South Florida Ecosystem Restoration Task Force

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System-wide Ecological Indicators for Everglades Restoration 2016

EvergladesRestoration.gov
Restoring America's Everglades

Suggested citation: Brandt, L.A., J.A. Browder, M. Cherkiss, P. Frederick, E. Gaiser, D. Gawlik, S. Geiger, C. Kelble, S. Kelly, J. Kline, K. Kotun, J. Lorenz, C. Madden, F. J. Mazzotti, L. Rodgers, A. Rodusky, D. Rudnick, B. Sharfstein, R. Sobszak, J. Trexler, A. Volety, 2016. System-wide Indicators for Everglades Restoration. 2016 Report. Unpublished Technical Report. 98 pp.

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.** Five indicators are red (crocodilians, fish & macroinvertebrates, wading birds (white ibis a & wood stork), Southwest Coastal Systems Phytoplankton Blooms, wading birds (roseate spoonbill), four are yellow, (invasive exotic plants, Lake Okeechobee nearshore zone submerged aquatic vegetation, periphyton, Florida Bay submersed aquatic vegetation and monitoring for one (pink shrimp) is no longer adequate to provide a system-wide stoplight color. In addition, some (crocodilians and fish) are showing increasing consecutive years with red stoplights (well below restoration targets) while others (wading birds) are seeing some components of the indicator (timing of nesting) going in the wrong direction (proportion nesting in coastal colonies, timing of wood stork nesting is later rather than earlier). These results reflect that current ecological conditions are close to the tolerance for many of the indicators and emphasize the importance 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 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 ecological beneficial stage envelope, should enhance SAV coverage and density in the nearshore region.

- **Invasive exotic plants and animals continue to present challenges to Everglades restoration**. While integrating herbicide treatments, fire, and biological controls though the CERP Biological Control Implementation Project 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. 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 pythons, tegus, and non-native fish threaten native species directly through predation and indirectly through changes in foodwebs. Evidence at wading bird colonies and wading bird food habits suggest wading bird nesting aggregations may be highly vulnerable to python predation. Tegus have been observed taking eggs from alligator nests and visiting crocodile nests, suggesting that crocodile nests are also at risk. At their current densities, there is empirical evidence that non-native fish 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.

- **Although concentrations have been reduced substantially, phosphorus continues to be a regional water quality concern.** Elevated concentrations complicate water management operations and legal constraints and as such, constrain our ability to supply more water to the natural system. As indicated by periphyton nutrient content and biomass, water quality has declined since 2014, likely resulting from increased water flows and hence additional P load, particularly in the wet season following the 2015 prolonged drought. 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 in the periphyton indicator than dry years. Water flows are key to restoration of the Everglades and restoration planning should also take into account timing and distribution of water movement through the system as they will influence phosphorus concentrations and loads entering the marshes.

- **Natural events will continue to affect how indicators respond, and we see those responses in the indicators.** Because conditions in the ecosystem are close to the tolerances of many indicators, natural extreme events such as drought have more extreme effects than they would in the natural system. For example, Florida Bay is in a chronic state of low flow which results in a lack of resilience, exacerbating natural periods of drought. Restoration will improve ecosystem resilience and increase operational flexibility.

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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 exotic species.

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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 (http:// www.evergladesrestoration.gov/content/scg_docs.html).

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 duties of the Task Force are 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 will help them understand in the broadest terms how the ecosystem, and key components, are responding to restoration and management activities via implementation of the Introduction 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 will afford 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 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)

Introduction

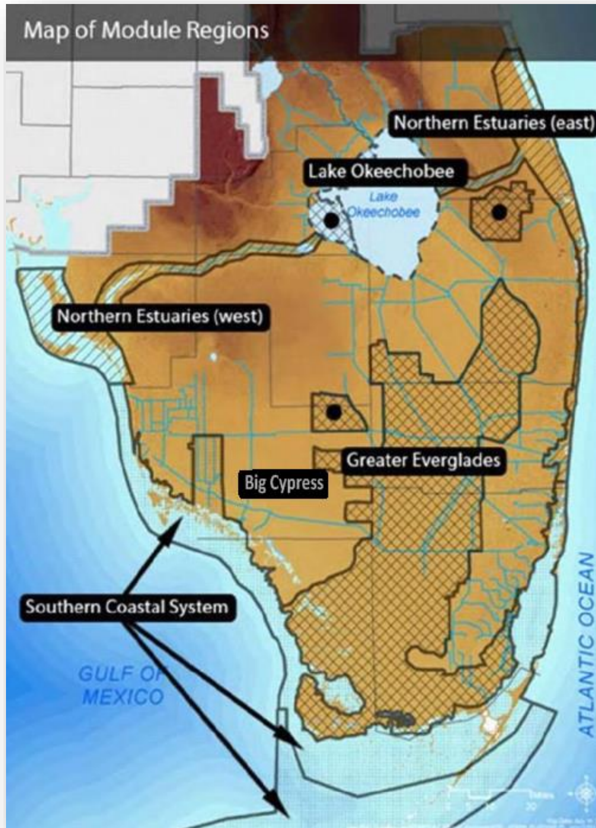

Figure 1. Map of south Florida illustrating the boundary of the SFWMD and the regional assessment modules. Figure courtesy of RECOVER's 2009 System Status Report.

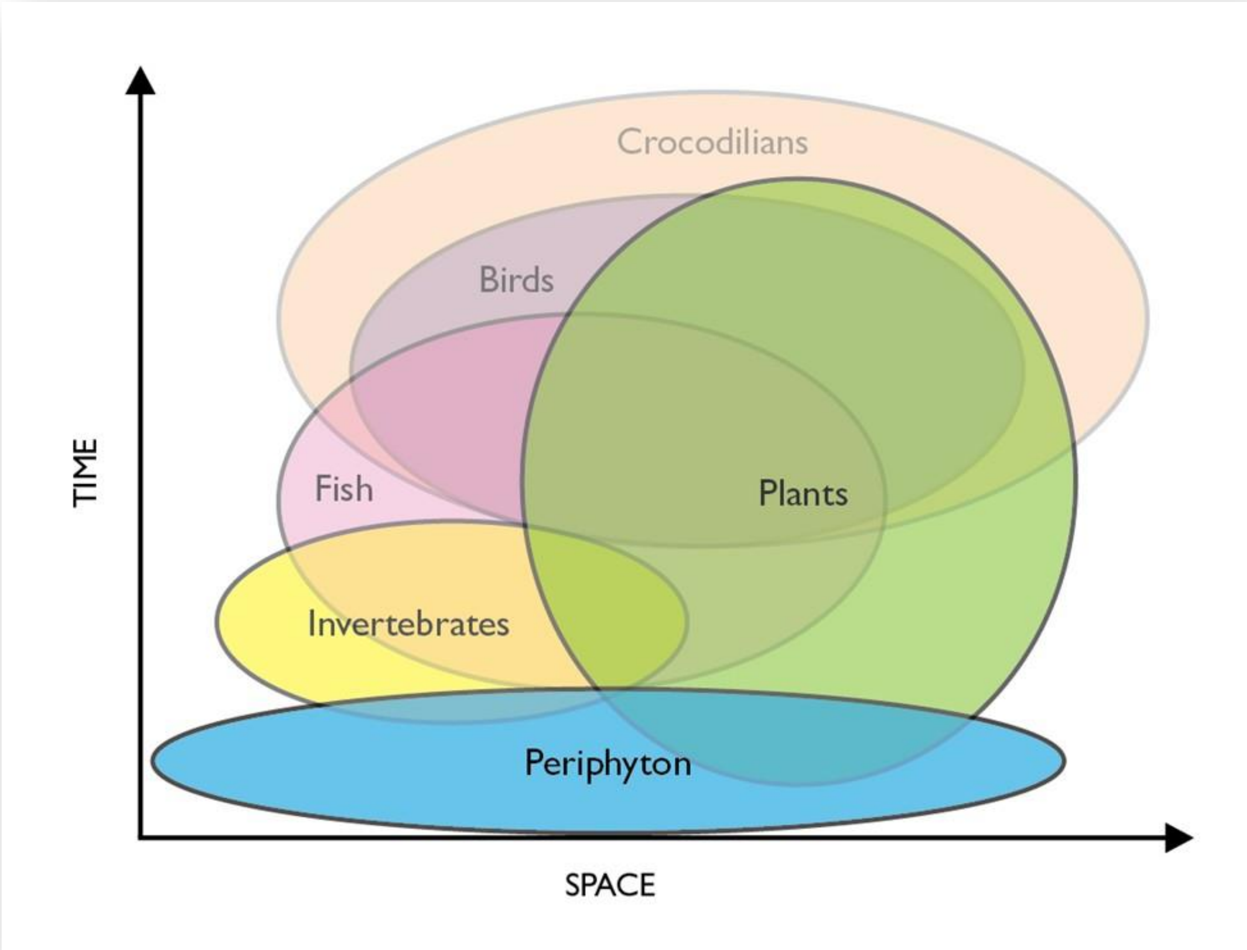

Figure 2. The suite of system-wide ecological indicators was chosen based upon their collective ability to comprehensively reflect ecosystem response in terms of space and time. For example, periphyton responds to change very rapidly at both small and large spatial scales while crocodilians respond more 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 sys- tem-wide ecological indicators.

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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 2016 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 2015– 2016

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 2015 (May 1, 2014 to April 30, 2015) and 2016 (May 1, 2015 to April 30, 2016).

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 water year 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 sur- face 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. Water year 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 meteorologic 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 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 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.

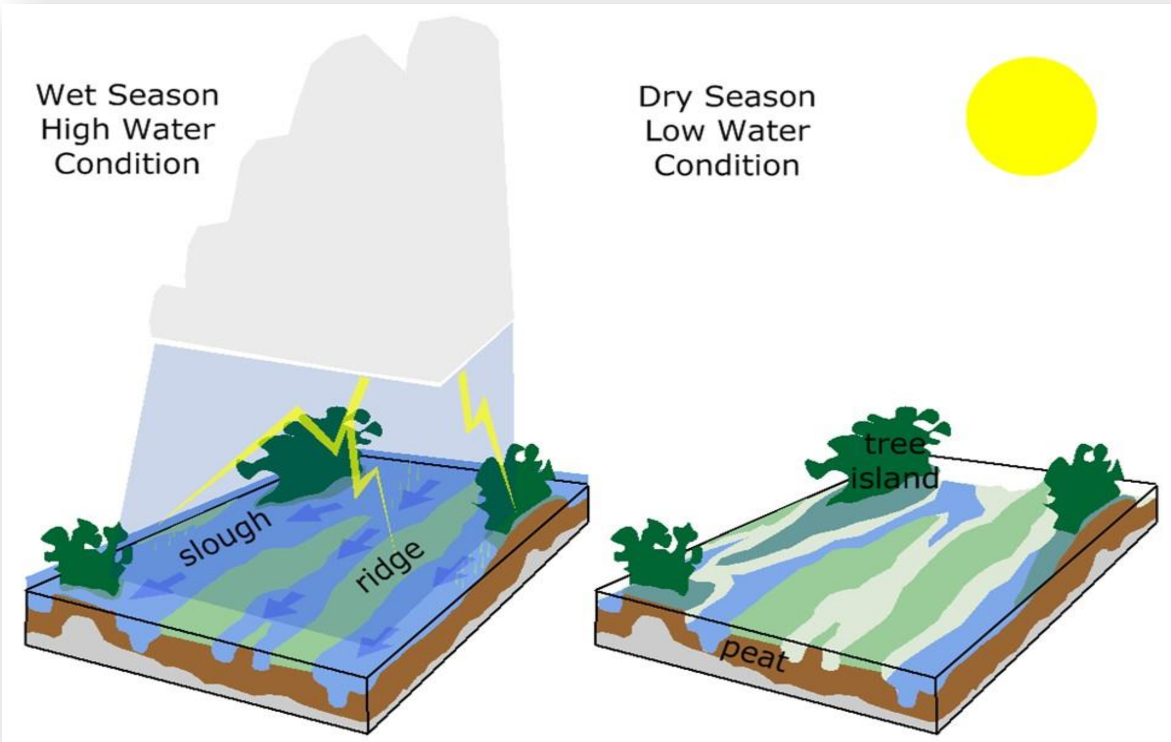

Figure 3. This diagram displays artistic representations of the Everglades during fall high-water and spring low water conditions. During the summer/fall rainy season, a shallow and slow-moving sheet of water inundates the entire slough and ridge landscape (except for the tree islands that usually remain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

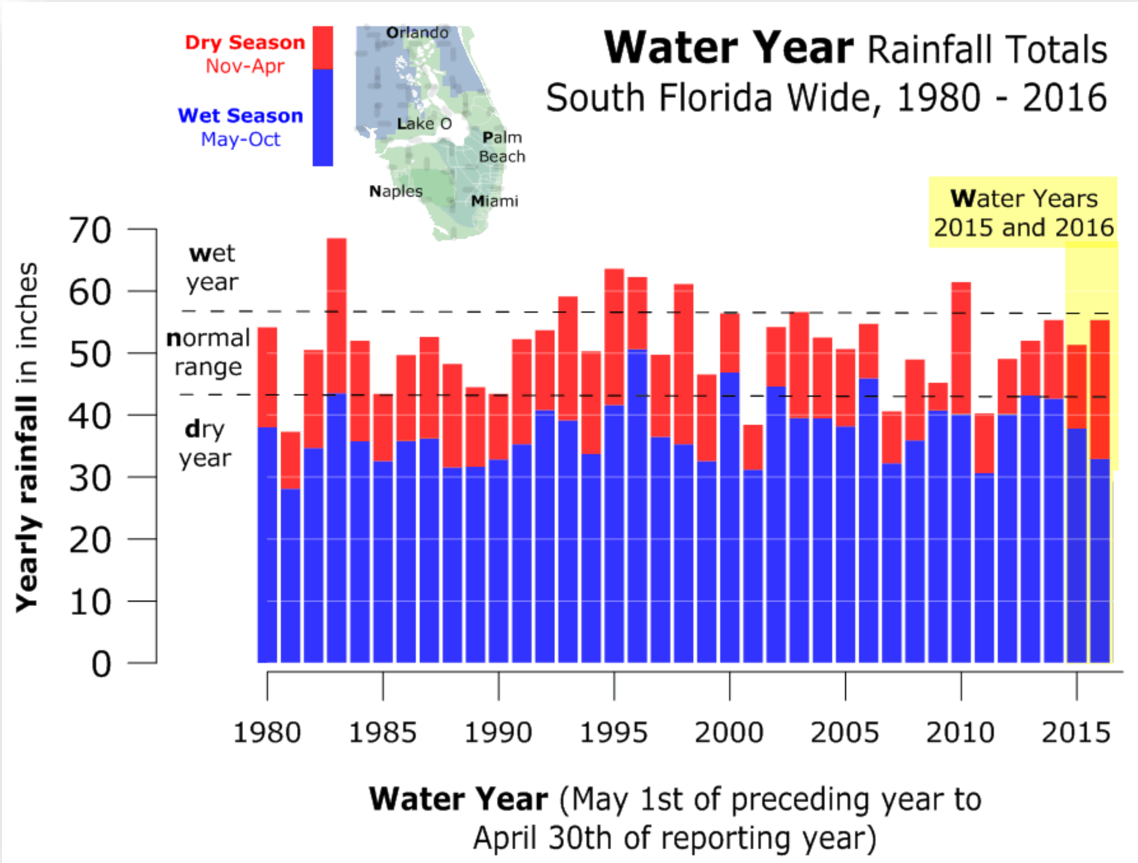

Figure 4. Yearly rainfall (inches) throughout the South Florida Water Management District. This graph was produced using daily rainfall data provided by the South Florida Water Management District. District meteorologists compute a daily rainfall value for the fourteen major basins and district wide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

