaluation period (Fig. 1). Only one site in each of those regions was within the statistically determined range for the target density and both of those sites were on the slough edges. This condition has extended back to WY 2013. These results are in contrast to the same indicator in WCA 3A and 3B, where they have been within or exceeded expectations based on rainfall with the lone exception of a site north of Alligator Alley in WCA 3A. Bluefin Killifish, Flagfish, and Everglades crayfish densities,

Figure 1. Stoplight colors for small fish indicator at long-term study sites in WCA 3A, 3B, and ENP. Plus and minus signs on stoplights indicate is color assigned for more or fewer fish than expected.



three performance measures sensitive to the frequency of drying, suggest marshes in ENP have been dried more frequently than expected based on our rainfall-based target (Table 1).

Table 1. Stoplight Table for Fish & Macroinvertebrates Indicator (WCA3 and ENP only) for Water Years 2014- 2018

Performance Measure	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018
Overall	Red	Red	Red	Red	Red
Shark River Slough					
Total Fish	Red	Red	Red	Red	Red
Non-Native Fish	Yellow	Red	Red	Red	Yellow
Bluefin Killifish	Yellow	Yellow	Red	Yellow	Yellow
Flagfish	Green	Green	Green	Yellow	Yellow
Easter Mosquitofish	Yellow	Red	Red	Red	Red
Everglades Crayfish	Green	Yellow	Red	Green	Yellow
Taylor Slough					
Total Fish	Green	Yellow	Red	Red	Red
Non-Native Fish	Yellow	Yellow	Red	Red	Red
Bluefin Killifish	Green	Red	Yellow	Yellow	Green
Flagfish	Green	Yellow	Red	Red	Red
Eastern Mosquitofish	Green	Green	Yellow	Red	Yellow
Everglades Crayfish	Yellow	Yellow	Yellow	Red	Red
Water Conservation Area 3 A					
Total Fish	Yellow	Yellow	Yellow	Green	Green
Non-Native Fish	Yellow	Yellow	Yellow	Yellow	Yellow
Bluefin Killifish	Yellow	Yellow	Green	Yellow	Green
Flagfish	Yellow	Green	Yellow	Yellow	Yellow
Eastern Mosquitofish	Yellow	Yellow	Yellow	Green	Green
Water Conservation Area 3 B					
Total Fish	Red	Red	Green	Green	Green
Non-Native Fish	Yellow	Yellow	Yellow	Yellow	Yellow
Bluefin Killifish	Yellow	Yellow	Yellow	Yellow	Green
Flagfish	Green	Green	Yellow	Green	Green
Eastern Mosquitofish	Yellow	Green	Green	Green	Green

The non-native African Jewelfish averaged as high as 20% of the fish collected at some study sites in Shark River Slough between WY 2015 and 2017. Interestingly, the relative abundance of this non-native species declined in WY 2018 to below our 2% cutoff. In Taylor Slough, a mix of non-native species increased in density over the assessment period. Mayan Cichlid density has fully rebounded from the effects of the cold event in 2010 and their numbers are at or above those at the previous peak. Non-native eels, Asian Swamp Eels and Spotfin Spiny Eels, have dramatically increased in abundance, particularly in electrofishing catches. The red stoplights indicating too low values of total fish density in WY 2015 through 2017 in Shark River Slough appear to result from, or be exacerbated by, African Jewelfish increase. Observed total fish density and density of native species is now lower than expectations based on data gathered prior to Jewelfish arrival. Eastern Mosquitofish and Least Killifish were substantially below hydrologically based targets at sites with high Jewelfish relative abundance. Interestingly, density of these species increased in Shark River Slough in WY 2018 coincidentally with a decline in Jewelfish, providing hope for recovery of impacts from this non-native species.

Though fish and macroinvertebrate density continue to be inconsistent with restoration targets based on rainfall in Shark River Slough and Taylor Slough, they are generally at expectations in WCA 3A and 3B. Based on simulations of historical hydrological conditions in WCA 3A, the long hydroperiods characteristic of this area today are consistent with historical expectations. However, this area currently lacks sheetflow because of hydrological compartmentalization of the area. We currently have no basis to assess the impact of lost sheetflow on fish and macroinvertebrate communities. Research in the DECOMP Physical Model suggests that a flowing Everglades may have different nutrient dynamics than in the current compartmentalized condition with implications for food-web structure and function.

For this biennial report, WY 2018 included data collected through April 2018. Emergency water releases necessitated by large volumes of rain may have created hydrological conditions close to those expected in the restored ENP wetlands of Northeast Shark River Slough and elsewhere for the past two years, while the dry season of WY 2018 (December 2017-April 2018) experienced relatively little rain and water recession was steep and continuous. In spite of these conditions, the abundance of prey species was generally lower than expected based on historical data and rainfall in Shark River Slough and Taylor Slough.

The most striking result in the last reporting period was the rapid increase of non-native species in ENP, with strong statistically supported evidence of impacts on native species decreasing both density and biomass (analyses available upon request). Exciting results in this reporting period are the decline of African Jewelfish in WY 2018 and increase in relative abundance of some native taxa that may have been impacted at sites that experienced high densities of this invader. This decline may be consistent with past experience that explosive growth of non-native fish species is followed by a decrease in their abundance for reasons that are poorly understood, followed by persistence at low density but widespread distribution. Continued monitoring will be needed to determine if this optimistic scenario is appropriate. At their current densities, we have empirical evidence that non-native fishes are re-shaping the function of Everglades aquatic animal communities. How this will ultimately affect the ability of these aquatic communities to provide critical food for iconic predators, including wading birds and alligators, remains to be learned. Filling canals to depths that eliminate winter thermal refuges is currently the most promising restoration action to diminish the abundance of the non-native fishes already in the Everglades. Completing restoration of historical hydroperiods may provide greater resilience of native aquatic communities and diminish impacts of some non-native species, whose expansion and success may be facilitated by the drier environment currently prevailing because of past water allocation and delivery choices. Unfortunately, deeper conditions may facilitate other non-native species such as Peacock Bass and Oscars that thrive in lacustrine habitats.

Data and Calculations

Updates on Calculation of Indicator

There have been no major changes from past biennial reports in the way this indicator was calculated. We used a ‘dynamic target’ approach that models the expected value for each performance measures based on target hydrological conditions (Trexler and Goss 2009). Hydrological targets were calculated based on the relationship of rainfall and stage at our long-term study sites between November 1,1993 – November 1, 1999. This period was selected because it includes the last large El Niño event that yielded two years of particularly wet conditions (1997-1998) and hydrological stages in ENP near those predicted by the Natural System Model (SFNRC 2005). This is also a period before operational changes for the Combined Structural and Operational Plan (CSOP), Interim Operational Plan (IOP), and Everglades Restoration Transition Plan (ERTP) programs. We used these hydrological targets to estimate prey-base performance measure values given the observed rainfall during the assessment period of WY 2017 (June 2015-May 2016) and WY 2018 (June 2017-May 2018).

Our overall assessment of wading bird and alligator prey is based on five performance measures: total fish density (all species of fish summed), Eastern Mosquitofish (*Gambusia holbrooki*), Flagfish (*Jordanella floridae*), Bluefin Killifish (*Lucania goodei*), and Everglades crayfish (*Procambarus alleni*). Past work has demonstrated that these fish are representative of the variety of life-history responses to drying events (Trexler et al. 2005; DeAngelis et al. 2005). Flagfish and Eastern Mosquitofish typically recover quickly from marsh drying, while Bluefin Killifish recover more slowly (DeAngelis et al. 2005). Additionally, the Everglades crayfish has been shown to survive some marsh drying conditions and is typical of short-hydroperiod marshes in the southern Everglades (Hendrix and Loftus 2000; Dorn and Trexler 2007). We analyzed these data using hydrological parameters that estimate the time passed since re-flooding from the most recent drying event. We define drying as water depth dropping below 5 cm and flooding as when previously low water levels rise above 5 cm. To account for ecological responses driven by hydrology operating at different spatial scales, we created three different hydrological parameters: local days since flooding (LDSF), local days since flooding adjusted for regional drying (ADSF), and regional days since flooding (RDSF). We also include a ‘season’ parameter to capture seasonal patterns of recruitment that may inflate densities from the production of juveniles that occurs primarily between April and August. We used linear regression to capture patterns of recovery following marsh flooding and evaluated our models using Akaike’s Information Criterion (AIC) to select a preferred model from a hierarchy of models. Our final models generally describe the data well, although fit varies among species and regions. Stoplights are calculated to accommodate inter-site variation in model fit and uncertainty by use of the deviation of observed and target predictions (Trexler and Goss 2009). We assign red stoplights for extreme deviation of observed from expected in a single year or lesser deviations that are consistent in runs of previous years (3 or 5 years with consistent deviations yield red with relatively less deviations in the assessed year). This year we repeated the assessment using biomass (wet weight grams/meter^2) to compare with results using density (individuals/m^2). The results were consistent between the two methods, so we report the density values to be consistent with past reports.

This year, as in previous years, we assessed non-native species by comparing their regional relative abundance to an arbitrary value of 2%. When the entire regional collection of non-native fishes exceeds 2% of all fishes collected, a red light is assigned; yellow lights are assigned when non-native species are present in the collections but comprise less than 2% of the total; and green when no non-native fish species were collected. This year we have developed a modeling approach to link changes in performance measures that can be linked to non-native species invasions. We are currently circulating that model for discussion before including it in this formal assessment.

How these data are being used

The data have been used in the RECOVER Systems Status Reports and to produce the RECOVER performance measure documentation sheets for the Prey-based Freshwater Fish performance measure. Performance measures are planning tools used by RECOVER to determine the degree to which proposed alternative plans are likely to meet CERP restoration objectives or implemented plans have met restoration objectives. Documentation sheets provide technical information about the indicator and describe desired future conditions and how the indicator can be used for evaluation and assessment. The freshwater fish documentation sheet was approved in May 2011. This information also can be used in the context of interim goals.

This assessment uses a model-based target for assessment of current status and assigning stoplights. The same models have also been used for evaluation purposes, most recently for the Central Everglades Planning Process (CEPP) and other scenario-based evaluations of possible future Everglades conditions (USACE 2014; SERES Project 2012; Catano et al. 2015; Beerens et al. 2017).

New insights relevant to future restoration decisions

Ongoing trends of change in the status of the prey-base small fish communities in Shark River Slough, and to a lesser extent Taylor Slough, have continued since the last biennial report with implications for restoration decisions that warrant further evaluation. Past reports have documented and discussed a long-term trend of declining prey biomass in these areas compared to data from the late 1970s (based on data from three of the long-term study sites in Shark River Slough) and from the late 1990s (based on data from all sites included in this report). Since 2000, there has been a gradual decline beyond what is expected based on hydrological variation alone, possibly resulting from regional-scale effects of cumulative drying and shortened hydroperiods.

This assessment reports data indicating continuing changes in density and biomass relative to expectations in the Shark River Slough that are correlated with a sharp increase in the frequency of a non-native fish, the African Jewelfish. Our analyses indicate that including the numbers and biomass of the non-native fish in the calculations does not compensate for the low values, suggesting a less efficient food web with the invasion of Jewelfish. The most recent data, WY 2018, give reason for optimism in this long-term pattern in Shark River Slough, but no change in Taylor Slough. These results require further monitoring to determine if the immediate warning signs suggest long-term consequences. Past invasions with spikes in abundance of non-native fish have been followed by their decline and persistence at low density; it is unclear at present if the more recent data indicate ecological resilience and recovery in Shark River Slough, or an increase in inter-annual variation that could accompany fundamental change in aquatic community function. The expansion of Jewelfish may be linked to access from canals bordering ENP and may represent an unintended consequence of restoration activities (Kline et al. 2014). The frequency of non-native species has also increased in Taylor Slough since the last biennial report. This increase results from expansion and increase in density of Asian Swamp Eels and Spotfin Spiny Eels, and recovery of Mayan Cichlids following low temperatures in 2010. The ecological impacts of these species are a focus on ongoing study.

We are in the process of updating our assessment models to accommodate changing conditions and knowledge. We have been working with models that directly assess non-native taxa impacts on our performance measures for restoration success, including wading bird prey and aquatic food-web function. We are also gathering information that can be used to consider water flow impacts on these performance measures, though hydrological data that we currently obtain from Everglades Depth Estimation Network (EDEN) will need to include metrics of flow velocity and water quality to most fully account for all restoration-affected environmental drivers that impact this indicator.