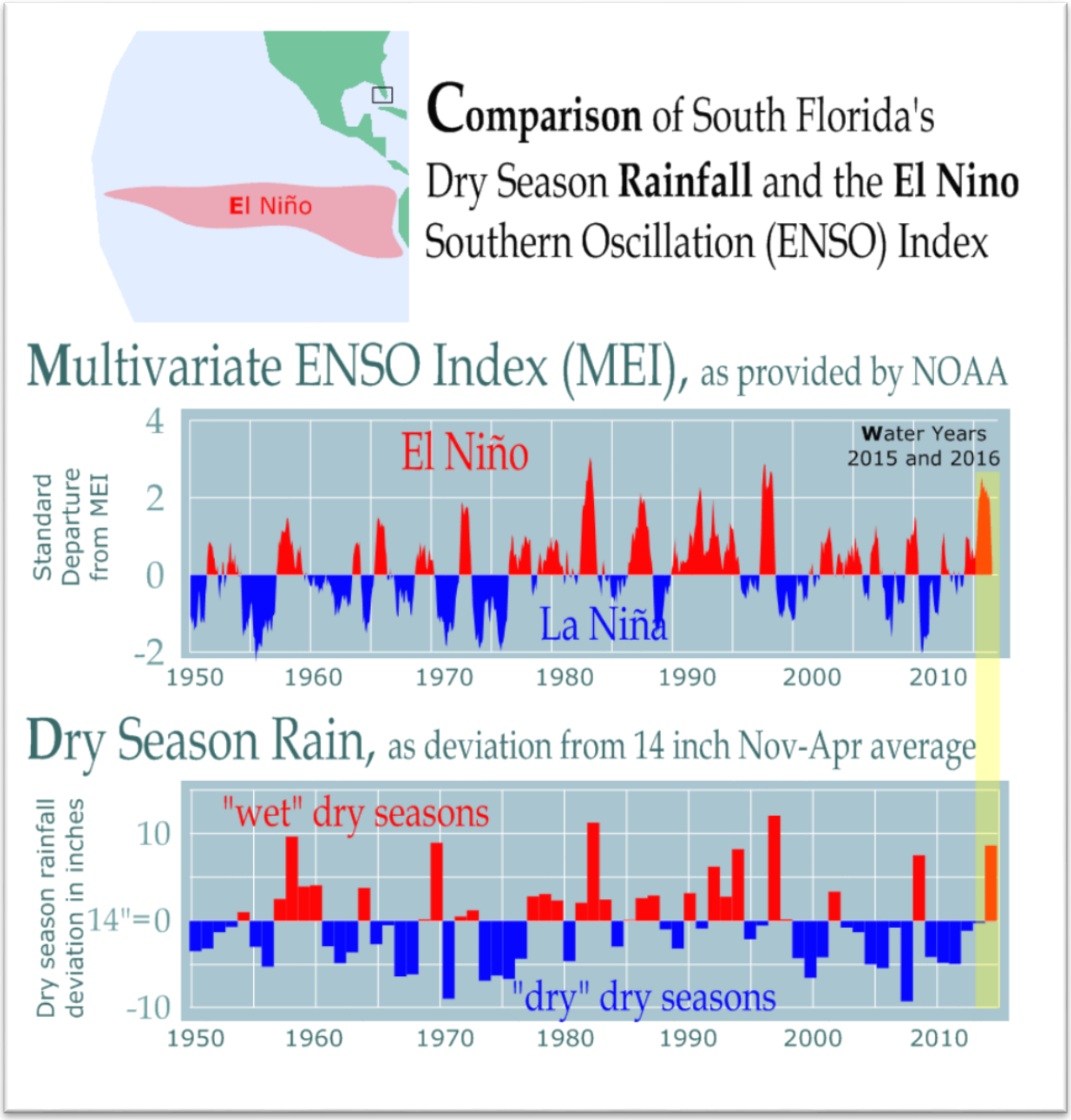

Figure 5. The graphs above show the correlation between the Multivariate ENSO Index (MEI) and winter dry season rain totals for south Florida. The top graph displays the standard departure of the MEI from 1950 to present. The bottom graph shows dry season rainfall for south Florida expressed as a departure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

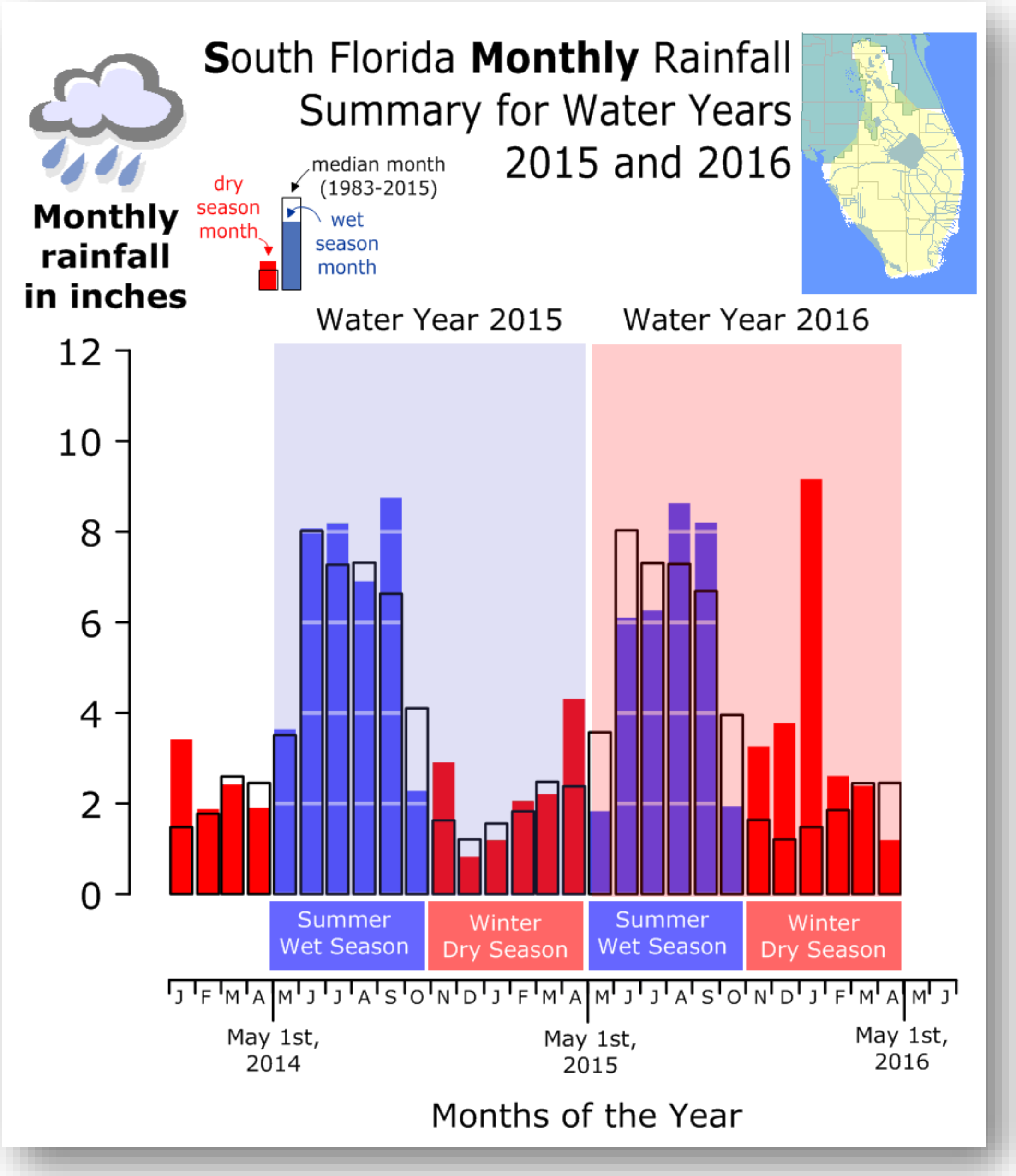

Figure 6. Summary of monthly rainfall in Water Years 2015 and 2016 throughout the South Florida Ecosystem. The graph was produced using daily rainfall data provided by the SFWMD. SFWMD meteorologists compute a daily rainfall value for the fourteen major basins and district-wide from rain gage measurements. See http://www.gohydrology.org/p/about.html for more information.

Water Year Summaries

Water Year 2015 (May 1, 2014 to April 30, 2015)

Water Year 2015 was about as normal as they come in south Florida. Both the wet and dry season rainfall totals very closely matched the long-term averages — 38 inches of rain fell across south Florida during the six-month wet season (May through October) and 14 inches fell in the six-month dry season (November through April) that followed, for a total of 52 inches.

Accordingly, wetlands and waterways of the Everglades filled up through the wet season and receded during the dry season months. The biggest boost of rain came in September (and, in particular, in Arthur R. Marshall Loxahatchee National Wildlife Refuge and WCA 2 where 11 inches were recorded for the month) resulting in slough water depths cresting at a 2-foot depth throughout much of the Everglades by early October, more or less coinciding with the vast wetland's normal annual peak (See Figures XX).

October had little rain to offer, even though this month historically accounts for a quarter of Florida's hurricane-strength storms. Thus, an early dry season was ushered in and the decade-long trend of anomalously low tropical storm activity continued.

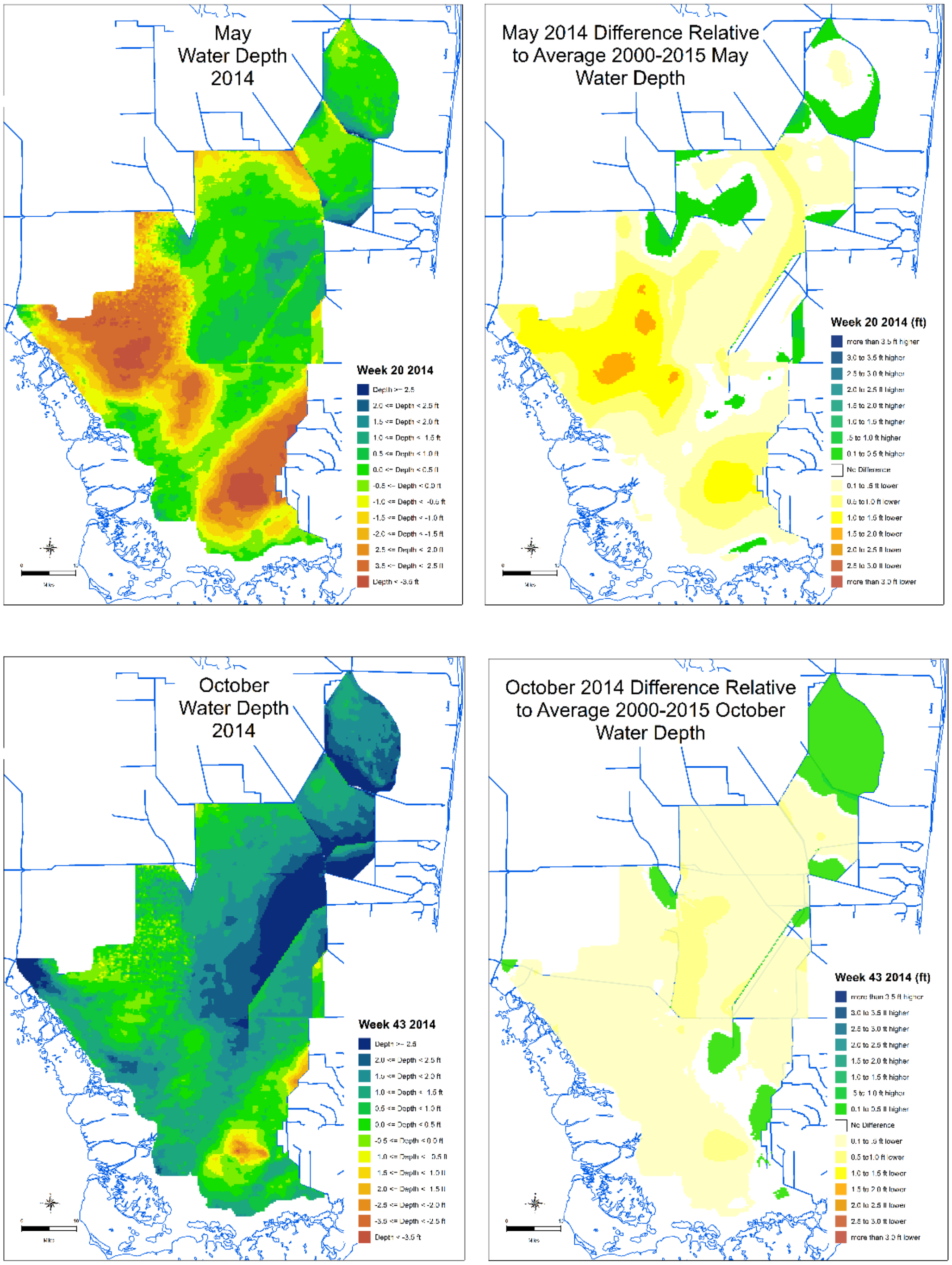

Figure 7. Water depth at the beginning of the 2015 water year (end of dry season) (top left) and wet season (bottom left) and difference from the average water depth at the same time from 2000-2015 (right panels).

Hydrologic Context for the System-wide Ecological Indicators Water Years 2015– 2016

Water Year 2016 (May 1, 2015 to April 30, 2016)

Water Year 2016 proved to be an unusual, though not unprecedented, water year by merit of a paradoxical "double whammy" effect: a very dry summer (33 inches) followed by an extremely wet winter (22 inches) that resulted in a deceivingly normal 55 inches of annual rain. On a month by month basis, however, this water year was anything but normal.

Abnormal conditions prevailed from beginning to end. The trend started with a delay to the normal onset of summer wet season rains. The two month span from early May to the Fourth of July — a period when regular afternoon rain showers usually soak in and rebound the water table out of springtime drought — registered only 60 percent of its normal rainfall amount. The ecological consequences of this summer rainfall deficit manifested in various ways throughout south Florida: instead of rising, water levels fell everywhere well into July and August, leaving wetlands parched and sheet flow non-existent through the first half of summer. To the south, the often hypersaline conditions in Florida Bay took a turn for the worse resulting in a catastrophic seagrass die-off while, to the west, a 35,000 acre wildfire spread across the desiccated Big Cypress Swamp.

The water table eventually rebounded to a semblance of its normal self by late summer, thanks to the arrival of a rainy pattern in August and September (almost 17 inches of rain were recorded over the two months). However, the rise in the water table was short-lived as upper atmosphere and westerly sheer winds from a strengthening El Niño yet again contributed to a lack of fall season tropical storms.

As fall turned to winter, the same westerly wind flow set the stage for the stunningly wet winter. Dubbed a "Super" El Niño, conditions produced above average rains in November and December (reminiscent of epic winter rains last seen in Water Year 1999), punctuated by a record-setting 9 inches of rain in January (6 times the monthly normal). As a result, instead of the gradual decline of the water table the winter dry season usually produces, waters levels reached their annual peak in February, in most cases even higher than the previous fall peak and in some locations (i.e., ENP and Big Cypress National Preserve) establishing historic winter high-water levels.

A series of emergency measures were taken to alleviate the unusual surplus of winter water, some of which had detrimental consequences — such as mandatory releases from Lake Okeechobee to the Caloosahatchee and St. Lucie estuaries due to the need to protect the integrity of the lake's perimeter levee currently under repair — whereas other measures were more aligned with Everglades restoration goals. Most notable in that regard were three efforts focused on sending the water southward: (1) to the east, water managers sent water through the new Tamiami Trail one-mile bridge into ENP's Northeast Shark River 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, efforts were initiated to reintroduce long-diverted overland flows into the Sweetwater Strand watershed downstream of Big Cypress National Preserve.

Despite the lingering concerns of continued rains, Water Year 2016 ended on a dry note with many areas returning to near normal conditions, including Lake Okeechobee, thanks to a drier March and April.

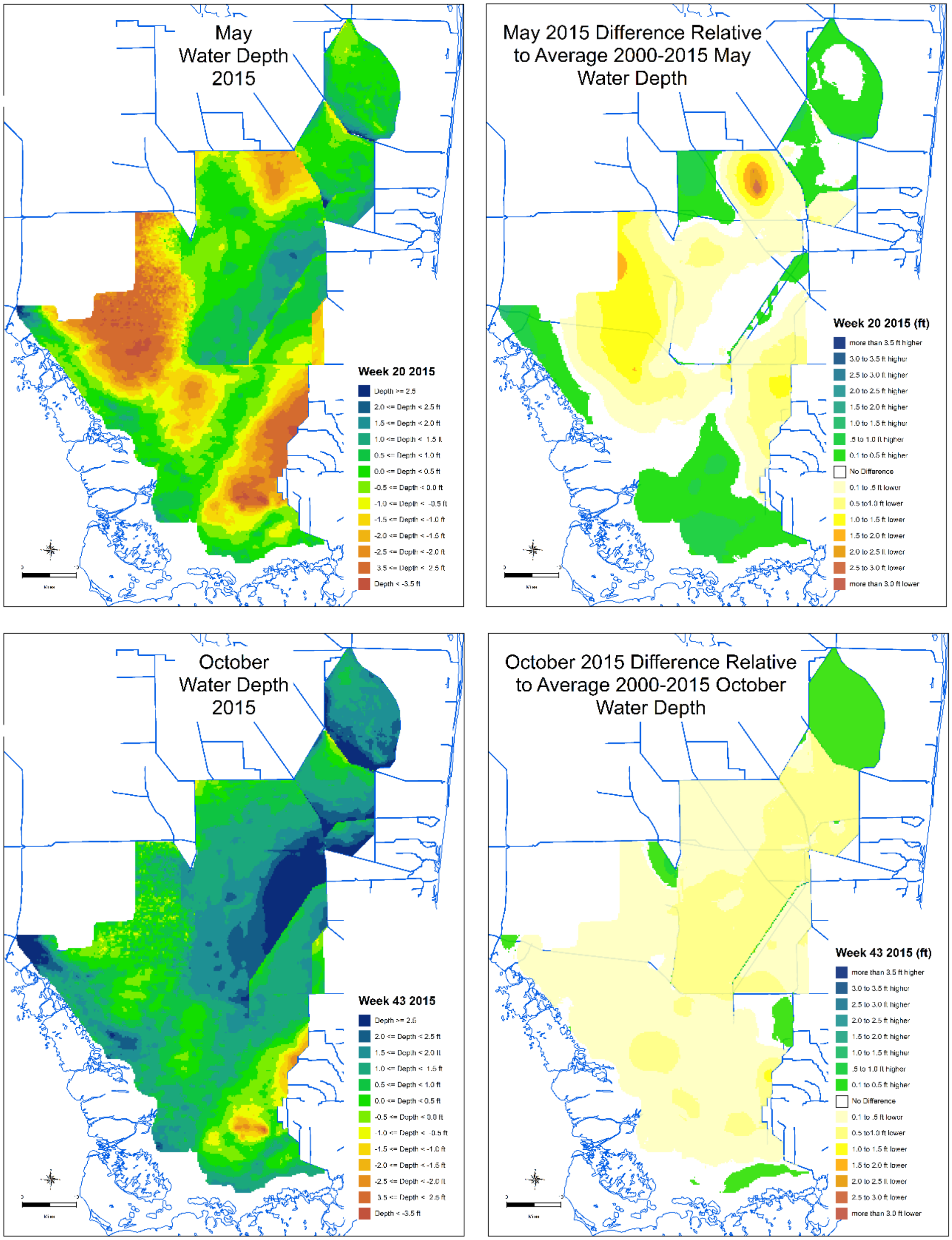

Figure 8. Water depth at the beginning of the 2016 Water Year (end of dry season top left), WY2016 wet season (bottom left). Right panels show differences from the average water depth at the same time from 2000-2015.

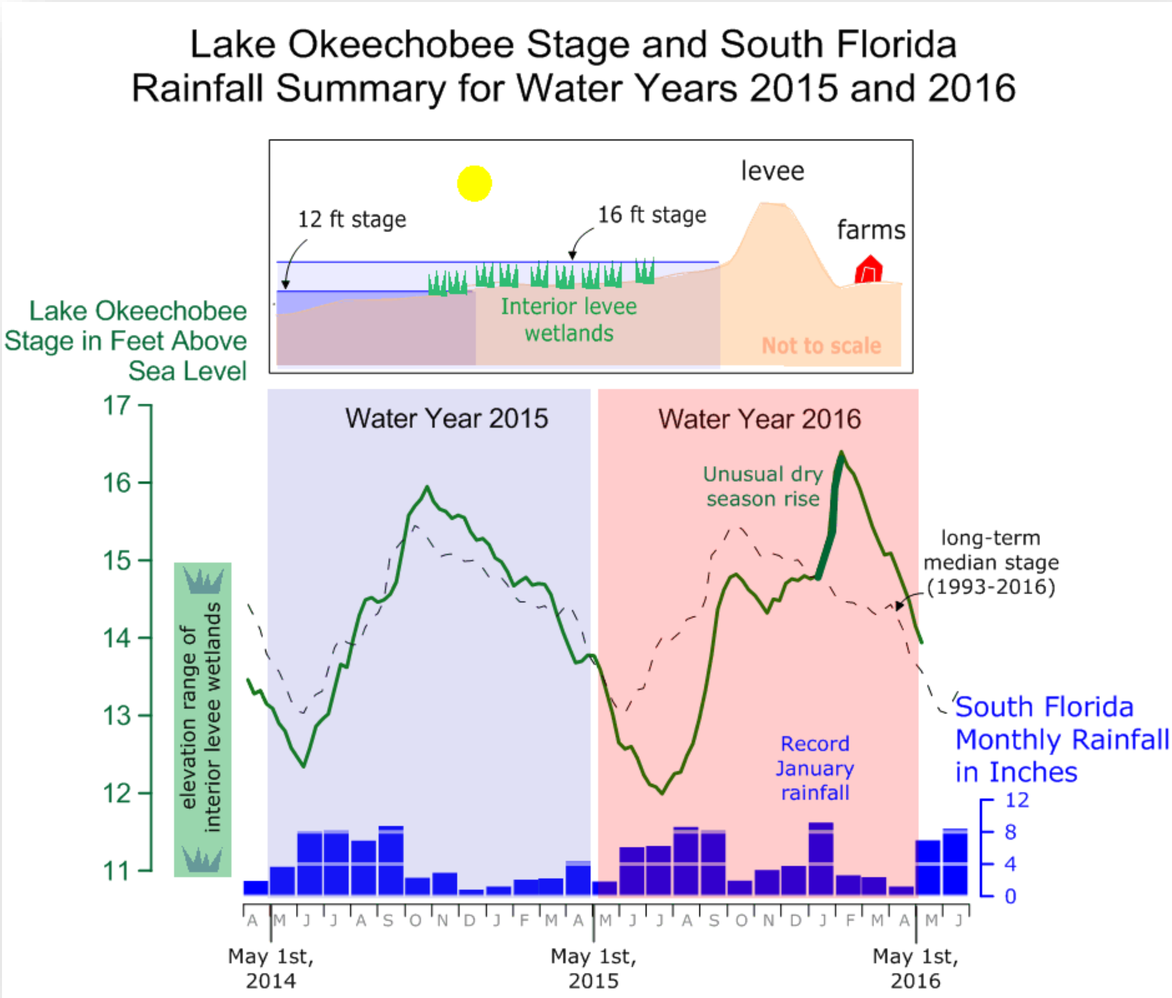

Figure 9. Lake Okeechobee stage and summary of monthly rainfall in the South Florida Water Management District in water years 2015 and 2016. Daily rainfall data provided by the South Florida Water Management District. District meteorologists compute a daily rainfall value for the fourteen major basins and district wide from rain gauge measurements. See GoHydrology for more information.

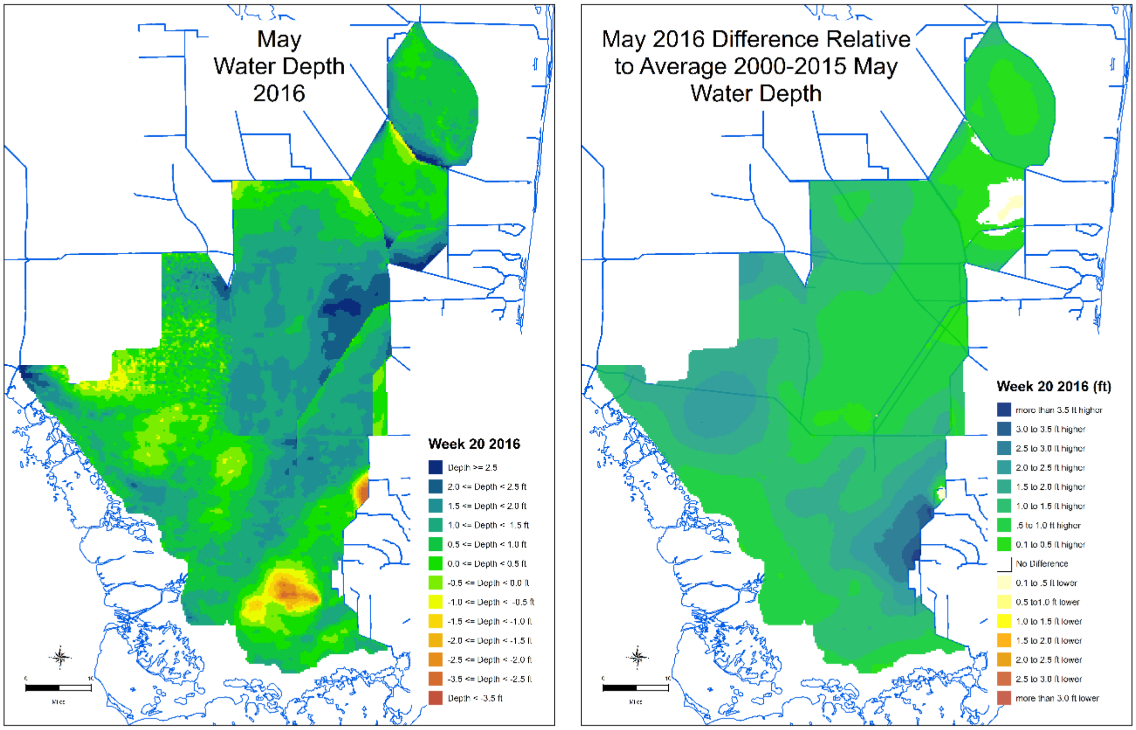

Figure 10. Water depth at the beginning of the 2017 Water Year (end of dry season top left). Right panel shows difference from the average water depth at the same time from 2000-2015. Most areas were well above the 2000-2015 averages at the end of the WY2016 dry season/start of the WY2017 wet season.

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 3 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 V9 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. Further Indicator Details

This 2016 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 2014 Report , the 2016 South Florida Environmental Report, and the RECOVER 2014 System Status Report (SSR) which 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, spans multiple spatial scales, and in some cases decades worth of information. Because of the broad inter- governmental coordination, the SSR incorporates elements of the 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.

Indicators Overview

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, 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 Lake Okeechobee nearshore SAV indicators consist of two performance measures; total area of summer SAV coverage (in acres, > 40,000 is target) and percent of SAV comprised of vascular taxa (>50% is target). 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 (this performance measure is not currently included in the calculation since sampling has not been conducted since 2012.) in Everglades National Park measured over the last 5, 3, and 3 years, respectively. For crocodiles the performance measures are juvenile growth and survival measured over the last 3 and 5 years, respectively.

Fish & Macroinvertebrates

- Fish & Macroinvertebrates are critical as a food for predators such as wading birds and alligators.
- Fish & Macroinvertebrates density and community composition are correlated with hydrology.
- Fish & 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.

Indicators Overview

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 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

- Florida Bay has one of the largest seagrass beds in the world, covering 90% of the 180,000 hectares of the bay.
- Submersed aquatic vegetation (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 hydrological system.

Indicators Overview

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 Roseate Spoonbill relative to hydrological changes permit an assessment of positive or negative trends in restoration.

Indicators Overview - Indicators at a Glance

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 reduction in sample. 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 2012	WY 2013	WY 2014	WY 2015	WY 2016
Invasive Exotic Plants	Y	Y	Y	Y	Y
Lake Okeechobee Nearshore Zone Submerged Aquatic Vegetation	R	G	Y	Y	Y
Eastern Oysters - Modified (Northern Estuaries only)	Y	No info	Y	No info provided	Y
Crocodilians (American Alligators & Crocodiles) - Modified (DOI Lands Only)	Y	Y	R	R	R
Fish & Macroinvertebrate	R	Y	R	R	R
Periphyton - Modified (No composition)	Y	Y	Y	Y	Y
Wading Birds (White Ibis & Wood Stork)	R	R	R	R	R
Southwest Coastal Systems Phytoplankton Blooms - Modified (No southwest shelf)	Y	Y	Y	Y	R
Florida Bay Submersed Aquatic Vegetation	Y	Y	Y	Y	Y
Juvenile Pink Shrimp - Modified (no sampling)	Y	B	B	B	B
Wading Birds (Roseate Spoonbills)	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.***

White Data have been collected but not processed yet.

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

Indicators Overview - About the Indicator Sections

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 section they were asked to provide information for the last five years. Time series from earlier years can be found in the 2014 System-wide Ecological Indicators for Everglades Restoration report.

- Summary/Key Findings
- Time series of stoplights
- Map of WY2016 stoplight colors
- Updates on calculation of indicator
- How have these data been used?
- New insights relevant to future restoration decisions
- Literature cited, reports and publications for more information

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Invasive Exotic Plant Indicator

Summary/Key Findings

The status of the invasive exotic plant indicator (Doren et al. 2009) was below the restoration target (yellow stoplight) at the end of WY2014 and remains below the restoration target at the end of WY2016. Though there were positive results for some invasive plant species in some ecological systems, others showed negative results as measured by abundance and/or geographic distribution.

The region-wide interagency effort to manage the highly invasive tree, melaleuca, remains a national example of coordination success. Melaleuca distribution and abundance within the Everglades Protection Area decreased 54% in areas with intermediate to high infestation levels between 1995 and 2015 (Rodgers and Pernas, 2015). However, the overall geographic distribution of the species has increased and, due to a lack of maintenance control measures, 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, Everglades tree islands of Arthur R. Marshall Loxahatchee National Wildlife Refuge, and cordgrass marshes of ENP. Current conditions in these areas do not meet restoration criteria.

Given the diversity of south Florida's invasive species and their varied impacts, managers have to prioritize response. 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 is improving overall management outcomes for some invasive species. Continued improvements in invasive species management through coordinated planning, construction, and operation phases of restoration efforts (see CERP Guidance Memorandum 062.00, 2012) are necessary to promote more cost-effective management.

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.

Stoplight Table for Invasive Exotic Plants for Water Years 2012- 2016

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

Data and Calculations

Updates on calculation of indicator
No changes were made for the calculation of the WY2015 and WY2016 scores; however, results were modified to include separate assessments of management areas within the Greater Everglades as described in the **2006 South Florida ecosystem restoration "exotic plant indicator" development of an invasive exotic plant metric.** This division of the module allows for a more detailed evaluation of individual management areas within this large landscape.

How have these data been used?
Data were used to update the RECOVER System-wide Science Chapter sections on invasive species. The System-wide Science 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 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. There are now 68 Category I Invasive Plant Species (FLEPPC 2015) 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.
Critical regions affected by the continued expansion of Old World climbing fern include the Arthur R. Marshall Loxahatchee National Wildlife Refuge, Kissimmee River basin, and southwestern Everglades National Park. Aerial assessments in 2015 determined that roughly 11,400 ha of the A.R.M. Loxahatchee National Wildlife Refuge contains high infestations of Old World Climbing fern (LeRoy Rodgers, SFWMD, unpublished data). Areas within the Kissimmee River Basin containing high to moderate infestation levels increased 19% to 625 ha between 2011 and 2016 (Rodgers et al. 2016). These remote, difficult to access natural areas present unique challenges to managing this invasive climbing fern.

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 for release within 1-2 years. 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 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.

Invasive Exotic Plant Indicator

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. Prevention, monitoring, and control programs would have to be expanded in order to do that.

Literature cited, reports, and publications for more information

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LAKE OKEECHOBEE NEARSHORE ZONE SUBMERSED AQUATIC VEGETATION INDICATOR

Summary/Key Findings

The status of the Lake Okeechobee Nearshore submerged aquatic vegetation (SAV) indicator was below the restoration target (yellow stoplight) at the end of WY2014 and remains below the restoration target at the end of both WY2015 and WY2016. SAV covered less than the 40,000 acre target threshold during the annual mapping exercise in both WY2015 and WY2016, although the criterion that 50% or more of the plant taxa present be vascular plants was met during both years. The total number of acres covered by SAV did increase slightly during WY2016 as compared to WY2015.

Since its establishment in 2008, the Lake Okeechobee Regulation Schedule (LORS) has generally kept the lake within or below the ecologically preferred range of 12.5 to 15.5 ft above sea level. That changed in 2016 when El Niño generated very wet conditions in January and February. As a result, the lake stage went above 16 ft at the end of January and remained above 15.5 ft until the middle of March. Most of the sentinel sites when sampled in November 2015 and February 2016 had associated losses of SAV.

On the basis of annual SAV coverage data collected since 2000, 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 ecological 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 winter and spring of WY2015 and 2016 were characterized by higher than ideal lake stages. Synoptic winter and spring surveys indicated that the SAV population at quarterly sentinel sites was significantly reduced compared to previous summer populations at the same sites. Given that the end of WY2016 spring lake level was almost two feet higher than ideal, unless the summer wet season is drier than average or large lake releases continue to be made to lower the lake and keep it in an environmentally favorable range, we anticipate static conditions or a further reduction in SAV coverage and vascular/nonvascular ratios for WY2017. Barring any major climatic events we anticipate that SAV coverage and vascular/nonvascular ratios may improve in WY2018.