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Summary/Key Findings

The status of the modified periphyton indicator (an indicator of water quality) was below the restoration target (yellow stoplight) at the end of WY 2016 and remains below the restoration target at the end of WY 2018 (Fig. 1, Table 1). The system-wide status assessment for periphyton for WY 2016 was based on a combined quality, quantity, and composition metric (using periphyton total phosphorus content, ash-free dry biomass, and percentage endemic diatoms, as previously reported). The status report for WY 2018 is based on quality and quantity only because funding for the endemic diatom estimate, based on archived samples, has not yet been made available. Surveys were conducted in A.R.M. Loxahatchee NWR (WCA 1), ENP [Shark River Slough (SRS) and Taylor Slough (TS)], and WCAs 2 and 3.

The status of the periphyton indicator in the areas listed above remained below the restoration target (yellow stoplight) in WY 2016 and 2017 (overall score = 77% in both years). This score has remained relatively consistent for the last nine consecutive years. There are fluctuations from year to year, but overall this result reflects low biomass of calcareous periphyton mats, higher periphyton total phosphorus (TP) content than expected background levels, and a higher number of “weedy” diatom taxa inhabiting the mats (indicative of enrichment). Some temporal trends are noted at some subsets of sites, but there is no consistent trend at the regional or full-system scale.

The sampling sites with lower periphyton quality were clustered near the L-67 canal, the central WCA 3A flowpath, and near canal boundaries of A.R.M. Loxahatchee NWR and WCA 2A. Several sites in coastal areas also had lower periphyton quality, possibly driven by marine sources of phosphorus.

The Periphyton indicator remains below the restoration target.

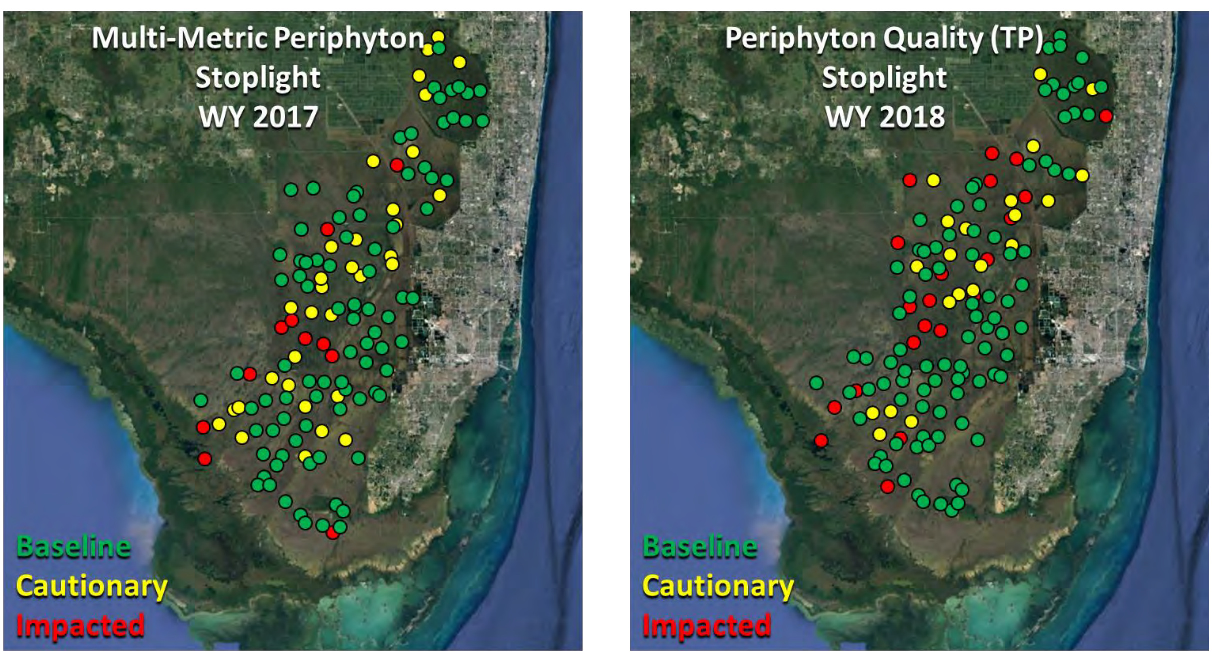

Figure 1. Stoplight colors for the multi-metric periphyton indicator for WY 2017 (left) and the TP-only quality indicator for WY 2018 (right).

Table 1. Stoplight Table for Periphyton Indicator for Water Years 2014 - 2018. These scores were calculated using an updated methodology from previous reports (see Updates on calculation of indicator section below).

	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018
SYSTEM-WIDE					
Quality (TP)					
Biomass					
Composition					N/A
Multi-Metric					N/A
WCA 1 (A.R.M. Loxahatchee NWR)					
Quality (TP)					
Biomass					
Composition					N/A
Multi-Metric					N/A
WCA 2A					
Quality (TP)					
Biomass					
Composition					N/A
Multi-Metric					N/A
WCA 3A					
Quality (TP)					
Biomass					
Composition					N/A
Multi-Metric					N/A
SRS					
Quality (TP)					
Biomass					
Composition					N/A
Multi-Metric					N/A
TS					
Quality (TP)					
Biomass					
Composition					N/A
Multi-Metric					N/A

Data and Calculations

Updates on calculation of indicator

The thresholds used for the periphyton quality (reflection of TP) and quantity (biomass) metrics described above were refined from earlier experimental studies and CERP MAP data that have been collected for nearly a decade for the periphyton mapping program (Table 2). The quality cut-offs were based on experimental data reported in Gaiser et al. (2006) and Gaiser (2009). The quantity and composition cut-offs were revised according to the 12 years of data from each site with baseline values being within one standard deviation of the mean and caution and impacted values representing greater than one and two standard deviations of the mean. Another update is the approach used to calculate a basin-wide score. Previous reports were based on a frequency of baseline, caution and impacted sites, whereas this updated report used an approach applied to other indicators of scoring each site with a 100, 50 or 0 for each category, respectively. The sites are then averaged within each wetland basin and the basin scored as baseline, caution or impacted if the mean is ≥85, <85 and >50, and ≤50, respectively. The compositional metric is most closely correlated with inflowing weighted mean TP concentrations at inflow structures, and this correlation remains high for sites well to the interior of the wetland. The full interpretation of the periphyton metric for marsh impairment must consider inflow and legacy TP, local biogeochemical processes, and other factors (hydroperiod, soil compaction, and subsidence) influencing periphyton ecology.

Table 2. Stoplight values for the periphyton indicator multi-metric.

Metric	Measurement	Stoplight	WCA1	WCA2A	WCA3A	SRS	TS
Quality	Total Phosphorus (ug/L)						
Quantity	Ash-Free Dry Mass (ug/g)						
Composition	Endemic Diatom s (%)						

How these data being used

These data and findings were also reported in the RECOVER 2016 and 2019 System Status Reports and are being used to support models for synthesis efforts. Funding for composition has resumed so we will be able to incorporate that metric in the next reporting period. This information also can be used in the context of interim goals. We have also conducted comparative studies in other karstic wetlands in the Caribbean region and have provided this tool for use there (La Hée and Gaiser, 2012; Gaiser et al. 2015).

New insights relevant to future restoration decisions

New insights stemming from the 9-year analysis (Gaiser et al. 2015) suggest that periphyton is responsive to inputs of phosphorus from inflow structures at scales of meters to tens of kilometers. Average wet season values of quality, biomass, and composition for each of the basins were highly correlated with inflowing TP concentrations, suggesting high sensitivity to loads that change with water flow. This explains why wet years on record show greater impairment than dry years.

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Summary/Key Findings

The status of the Wood Stork and White Ibis wading bird indicator was well below the restoration target (red stoplight) in the previous reporting year (WY 2016) and the current reporting year (WY 2018) in all but one indicator. Normal water levels in calendar year 2016 and early 2017 were followed by a reasonable drying pattern, resulting in strong but not exceptional nesting in spring 2017. Nest starts were relatively early for Wood Storks (December for some nests) and the second highest nesting numbers for Wood Storks in 18 years were recorded. Because the end of the WY (April) falls inconveniently in the middle of the wading bird nesting season, the water year reporting reflects the previous spring nesting. For this reason, this report is on the spring 2017 nesting season, with appropriate comments on the 2018 season.

Three of the four key restoration parameters for wading birds remained in the red, or poorest response category. Although there was some progress on timing of nesting in 2017 for Wood Storks, the indicator is a five- year average and the single result from 2017 did not move that dial appreciably. The mean interval between exceptional ibis nesting years now routinely exceeds target levels and has in both 2017 and 2018 nesting years.

While still ongoing, it is possible to make some inferences about the 2018 nesting season which will be reported on in WY 2019. Nesting by storks was early (December and January) and largely successful. Exceptional numbers of ibises have begun nesting on a normal schedule (March and April) and, notably, several very large colonies have formed in the coastal zone in ENP. These trends of more nesting in the coastal zone and earlier nesting are both positive developments that are likely to affect the averages of those two indicators. The proportion of tactile to visual foragers does not seem to be strongly affected in 2018.

Overall, both 2017 and 2018 spring nesting events occurred under good water and weather conditions nd had reasonable to exceptional responses. However, this might be predicted as a result of the weather patterns alone, and it is not clear that any of the positive results are directly attributable to restoration actions. These responses of wading birds are what would be predicted (trends are stable to negative) since large scale restoration of hydrological conditions that should positively affect birds has not yet taken place.

The Wood Stork and White Ibis wading bird indicator remains well below the restoration target.

Table 1. Stoplight Table for Wading Birds (Wood Stork & White Ibis) for Water Years 2012- 2017

	WY 2013	WY 2014	WY 2015	WY 2016	WY 2017
Wading Bird Indicator Summary					
Ratio of Wood Stork + White Ibis nests to Great Egret nests					
Month of Wood Stork nest initiation					
Proportion of nesting in headwaters					
Mean interval between exceptional Ibis nesting years					

Data and Calculations

How have these data been used?

The information that results in these indicators is reported annually in the publicly available South Florida Wading Bird Nesting Report published by the SFWMD. This outlet is quite popular with the media and is an important tool for communicating up to date results with the public and decision makers. This information is also used in weekly operations decisions at the District. Foraging and nesting information also goes into predictions about future nesting years, usually in December or January of each year (U.S. Geological Survey and SFWMD). In July 2018, ENP sponsored a public meeting to disseminate information about the exceptional 2018 nesting season and what it meant for Everglades restoration.

New insights relevant to future restoration decisions

1. WADEM Models developed by James Beerens and collaborators at Florida Atlantic University (Beerens et al. 2015) have shown increasing ability to predict foraging and nesting based on antecedent hydrology and relationships between fish abundance and drydown interval. This work is of direct importance because it tests some of the long-held assumptions underpinning a predictive relationship between hydrology, food production, and nesting success. During the 2017 and 2018 nesting seasons these models have done well at predicting annual nesting effort.

2. Just as these relationships between nesting and hydrology are being firmed up, there is increasing awareness that predation, long a minor factor in nesting success, might be an important consideration because of the increase of Burmese pythons. During 2015 - 2018, evidence from trail cameras aimed at nests suggests pythons do prey on wading bird nests; and may account for twice the effect that native predators do. Sampling of python eDNA in water samples near and far from colonies suggests that 1) python occupancy of all sites is >90%, and 2) pythons appear to be attracted to wading bird colonies.

3. Recent research has illustrated a strong positive relationship between nesting wading birds and alligators within the colony. Alligators appear to protect the colony from predation by mammals, and alligators derive substantial benefit and higher body condition indices by associating with colonies (Nell et al. 2016), probably because of chicks dropped from nests (Nell and Frederick 2015). The degree of benefits for both animal groups suggests strongly that the Everglades has been an important nesting site for birds in large part because of the presence of alligators. In this light, declines in alligator populations and alligator condition (this report) should be seen as a threat to wading bird nesting populations.

4. Mercury has long been a contaminant of concern in the Everglades, and despite widespread declines in exposure throughout the system in the late 1990s, important pockets of exposure persist. The net effects of mercury exposure on reproductive success are currently being measured using novel techniques that allow nondestructive sampling of the same individuals through egg and chick periods. Preliminary analysis suggests that even at low and intermediate levels, mercury has measurable effects on nest success, largely through the effects on parental behavior (eg, egg and chick neglect).