LAKE OKEECHOBEE NEARSHORE ZONE SUBMERSED AQUATIC VEGETATION INDICATOR

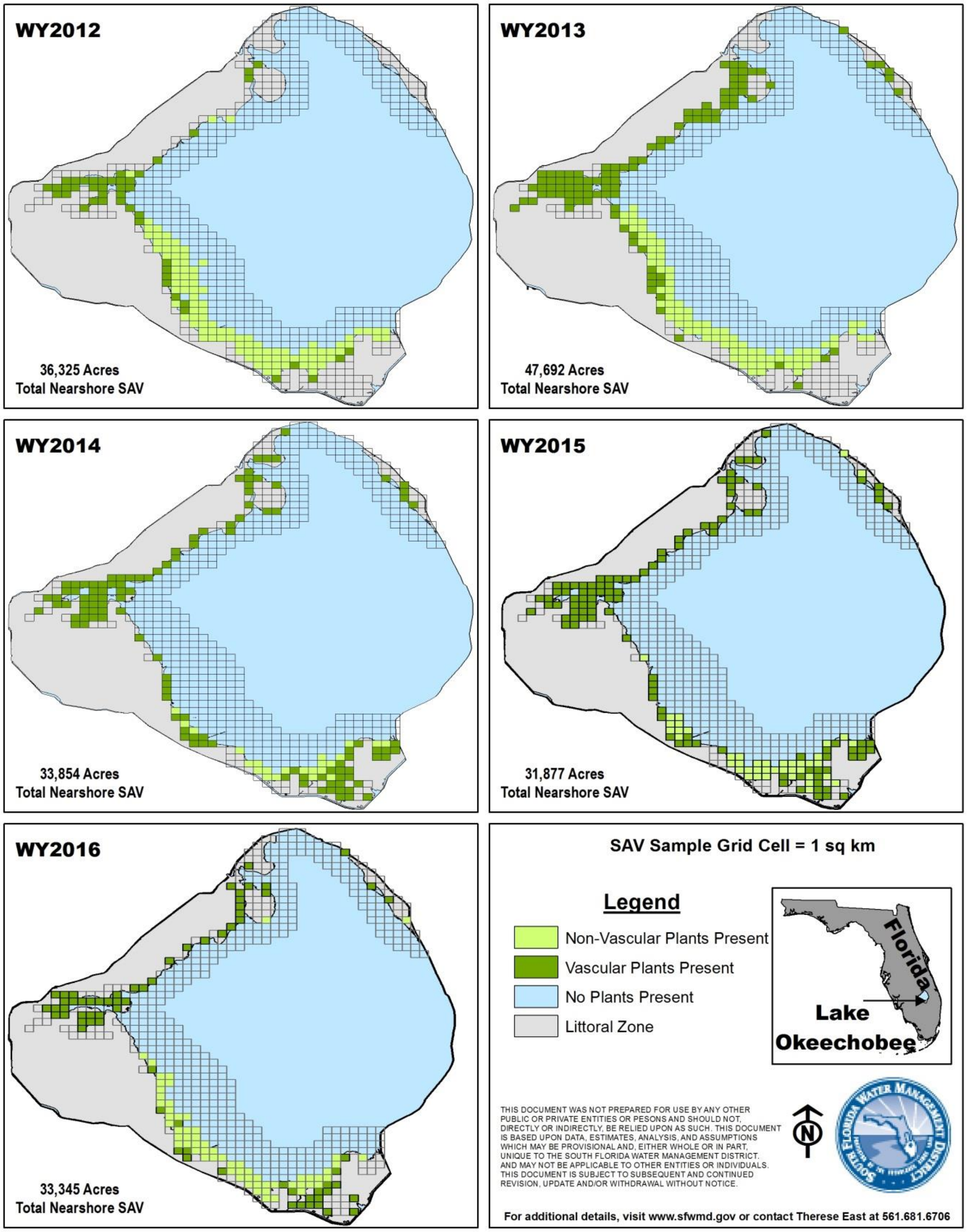

Figure 1: Distribution of SAV in Lake Okeechobee from 2012-2016.

LAKE OKEECHOBEE NEARSHORE ZONE SUBMERSED AQUATIC VEGETATION INDICATOR

Stoplight Table for Lake Okeechobee Nearshore Zone Submersed Aquatic Vegetation for Water Years 2012- 2016

	WY 2012	**WY 2013**	**WY 2014**	**WY 2015**	**WY 2016**
Combined Score	R	G	Y	Y	Y
40,000 or more acres of SAV	R	G	R	R	R
Fifty percent or more vascular	R	G	G	G	G

Data and Calculations

Updates on calculation of indicator

In WY2011, an additional set of grid cells were added to cover the lake's inner marsh (**Figure2**). These data are only collected when lake levels are high enough to have inundated the marsh for a suitable period of time; and are reported separately from the older near shore data set. In WY2012, the location of the quarterly sentinel sampling sites was changed to align with annual grid cells making it easier to compare seasonal and annual data (**Figure 3**). The location of the quarterly sentinel sampling sites were moved in WY2015 (**Figure 3**) since some of the sites were littoral marsh sites dominated by emergent aquatic vegetation.

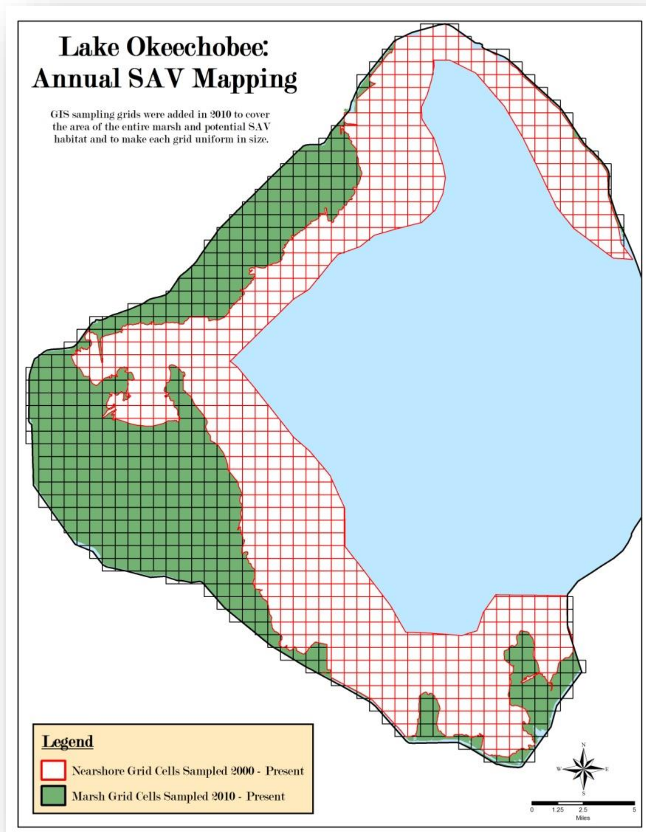

Figure 2. Map showing the extension of the annual mapping grid cells to incorporate the marsh habitat. The grid cells outlined in red are the nearshore grid cells that have been sampled since 2000 (WY 2001). The grid cells outlined in black are the marsh grid cells that were added in 2010 (WY 2011). Grid cell size = $1 km^2$

LAKE OKEECHOBEE NEARSHORE ZONE SUBMERSED AQUATIC VEGETATION INDICATOR

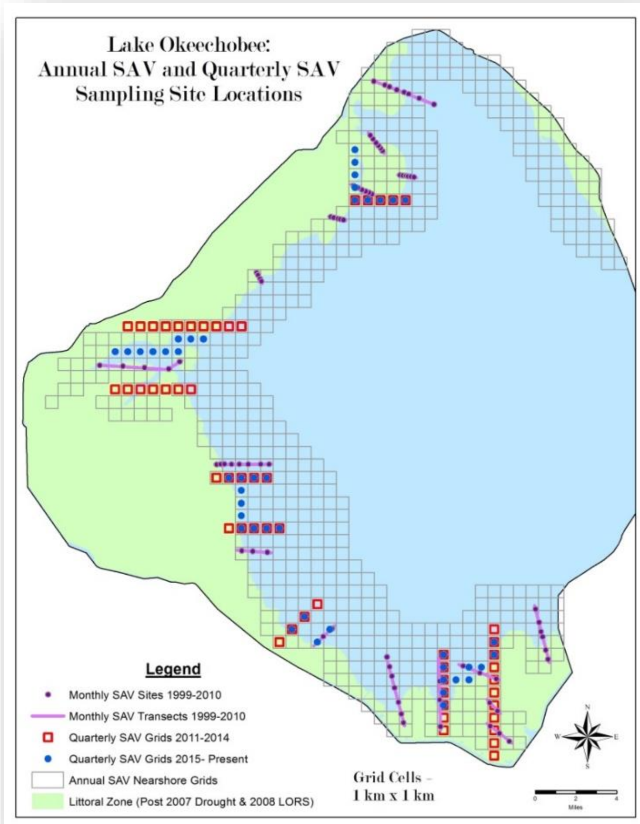

Figure 3. Map showing the transects used for quarterly nearshore SAV sampling between 1999 (WY2000) and 2010 (WY 2011) and the quarterly grid cell locations sampled between 2011 (WY2012) and 2015 (WY2016) and since WY2016.

How are these data being used?

Lake Okeechobee SAV data are used for multiple purposes. Annual summer SAV data is one of the key performance measures that are used to measure the ecological status of the lake and as such are routinely reported in the South Florida Environmental Report and the RECOVER System Status Report. Quarterly SAV data is used to inform managers and stakeholders regarding short term effects of climatic variability and lake management activities, such as lake stage regulation, on the health of the SAV community.

The long term annual SAV data set has been used to calibrate and validate an SAV module that has been added to the Lake Okeechobee Environmental Model (LOEM) (Jin and Ji, 2013). Similarly, this data set has recently been used to develop two performance measures, one that allows for the evaluation of stage hydrograph model output data in terms of vascular SAV abundance, and one assessment measure that expresses SAV abundance as a function of the percent of maximum potential area colonizable by SAV based on nearshore depth gradients between the outer edge of the littoral marsh and the farthest depth offshore SAV has been observed between WY2002 and WY2016.

LAKE OKEECHOBEE NEARSHORE ZONE SUBMERSED AQUATIC VEGETATION INDICATOR

New insights relevant to future restoration decisions

Lake Okeechobee nearshore SAV has been monitored on a quarterly basis at sites along transects and on an annual basis each summer over the entire nearshore region since 2000. The SAV data set was the primary source of information used to establish the temporal and spatial components of the Lake Okeechobee Ecologically Preferred Stage Envelope of 12.5-15.5 feet NGVD; with the top of the envelope stages occurring in mid-autumn and the bottom of the envelope elevations occurring in late spring or early summer. Nearshore SAV coverage shows clear responses to lake stages and over the past 16 years has clearly demonstrated the importance of operational restoration strategies that contribute to keeping the lake in the preferred stage envelope more often. With potential changes in amount and distribution of rainfall, and changes in temperature and evapotranspiration over the next century, nearshore SAV may serve as a good ecological indicator to examine the impacts of climate variability and how it interacts with lake restoration and management goals and activities. SAV data has also indicated that it is possible to have an ecologically healthy marsh and near shore zone without necessarily attaining the Lake Okeechobee TMDL; providing that lake hydrology remains within the preferred stage envelope most of the time. When this occurs, relatively abundant marsh EAV and nearshore SAV abundances and reduced nearshore water column P concentrations, due to plant and associated periphyton uptake result. Conversely, analysis of SAV distribution data, along with EAV data, have shown that even short periods of excessively high lake stages results in (e.g, El Nino impacts during the winter of WY2016) dramatically reduced plant habitat which then typically takes 2 to 3 years of favorable hydrologic conditions to recover; while excessively low lake stages lead to the replacement of SAV habitat with EAV littoral marsh habitat with as yet unknown ecological effects.

Literature cited, reports, and publications for more information

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EASTERN OYSTERS INDICATOR (NORTHERN ESTUARIES ONLY)

Summary/Key Findings

The status of the eastern oyster was below the restoration target (yellow stoplight) at the end of WY2014 and remains below the restoration target at the end of WY2016. This summary reports on the status of the eastern oyster in the Northern Estuaries (Caloosahatchee Estuary, St. Lucie Estuary, Loxahatchee River Estuary, and Lake Worth Lagoon). Oyster monitoring in Southern Estuaries ended in 2012 and therefore no trends could be assessed. Monitoring in Lake Worth Lagoon is funded by Palm Beach County through calendar year 2016 and is tentatively scheduled for a 2-year extension.

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. 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* pathogen.

The oysters in the Caloosahatchee and St. Lucie Estuary were impacted by too much fresh water in summer and too little fresh water in the winter in WY2015. In contrast, large amounts of freshwater runoff and managed releases impacted the Caloosahatchee and St. Lucie Estuaries during the winter season of WY2016. It appears that the freshwater inflows into the estuaries during winter season in WY2016 occurred when oysters were reproductively inactive and fewer larvae were present. As a result, negative impacts on oyster populations were minimized.

Mortality of oysters in the Caloosahatchee ranged between 9-26% and is deemed normal. In the Caloosahatchee River, disease levels were moderate and living densities good between WY2012-2016. In the St. Lucie River, there were both low-salinity mortalities in both water years, as well as periods of high salinity in both water years, resulting in an increased incidence of disease. There were very few months where salinity remained within the optimal band for oysters.

The oysters in Lake Worth Lagoon and Loxahatchee River were consistently impacted by salinities that were too high resulting in high disease prevalence.

The oyster indicator remains below the restoration target.

Stoplight Table for Eastern Oysters Indicator (Northern Estuaries Only) for Water Years 2012- 2016

Eastern Oyster	WY 2012	WY 2013	WY 2014	WY 2015	WY 2016
Northern Estuaries	Y		Y		Y
Caloosahatchee Estuary	Y		Y		Y
Lake Worth Lagoon	Y		Y		Y
Loxahatchee River	Y		Y		Y
St. Lucie Estuary	G		R		Y

Data and Calculations

Changes in the calculation of the indicator

For Caloosahatchee Estuary, St. Lucie, Loxahatchee and Lake Worth Lagoon, condition index is no longer measured due to funding cuts. Also, Lake Worth Lagoon monitoring is no longer funded as part of the CERP/RECOVER program. Funding for Lake Worth Lagoon is currently provided by Palm Beach County through calendar year 2016 and is tentatively scheduled for a 2-year extension.

How have these data been used?

Oyster Habitat continues to serve as one of the principal Performance Metrics for the northern estuaries portion of CERP. Data is used for evaluation in the System Status Reports. 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 Northern Estuaries.

New Insights relevant to future restoration decisions

1. While there may be occasional dry years, in general, there is too much freshwater inflow into the Caloosahatchee Estuary and St. Lucie River in the summer months and too little freshwater inflow into the estuary in the winter months, disrupting natural patterns and estuarine conditions. There is too little inflow to the Loxahatchee River and Lake Worth Lagoon, resulting in high disease prevalence. The oysters in these estuaries are still being impacted by this unnatural water delivery pattern. Too much fresh water impacts reproduction, larval recruitment, survival and growth. Too little fresh water impacts the survival of oysters due to higher disease prevalence and intensity of *Perkinsus marinus* and predation.
2. Oyster responses and populations in the Northern Estuaries are below targets and may be in danger of declines under current salinity levels. Growth rates and recovery rates for abundances suggest that oyster index scores could be expected to increase given proper hydrologic conditions through restoration.
3. Restoration of natural patterns (less freshwater flows in the summer and more freshwater flows in the winter) along with substrate enhancement (addition of cultch) is essential to improving performance of oysters in the estuaries.
4. Current conditions do not meet restoration criteria, signifying that these estuaries need further attention.
5. If the hydrological conditions remain the same, we do not expect to see an improvement in oyster responses in these estuaries.

Continued monitoring of oysters in the Northern Estuaries will provide an indication of ecological responses to ecosystem restoration and will enable us to distinguish between responses to restoration and natural variation. Monitoring of Lake Worth Lagoon is no longer funded as part of the CERP process, and continued funding from local sources cannot be guaranteed.

Estuary Specific

Caloosahatchee Estuary

In general, oysters in the Caloosahatchee Estuary are still being impacted by too much fresh water in summer and too little fresh water in the winter. Too much fresh water impacts reproduction, larval recruitment, survival and growth, while too little fresh water impacts the survival of oysters due to higher disease prevalence and intensity of *Perkinsus marinus* and predation. For example, the past 3 years have been dry years resulting in higher *P. marinus* prevalence values in oysters. Water Year 2016 witnessed huge amounts of freshwater discharges the Caloosahatchee Estuary (and St. Lucie River) during late fall / winter season. Given that oysters are reproductively inactive during this season impacts on larvae were minimized and mortality due to freshwater releases low. However, the atypical stress during the reproductively inactive period may still relate to a reduced condition prior to the typically stressful summer wet season. Status of oysters is expected to improve if hydrologic conditions are restored to more natural patterns.

Management objectives for regulating freshwater inflows play an important part in determining oyster success in the Caloosahatchee Estuary. If conditions remain constant, prognosis for the future will be stable. However, if dry conditions were to persist, it will result in higher disease prevalence and predation of oyster spat and will result in decrease in oyster index score (from yellow to red)

Lake Worth Lagoon

Oysters in Lake Worth Lagoon exhibit small mean sizes, possibly due to high salinity conditions resulting in high predation of larvae and spat. However, Dermo presence is typically very high, but intensity of oysters is comparable to other estuaries in South Florida.

If conditions remain constant, prognosis for the future will be stable. However, if dry conditions were to persist, it will result in higher disease prevalence and predation of oyster spat and will result in decrease in oyster index score (from yellow to red). If the hydrological conditions remain the same, we do not expect to see an improvement in oyster responses in this estuary.

Funding currently provided by Palm Beach County is scheduled to end in 2016.

Loxahatchee River

Oysters in Loxahatchee River exhibit intermediate densities and recruitment possibly due to high salinity conditions resulting in high predation of larvae. Dermo prevalence is typically intermediate to high, though intensity of oysters is comparable to other estuaries in South Florida.

If conditions remain constant, prognosis for the future will be stable. However, if dry conditions were to persist, particularly in the south fork, it will result in higher disease prevalence and predation of oyster spat and will result in decrease in oyster index score (from yellow to red)

St. Lucie Estuary

The oysters in the St. Lucie Estuary are still being impacted by too much fresh water in summer and too little fresh water in the winter. They appeared to have higher tolerance during the winter release during 2015-2016, but continued low-salinity may result in reduced condition and delayed reproduction during 2016.

EASTERN OYSTERS INDICATOR (NORTHERN ESTUARIES ONLY)

Too much fresh water impacts reproduction, larval recruitment, survival and growth, while too little fresh water impacts the survival of oysters due to higher disease prevalence and intensity of *Perkinsus marinus* and predation. These negative impacts seen during the wet season may be exacerbated by poor condition following an atypically wet dry season.

Management objectives for regulating freshwater inflows play an important part in determining oyster success in the St. Lucie Estuary. If conditions remain constant, prognosis for the future will be stable. However, if wet conditions were to persist, it will result in reduced abundance and settlement higher disease prevalence and predation of oyster spat and will result in decrease in oyster index score (from yellow to red). Continued periods of suboptimal salinities will likely result in loss or burial of the reefs in the uppermost reaches of each river fork.

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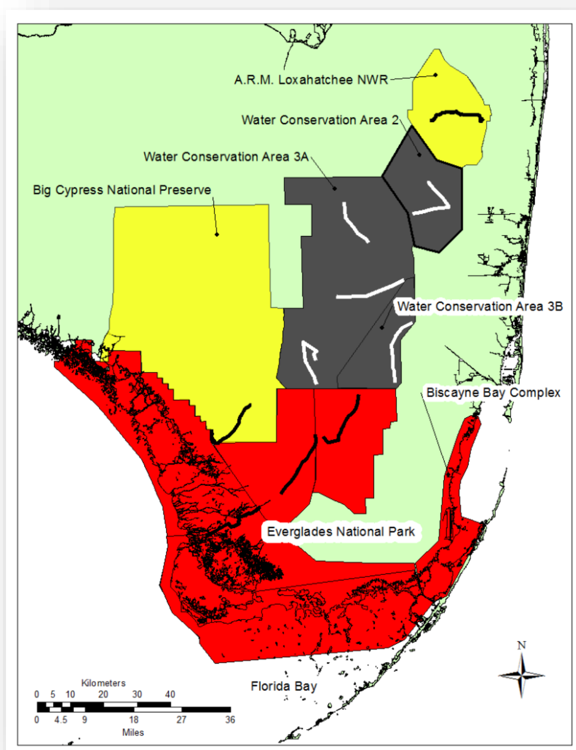
CROCODILIANS (AMERICAN ALLIGATORS & CROCODILES) INDICATOR—MODIFIED (DOI LANDS ONLY)

Summary/Key Findings

A full system-wide status assessment for crocodilians for WY2014–WY2016 cannot be provided because some survey routes have not been sampled since funding was suspended in WY2012. However, surveys have continued on Department of Interior lands (Arthur R. Marshall Loxahatchee National Wildlife Refuge, Big Cypress National Preserve, Crocodile Lake National Wildlife Refuge, Biscayne National Park, and Everglades National Park).

The status of the crocodilian indicator on Department of Interior (DOI) lands has remained well below the restoration target (red stoplight) since WY2014 and remains well below the restoration target at the end of WY2016. This is the first time since 2008 that the overall score for DOI lands has remained well below the restoration target for three years in a row. While the score for Arthur R. Marshall Loxahatchee National Wildlife Refuge has remained yellow, Big Cypress National Preserve (alligators), Biscayne Bay Complex, which includes Biscayne Bay National Park and Crocodile Lake National Wildlife Refuge, (crocodiles) and Everglades National Park (both alligators and crocodiles) have fluctuated from yellow to red. Overall this result reflects low relative densities of alligators, variable alligator body condition, and low crocodile growth and survival.

Figure 1. Stoplight colors for crocodilian indicator by management unit for WY2016.



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

Stoplight Table for Crocodilians (American Alligators & Crocodiles) - Modified (DOI Lands Only) for Water Years 2012- 2016

American Alligators and Crocodile	**WY 2012**	**WY 2013**	**WY 2014**	**WY 2015**	**WY 2016**
System-wide	B	B	B	B	B
DOI Lands	Y	Y	R	R	R

American Alligator	**WY 2012**	**WY 2013**	**WY 2014**	**WY 2015**	**WY 2016**
A.R.M. Loxahatchee National Wildlife Refuge	Y	Y	Y	Y	Y
Water Conservation Area 2A	B	B	B	B	B
Water Conservation Area 3A	B	B	B	B	B
Water Conservation Area 3B	B	B	B	B	B
Everglades National Park	R	R	R	R	R
Big Cypress National Preserve	Y	Y	Y	R	Y
American Crocodile					
Everglades National Park	Y	Y	Y	Y	R
Biscayne Bay Complex	Y	Y	R	R	R

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

Data and Calculations

Updates on calculation of indicator
No changes were made for the calculation of the WY2015 and WY2016 scores; however, work is in progress for improvements to calculation of the crocodile growth and survival portions of the index.

The improvements to calculation of crocodile survival will include age-specific survival rates from capture-recapture histories of marked crocodiles of known age (i.e. individuals first captured as hatchlings). Capture-recapture analyses will be performed to estimate annual survival rates and recapture rates of crocodiles first captured in the early 1970's.

How have these data been used?
Data collected as a part of this project were used to update the RECOVER performance measure documentation sheets for alligators and crocodiles. 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 condition and how the indicator can be used for evaluation and assessment. The alligator documentation sheet was approved in June 2014 and the crocodile documentation sheet in October 2015. This information also can be used in the context of interim goals.

New insights relevant to future restoration decisions
We have used data collected since 1998 to not only follow trends in alligators but also to develop a better understanding of the relationship between hydrology and salinity and alligator relative density and body condition. We used data collected during 2004–2013 at Arthur R. Marshall Loxahatchee National Wildlife Refuge to examine effects of dry years on alligator abundance and to test a new way to analyze the survey data that takes into account detection probabilities and will allow for calculation of alligator abundance rather than reporting relative density. Alligators showed population responses to dry years with decreasing trends immediately after a dry year and increasing trends following subsequent wet years. These results support the hypotheses on the importance of multi-year hydroperiods in the Everglades (Waddle et al. 2015).

Survey data from 1998-2013 were used to examine hypotheses about alligator movement and trends in relative density in relation to salinity in Shark River estuary. Alligators move up and down the estuary in response to salinity with fewer alligators observed in areas of higher salinity. Overall there were few small alligators in the estuary. Over the study period there was a declining trend in relative density of alligators, particularly in the dry season. These results are consistent with our hypotheses about how salinity affects alligators and our expectation is that with restoration of more freshwater flows to the estuaries, alligator density will increase and that more medium and small alligators will be observed as salinity becomes more favorable (lower; Fujisaki et al. 2016).

We used alligator body condition data to examine both how patterns of body condition are changing in the Everglades in response to hydrology (Brandt et al. 2016), but also to see how body condition of Everglades alligators compares to alligators in lakes in Florida (Brandt et al. In Press). Alligator body condition is related to fluctuations in water levels that are important for wetland health. However, body condition has declined in the Everglades since the early 2000s and is about 12% lower than in other areas. Our hypothesis is that lower body condition is related to the oligotrophic nature of the Everglades and to a decline in food resources related to altered hydrology. We expect that as restoration creates more natural hydrologic patterns that alligator body condition will increase.
Recent research has illustrated a strong positive relationship between nesting wading birds and alligators within the colony (see Wading Bird indicator). 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 should be seen as a threat to wading bird nesting populations.

Survey data for both alligators and crocodiles were used to assess the effects of the 2010 cold snap on trends in relative density as measured by encounter rates (Mazzotti et al. 2016) using linear regression analysis. These analyses indicated that alligator encounter rates in the Greater Everglades have been steadily declining since 2003 (slope = -0.07, p-value << 0.001) but were not affected by the cold-snap.

For crocodiles our linear regression model indicated that American crocodiles encounter rates in ENP have been slowly increasing since 2004 (slope = 0.03, p-value = 0.048). The cold-snap had a negative effect on encounter rate with significantly fewer crocodiles observed after the cold snap. Encounter rate after the cold was similar to that seen six years earlier (Figure 3). Our long-term dataset allows us to do these kinds of analyses that help to separate out the factors that influence fluctuations in relative density.

Capture data from 1978 to 2014 were used to examine crocodile survival. Survival estimates for one-year old juvenile crocodiles ranged from 8% (0.09-0.42.3% CI) to 85% (2.0-195% CI) and generally were between 20-40% with no temporal trend (Mazzotti et al. 2016) Two-year old juvenile crocodiles had a higher survival rate typically between 65-95% until 1995, after which there was a significant decrease over time to a range of 38% (7.9-80.9 95% CI) to 85% (0.9-195% CI). Low sample size of recaptured individuals did not allow for annual survival estimates for crocodiles older than three years (Mazzotti et al. 2014). Contrary to survival rates, recapture rates did not vary significantly throughout the period of record, however once regular surveys were implemented in 2004, recapture rates improved in consistency and ranged between 1% (95% CI: 0.006-0.035) and 3% (95% CI 0.011-0.072) recapture rate of crocodiles (Mazzotti et al. 2014).

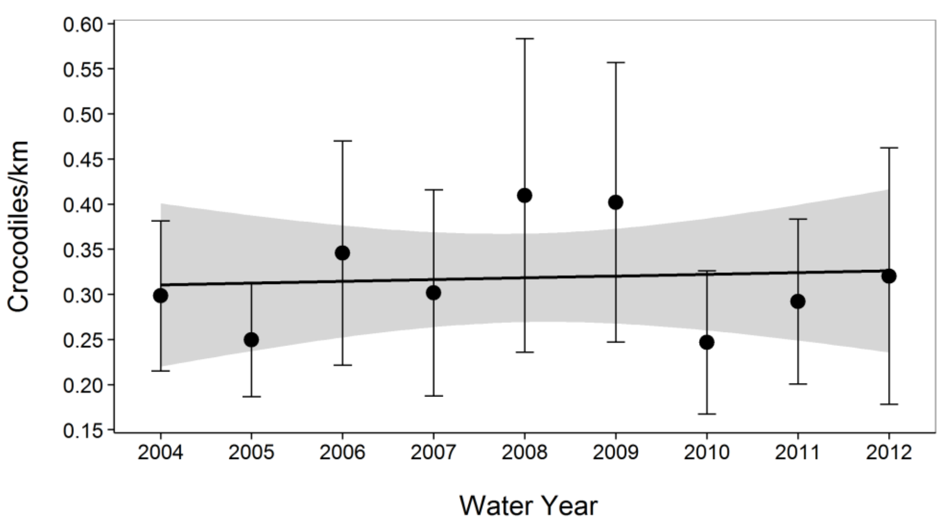


Figure 3. Non-hatchling crocodile density calculated as encounter rate per kilometer of route surveyed during 2004-2013. A regression line is drawn and the 95% confidence interval is shaded in gray (slope = 0.03, p-value = 0.048). The cold-snap had an effect on encounter rates, approximately six times as large as the per annum rate of increase of encounters (estimate = -0.17, p-value=0.027). Data are aggregated from four survey routes, Joe Bay/Little Madeira Bay, Buttonwood Canal, Cape Sable/Lake Ingraham, and Biscayne Bay Complex (Figure from Mazzotti et al. 2016).

These age-specific survival rates are higher than previously reported values of crocodile survival in ENP, which were based on minimum known alive analysis, and represents our ability to model true survival, not just the minimum known annual survival rate. Refined statistical techniques are allowing us to get better estimates of crocodile survival.

In addition to understanding how environmental conditions affect alligators and crocodiles in the Greater Everglades, we must also consider impacts from other factors such as invasive species. Both Burmese python and Black and White Argentine tegu populations are already within or near to alligator and crocodile habitat. Predation on alligators has been documented by pythons (Snow et al. 2007) and on alligator nests (eggs), by tegus (Mazzotti et al. 2014). While predation has not been reported on crocodiles or their nests by either pythons or tegus, we have direct evidence that a tegu repeatedly visited a crocodile nest (Mazzotti et al 2014). In Florida crocodilians use elevated areas such as levees and berms for nesting, areas also used by pythons and tegus. It is essential that efforts are taken to manage and mitigate impacts from these invasive species, with the goal of protecting native fauna, including alligators and crocodiles.

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FISH & MACROINVERTEBRATES INDICATOR (WCA3 AND ENP ONLY)

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 WY2015 and WY2016. This indicator contains multiple components (see Full System-wide Ecological Indicators Report) and those in Shark and Taylor Sloughs in Everglades National Park (ENP) that are sensitive to hydrological drying have been below rainfall-based expectations at most long-term monitoring sites extending back to WY2013. This is in contrast to the same indicators in WCA 3A and B, where they have been within expectations based on rainfall. There is continued evidence that Shark River Slough and Taylor Slough dried more than required to meet our rainfall-based restoration targets.

In this reporting period, the regional relative abundance of non-native fish has exceeded 2% for the first time in Shark and Taylor Sloughs, but not WCA 3A. This is the first time that non-native fish (African Jewelfish, Mayan Cichlids, Asian Swamp eels, and Spotfin Spiny Eels) have been identified as a potential cause of failure to meet restoration targets since reporting began in WY2002. There is strong statistically supported evidence that non-native fish are impacting native species by causing decreases in both density and biomass. At their current densities, we have empirical evidence that they 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. Completing restoration of historical hydroperiods could provide greater resilience of native aquatic communities and diminish impacts of non-native species, whose expansion and success may be facilitated by the drier environment currently prevailing as a result of past hydrologic conditions.

The Fish & Macroinvertebrates indicator remains well below the restoration target.
The density of prey-base fishes in Shark and Taylor Sloughs in Everglades National Park (ENP) have been below rainfall-based expectations at most long-term monitoring sites over the current evaluation period (Fig. 1). This condition has extended back to WY2013. This is in contrast to the same indicator in WCA 3A and B, where they have been within 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, three PMs sensitive to the frequency of drying, suggest marshes in ENP have been dried more recently than expected based on our rainfall-based target (Table 1).

The non-native African Jewelfish have averaged as high as 20% of the fish collected in Shark River Slough during WY2015 and 2016, with some sites far exceeding that in some months. 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, Swamp Eels and Spotfin Spiny Eels, have dramatically increased in abundance, particularly in electrofishing catches. The red stoplights for total fish density in WY2015 and 2016 in Shark River Slough appear to result from, or be exacerbated by, African Jewelfish increase. Observed total fish density is now lower than expectations of density of native species modeled by hydrological variation prior to Jewelfish arrival. Eastern Mosquitofish and Least Killifish are substantially below hydrologically based targets at sites with high Jewelfish relative abundance. This is the first time non-native fish have been identified as a potential cause of failure to meet restoration targets since reporting began in WY2002.

Though fish and macroinvertebrate abundance continue to be inconsistent with restoration targets based on rainfall patterns in Shark River Slough and Taylor Slough, they are generally at expectations in WCA 3A and 3B. There is continued evidence that Shark River Slough and Taylor Slough dried more than required to meet our rainfall-based restoration targets. 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.

FISH & MACROINVERTEBRATES INDICATOR (WCA3 AND ENP ONLY)

For this biennial report, data for WY2016 were included through April, 2016. 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. However, those releases were after the end of this evaluation period. WCA 3A continues to be at or near restoration targets for this indicator, though because water is impounded in this region. The loss in sheetflow associated with that impoundment is ultimately harmful for this performance measure, but its effects are too subtle to be documented at the time scale of this assessment. The most striking result in this reporting period is 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). The prospects of this impact in the future must be treated with caution because these species (African Jewelfish, Asian Swamp eels, Spotfin Spiney Eels) are in a period of exponential population growth and range expansion. Past experience indicates that this may be followed by a similarly rapid decrease in abundance for reasons that are poorly understood, followed by persistence at low density but widespread distribution. This is the optimistic possibility and only continued monitoring and time will tell if optimism is warranted. At their current densities, we have empirical evidence that they 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. There are currently no promising restoration actions that could be taken to diminish the abundance of the non-native fishes already in the Everglades. Completing restoration of historical hydroperiods could provide greater resilience of native aquatic communities and diminish impacts of non-native species, whose expansion and success may be facilitated by the drier environment currently prevailing as a result of past water allocation and delivery choices.