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Summary/Key Findings

The algal bloom stoplight indicator in the Southern Coastal System (SCS) applies to the estuarine and coastal waters from Biscayne Bay to Florida Bay to the Ten Thousand Islands. Indicator scores commonly were below the restoration target in water years 2017 and 2018 (Figure 1), but scores varied widely among sub-regions and between these years. Poor (red, well below target) scores continued in northern and central Biscayne Bay in both years. A long period with good scores in north-central and western Florida Bay ended in WY 2017. Following the large-scale seagrass die-off in these regions in the summer and fall of WY 2016, chlorophyll *a* concentrations increased in WY 2017, yielding cautionary (yellow) scores in that year and poor scores in WY 2018. The effects of Hurricane Irma were evident throughout the SCS, with poor scores in five of the ten sub-regions and a good (green) score in only one sub-region.

The algal bloom indicator, described in Boyer et al. (2009), is based on the concentration of chlorophyll *a* in the water column, which is a proxy for phytoplankton biomass and typically reflects overall water quality. The indicator's target is to sustain long-term chlorophyll *a* concentrations in SCS waters at or below the median concentration of these waters during a pre-CERP reference period (early-mid 1990s through 2004). In essence, the target is for restoration actions to "do no harm" to SCS water quality. The indicator's stoplight scoring categories correspond to each sub-region's observed annual median chlorophyll *a* concentrations being below the reference period median of that sub-region (green), or from its reference period median to 75th percentile (yellow), or above its reference period 75th percentile (red).

Biscayne Bay bloom indicator results from the last 14 years (sub-regions NBB, CBB, and SBB in Table 1) have all been yellow or red, meaning that annual median scores in the bay have shifted to a state with more chlorophyll *a* than occurred during the indicator's reference period (calendar years 1993 through 2004). The most pronounced shift was in the central and northern bay, with 9 of 10 stoplight scores being red in the past 5 years, following a 9 year period when only 1 of 18 scores was red.

Florida Bay bloom indicator results show that most of the bay had good water quality for the decade following the indicator's reference period (Table 1). Green scores were most common in the western and north-central bay. However, these sub-regions' 8 to 11 successive years with green scores ended following the seagrass die-off event of the summer and fall of calendar year 2015 (WY 2016), which occurred only in these two sub-regions. The timing of chlorophyll a concentration increases in these sub-regions is consistent with the die-off being a local cause of phytoplankton blooms.

Algal blooms in Florida Bay also appeared to be immediately and strongly stimulated by Hurricane Irma's disturbance, with chlorophyll *a* concentrations hitting record high values at almost all north-central and western bay sampling sites. Irma's strongest influence appeared to be in these seagrass die-off areas and the northeastern bay and weakest influence in the southern bay. These patterns are consistent with the storm's influence being driven by high watershed rainfall and flow increasing the export of wetland nutrients to the bay, as well as the mobilization of nutrients already resident in the bay (especially in areas with dead seagrass).

Hurricane Irma also appeared to impact the waters along the southwest Florida coast, with both offshore waters (Southwest Florida Shelf, SWFS sub-region) having a poor (red) indicator score and nearshore and inland waters (Mangrove Transition Zone, MTZ sub-region) having a cautionary (yellow) in WY 2018 (Table 1). The MTZ sub-region's WY 2018 median chlorophyll a concentration was the highest since the reference period.

The Southern Coastal Systems phytoplankton blooms indicator remains well below the restoration target.

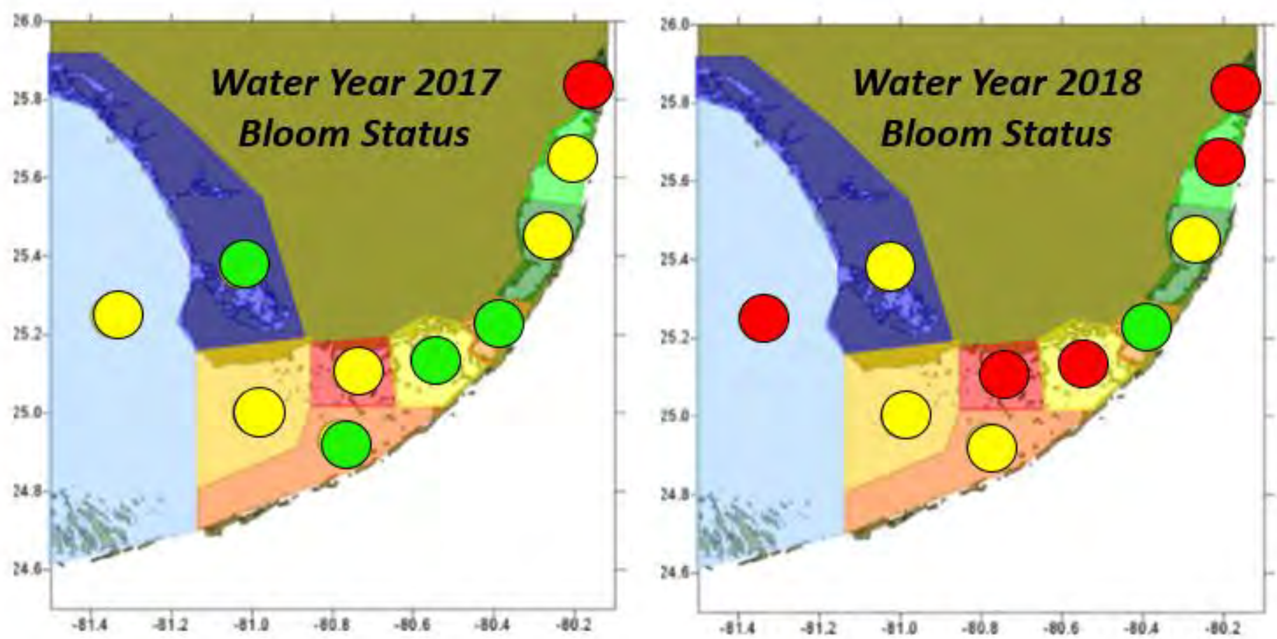

Figure 1. Map showing the spatial distribution of the water quality indicator scores throughout the SCS in WY 2017 (left) and WY 2018 (right).

Table 1. Florida Bay and lower southwest coast algal bloom indicator stop-light scores, based on Boyer et al. 2009. Green results are considered good and red are considered very poor. Results are derived from chlorophyll-a concentrations, which have been measured by SFWMD, the Miami-Dade Department of Environmental Management (DERM), and National Oceanic and the Atmospheric Administration (NOAA) monitoring programs. The number of stations and frequency of sampling per sub-region was not constant through the period of record shown here. Sub-regions shown are: Southwest Florida Shelf (SWFS); southwestern mangrove transition zone (MTZ) from Whitewater Bay to Cape Romano; western Florida Bay (WFB); southern Florida Bay (SFB), north-central Florida Bay (NCFB); northeastern Florida Bay (NEFB); Barnes Sound, Manatee Bay and Blackwater Sound (BMB); southern Biscayne Bay (SBB); central Biscayne Bay (CBB); and northern Biscayne Bay (NBB). Years shown in black (B) had insufficient data for reliable reporting. The System-Wide score represents the median condition of the set of sub-regions, without spatial weighting and tie-breaking to the poorer, more cautionary score.

WATER-YEAR	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
SYSTEM - WIDE	Green	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Red
SWFS	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Red	Red	Black	Black	Green	Yellow	Yellow	Red
MTZ	Green	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Green	Green	Yellow
WFB	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Yellow
SFB	Green	Yellow	Yellow	Red	Green	Yellow	Green	Green	Green	Green	Yellow	Yellow	Green	Yellow
NCFB	Green	Yellow	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Yellow	Red
NEFB	Green	Red	Yellow	Yellow	Green	Green	Yellow	Yellow	Red	Yellow	Green	Green	Green	Red
BMB	Green	Red	Red	Red	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Green
SBB	Yellow	Red	Red	Yellow	Yellow	Yellow	Red	Yellow	Yellow	Red	Yellow	Yellow	Yellow	Yellow
CBB	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Yellow	Red
NBB	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Red	Red

Data and Calculations

Updates on calculation of indicator

Calculation methodology for the SCS algal bloom indicator remains unchanged from the description in Boyer et al. (2009), but indicator results have been affected by decreases in the number of field sample sites, changes in sample site locations, decreased sampling frequency, and changes in analytical methods. The stoplight threshold chlorophyll *a* concentrations for the SWFS sub-region were recalculated for this report because Boyer et al. (2009) merged data collected at two sets of stations [by Florida International University (FIU) and by NOAA], but FIU station sampling ended in WY 2008. For this report, only NOAA data from WY 1998-2004 were used to recalculate the reference period thresholds that define stoplight categories, and only NOAA data were used to assess SWFS bloom conditions from WY 2005-2018.

The effects of other sampling and analytical changes have not been thoroughly analyzed. Most of the station and sampling frequency changes occurred between 2010 and 2012, so confidence in consistency is higher for the results within the past 6 years, and results prior to 2010, than confidence in the consistency of results between these two periods. No obvious change in the chlorophyll *a* concentration patterns occurred around 2011.

How are these data being used

The occurrence of algal blooms in south Florida coastal waters has drawn strong public attention in recent years. While most of this attention has been focused on the Northern Estuaries, blooms along the southwest coast (including red tides), in Florida Bay, and in Biscayne Bay also have been a concern. The data presented here provide an easily understood indictor of bloom status throughout these southern coastal waters. The underlying data have been used to track the status and trends of these systems and gain insight of bloom causes and effects. Most importantly, the data are providing insight of how potential restoration actions can directly (e.g., via nutrient loading from the watershed) or indirectly (e.g., via affecting the health or mortality of seagrass beds) affect the frequency, spatial extent, intensity, duration and ecological effects of blooms. The results shown here point toward the importance of major storm events as drivers that strongly influence algal bloom dynamics concurrently with anthropogenic drivers.

New insights relevant to future restoration decisions

Long-term water quality monitoring data and the results of this report show the susceptibility of coastal waters to conditions producing algal blooms. Biscayne Bay appears to have changed its ecological state over the past 15 years, with increased phytoplankton biomass. This change has been most apparent in the central and northern bay over the past 5 years. This finding, combined with observations of increased macroalgae and seagrass die-off in these Biscayne Bay sub-regions, likely indicate increased nutrient enrichment. The source of such nutrients is unclear but may be related to local urban land use or local sea-level rise effects on local nutrients, especially via ground-water changes. Restoration projects affecting water inputs to Biscayne Bay should be aware of these uncertainties. Research to identify causes of changing Biscayne Bay water quality and potential management actions for improving the Bay is needed.

Recent increases in Florida Bay phytoplankton biomass appear to be related to the health of seagrass beds and hurricane disturbance. In the decades following the late 1980s and early 1990s seagrass die-off event, seagrass recovered and algal blooms decreased, yielding good algal bloom indicator scores from WY 2005 to WY 2015 (Table 1). However, following another seagrass die-off event in WY 2016 and then a major hurricane, intense blooms occurred. Extremely high salinity conditions in the summer of 2015 contributed to initiating the die-off and Everglades restoration is expected to decrease the risk of high salinity stress in the future. Sustaining the health of seagrass beds appears be a key to sustaining good water quality in Florida Bay, and seagrass community health has been identified as a key CERP target.

Similarly, sustaining the health of the coastal wetland's plant community and soils is likely a key to protecting the water quality of the southwest coast's mangrove transition zone and coastal waters. Sea-level rise is a threat to this region, with saltwater intrusion potentially causing peat collapse and nutrient releases from the wetland. Implementation of the Modified Water Deliveries Project to ENP and CEPP, combined with the operation of upstream stormwater treatment areas, can mitigate this threat.

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Summary/Key Findings

The status of the Florida Bay SAV indicator is below the desired restoration target. The indicator is yellow for fair for both WY 2017 and WY 2018, continuing a long-term pattern of fair status bay-wide. The Composite Index that summarizes SAV status for five zones indicates that seagrass condition remained below targets in the Transition, Central, and Southern zones for both years, improved in the Western zone to green (Figure 1) while it remained green in the Northeastern zone. This reporting period follows the large die-off event in 2015 and includes the passage of Hurricane Irma in September 2017. Die-off occurred only in parts of the bay, primarily the western Central zone and in the Western zone, while the hurricane impacted the entire bay. In both events, in addition to physical loss of seagrass, a release of excess nutrients to the water caused prolonged algal blooms of six months or more which increased turbidity and reduced seagrass photosynthesis, inhibiting the recovery of SAV. Nonetheless, underlying indicators reveal that recovery is occurring in some areas of the bay, while other areas are of continuing concern.

The Florida Bay SAV indicator remains below the restoration target.

MAJOR INDICES OF ABUNDANCE AND DIVERSITY

The Composite Index is composed of two indices (Figure 2). The Abundance Index, which measures both a spatial coverage component and a density component, was poor in WY 2017 and WY 2018 in the Southern Zone, fair in the Transition, Central, and Western Zones and good only in the Northeastern Zone. The score of fair in the Western Zone represents a regression following a grade of good during WY 2016 prior to the die-off. The score was reduced primarily by a decline in density rather than in spatial extent (the basin area covered by seagrass beds). The net effect of the loss in density is that as of WY 2018, four of the five zones are below targets for abundance. The Target Species Index, which combines a score for species diversity and a score for presence of ecologically valuable seagrass species, showed declines in status in several zones, falling from good to fair for WY 2017 and WY 2018 in the Northeastern Zone, remaining fair in the Transition Zone and falling from good to fair in the Central Zone in WY 2018. Notably, sub-indicators fell from yellow to red for diversity in the Northeastern Zone in both years and in the Central Zone in WY 2018. The effect of these declines is that as of WY 2018, four of the five zones are in yellow status for the Target Species indicator.

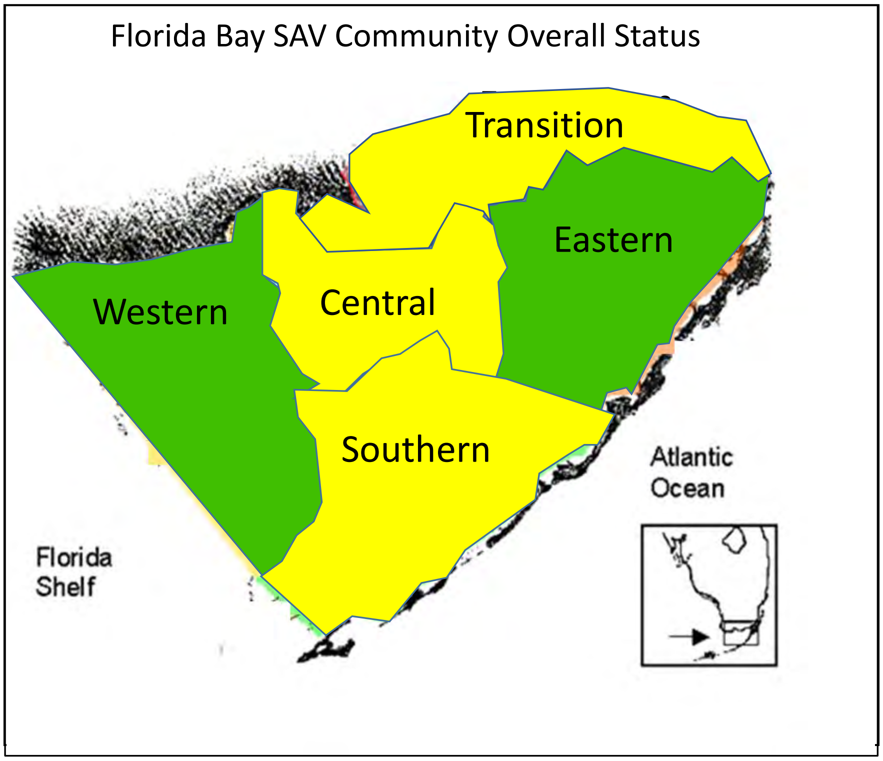

Figure 1. Overall SAV status scores for each Florida Bay zone for WY 2018

INDEX BREAKDOWN

ABUNDANCE

The aggregate Abundance Index (Index A) dropped from green to yellow in the Western zone due to the die-off and hurricane in WY 2017 and WY 2018. Examination of the underlying sub-indices reveals that a decline in density was responsible, dropping from good to fair in the Western Zone. The spatial extent component of abundance was in the good range for all basins during and after the die-off. This continuation of good status for spatial extent even in the die-off area is attributable to two factors. First, the die-off did not affect all areas of most basins where it occurred (excluding Rankin which was completely involved), and adult seagrasses were present in basins affected by the die-off at least during the May measurement period in both 2017 and 2018. Second, recovery began during the period between die-off initiation and the WY 2017 seagrass survey. Short regrowth of *Halodule* and *Thalassia* could be seen in many areas, even including Rankin, in 2016-17 which, despite low density, made progress toward improved spatial extent. In the Western Zone, the density declined from good in WY 2016 to fair for both WY 2017 and WY 2018, and resulted in a decline in Index A to yellow for abundance there in both years. It was the only zone to decline from WY 2016 in abundance status. Many individual basins throughout the bay declined in density following the die-off including Johnson, Rankin, Duck, Eagle Key and Alligator but all are showing improvement in WY 2018. Even Rankin, hardest hit by the die-off and virtually denuded of vegetation, has improved from poor to fair for abundance in the most recent survey as recovery has taken hold.

SPECIES DIVERSITY

The aggregate Species Index (Index B) dropped to fair in the Northeastern Zone and at first improved to good for the Central Zone in 2017 before falling back to fair for WY 2018. The overall diversity status for FY 2018 shows four of the five zones are at fair status for species diversity, with only the Western Zone consistently showing good status. It is concerning that the Northeastern and Central Zones are trending to fair status in recent years after consistently showing good status prior to 2017 and 2015 respectively. Only Rankin, Oyster, and Whitewater show good diversity status currently and most other areas are in the yellow and trending downward, with Alligator, Eagle Key, and Davis in the red. This might be a reflection of the 2014-15 drought which would tend to drive the system toward monoculture in areas where *Thalassia* survived and other species were eliminated by high salinity, and toward a temporary monoculture of *Halodule* in areas where *Thalassia* died off and the faster-growing shoalgrass quickly moved into empty basins after salinity declined. A check of underlying factors shows that the sub-index for diversity is in fact in the red for all of the bay except for the Western Zone, which is in the yellow. At a basin scale, Blackwater, Barnes, Long, Madeira and Johnson improved from red to yellow while all other basins continued at or turned red in WY 2018. Only Whitewater and Oyster are green for diversity on a consistent basis.

The other sub-index for species, the presence of target species also declined for WY 2017-WY 2018. Its status switched from green to yellow in the Northeastern and Transition Zones, joining the Southern, which is consistently yellow for target species, so that now there are three zones in fair condition and only the Central and Western Zonesare in good condition for target species in WY 2018. Notable declines in target species at the basin level are in Alligator and Eagle Key, both to red, and Johnson, Trout, Barnes, and Little Blackwater to yellow. Overall, these changes influenced a downward trend in species diversity in the two most recent years surveyed.

<u>OVERALL STATUS</u>

Previous incremental gains in the quality of SAV habitat over several years were reflected in generally improving scores in the late 2000’s and early 2010’s. The wetter years of 2012 and 2013 resulted in lower salinities and more favorable conditions and improving SAV status in many areas of the bay. These improvements proved to be transient and were reversed by two climatological events in 2015 through 2018: prolonged drought and a tropical cyclone. The extreme drought of 2015-16 led to the SAV die-off event in areas of the bay that became most hypersaline (in the Central Zone as high as 75 psu) or basins that supported the densest *Thalassia* populations (Western Zone). The hypersaline condition and die-off was fortuitously curtailed by the very wet dry season of WY 2016 and the el Niño rains continuing into WY 2017 which brought freshwater to the bay even during the dry season. Active die-off has not been observed in the bay in WY 2018. The two algal bloom events each subsided within six - eight months, improving water clarity after a period of high turbidity. Recent indications are that SAV regrowth is occurring and may show more favorable status in the next indicator report, barring additional negative climatological events.

Table 1. Stoplight Table for Florida Bay Submersed Aquatic Vegetation, Abundance (Index A), Diversity (Index B) and Overall (Index C) for Water Years 2014- 2018.

	WY 2014	WY 2015	WY 2016*	WY 2017	WY 2018
BAYWIDE OVERALL	Yellow	Yellow	Yellow	Yellow	Yellow
NORTHEAST ZONE Overall	Green	Green	Green	Green	Green
Abundance	Green	Green	Green	Green	Green
Diversity	Green	Green	Green	Yellow	Yellow
TRANSITION ZONE Overall	Green	Yellow	Yellow	Yellow	Yellow
Abundance	Yellow	Yellow	Yellow	Yellow	Yellow
Diversity	Green	Yellow	Yellow	Yellow	Yellow
CENTRAL ZONE Overall	Green	Yellow	Yellow	Green	Yellow
Abundance	Yellow	Yellow	Yellow	Yellow	Yellow
Diversity	Green	Yellow	Yellow	Green	Yellow
SOUTHERN ZONE Overall	Yellow	Yellow	Yellow	Yellow	Yellow
Abundance	Red	Red	Red	Red	Red
Diversity	Yellow	Yellow	Yellow	Yellow	Yellow
WESTERN ZONE Overall	Green	Green	Yellow	Green	Green
Abundance	Yellow	Yellow	Yellow	Yellow	Yellow
Diversity	Green	Green	Green	Green	Green

**Index scores were recalculated for the Western Zone in WY2016 based on supplementary data due to seagrass die-off.*

Data and Calculations

Status indicators for SAV are calculated each year to summarize the status and trends of benthic vegetation in Florida Bay. For WY 2017 the overall SAV indicator showed a continued yellow status for the bay as in previous years, falling short of restoration targets in several metrics and geographic areas. While holding steady in some sectors, the SAV community showed decline in the Transition, Central and Western bay relative to prior years' status. This is the result of low rainfall and low freshwater input to the bay beginning in 2014 and continuing in subsequent years. A severe drought in the summer of 2015 further reduced SAV status for the latter half of WY 2016 as SAV dieoff occurred in substantial portions of the central and western bay during the summer.

Updates on calculation of indicator

The basic methodology for calculating the SAV Indicator, underlying Indexes and component scores for SAV are detailed in Madden et al. 2009. Scores for each of four components are calculated based on data gathered from an annual survey conducted under the Fish Habitat Assessment Program. Two underlying components comprise each index: the Abundance Index is comprised of spatial extent and density components; the Diversity Index is comprised of species dominance and target species components. Scores are normalized to a 0-1 scale and compared, for each of the four indexes, to pre-established ranges indicating poor, fair and good status based on historical data and desired performance targets.

Score ranges are set for each of five zones based on history and expectation and each basin in the zone is averaged to give a zonal average for the sub-indices and Indexes. Scores from each zone are combined to create Index C, the overall score for the zone. For the bay as a whole a single system status indicator is taken as the minimum score from the five zones. That is, the baywide score is determined by the lowest Index C zone score. The rationale for this procedure is that the entire bay should assume the lowest score rather than an average which would always bias the status positively. Our aim is that the most conservative assessment should characterize the bay for restoration applications and that if all five zones are not green, it is important that a lower indicator flag the bay as requiring monitoring, management attention and restoration action.

How are these data being used

Data from the indicator analysis were used in a variety of ways in 2017-18: to communicate SAV status internally within the SFWMD and to its Governing Board and to the Water Resources Analysis Coalition; to communicate with research collaborators and interagency partners, including USGS, NOAA, DOI, FDEP, Miami-Dade DERM, ENP, USEPA, RECOVER and others; to provide a visual status report to Congress and to the public via presentations; to formally document and report SAV status in such publications as the 2018 and 2019 South Florida Environmental Report, the 2019 System Status Report, the 2017 and 2018 C-111 Annual Ecological Reports, the C-111 Spreader Canal Western Features Project Monitoring and Assessment Report, the Minimum Flows and Levels (MFLs) for Florida Bay Review and Update report and other published documents.

The indicator and components are continuously used to evaluate progress in and success of restoration activities in the southern Everglades and Florida Bay. MFL rule for Florida Bay (SFWMD 2006, 2014) establishes minimum acceptable water delivery from upstream to maintain downstream SAV habitat, particularly *Ruppia* (Strazisar et al. 2013a) in the Transition Zone *Thalassia* and *Halodule* in the open bay. The SAV Indicator and components are used to monitor and assess the success of the MFL rule and assess how violations of the rule affect the SAV resource that may trigger requirement of an MFL recovery strategy (Strazisar et al. 2013b). CERP and CEPP evaluations of restoration strategies use the SAV Indicator in evaluating potential management strategies and performance targets. The indicators continue to be integrated into the Florida Bay Seagrass Ecosystem and Assessment and Community Organization Model (SEACOM) so that model runs will automatically update stoplight indicators on a basin scale (Madden and McDonald 2010, Madden 2013).