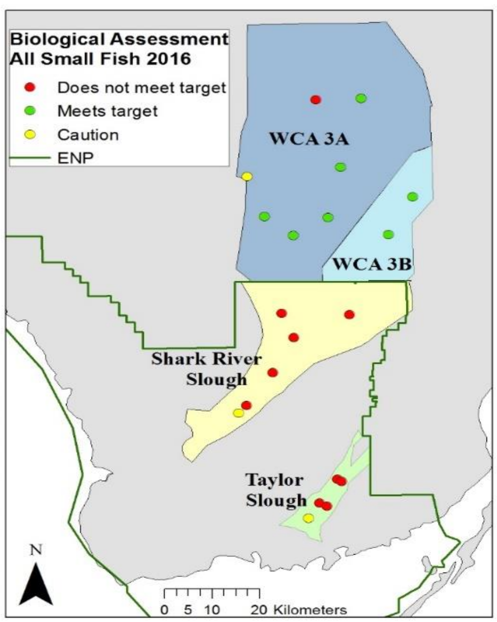

Figure 1 Stoplight colors for small fish indicator at long-term study

Stoplight Table for Fish & Macroinvertebrates Indicator (WCA3 and ENP only) for Water Years 2012- 2016

Performance Measure	WY 2012	WY 2013	WY 2014	WY 2015	WY 2016
Overall	R	Y	R	R	R
Shark River Slough					
Total Fish	Y	R	R	Y	R
Non-Native Fish	Y	Y	Y	R	R
Bluefin Killifish	R	R	R	Y	R
Flagfish	G	G	G	G	Y
Easter Mosquitofish	Y	Y	Y	R	R
Everglades Crayfish	Y	Y	G	Y	R
Taylor Slough					
Total Fish	Y	Y	Y	R	R
Non-Native Fish	Y	Y	Y	Y	R
Bluefin Killifish	Y	R	Y	R	Y
Flagfish	G	G	Y	Y	R
Eastern Mosquitofish	G	G	G	Y	R
Everglades Crayfish	G	R	R	R	R
Water Conservation Area 3 A					
Total Fish	Y	Y	Y	Y	G
Non-Native Fish	G	Y	Y	Y	Y
Bluefin Killifish	Y	G	Y	G	G
Flagfish	G	G	G	G	G
Eastern Mosquitofish	G	G	G	G	G
Water Conservation Area 3 B					
Total Fish	Y	R	Y	Y	G
Non-Native Fish	G	Y	Y	G	Y
Bluefin Killifish	Y	Y	Y	Y	Y
Flagfish	Y	G	G	G	G
Eastern Mosquitofish	Y	Y	Y	Y	G

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 PM based on target hydrological conditions (Trexler and Goss 2009). Hydrological targets were calculated based on the relationship of rainfall and stage are our long-term study sites between November 1,1993 – November 1, 1999. This period was selected because it includes the last large El Nino event that yielded two years of particularly wet conditions (1997-1998) and hydrological stages in Everglades National Park near those predicted by the Natural System Model (SFNRC 2005). This is also a period before operational changes for the CSOP, IOP, and ETRP programs. We used these hydrological targets to estimate prey-base PM values given the observed rainfall during the assessment period of water years 2015 (June 2014-May 2015) and 2016 (June 2015-May 2016).

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*), and 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 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). This year we added 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 described the data well, although fit varied across species and regions. Stoplights are calculated based on the deviation of observed and target predictions accounting for model uncertainty (Trexler and Goss 2009) and 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).

Note that we re-calculated the past stoplights reported in Table 1 compared to past years using the models that included 'season'. This led to few changes in past assessments, but improved model fit in some cases.

We also assess non-native species based on their relative abundance and an arbitrary value of 2% of the fishes collected in a region. 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.

How have these data been used?
The data used for this assessment were also used to produce the RECOVER performance measure (PM) 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 condition 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).

New insights relevant to future restoration decisions
There has been a dramatic change in the status of the prey-base small fish communities in the Shark River Slough, and to a less extent Taylor Slough, since the last biennial report that has implications for restoration decisions and warrants 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, possible resulting from regional-scale effects of cumulative drying and shortened hydroperiods. This assessment reports data indicating even lower density and biomass than expected from the previous trend in Shark River Slough, and 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 foodweb with the invasion of Jewelfish. These patterns 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 this new invasion is fundamentally different and represents a persistent change in aquatic community function. The expansion of African Jewelfish has been linked to changes in water delivery from canals bordering Everglades National Park (Kline et al. 2014) and may represent an unintended consequence of restoration activities. 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 Spiney Eels. The ecological impacts of these species is unclear at present.

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PERIPHYTON INDICATOR (MODIFIED NO COMPOSITION)

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 WY2014 and remains below the restoration target at the end of WY2016. The periphyton indicator is no longer calculated as originally developed because of funding limitations beginning in WY 2012 (for more information, see 2016 System-wide Ecological Indicators for Everglades Restoration report).

The modified indicator includes only two components: 1) periphyton quality (a reflection of TP) and 2) quantity (biomass). In WY2016, because many sites still show altered or cautionary quality (33% of sites) and quantity (42% of sites), the status of the indicator was considered below the restoration target (yellow stoplight). This represents a significantly increased number of sites classified as yellow relative to WY2014. The sampling sites with lower periphyton quality (sites with higher TP concentrations, or enriched sites) were clustered near the L-67 canal, the central WCA 3A flowpath, and near canal boundaries of Arthur R. Marshall Loxahatchee National Wildlife Refuge 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.

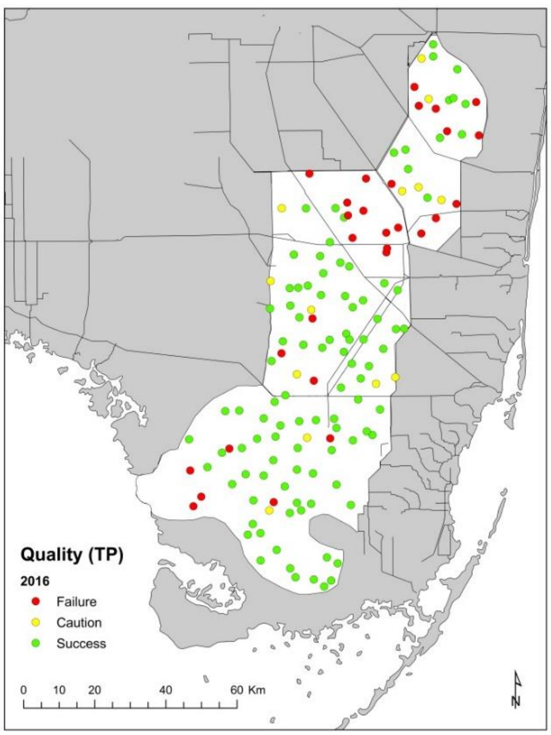

Figure 2 Stoplight colors for periphyton indicator by management unit for WY2016.

Stoplight Table for Periphyton Indicator (Modified No Composition) for Water Years 2012- 2016

	WY 2012	WY 2013	WY 2014	WY 2015	WY 2016
SYSTEM-WIDE					
Quality (TP)	Y	Y	G	G	Y
Biomass	Y	Y	Y	Y	Y
WCA 1					
Quality (TP)	Y	Y	G	G	Y
Biomass	G	G	G	G	Y
WCA 2A					
Quality (TP)	Y	Y	G	G	Y
Biomass	Y	Y	G	Y	Y
WCA 3A					
Quality (TP)	Y	Y	G	G	Y
Biomass	R	Y	Y	Y	Y
SRS					
Quality (TP)	G	Y	G	G	G
Biomass	Y	Y	Y	Y	Y
TS					
Quality (TP)	G	G	Y	Y	G
Biomass	G	Y	G	G	G

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 data that have been collected for nearly a decade for the periphyton mapping program. A third metric, the species compositional metric, discontinued in WY2012, improves detection of water quality improvement or impairment by more than 20% because the ratio of weedy to native diatoms is the most sensitive of the three metrics to changes in TP concentration exposure. We now have a better understanding of the utility of the quality, quantity, and species composition metrics and relationships to phosphorus loading from boundary canals (Gaiser et al. 2015). Wet season compositional values for the 6 years of record are highly correlated with flow-weighted mean TP concentrations at inflow structures. The high correlation between inflow concentration and condition status across each wetland is surprising, since it includes locations 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. Additional analysis level may resolve interpretation of sources for impairment.

How have these data been used?

These data and findings were also reported in the RECOVER 2014 System Status Report (Section 3B) 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. In Press and 2014 System Status Report) 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. In addition, absence of species data from WY 2012-2016 suggest ~20% are being misinterpreted, but samples were retained and will be analyzed for species in the coming year, which will improve the metric in the future.

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Summary/Key Findings

The status of the wading bird indicator was well below the restoration target (red stoplight) at the end of WY2014 and remains well below the restoration target at the end of WY2016. The El Niño conditions that began in July 2015 led to a much reduced hydroperiod throughout much of the Everglades during the critical summer growing season for fish that are prey for wading birds. Conversely, during the 2015/2016 winter, record wet conditions were experienced, with exceptionally slow drying trends during the nesting season. Reversals in water level were common during January – June 2016. This led to relatively little food for wading birds, and because water levels did not recede as usual, the prey that was available was difficult for the birds to capture during 2016. The number of nests started was very low and initiation was delayed nearly two months in comparison to most seasons on record.

During the last five years, none of the components of the wading bird indicator showed much change in trend or degree. Although one component (White Ibis supercolony nesting) now routinely exceeds the restoration target, the other three components remain stable and are well below target levels. Although the proportion of nesting in coastal colonies showed some positive trend prior to 2014, that number has decreased in the last three years. The timing of nesting for storks has gotten later, in the opposite direction of predicted responses to restoration.

The 2016 nesting season should probably not be seen as alarming, since El Niño winters nearly always produce exceptionally poor nesting and low nesting success. However, the 5-year trends include years with more favorable hydrology, and present a stark picture of stable to declining trends. These responses of wading birds are what we would predict (trends are stable to negative) since large scale restoration of hydrological conditions that should positively affect birds has not yet taken place.

The wading birds indicator remains well below the restoration target.

Stoplight Table for Wading Birds (Wood Stork & White Ibis) for Water Years 2012- 2016

	WY 2012	WY 2013	WY 2014	WY 2015	WY 2016
Wading Bird Indicator Summary	R	R	R	R	R
Ratio of Wood Stork + White Ibis nests to Great Egret nests	R	R	R	R	R
Month of Wood Stork nest initiation	R	R	R	R	R
Proportion of nesting in headwaters	Y	R	R	R	R
Mean interval between exceptional Ibis nesting years	G	G	G	G	G

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 South Florida Water Management District. 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 (USGS and SFWMD).

New insights relevant to future restoration decisions

1. WADEM Models developed by James Beerens and collaborators at Florida Atlantic University now show increasing ability to predict foraging and nesting based on antecedent hydrology and relationships between fish abundance and drydown interval. During the last year, the relationship between predicting foraging wading birds and predicting success of nesting wading birds was strengthened by further modeling (Beerens et al. 2015). 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.

   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. Both evidence at colonies and food habits suggest wading bird nesting aggregations may be highly vulnerable to python predation. Measurement of predation is currently being carried out using over 60 trail cameras aimed at nests, and detection of pythons is being developed using eDNA techniques – sampling water for minute concentrations of python-specific DNA. If the latter becomes a feasible method, it may allow protection of high value resources like wading bird colonies from pythons.

2. 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.

3. 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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Southern Coastal Systems Phytoplankton Blooms Indicator (Modified No Southwest Shelf)

Summary/Key Findings

The status of Phytoplankton Blooms [an indicator of water quality (Boyer *et al.*, 2009)] varied throughout the Southern Coastal System in water years 2015 and 2016. Most notable was the continued degradation of water quality in Biscayne Bay. All three sub-regions in Biscayne Bay have long-term significant increases in chlorophyll *a* since 1995. Moreover, all regions received a red indicator score for 2015 and 2016, except north Biscayne Bay, which was yellow in 2016. The other area of significant concern is the southwest Florida (SWFS), which has a significant trend of degrading water quality and a yellow score in both 2015 and 2016. On the positive side, Florida Bay has phytoplankton blooms that are either decreasing or remaining steady suggesting that water quality is not degrading. Moreover, all of Florida Bay received a green score for both years, except the north-central sub-region in 2016, which received a yellow score. Despite the currently good conditions of water quality in Florida Bay, it experienced a large-scale seagrass die-off in the summer of 2015 (see the SAV indicators in this report). The last similar seagrass die-off in Florida Bay that happened in the late 1980s was followed within several years by an unprecedented and ecologically devastating phytoplankton bloom (Butler *et al.*, 1995; Peterson *et al.*, 2006; Phlips and Badylak, 1996). Thus, there is a need for increased investigation into how water quality in Florida Bay will respond to this die-off event.

The Southern coastal systems phytoplankton blooms indicator remains well below the restoration target.

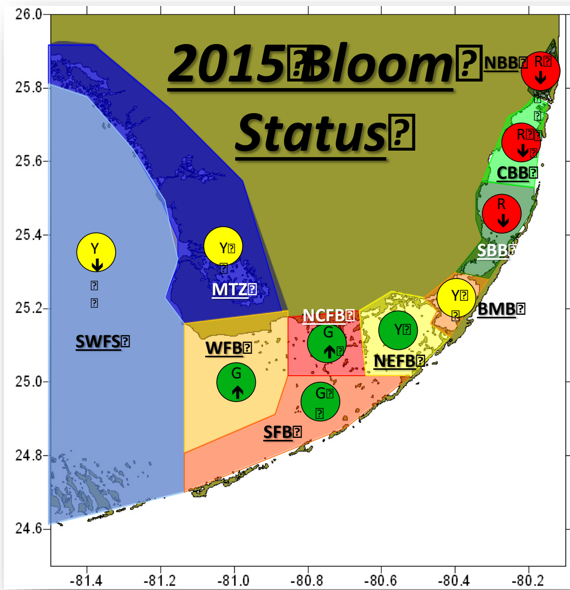
Recommendations:

The top priority remains the same as in 2014, we need to investigate the underlying causes of the increased phytoplankton blooms in Biscayne Bay and use this information to enact appropriate nutrient control measures to stem the degradation. There was an unprecedented phytoplankton blooms in Biscayne Bay in WY2104 through WY2016 causing all sub-regions, but one, to receive a red score. Moreover, there are significant increases in phytoplankton throughout Biscayne Bay over the past 20 years and there has been an unprecedented bloom in benthic macroalgae in Biscayne Bay that is replacing seagrass (Collado-Vides *et al.*, 2013). Without understanding the cause(s) of this water quality degradation, we cannot propose efficient mitigation actions that are necessary to improve water quality and return phytoplankton blooms in this area to their baseline conditions before the Bay ends up being dominated by phytoplankton rather than seagrass.

Given the seagrass die-off in Florida Bay and the fact that an ecologically devastating algal bloom followed the prior seagrass die-off, there is a significant need for increased monitoring of water quality in Florida Bay. Moreover, scientific, process-studies are needed to investigate the fate of decaying organic matter and the associated nutrient releases after a seagrass die-off in Florida Bay.

The other concern is on the southwest Florida shelf where a significant increasing trend in phytoplankton blooms suggests water quality is degrading. This degraded water quality condition is made difficult to understand and monitor, because there continues to be minimal water quality sampling in the offshore regions of the southwest Florida shelf and limited sampling in the nearshore areas. This sub-region is directly upstream from the Florida Keys National Marine Sanctuary and without sufficient monitoring it will be difficult to ascertain the potential cause and mitigation methods if water quality continues to degrade.

SOUTHERN COASTAL SYSTEMS PHYTOPLANKTON BLOOMS INDICATOR (MODIFIED NO SOUTHWEST SHELF)



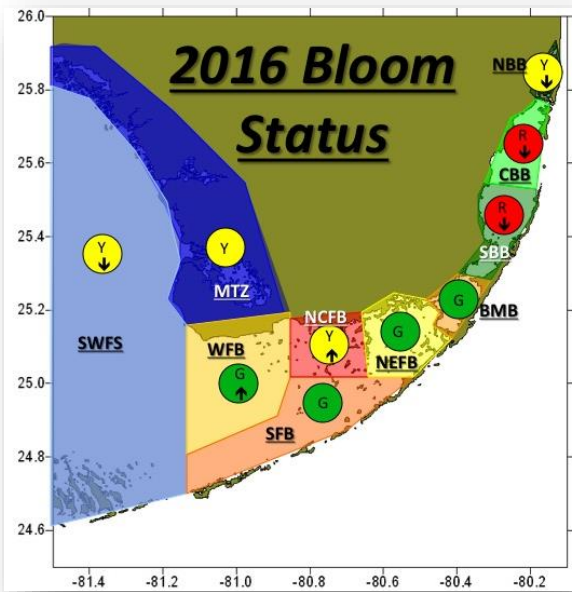


Figure 1. Map showing the spatial distribution of the water quality indicator scores throughout the SCS in WY2015 (top) and WY2016 (bottom). The arrows indicate trends of degrading water quality (downward arrows) and improving water quality (upward pointing arrows).