New insights relevant to future restoration decisions
It is known that the gains in the quality of SAV habitat over the past several years are precarious and can be reversed within a short timescale by climatic events. The long-term steady rebound of the SAV community from a massive seagrass die-off in 1987 and a severe algal bloom in the eastern bay in 2005-2008 was reflected in gradually improving status scores in the late 2000's and early 2010's through the relatively wet years of 2012 and 2013 with lower salinities. The dry years that followed in 2014 and 2015 caused a decline in SAV status indicators which are still low. However, signs of recovery with reduced algal and nutrient concentrations (Madden et al. in prep) and positive trends in some SAV indicators are developing. Water management initiatives that deliver more water to Florida Bay will aid in continuing these trends.

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Summary/Key Findings

A full system-wide status assessment for pink shrimp for WY 2017 and WY 2018 cannot be produced because funding for the South Florida Fish and Invertebrate Network (FIAN), which was the basis for that assessment, was suspended in WY 2012. However, this report provides a view of the status of pink shrimp in WY 2017 and WY 2018 for southern Biscayne Bay, near a former FIAN monitoring network. Data reported here are from the current 47 sites of the Epifauna component of the Integrated Biscayne Bay Ecological Assessment and Monitoring (IBBEAM) Project of the National Park Service, NOAA Fisheries, and the University of Miami Rosenstiel School of Marine and Atmospheric Science.

> The pink shrimp *Farfantepenaeus duorarum* is a valuable commercial species in south Florida with annual landings valued at as much as $21M. In south Florida, the species supports an extensive commercial food fishery on the Tortugas Grounds and both food and live bait fisheries within Biscayne Bay. Pink shrimp also are ecologically valuable because they convert smaller organisms and their forage of detritus and microbes to biomass of sufficient size to be preyed upon by higher trophic level fishes such as spotted seatrout, great barracuda, bonefish, and gray snapper as well as water birds such as great white herons. Pink shrimp are found ubiquitously in south Florida estuaries, which are their nursery grounds. The life cycle of the species consists of offshore spawning, larval immigration into nearshore nursery grounds by means of tidal and other currents, settlement and growth through the juvenile stage, and emigration as young adults back offshore to spawning grounds.

Sampling is conducted twice each year, dry season and wet season. During the 11.5-yr monitoring period, pink shrimp density reached the green zone in five dry seasons, each averaging more than 1.82 shrimp/m^2 (Figure 1A). The green "stoplight" zone was reached or exceeded in four wet seasons, reaching or exceeding a mean of about 1.07 shrimp/m^2 (Figure 1B). Of the assessment years, pink shrimp density reached the green zone in the 2017 and 2018 dry seasons and the 2016 and 2017 wet seasons but was in the red zone in dry 2015 and 2016 and wet 2014 and 2017. Dry 2016 was an especially wet dry season. Hurricane Irma may have been a factor causing the low 2017 wet season density. If so, system resilience was indicated by the recovery to record highs in dry 2018. Calendar years are represented in Figure 1. Relationships between calendar-year seasons and water years are indicated in Table 1, which also provides the values for means and confidence limits plotted in Figure 1.

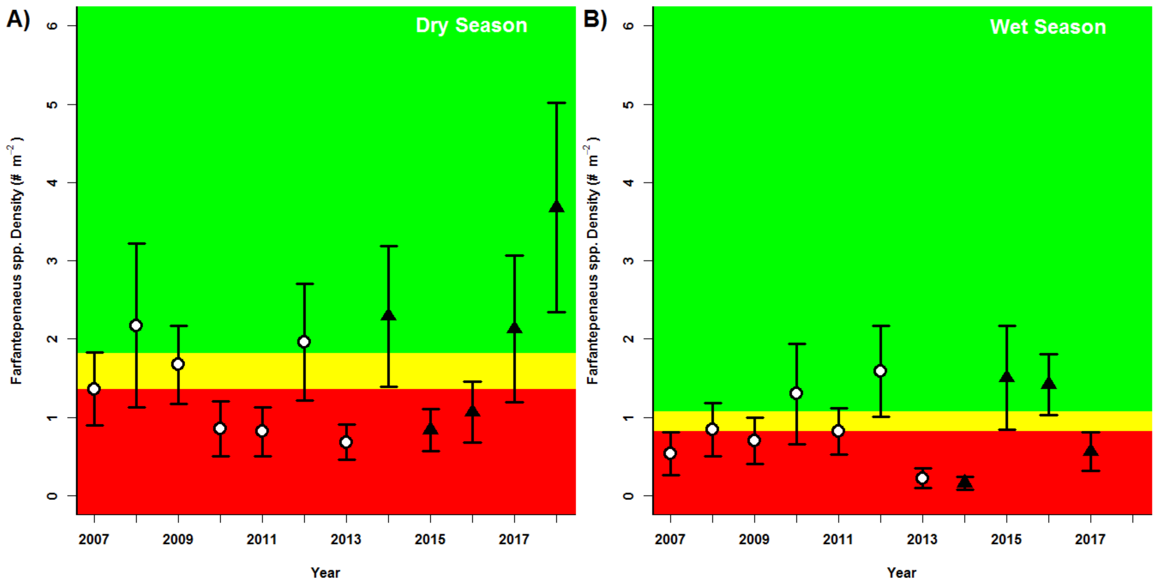

Figure 1. Dry season (A) and wet season (B) mean density of pink shrimp per square meter for the two latest calendar years, 2016-2018, in relation to nine previous calendar years. Boundaries between red (poor), yellow (neutral), and green (good) ranges in the background were set by the median and upper (75%) quartile of the distribution of annual mean reference values (2007-2013). The plots reveal that 2018 dry season density in nearshore Biscayne Bay, although highly variable spatially, was the best on record, scoring green for "good"; 2016 wet season density also was in the green for "good" range. The 2017 dry season was also "good", although the 2017 wet season (shortly following Hurricane Irma) shrimp density scored red for "poor." Stoplight boundary values—Dry: Green-Yellow 1.82, Yellow-Red 1.36; Wet: Green-Yellow 1.07, Yellow-Red 0.82.

Table 1. Mean and confidence interval values plotted in Figure 1.

Water Year	**WY 13**	**WY 14**		**WY 15**		**WY 16**		**WY 17**		**WY 18**	
Calendar Year	CY13	CY13	CY14	CY14	CY15	CY15	CY16	CY16	CY17	CY17	CY18
Season	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Lower 95 % CI	1.22	0.46	1.39	0.08	0.57	0.84	0.67	1.03	1.2	0.31	2.34
Mean	1.96	0.68	2.29	0.16	0.84	1.5	1.06	1.42	2.13	0.56	3.68
Upper 95% CI	2.7	0.9	3.19	0.24	1.11	2.16	1.45	1.81	3.06	0.81	5.02

Data and Calculations

Updates on calculation of the indicator

The indicator is pink shrimp mean density over 47 sites sampled in the year-season indicated. The boundaries between red and yellow and yellow and green were calculated as the median and 75th percentile, respectively, of data from the first seven year-seasons shown in each panel. These are the same seven years used in the previous report, so assessment of year-season means of the most recent four years (five years for dry) to stoplight zones by location of their means relative to the green-yellow-red boundaries is consistent.

How these data are being used

The data on which these stoplight values were based also appear in the annual report of IBBEAM (Integrated Biscayne Bay Ecological Assessment and Monitoring). The Epifauna project is one of four integrated projects in IBBEAM. The principal objective of the project from inception to present has been to build an understanding of variation in indicator status in relation to routine variation in environmental forcing such as weather and seasonality as well as responses to extreme events. This understanding will help separate CERP's effects post implementation from effects of environmental variability inherent in natural systems. Several papers have been published or are in progress within the scope of this objective. In a recent paper (Zink et al.2018a), pink shrimp spatiotemporal density data spanning 2007-2016 were analyzed with respect to Biscayne Bay interim goals for this indicator. Other studies currently underway include an investigation of immediate pre- and post-Hurricane Irma changes in nearshore salinity regime and epifaunal communities at a subset of these sampling sites, an analysis of epifaunal community response to, and recovery from, the hurricane and other identified disturbances across the entire sampling domain, and monitoring of localized ecological impacts of Sargassum accumulation and decomposition in Biscayne Bay. This sampling program has also contributed to other papers, including one reporting the occurrence of the non-native Asian tiger shrimp Penaeus monodon within Biscayne Bay (Zink et al. 2018b).

New insights relevant to future restoration decisions

We note that pink shrimp density reached the green zone in both seasons within the last four years (but not during the same years), including the 2017 dry season. More recently, pink shrimp density in the dry season of 2018 was the highest that has been observed in this monitoring program. Future studies will attempt to determine why such high abundance occurred.The season of exceptionally high density followed the season of Hurricane Irma and may have been a rebound or recovery effect, indicating resilience. A recent review of juvenile pink shrimp-salinity relationships found the majority of reported abundances were maximal in salinities of ~20-35 ppt and meta-analysis of laboratory studies revealed a parabolic relationship with high (≥80%) survival in salinities ranging from ~15 to 40 ppt and a maximal at ~30 ppt (Zink et al. 2017). A juvenile pink shrimp habitat suitability investigation (Zink 2017) incorporating potential future Biscayne Bay salinity conditions (Stabenau et al. 2015) is currently being prepared as a manuscript. The Biscayne Bay epifaunal individual species data are being used to investigate abundance-salinity relationships of pink shrimp and other species, including Gulf pipefish *Syngnathus scovelli*, goldspotted killifish *Floridichthys carpio,* and Palaemonetes *intermedius* shrimp. Rainwater killifish *Lucania parva* densities have been analyzed with respect to salinity regime and other habitat attributes (Serafy et al. In prep). Whole epifauna community response as an indicator of salinity regime is in preparation. Monitoring results were analyzed to inform planning laboratory studies to investigate salinity tolerance and benthic habitat preference of the caridean shrimp Palaemonetes intermedius. Density limitation by salinity was examined by Goldston (2017) and used to inform design of laboratory-based salinity tolerance experiments. Analyses of epifaunal communities relative to salinity regime is being conducted to provide insight on how community composition of the nearshore epifauna is likely to shift after implementation of the CERP Biscayne Bay Coastal Wetlands project. Salinity is being given special attention as an influencing factor in IBBEAM and the Epifauna Project because it varies in estuaries and coastal systems such as Biscayne Bay as a function of freshwater inflow, a factor that will be changed by CERP.

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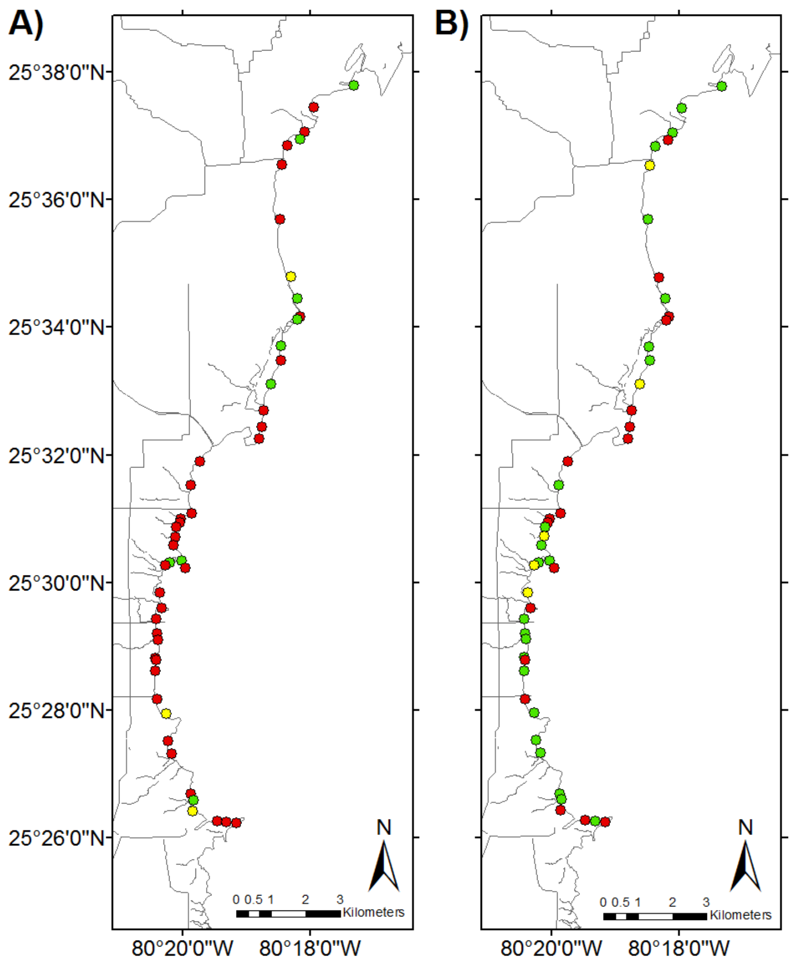

Figure 2. Maps depicting 2018 Water Year wet season (CYR 2017) (A) and dry season (CYR 2018) (B). Pink shrimp density per square meter observed at the 47 Biscayne Bay nearshore epifaunal monitoring sites, color coded using the same red (poor), yellow (neutral), and green (good) ranges representing the median and upper (75%) quartile of the distribution of annual mean reference values from 2007 through 2013 as used in Figure 1.