SOUTHERN COASTAL SYSTEMS PHYTOPLANKTON BLOOMS INDICATOR (MODIFIED NO SOUTHWEST SHELF)

Stoplight Table for Southern Coastal Systems Phytoplankton Blooms (Modified No Southwest Shelf) for Water Years 2012- 2016

CHLOROPHYLL A INDICATOR	WY 2007	WY 2008	WY 2009	WY 2010	WY 2011	WY 2012	WY 2013	WY 2014	WY 2015	WY 2016
System-wide	Y	Y	Y	Y	Y	Y	Y	Y	Y	**R**
Southwest Florida Shelf (SWFS)	G	G	Y	Y	Y	R	B	R	Y↓	Y↓
Mangrove Transition Zone (MTZ)	Y	Y	Y	Y	Y	Y	Y	Y	Y↓	Y↓
West Florida Bay (WFB)	G	G	G	G	G	G	G	G	G↑	G↑
South Florida Bay (SFB)	R	R	G	Y	Y	Y	Y	Y	G	G
North-Central Florida Bay (NCFB)	Y	G	G	G	G	G	Y	G	G↑	**Y**↑
Northeast Florida Bay (NEFB)	Y	G	G	G	Y	Y	Y	Y	G	G
Barnes, Manatee, & Blackwater Sounds (BMB)	R	R	G	G	Y	Y	Y	Y	**Y**	G
South Biscayne Bay (SBB)	R	Y	Y	Y	R	Y	Y	R	R↓	R↓
Central Biscayne Bay (CBB)	Y	Y	Y	Y	Y	Y	Y	R	R↓	R↓
North Biscayne Bay (NBB)	Y	Y	Y	Y	Y	Y	Y	R	R↓	Y↓

SOUTHERN COASTAL SYSTEMS PHYTOPLANKTON BLOOMS INDICATOR (MODIFIED NO SOUTHWEST SHELF)

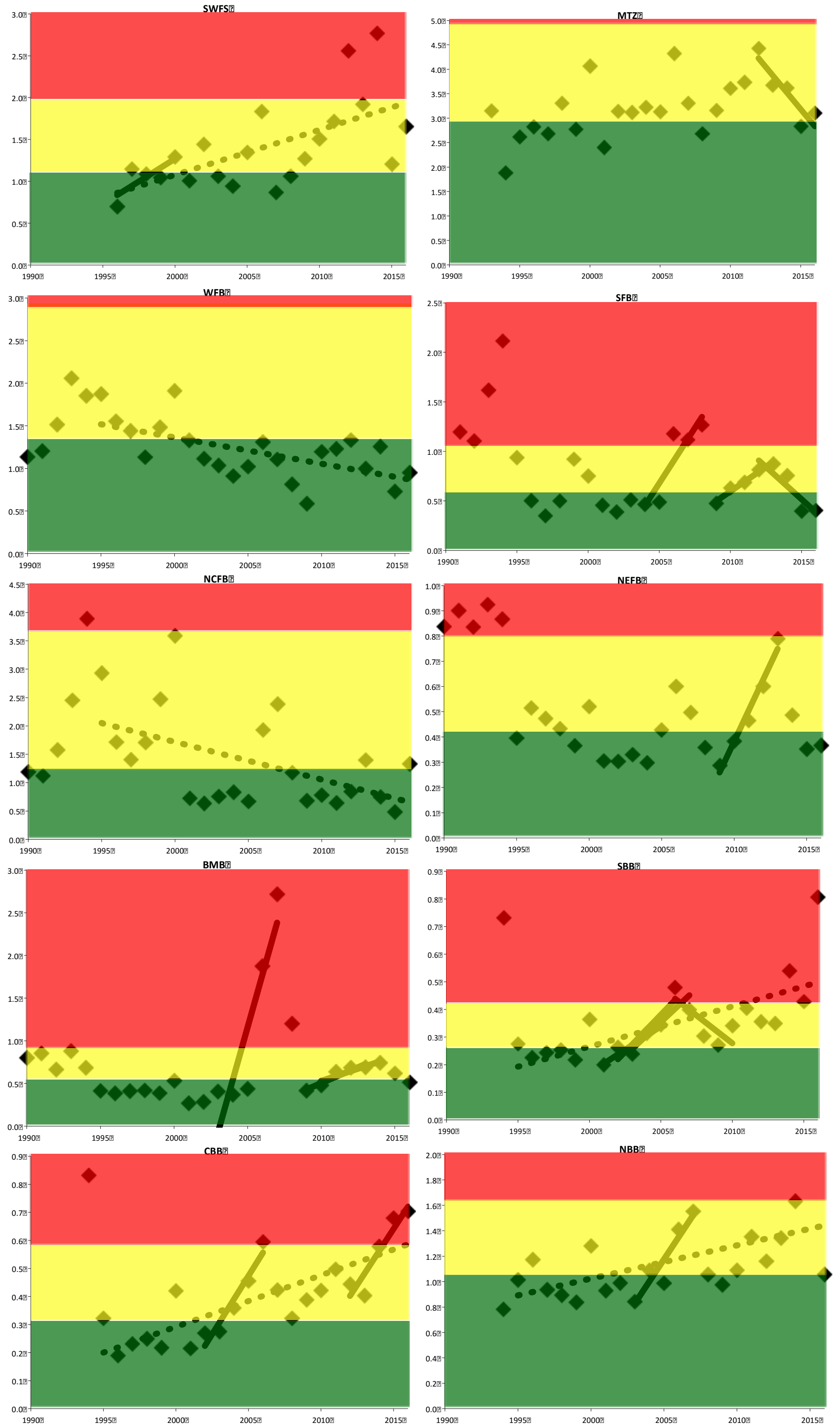


Figure 2. These plots show the annual geometric mean chlorophyll *a* concentrations in 10 sub-regions of the SCS. The green, yellow, and red shading show where each year scores relative to the indicator criteria established for chlorophyll a in the SCS (Boyer et al. 2009). The solid lines depict statistically significant 5-year linear trends in chlorophyll *a* from WY2005 through WY2015. The dashed lines depict statistically significant long-term linear trends in chlorophyll *a*.

Southern Coastal Systems Phytoplankton Blooms Indicator (Modified No Southwest Shelf)

Data and Calculations

Updates on calculation of indicator

This indicator is still calculated based on the calculations in Boyer et al. (2009). However, the trends are now investigated using the period from WY95 through WY16. This period was selected since it is after the change in the AMO prior to WY95 that was found to significantly change chlorophyll *a* in the southern coastal system (Briceño and Boyer, 2010).

How have these data been used?

The data from this indicator was used in assessing the impact of the C-111 spreader canal western project on Florida Bay. It was found that this project did not significant alter chlorophyll *a* in Florida Bay. This is the desired result, because the goal for this indicator is to not increase the magnitude, duration, or spatial extent of blooms. This indicator is also essential in contributing to the system status report (SSR) as it forms the basis for assessing water quality in the southern coastal system. Figures directly from this indicator report have also been used in the SSR. This data is also essential in our endeavor to develop a useful water quality model for the southern coastal system. We need this water quality model to allow us to evaluate the likely effect of proposed Everglades Restoration projects on water quality in the southern coastal system.

New insights relevant to future restoration decisions

The unprecedented algal bloom and increasing phytoplankton blooms over the past 20 years suggest water quality in Biscayne Bay is systematically degrading and appears to be near a tipping point with macroalgae and phytoplankton replacing seagrass. If this tipping point is surpassed it will be far more costly to restore Biscayne Bay than it is to protect and improve water quality now. Thus, future restoration decisions should in the near-term focus on improving water quality in Biscayne Bay and at an absolute minimum stop the degradation of water quality. Any restoration project with the potential to degrade water quality in Biscayne Bay should be carefully evaluated to ensure that water quality degradation is not an unwanted byproduct of the project.

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FLORIDA BAY SUBMERSED AQUATIC VEGETATION INDICATOR

Summary/Key Findings

The status of the overall Florida Bay submersed aquatic vegetation (SAV) indicator was below the restoration target (yellow stoplight) for both WY2015 and WY2016. The Composite Index summarizing overall system status for SAV in Florida Bay indicates that during WY2015-16, the SAV status regressed in several areas and improved in a few. The Abundance Index, which combines both spatial coverage and density, was good in the Northeast Zone, fair in the Transition, Central and Western Zones and poor in the Southern Zone. For 2015 the Abundance Index was reduced by the density component, reflecting sub-optimal density in many areas, including a reduction to fair in the Western Zone, poor density in the Southern Zone and good only in the Northeast Zone. Notably, abundance remained poor in Madeira Bay and Twin Key Basin and fair in Rankin, Rabbit, Long and Joe Bay and surrounding basins. Abundance in the Western Zone improved to good in early WY2016.

The Target Species Index, which combines indicators for presence of ecologically valuable species and for a healthy mixed species composition, showed continued good status in only the Western Zone for both WY2015 and WY2016 and a decline from good to fair in the Northeast, Transition, and Central Zones and continuing status of fair in the Southern Zone. The underlying indicators reflect generally good spatial extent of SAV in almost all basins throughout the bay, including an improvement to good in Joe Bay. There were no large-scale die-off events in WY2015. Indicators for WY2016 were based on data from May 2015 (which represents WY2016) and reflects conditions prior to a large-scale SAV die-off in late summer 2015. That die-off event will be reflected in the WY2017 data collected in May of 2016. Early results from the period indicate that the Central and Western Zones will be particularly decimated by die-off in WY2016-17 with overall declining indicator scores.

Gains in the quality of SAV habitat over the past several years are precarious and can be reversed within an annual timescale. After habitat losses from the seagrass die-off event in 1987 and a severe algal bloom in the eastern bay in 2005-2008, there was a steady rebound of the SAV community reflected in improving scores in the late 2000's and early 2010's. Especially after the relatively wet years of 2012 and 2013, the resulting in lower salinities brought favorable conditions and improving SAV status in many areas of the bay. The dry years that followed in 2014 and 2015 are characterized by a decline in SAV status and indicator scores. The extreme drought of 2015-16 will likely continue this negative trend.

The Florida Bay SAV indicator remains below the restoration target.

Status indicators for Submersed Aquatic Vegetation (SAV) are calculated each year to summarize the status and trends of benthic vegetation in Florida Bay. For WY2016 the overall SAV indicator showed a continued yellow status for the bay as in previous years, falling short of restoration targets in a number of 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 WY2016 as SAV dieoff occurred in substantial portions of the central and western bay during the summer.

The status indicators for SAV include an Abundance Index combining underlying measures of SAV areal extent and density, and a Species Index combining underlying measures of species diversity and the presence/absence of desired target species. These values are calculated at the basin scale and then spatially averaged across representative zones within the bay: Northeast, Transition, Central, Southern and Western. The Abundance and Species indices are combined to generate a Composite score per zone, Index C (Figure 1). The score for the entire bay is taken as the lowest zonal Composite score for the most recent period measured.

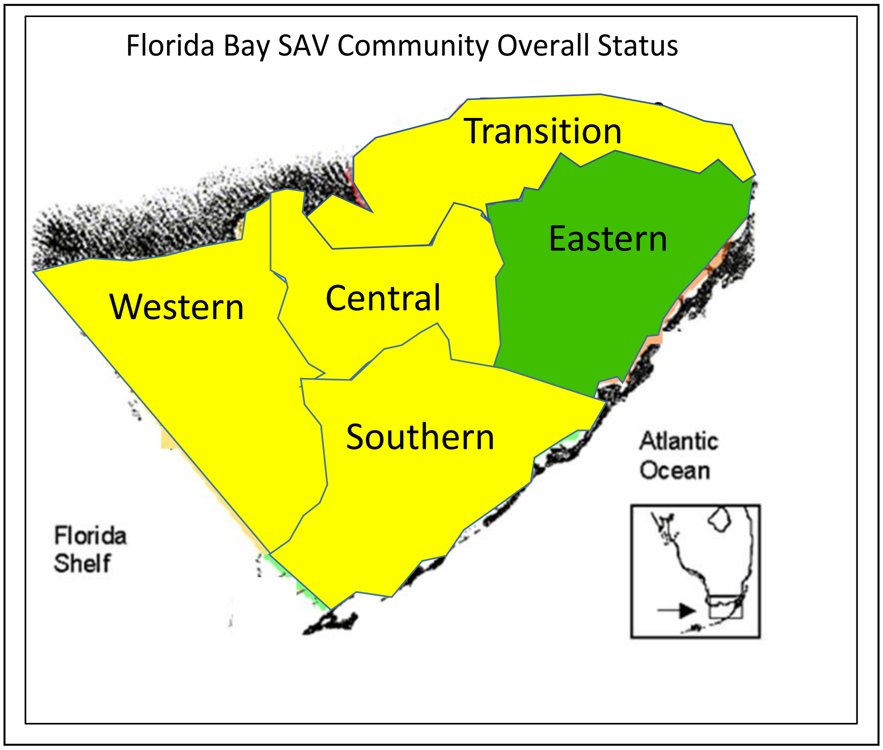

Figure 1. Overall SAV status scores for Florida Bay zone

ABUNDANCE

The Abundance Index (Index A) remained in the good range for the Northeast Zone during WY2015 and WY2016. The underlying spatial extent component of this score was in the good range for all basins in the NE. However, due to deterioration in the density score for several basins, there were notable declines in Index A scores at the basin level: Duck Key declined to fair in ’15 then rebounded in ’16; Barnes Sound declined to fair in ’16. Eagle Key Basin declined to fair in both years. For the Transition Zone the Abundance Index A continued fair in ’15-’16 since declining from good a decade ago. All basins had spatial extent scores of good except Highway Creek, which declined dramatically from good to poor in ’16. The density component remained at fair for most basins and good for Little Madeira Bay.

The Abundance Index in the Central Zone remained in the fair range for ’15-‘16, since improving from poor in ’08. Spatial extent was good in all basins until dieoff affected Rankin Lake in WY2017. Density declined to poor in Rankin, remained poor in Madeira, and was fair in most other basins, reducing the density score and the overall Index A score for the Central Zone to fair. The Southern Zone continued to reflect a poor rating in the Abundance Index A in WY2015 through WY2016. Despite high scores for spatial extent in all southern basins, aggregate scores were reduced by a poor density component score in Twin Key Basin and fair in Crane Key. The Western Zone Abundance Index A remained in the fair range in WY2016 due to dieoff in Johnson reducing the extent and density to fair.

SPECIES

The aggregate Species Index B in the Northeast Zone fell to fair for WY2015-WY2016, with fair (Barnes, Blackwater, little Blackwater) or poor (Duck, Manatee, Eagle Key) scores for most basins in the underlying species dominance score, meaning that desired mixed species communities are not well-established. The target species component barely averaged good overall with fair scores for Blackwater, Manatee, Duck and Eagle Key and good for Little Blackwater and Barnes Sound. The Species Index also declined to fair for WY2015 and WY2016 in the Transition Zone as salinity conditions deteriorated in this region and *Ruppia* declined. The species dominance component was fair or poor in all zones in WY2015 through WY2016. The target species component remained at good although Long Sound dropped to fair, and Davis Cove to poor while Alligator improved to fair. Target species in Joe Bay and Little Madeira remained good for all years. The Species Index B fell to fair for the Central Zone in WY2015 and WY2016 after several years in the good range. The Species Index has remained in the fair range in the Southern Zone since WY2009 following several years in the poor range. In the Western Zone, the Species Index remained good for both years continuing a long-term pattern.

OVERALL

The Composite Index C that gives a summary of overall status for each zone in WY2015-WY2016, shows that SAV status receded in three zones: the Transition Zone, the Central Zone and the Western Zone as vegetation declined and then dieoff took hold in parts of Florida Bay. Therefore, in the most recent evaluation, four of five zones of the bay are in yellow, or fair condition. Taking the lowest extant zonal score to assign a baywide status, Submersed Aquatic Vegetation (SAV) in Florida Bay for WY2015-16 continues to reflect a status of fair.

Stoplight Table for Florida Bay Submersed Aquatic Vegetation for Water Years 2012- 2016

	WY 2012	WY 2013	WY 2014	WY 2015	WY 2016
OVERALL	Y	Y	Y	Y	Y
NORTHEAST ZONE					
Abundance	G	G	G	G	G
Diversity	Y	G	G	G	Y
TRANSITION ZONE					
Abundance	Y	Y	Y	Y	Y
Diversity	Y	Y	G	Y	Y
CENTRAL ZONE					
Abundance	Y	Y	Y	Y	Y
Diversity	G	G	G	Y	Y
SOUTHERN ZONE					
Abundance	R	R	R	R	R
Diversity	Y	Y	Y	Y	Y
WESTERN ZONE					
Abundance	G	Y	Y	Y	Y
Diversity	G	G	G	G	G

Data and Calculations

Updates on calculation of indicator

The ranges determining system status and the basic methodology for calculating the SAV Indicator, Indexes and underlying component scores for SAV have remained unchanged since inception (Madden et al. 2009). However a new protocol for combining the scores over a two year measurement period for each zone has been introduced since the 2013-14 assessment. This change calls for the additional step of rolling up the annual scores from each two year reporting period for each zone by "averaging" the two colors per zone (one for each year), and rounding down when applicable. Therefore, for example, red plus green averages to yellow and red plus yellow rounds down to red. Note however that the Southern zone is currently exempt from this change owing to the small amount of data from that region. Further analysis and study is required before making this change applicable to the Southern zone which remains under the previous system of averaging scores. The rounding down step for the other zones is based on the fact that managers should be conservative in evaluating SAV status over a two year period because interannual variability can create transient positive indications that may not be permanent due to lags in population controls, such as seedbank replenishment and belowground infrastructure condition. Ecological responses to these demographic population factors are integrated over longer periods than a single growing season and this is reflected in the conservative approach to multi-year scoring as deliberately biased downward as a trailing indicator of SAV status.

An additional protocol is introduced here to roll up SAV scores from all five zones to create a single system status stoplight Indicator for the entire bay. The new protocol assigns the minimum score for the five zones as the baywide score. Previously the stoplights were only reported by zone. The rationale for this procedure assumes that the entire bay should be of good status before conferring green as the overall score. Short of having all five zones green, it is important that a lower baywide indicator in any zone flag the bay as requiring continued monitoring, management attention and restoration action as determined by the lowest score awarded.

The rolled-up zone and baywide scores determine Index C the SAV Indicator which is the highest level of the status hierarchy (previously called the "carrying capacity" index). The two Indexes that comprise the SAV Indicator occupy the next hierarchical level, herewith entitled the Abundance Index (unchanged, and also called Index A) and the Diversity Index (previously called the Species Index and Index B). Two underlying components comprise each index: spatial extent (name unchanged) and density (previously called Seagrass Abundance) components comprise the Abundance Index; species dominance (name unchanged) and target species (name unchanged) components comprise the Diversity Index.