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Summary/Key Findings

Overall, the stoplight color for the wading bird (Roseate Spoonbill) indicator remains red for WY 2018, though conditions throughout Florida Bay appear to be somewhat improving for spoonbills based on nest production and nesting success in recent years.

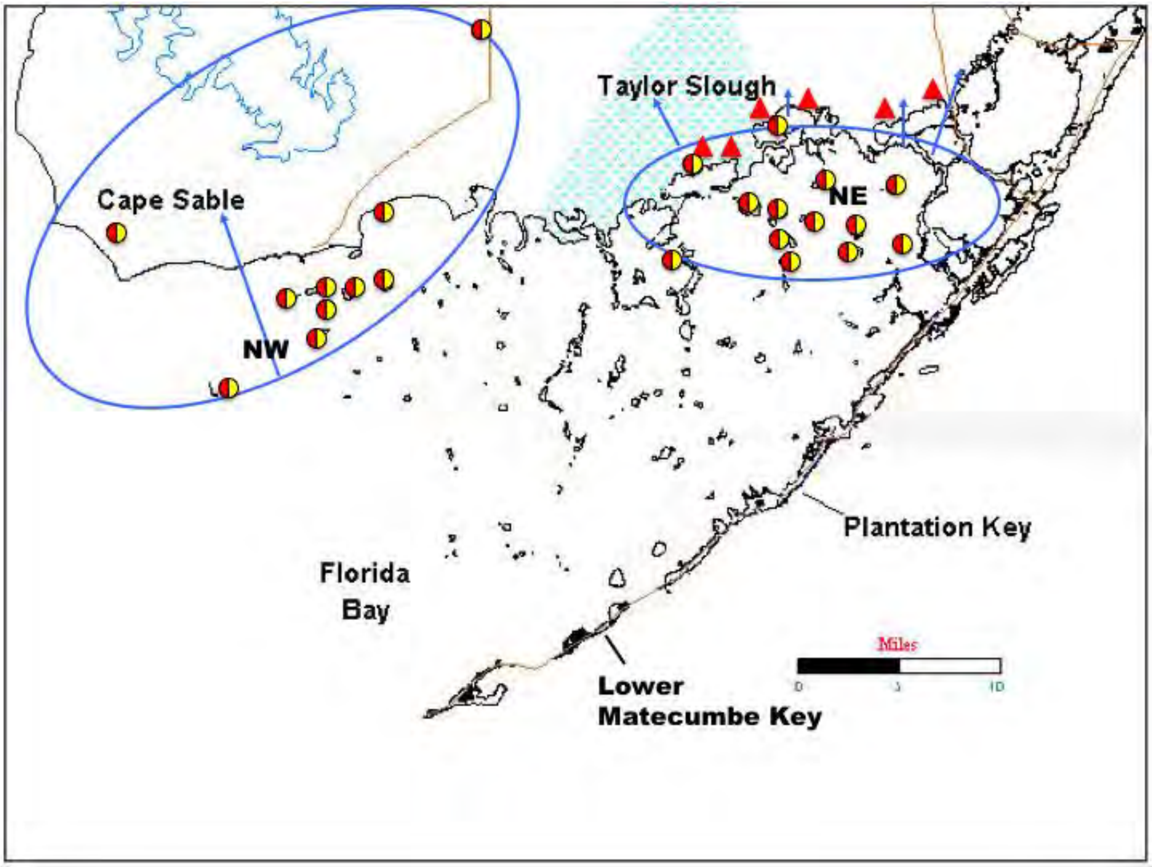

Figure 1. Map of northern Florida Bay showing approximate spoonbill nesting locations (circles) in both the northeastern and northwestern regions of Florida Bay as well as prey base sampling locations (triangles) on their foraging grounds. Right half of each circle represents the 2018 score for the nest number sub-metric and the left half of each circle represents the 2018 score for the nest production sub-metric within each region. The triangle color represents the prey score of the mangrove prey base fish metric.

Spoonbills were largely extirpated in Florida prior to 1900 due to excessive hunting for the millinery trade. In 1935, spoonbill nesting activity was found on Bottle Key in southern Florida Bay and intermittent estimates of total nest numbers have been collected since (Figure 1). Although spoonbills nest throughout Florida Bay, nesting became most concentrated in the northeastern region of the Bay beginning in about 1960 (Figures 1 and 2). Birds nesting in this region concentrate their foraging in the dwarf mangrove forests that line the mainland coast from Taylor River to Card Sound. Nest numbers in this region began to decline in the mid-1980's (Figure 2) following the completion of a set of canals and water control structures known as the South Dade Conveyance System (SDCS) in 1984 which has been shown to have negatively altered Florida Bay both physically and ecologically (McIver et al. 1994, Lorenz 2014a). Spoonbills also began concentrating nesting in the northwestern region of Florida Bay (Figure 2) in the 1970's with a steady increase in numbers that coincided with the declining numbers in the northeastern region in the 1980's, however, numbers in the northwestern region also began to decline in the mid-2000s (Figure 2).

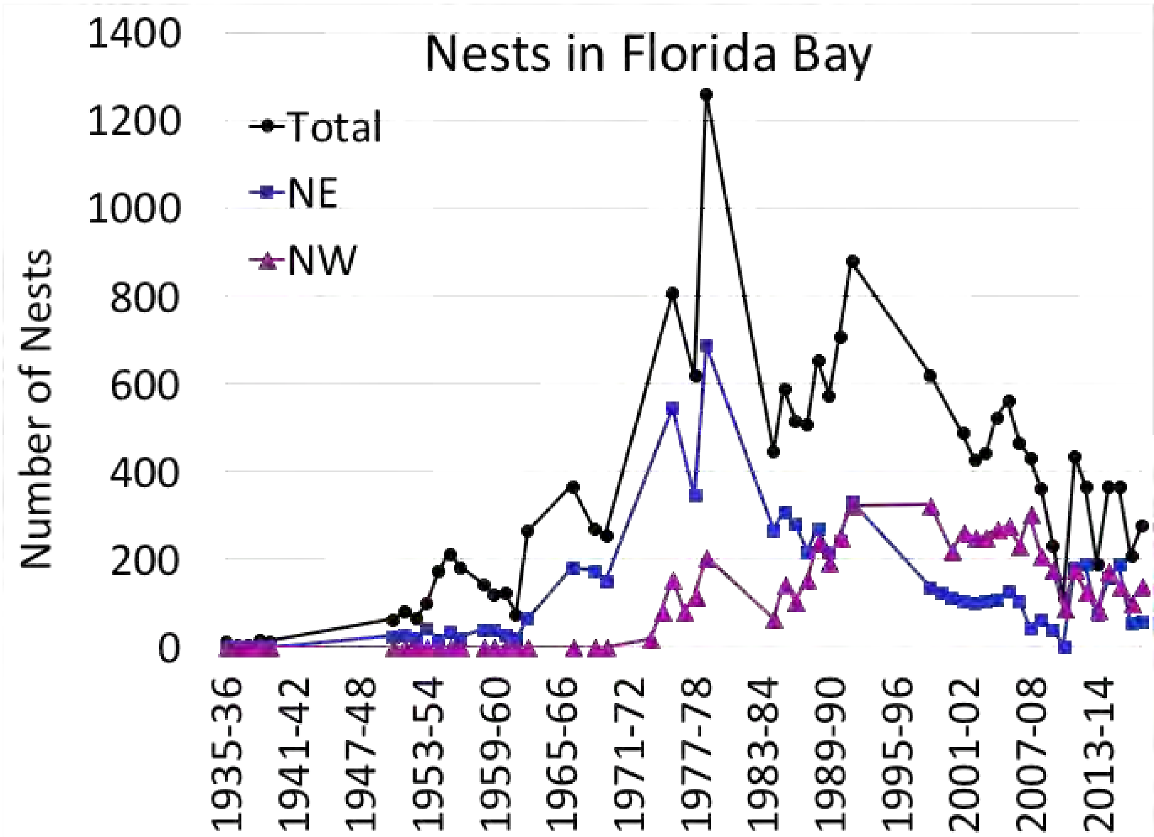

Figure 2. Number of roseate spoonbill nests in Florida Bay and for the Northeastern and Northwestern regions of Florida Bay.

The indicator sub-metrics for spoonbills are total nest numbers for all Florida Bay and the numbers of nests, estimated nest production, and nesting success for the northeastern and northwestern nesting areas of Florida Bay. The target for total spoonbill nests is 1258, the highest number of nests prior to completion of the SDCS. This sub-metric is the average from the previous five years expressed as a percentage of 1,258 (Table 1). All years from the 2013-14 nesting cycle through 2017-18 ranged from 21% to 27% and show no trend in response to ongoing restoration projects that affect Florida Bay. The sub-metric for the number of nests in northeastern Florida Bay is the five-year average expressed as a percentage of 688 nests (the maximum number of nests recorded prior to SDCS completion). This sub-metric was even less encouraging than the total nests in Florida Bay ranging from between 14% to 23% and showing no change in trend in response to completion and operation of the C-111 Spreader Canal Western Phase (C-111 SCWP) CERP project in 2012. The project was designed to increase flows through Taylor Slough but certain operations that were part of the design structure for the C-111 SCWP have not been implemented (i.e., raising the canal stages at the S-18C structure and minimizing flows to tide through the S-197 structure) and the restoration benefits of the project have not been realized. The sub-metric for the number of nests in the northwest region is also expressed as a percentage but is based on the minimum, maximum and mean of the number of nests found in the northwest region at the time the sub-metrics were established. Similar to the total nests and northeastern region nests sub-metrics, the northwestern region is low but stable. The sub-metric ranged from 19% to 25% over the five-year period without any clear trend. This region is dependent on projects that will restore flows to Shark River Slough and projects associated with Cape Sable which largely remain unimplemented.

Table 1. Stoplight scores[1] for each sub-metric, the cumulative score for each sub-metric and the overall score for the indicator for the last five years.

Water Year	WY 2014	WY 2015	WY2016	WY 2017	WY 2018
Total Nests in Florida Bay					
Number of Nests in NE Florida Bay					
Number of Nests in NW Florida Bay					
NE Production and Success					
NW Production and Success					
Overall Spoonbill Nesting Score					

[1]Scores assigned a green if the average score of the 4 parameters was >0.67, yellow for 0.34-0.66 and red for <0.33.
[2]Overall stoplight score is the numerical average of the 5 sub-metrics.

Nest production is the average number of chicks produced per nest attempt (c/n) for a given year. The sub-metric is the five year mean of these estimates and is expressed as a percentage of several thresholds (0-0.7c/n is a declining population, 0.7 to 1.0 is stable, <1.0 c/n is an increasing population and 1.38 c/n was the average production prior to completion of SDCS). The nesting success sub-metric is simply the percentage of years out of the last 10 that spoonbills nested successfully (i.e., produced 1.0c/n or more on average). For each region, the lowest of the two scores is the nest production and success sub-metric. In the northeast, the nest production sub-metric was relatively high in 2013-14 and 2014-15 but declined to 34% in 2017-18 (Table 2). In spite of this, spoonbills nesting in the northeastern bay have nested successfully in almost every year with 70% in 2012-13 and increasing to 80% from 2014-15 to 2017-18 (Table 2). The overall sub-metric score for the northeast region is therefore the same as the nest production score (Table 2). In contrast to the northeastern region, spoonbill production in the northwestern region has greatly improved in recent years with a steady increase from 34% in 2013-14 to 88% in 2016-17 followed by a slight drop in 2017-18 to a still respectable 79% (Table 2). The nesting success sub-metric for the northwestern region was 60% for all years (Table 2). Therefore, the nest production and success sub-metric for the northwest was the nest success sub-metric for all years except for 2013-14 and 2014-15 when the nest production sub-metric was lower than the success sub-metric (Table 2). The nest production and nesting success sub-metrics for both the northeast and northwest regions were yellow for all five years which can be considered a positive response when considering that the 2012 Stoplight Report indicated a downward trend at that time.

Table 2. Nest production and nesting success sub-metrics by nesting sub-region of Florida Bay.

Water Year	WY 2014	WY 2015	WY2016	WY 2017	WY 2018
Nest Production Northeast					
Northeast (NE) Nesting Success					
NE Production and Success					
Northwest (NW) Nest Production					
NW Nesting Success					
NW Production and Success					

The overall spoonbill stoplight score is calculated as the average of the individual indicator sub-metrics and can be thought of as the percentage of what the spoonbill population should look like if the bay were fully restored to pre-SDCS conditions. The overall spoonbill restoration metric ranged from 27% to 34% of restored for the period from 2013-14 to 2017-18 but appears to be approximately 30% in the more recent years (Table 1) with no indication that restoration efforts are improving the conditions needed for a fully restored indicator species.

Mangrove Prey Base Fish Community Indicator

Fishes at primary foraging locations of wading birds (including spoonbills) nesting in Florida Bay have been quantified at six mangrove locations in the Taylor Slough and C-111 drainage basins north of Florida Bay (Figure 1) since 1990. The prey community structure is simply the percentage of the fish prey base that are classified as freshwater species (Lorenz and Serafy 2006). This is based on the finding that prey are more abundant and have higher biomass when a significant component of all prey base fishes are freshwater species (Lorenz and Serafy 2006). Simply stated; prey productivity is greater at lower salinity and the presence of freshwater species is representative of that increased production. The target is to have at least 40% of all prey fish be classified as freshwater based on the findings of Lorenz and Serafy (2006) with a percentage of higher than 5% indicating a positive response to restoration efforts. Results for the 5 year period from the 2012-13 Water Year to 2016-17 are presented in Table 3. The only year above the 5% threshold was 2013-14. It was hoped at the time that this was a positive response to the completion and operation of the C-111 SCWP. This project was completed in 2012, is located just upstream of the sampling sites, and was designed to deliver more freshwater to the region. Unfortunately, the percentage of freshwater species was virtually non-existent for the three following years and, although the data for 2017-18 has not been fully analyzed, preliminary examinations of the data indicate it will be scored red as well. The findings indicate that the C-111 SCWP project may not be delivering the benefits that it was designed to have on Taylor Slough and Florida Bay.

Table 3. Percentage of overall fish catch that were classified as freshwater species at the Mangrove Prey Base Fishes sampling locations (Figure 1).

Year	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018
Actual percent of catch that are freshwater species					
Stoplight Percentage score					

Data and Calculations

Updates on calculation of indicator

Separation of Mangrove Prey Base Fishes metric from spoonbill stoplight. The prey fish indicator was originally a sub-metric of the overall Roseate Spoonbill indicator but recent changes in sea level (see New insights section below) that strongly affect spoonbill nesting activities have a lesser impact on the prey fish community. Therefore, the prey fish community sub-metric needs to be elevated to a stand-alone stoplight indicator independent of the spoonbill indicator. Lorenz (2014b) demonstrated that certain spoonbill nesting parameters (nest numbers and nesting success) are strongly related to water depths at the foraging sites and therefore directly affected by increasing sea levels (Lorenz et al. 2011). Furthermore, the mangrove prey base fishes sub-metric was one of 4 sub-metrics in the spoonbill stoplight and accounted for 25% of the overall score. With the splitting of the nesting location and nesting production and success sub-metrics into two regions (see discussion below this section), the prey base sub-metric would be devalued and become one of six sub-metrics. Given that the spoonbills are demonstrably responding to sea level rise, the prey fish sub-metric would be further masked and devalued when the changes in spoonbill nesting patterns caused by sea level rise suggest it should carry more weight not less. For these reasons, it was decided that the sub-metric for Mangrove Prey Fish community structure be removed from being just a sub-metric of the spoonbill stoplight and elevated to a stand-alone indicator independent of the spoonbill nesting sub-metrics. In an effort to standardize stoplight metrics, the mangrove prey base fishes metric was recalculated such that it would be on a 0-100% grading scale such that if, for example, the metric was scored at 80% than restoration efforts have been 80% effective (see details of this conversion below).

Termination of the 7P fish collection site. In addition to removing the mangrove prey base fishes sub-metric from the spoonbill stoplight and elevating it to a stand-alone metric, one of the prey fish sampling sites (7P) used in the published metric is no longer being monitored due to financial cutbacks in the monitoring program. The six remaining sites will be used to calculate this metric. For this particular metric, the loss of the 7P site does not have a large influence since the other six sites tend to statistically mask the data from the 7P site. Therefore, we did not feel it necessary to redo the calculations for previous years. The importance of the 7P site should not be underestimated based on this metric alone, however. 7P is a freshwater mangrove site that provides an annual target for what the fish community should look like at the other six sites under restored conditions. Without this site we have no "comparison" site for restoration that incorporates inter-annual variation in rainfall and freshwater flow—a critical consideration in evaluating the fish community at the other sites.

No longer combine the northeastern and northwestern sub-metrics. The justification for using the Roseate Spoonbills stoplight indicator was originally published in 2009 (Lorenz et al 2009) using data through 2006. At that time, the sub-metrics for the northeastern and northwestern regions were aggregated together with the sub-metric with the lowest estimate from either region being used to evaluate restoration efforts (Lorenz et al. 2009). The thought process at the time was that if either region of the bay declined, it would be considered overall a bad thing. The decision to aggregate the two regions was made before the now apparent decline in nest numbers in the northwest region. Given the rapid decline in nesting in the northwestern region since that decision was made, we now feel that the regions should be evaluated separately because each region will be influenced by different components of restoration efforts with the northeastern region responding to restoration efforts that focus on Taylor Slough and the SDCS while those in the northwestern region will be more influenced by projects that restore Shark River Slough and Cape Sable. So, if we have an increase in nests in the northeast (indicating that restoration efforts are helping Taylor Slough) this should be considered a positive not just discarded because the restoration efforts at Cape Sable have been ineffectual. As the sub-metric is currently written, that would be the case. Therefore, the original sub-metric needs to be two separate and equally weighted sub-metrics.

Removal of southwestern Shark River Slough colonies from the stoplight. At the time of Ecological Indicators publication (Lorenz et al. 2009), small numbers of spoonbills were known to nest in the colonies in the mangrove transition zone of the lower Shark River Slough. Historically, these were the largest wading bird colonies in the Everglades with 90% of all nests occurring there in the 1930’s and 1940’s (Ogden 1994). In recent decades the importance of these colonies was greatly diminished with only about 15% of all nests found in these colonies (Ogden 1994). It was believed that restoration efforts would result in better estuarine production near these colonies resulting in a return of large numbers of wading birds, including spoonbills, to these historic colonies. Since the 2009 publication, these colonies have grown and in 2018, nest numbers approximated the nesting activity that occurred in the 1930’s and 1940’s including relatively large numbers of spoonbills. These colonies are extremely remote and hard to access so nest counts are generally made from aircraft. Spoonbills cannot be censused using aerial surveys because they are sub-canopy nesters and cannot be seen through the thick mangrove foliage. Currently, the cost of accessing these locations to perform a ground survey is prohibitive. The return of spoonbills in large numbers to these colonies should be considered a positive response to restoration efforts but quantification of the effort cannot be made. Should techniques become available that would allow for accurate surveys of spoonbills, this metric should be developed further and evaluated as a possible stand-alone stoplight metric for restoration efforts. For the purposes of this spoonbill stoplight, this metric was removed so that this metric is focused on restoration efforts that will affect Florida Bay

Placing all metrics and sub-metrics on a 0-100% restoration grading system. The use of this stoplight information has been incorporated into several other efforts to assess the ecological health of Florida Bay and the progress of Everglades restoration efforts. As a result of trying to make the individual stoplight more uniform and therefore more useful for this and other reporting efforts, it was decided that all the individual sub-metrics should be placed on a uniform numerical scale of the percentage of the restoration target achieved to date, i.e., a restoration “grading scale.” As an example as to why this change is useful, the overall spoonbill stoplight score for 4 of the last 5 years was red with only 2014-15 having a yellow score. Without the “restoration grade,” it would be up to the reader to decide what the magnitude of the 2014-15 improvement was, however, by adding the 34% score to the stoplight table, the report expressly indicates that the improvement was only incrementally above a red score.

Most of the individual spoonbill stoplights are essentially on a zero-to-one scale and therefore can be easily converted to a readily understandable percentage of restoration targets but several of the sub-metrics use thresholds rather than a continuous scale so calculations were made taking into account these thresholds such that the results could be placed on a zero-to-one hundred or percentage scale without changing the meaning of the sub-metric itself. The thresholds for red to yellow and yellow to green are now the 33rd and 66th percentiles for all sub-metrics and the overall stoplight score.

The sub-metrics that were not originally on a zero-to-one or percentage scale in the published stoplight indicator are the number of nests in northwestern Florida Bay and the nest production sub-metrics. The mangrove prey fish metric also had to be placed on a 0-100 scale to get a restoration "grade." The northwestern region sub-metric is based on the mean (210 nests), minimum (130 nests), and maximum (325 nests) number of nests found in the northwest between 1984 (completion of the SDCS) and 2006 (last data year used in the publication) with red < 130 nests, yellow from 130-210 nests and green >210 nests. Each of these thresholds need to be weighted to convert to a percentage scale. As such, 130 nests was the bottom threshold 210 a moderate threshold and >325 the top threshold. These calculations are presented in Table 4.

Table 4. Restoration grade calculations for the northwestern number of nests sub-metric.

Number of nests	Restoration Grade Percentage Range	Equation
0-130	0-20	$y = 0.1538x$
130-170	20-40	$y = 0.4878x - 43.415$
170-210	40-60	$y = 0.5128x - 47.692$
210-324	60-80	$y = 0.1754x + 23.158$
>=325	80-100	$y = 0.1754x + 23.158$

The nest production sub-metric is currently based on the concept that an annual nest production of less than 1chick/nest (c/n) is generally held as a declining population resulting in a red score if the sub-metric is <1c/n. From 2000-01 to 2006-07 the nest production sub-metric for the northeastern region was consistently below 0.75 c/n (range 0.41-0.75) from 2000-01 to 2006-7 and increased to 0.90 in 2007-08 and was consistently above 1.00 from 2008-09 to 2017-18. Spoonbills reach sexual maturity in about 3 to 4 years so birds hatched before 2007-08 should have been recruited into the nesting population by 2011-12. The nest number sub-metric in the northeastern region continually fell from 2005-06 to 2010-11 (from 109.6 nests to 51.4 nests) then in 2011-12 it increased to 66.8. This suggests that a nest production sub-metric of less than 0.75 results is a declining population and between 0.75 and 1.00 is stabilizing. Therefore, the thresholds for calculating the percentage scale were set at 0.75 c/n (declining population), 1.0 c/n (stable population, 1.24 c/n (the mean nest production in the northwest between 1984 and 2006) and 1.38 c/n (pre-SDCS nest production for Florida Bay).These calculations are presented in Table 5.

Table 5. Restoration grading calculations for nest production sub-metric

Production	Restoration Grade Percentage Range	Equation
0-0.75	0-20	y = 26.667x
0.75-1	20-40	y = 80x - 40
1-1.24	40-60	y = 83.333x - 43.333
1.24-1.38	60-80	y = 142.86x - 117.14
>=1.38	80-100	y = 142.86x - 117.14

The mangrove prey base fishes Stoplight Metric was also placed on a 0-100% grading scale using the calculations in Table 6.

Table 6. Restoration grading calculations for the Mangrove Prey Base Fishes Stoplight.

Percent Freshwater	Restoration Grade Percentage Range	Equation
0-5%	0-20	y = 4x
>5-40%	20-80	y = 1.6857x + 11.571
>40%	80-100	y = 0.35x + 65

A summary of all the changes made to the Florida Bay Roseate Spoonbill and Mangrove Prey Base Fishes Stoplights are presented in Table 7.

Table 7. Summary of changes to Lorenz et al. (2009) published sub-metrics used in the Florida Bay Roseate Spoonbill Stoplight. All sub-metrics were placed on a 0-100% restoration grade with a stoplight score of >67% is green, .33-67% is yellow and <33% is red.

Parameter	Published Target	Published Metric	2018 Changes
Total Number of Spoonbill Nests			
Total nests in Florida Bay (5 year runiing average)	1258 (based on peak number of nests recorded post plume era. Peak occurred in 1978.)	5 year mean as a percentage of 1258 (Scores: <.33=red; .33-.67	No Change
Nesting Location			
Number of nests in NE Florida Bay (5 year running average)	688 (based on peak number of nests recorded post plume era. Peak occurred in 1978.)	5 year mean as a percentage of 688 (Scores: <.33=red; .33-.67 Yellow; >.67=green)	No Change
Number of nests in NW Florida Bay (5 year running average)	Based on minimum, mean and maximum number of nests between 1984 (completion of SDCS) and 2006 (creation of indicator metric). This period assumed to be baseline for pre-CERP efforts	5 year mean number of nests (Scores: <130 (Min) =red; 130-210 (Mean) = Yellow; > 210 =green (325 was max)	Placed on a complex percentage scale where <130 nests is scaled to between 0-20%, >130-210 nests is scaled from 21-60%, >210-324 nests is scaled from 61 to 80% and >324 nests scaled to 81-100%.
Number of nests SW Everglades	Data not collected	Data not collected	Sub-metric elevated to its own metric but data collection still prohibitively expensive
Combined Nesting Location		Lowest score from either the NE or NW Nesting Numbers	NE and NW regions are no longer combined but are now stand alone sub-metrics
Nest production and Nesting Success			
Nest Production (5 year running average) NEFB	Mean >1.38 chicks/nest to 21d post hatch based on nest production prior to 1984.	<1c/n=red; 1-1.38c/n=yellow; >1.38 c/n=green	Placed on a complex 0-100 percentage scale where 0-0.75 c/n is scaled to between 0-20%, >0.76-1c/n is scaled to 21-40%, >1-1.24 c/n is scaled to 41-60%, >1.24-1.38c/n is scaled to 61-80% and >1.38-2c/n is scaled to c/n
Nest Production (5 year running average) NWFB			
Nesting success NEFB	Number of nesting seasons out of the last 10 that produced >1c/n on average	0-4=red; 5-6=yellow;7-10=green	No Change
Nesting success NWFB			
Combined Nesting Production and Success		Loest score of either nestproduction or nesting success for either region	NE and NW regions are not combined but are stand alone sub-metrics and use the lowest of either the Nest Production or Nesting Success parameters to score each region
Prey community Structure			This metric is not as affected by sea level rise and should be elevated to a stand alone Indicator of restoration success (i.e., not as a sub-metric of the spoonbill indicator)
Percentage of freshwater fish in prey fish collected at foraging sites	Freshwater fish percentage of all species collected at 6 locations in the Taylor Slough and C-111 Basins	<5%=red, 5-40%=yellow;>40%=green	Placed on a complex 0-100% scale where 0-5% freshwater species is scalled to 0-20%, <5-40% freshwater species is scaled to 20-80% and <40-100% freshwater species is scaled to 80-100%.

How these data are being used

Data from this monitoring program were used to evaluate overall wading bird health in southern Florida through the annual South Florida Wading Bird report for 2017 and 2018 as well as the South Florida Environmental Reports for 2017 and 2018 and the 2018 System Status Report. Information from this monitoring program was also influential in successfully acquiring a $2M grant from the National Fish and Wildlife Foundation for canal restoration on Cape Sable through the Everglades Foundation which resulted in restoration/repair of two dams on the Slaggle's and House' Ditches on Cape Sable in 2018. The information was also used as part of four presentations at the Greater Everglades Ecosystem Restoration Conference (2017), one presentation at the Coastal and Estuarine Research Federation Conference (2017) and more than 20 presentations at public forums.

New insights relevant to future restoration decisions

Effect of sea level rise on indicator.

Mean sea level in the Gulf of Mexico has a profound impact on water levels in the spoonbills' foraging habitats north of Florida Bay (Lorenz et al. 2011). In recent years, the steadily increasing sea surface elevation of the Gulf appears to be accelerating (Figure 3) and has resulted in higher water levels on the foraging grounds (Lorenz et al. 2011) likely causing reduced prey availability (Figure 3; Lorenz et al. 2011, Lorenz 2014b) resulting in altered nesting patterns in Florida Bay's spoonbill population. Alvear-Rodriguez (2001) estimated spoonbill nest initiation dates (first egg laid) in Northeastern Florida Bay for 51 years between 1936 and 2000 from field notes collected by various researchers. Nest initiation occurred between November 1 and December 31 in all years except 2 (one in October and one in January). As part of the South Florida Annual Wading Bird Report we have reported these dates since 2003. From 2003-04 to 2009-10 all initiation dates fell within the range reported by Alvear-Rodriguez (2001). From 2010-11 to 2013-14 all nest initiation dates were between January 1 to January 10. In 2014-15 the date was January 24 and in 2015-16 it was February 5, the latest ever recorded. Later and later nest initiation dates have occurred in all the other regions of the bay as well. Moreover, lay dates within and among colonies were highly asynchronous, spanning January through April. These results suggest that the important environmental cues that promote breeding were either lacking or weaker than normal. Indeed, water levels were abnormally high until very late in the year and rarely dropped to the critical level (13 cm) at which prey begin to concentrate (Lorenz 2014b). The delay in nesting and the fact that the majority of recent nesting occurred in two mainland colonies (Madeira Hammock and Paurotis Pond) suggest that conditions have deteriorated for nesting spoonbills within Florida Bay. This also likely explains the low nesting effort, asynchronous nest initiation, and changes in nesting location of Roseate Spoonbills in since 2010.

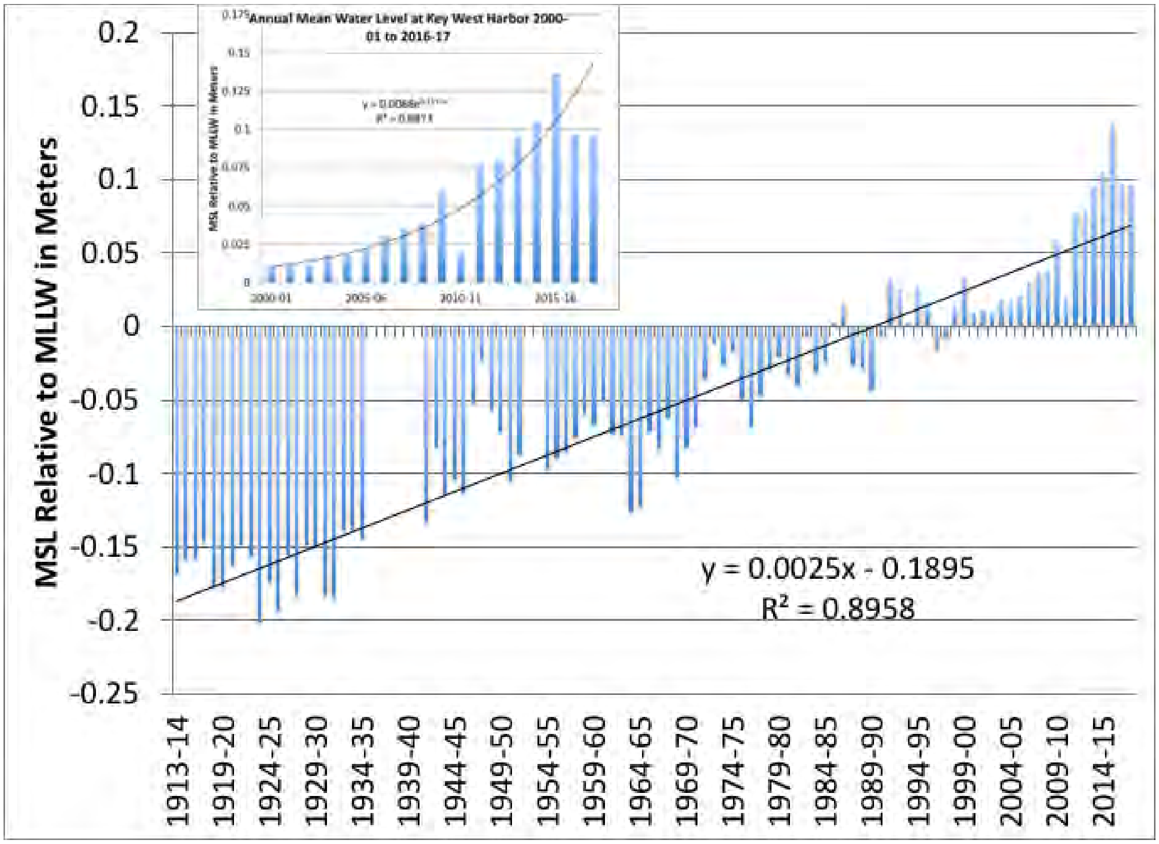

Figure 3. Mean sea level in relation to Mean Low Water for Key West Harbor 1913 to present. Inset is the same data from 2000 to 2015 indicating an exponential increase in sea level rise as predicted by many climatologists.

C-111 Spreader Canal Western Phase. The C-111 SCWP project began operation in June 2012 and the 2016 stoplight report summarized finding for the first three years of project operation. The main conclusion was that the C-111SCWP can provide ecological benefits to the existing system under low to moderate rainfall years. Based on these results, the project would also likely provide benefits under above average rainfall conditions. However, under drought conditions, the project as operated provided little or no benefits to the ecosystem. The secondary goal of augmenting the local water supply with a regional component was also not being accomplished. Analysis of 2015-16 data provided a unique opportunity to test these conclusions. During the 2015 wet season, the region was in the second year of a severe drought and rainfall was the second lowest during the period of record while the dry season had the highest rainfall during the period of record. This unique combination of a drought wet season and a very rainy dry season allowed for the examination of previous conclusion by examining the seasons independently. As per our previous findings, the C-111 SCWP project failed to perform to expectations during the drought wet season but performed to expectations in the rainy dry season. At this time, the 2016-17 data have not been fully analyzed due to delays caused by Hurricane Irma.

WADING BIRDS (ROSEATE SPOONBILL)

As noted previously, the operational plan for the C-111 SCWP originally contained a provision that water levels at S-18C would be raised a tenth of a foot each year of the project for the first five years. This part of the plan has yet to be implemented even though all of the pre-project modeling indicated that a half of a foot increase would increase total flows from Taylor Slough into Florida Bay by 40%. The modeling indicated that raising water levels at S-18C would further reduce seepage and pumping at S-199 and S-200 would be able to augment total flows to the system. This would suggest that with higher canal stages, the approximately hundred thousand Acre-Feet of water pumped at the two structures annually would not completely seep back into the canal (as it currently does under low rainfall conditions) thereby resulting in overland flow toward the slough. Our recommendation is that this part of the operational plan be implemented immediately, especially during low rainfall periods. Ultimately, however, it is our opinion that the only way to fully restore historical flows to Taylor Slough (or at least as close to historical as possible) is to move water from regional upstream sources across the landscape into Taylor Slough. Other components of the CERP that provide such an overland connection between Taylor Slough and the regional water supply (e.g. Modified Water Deliveries to ENP and the CEPP) must be fully implemented to avoid the disastrous ecological consequences that droughts currently present to Florida Bay. Increment 1 of Modified Water Deliveries was implemented in 2015-16 and our results were inconclusive as to any benefit, however, Increment 1 was designed more as a test of the Project's infrastructure and it is hoped that when the 2017-18 data are fully analyzed, it might provide some insight into how Increment 2 performed.

Cape Sable Canal Restoration. As detailed in the 2014 System Status Report, the unmanaged derelict canals on Cape Sable continue to degrade foraging habitat for spoonbills nesting in northwestern Florida Bay. This problem is only exacerbated by the steady increase in sea level described above. Data from this project were used to justify and acquire the funds to rebuild failing dams on two of these canals (House and Slaggle Ditches), possibly preventing the loss of these dams, thus preventing further damage. There are still uncontrolled flows through Raulerson Brothers Canal that began when the dam on that canal was compromised by Hurricane Wilma in 2006. Project data are being used to acquire the necessary funds to place a permanent structure on Raulerson Brothers Canal.

As a side note, the permanent structures that were built on the Homestead and East Cape canals in 2010 and 2011 took a direct hit from Hurricane Irma, The Homestead Canal Structure was undamaged but the East Cape Canal Structure, being more exposed to the hurricane surge, was severely damaged. Our data indicates, however, that, although the structure is in need of repair, the damage did not compromise the structures integrity. These results, demonstrate that these canals can be controlled even under the most severe conditions, and that if structures similar to those on the Homestead and East Cape canals are constructed on Raulerson Brothers Canal and on East Side Creek (an artificially and unnaturally large creek created by boats illegally accessing areas closed to motorized traffic), the damaging tidal flows can be stopped.

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