How have these data been used?

Data from the indicator analysis were used in a variety of ways in 2015-16: to communicate SAV status internally within the South Florida Water Management District and to its Governing Board; 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 South Florida Environmental Report, the System Status Report, the C-111 Ecological Status Report, the C-111 Spreader Canal Western Features Project Monitoring and Assessment Report, the Minimum Flows and Levels for Florida Bay Review and Update report and other published documents.

The Indicator and components are also used to evaluate progress in and success of restoration activities in the southern Everglades and Florida Bay. The Minimum Flows and Levels (MFL) rule for Florida Bay (SFWMD 2006, 2014) establishes minimum acceptable water delivery from upstream so as to maintain downstream SAV habitat, particularly *Ruppia* (Strasizar et al. 2013a) in the transition zone and also

Thalassia and *Halodule* in the open bay. The SAV Indicator and components are used to monitor and assess the success of MFL rulemaking and assess how violations of the rule affect the SAV resource that may trigger requirement of an MFL recovery strategy (Strasizar et al. 2013b). CERP (Comprehensive Everglades Restoration Plan) and CEPP (Central Everglades Planning Process) evaluations of restoration strategies use the SAV Indicator in evaluating potential management strategies and performance targets. Recently the indicators are being prepared for integration with 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

The gains in the quality of SAV habitat over the past several years are precarious and can be reversed within an annual timescale. The steady rebound of the SAV community from losses due to a severe algal bloom in the eastern bay in 2005-2008 and a seagrass die-off in 1987 were reflected in improving scores in the late 2000's and early 2010's. The relatively wet years of 2012 and 2013 resulted in lower salinities, favorable conditions and further improved SAV status in Florida Bay. The dry years that followed in 2014 and 2015 are characterized here by a decline in SAV status indicators. The drought of 2015-16 continued this negative trend with severe dieoff the result. Water management initiatives such as the C-111 Spreader Canal Western Project and the Florida Bay Restoration Project are designed to reduce the impacts of high salinity by retaining more water in Taylor Slough and supplying more freshwater to central Florida Bay.

Literature cited, reports, and publications for more information

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JUVENILE PINK SHRIMP INDICATOR

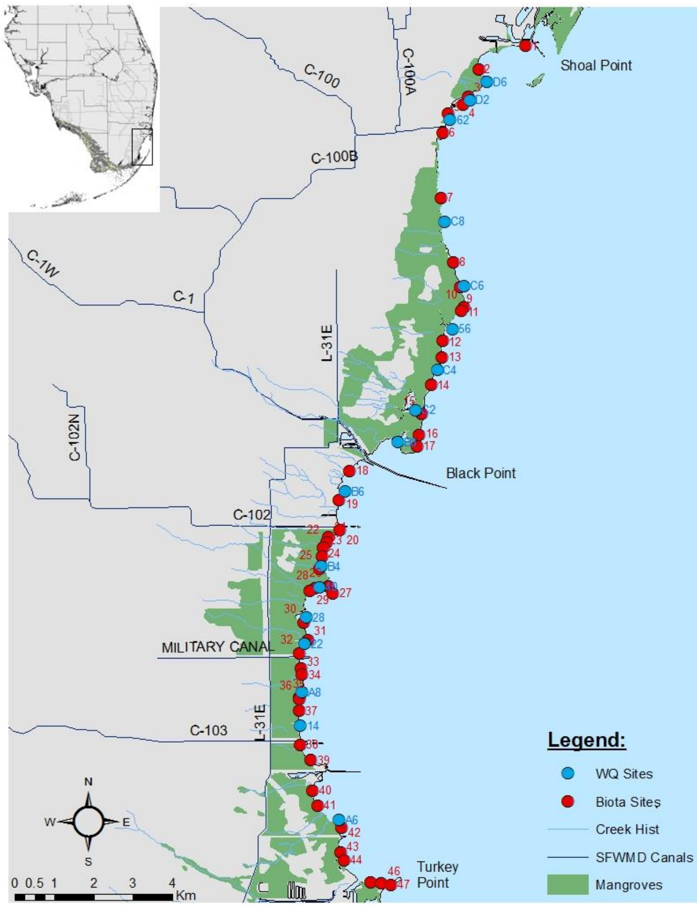
Summary/Key Findings

A full system-wide status assessment for pink shrimp for WY2015 and WY2016 cannot be produced because funding for the South Florida Fish and Invertebrate Network, which was the basis for that assessment, was suspended in WY2012. However, this report provides a view of the status of pink shrimp in WY2015 and WY2016 for southern Biscayne Bay, near a couple of locations covered by FIAN. Data are from the Integrated Biscayne Bay Ecosystem Monitoring and Assessment (IBBEAM) project. IBBEAM is a RECOVER monitoring and assessment project jointly conducted by the NOAA National Marine Fisheries Service, the National Park Service, and the University of Miami Rosenstiel School of Marine and Atmospheric Science.

The pink shrimp, *Farfantepenaeus duorarum*, is a highly valued commercial species in south Florida, a favorite recreational species, and a species frequently used for bait in recreational fishing. The bays and estuaries of the Southern Coastal System are pink shrimp nursery grounds.

This report is based on pink shrimp data collected in the Epifaunal component of the Integrated Biscayne Bay Evaluation and Assessment Monitoring Project (IBBEAM), which samples a narrow belt of shallow seagrass area north and south of Black Point (between Shoal Point and Turkey Point).

Sampling for pink shrimp and other epifaunal species has been conducted at 47 sites in this area since 2007. Two collections are made annually, dry season (January-March) and wet season (July-September). Like FIAN, IBBEAM uses a 1-m2 throw trap to sample pink shrimp and other epifauna. The trap is thrown 3 times at each location, where bottom vegetation and abiotic variables are also measured. Shrimp density is determined on a 3-m^2 basis. Salinity and temperature are measured at 15-min intervals at 17 nearby sites in close proximity to shore.



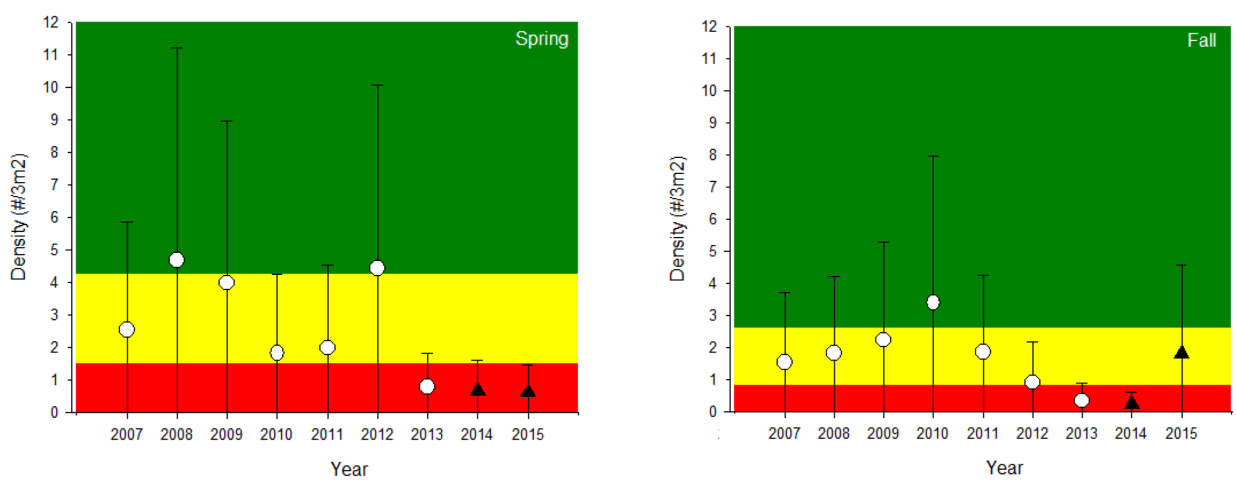


FIGURE 1. Stop-light pink shrimp status plots produced from IBBEAM data.

Figure 1 uses the same analytical framework used in the 2012 Ecological Indicator report to determine the status of pink shrimp in nearshore Biscayne Bay. The base years are 2007-2013, and the years being evaluated are 2014 and 2015. Most of the annual seasonal means are within the “neutral” (yellow) band, however, the means of the last three year-seasons, except for fall 2015, are in the “poor” (red) band.

Data and Calculations

Updates on calculation of indicator

Spring (dry) and fall (wet) shrimp density for the years 2007 through 2013 are used to calculate the 25th and 75th percentiles that demarcate the red (poor), yellow (neutral), and green (good) parts of the background. Pink shrimp status in 2014 and 2015 is plotted for assessment against this background. Open circles indicate mean values for the season of that year for all years included in the calculations. Solid black triangles are year-season means for the years assessed. Vertical lines indicate 95% confidence intervals.

How have these data been used?

FIAN data collected at the Port of Miami and a North Biscayne Bay site from 2005 to 2011 are presently being used to assess the effect of Port of Miami dredging and an associated seagrass mitigation site on nearby seagrass beds in the State of Florida Biscayne Bay Aquatic Preserve. Existing FiAN data, 2005-2011, provide the only view of initial conditions. IBBEAM data are being used to characterize the abiotic and biological status of the nearshore southern Biscayne Bay area prior to, and during, introduction of new water management structures and operations such as the Deering Estate Flowway and the L-31E Culverts. Pre and post implementation status will be compared by IBBEAM researchers. FIAN data are priceless because they were collected with the same sampling design and gear concurrently at 19 locations across the Southern Coastal System over seven years, though, of course, they would have been even more valuable had they continued. The ability to add to the FIAN time series relatively seamlessly as IBBEAM and Port of Miami sampling have done multiplies the potential information to be gained.

New insights relevant to future restoration decisions

Figure 2, which shows dry and wet season densities as a single time series, best illustrates the seasonality in the IBBEAM pink shrimp data and incidences of deviation from that pattern. As a general rule, pink shrimp density was higher in the dry season and lower in the wet season. But the pattern was broken in the 2010 dry season and has not been reestablished. In fact, pink shrimp density has been uncharacteristically low in dry seasons since 2012.

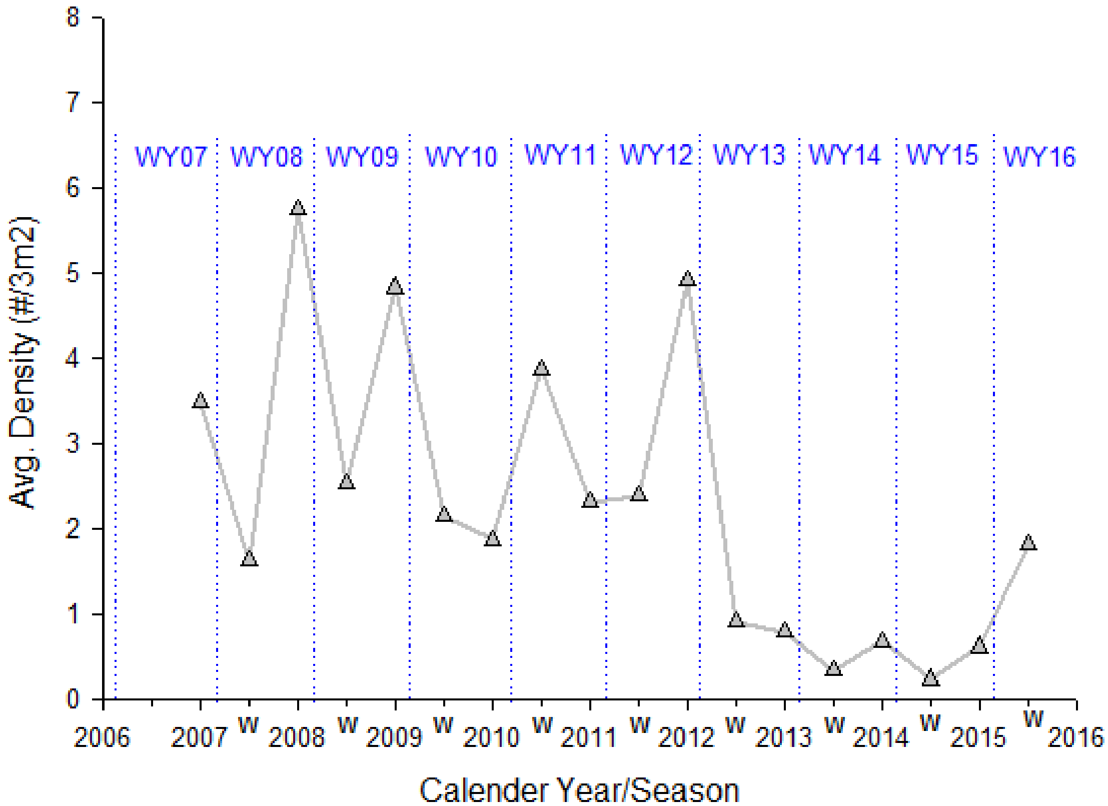


FIGURE 2. Pink shrimp density, by year-season, Dry 2007 through Wet 2015, from IBBEAM. Each data point represents spatially averaged density, dry (year tick) or wet (W tick), of a given year. Data-point pairs corresponding to Water Years are enclosed within vertical dotted lines, and Water Year is indicated between those dotted lines at the top of the graph. Note: Density values must be divided by 3 (because they were collected from 3 throw-trap throws= 3 square meters) to be compared to FIAN density values.

Examining density data in relation to bottom vegetation and environmental data, both salinity and temperature, allowed IBBEAM researchers to develop some insight into the low shrimp density of recent years and also led to creation of habitat suitability models to predict densities of pink shrimp and other species densities under combinations of weather and water management scenarios. The pink shrimp model, graphically represented in Figure 3, shows a relationship of pink shrimp density to salinity and the seagrass, *Halodule*. The pink shrimp model suggests an optimal density at a salinity of about 26 and a *Halodule* cover of about 50%. Salinity has been greater than 26 in the IBBEAM sampling area every dry season since 2012.

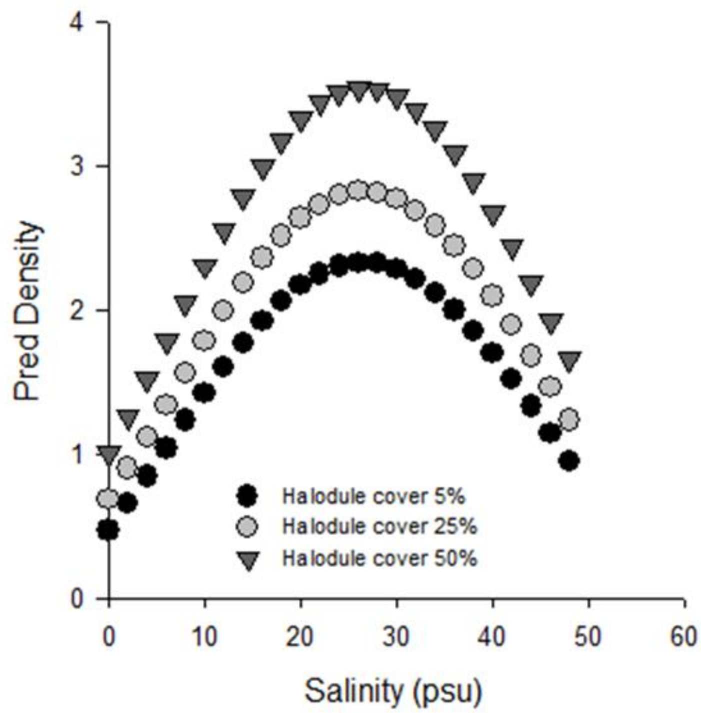


FIGURE 3. Habitat Suitability Model for pink shrimp, developed from data collected by IBBEAM and previous projects in the alongshore area of Biscayne Bay, 2005-2015. Sampling was extended from 47 to 72 sites (south to Manatee Bay) from 2007 to 2012 (dry only), then, due to funding reductions, reduced back to 47 sites from 2012 Wet forward. (Units of density are number of shrimp per 3 square meters.)

One of the advantages of pink shrimp as a system-wide indicator for the Southern Coastal systems is that it is present in sufficient quantity to be found consistently in all coastal systems of south Florida. The Fish and Invertebrate Assessment Network (FIAN), which sampled 19 locations within all three southern coastal systems, provided a full system-wide view of pink shrimp status through WY2011, but a full system-wide status report for WY2015 and WY2016 cannot be produced because FIAN funding was suspended after 2011.

IBBEAM has four components: epifauna (including pink shrimp), mangrove fish, submerged aquatic vegetation, and salinity. IBBEAM also has produced Habitat Suitability models for several other taxa.

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WADING BIRDS (ROSEATE SPOONBILL) INDICATOR

Summary/ Key Findings

Overall, the stoplight color for the wading bird (Roseate Spoonbills) indicator was well below the restoration target (red stoplight) at the end of WY2014 and remains well below the restoration target at the end of WY2016, though conditions throughout Florida Bay appear to be improving for spoonbills especially in Northeastern Florida Bay (NEFB).

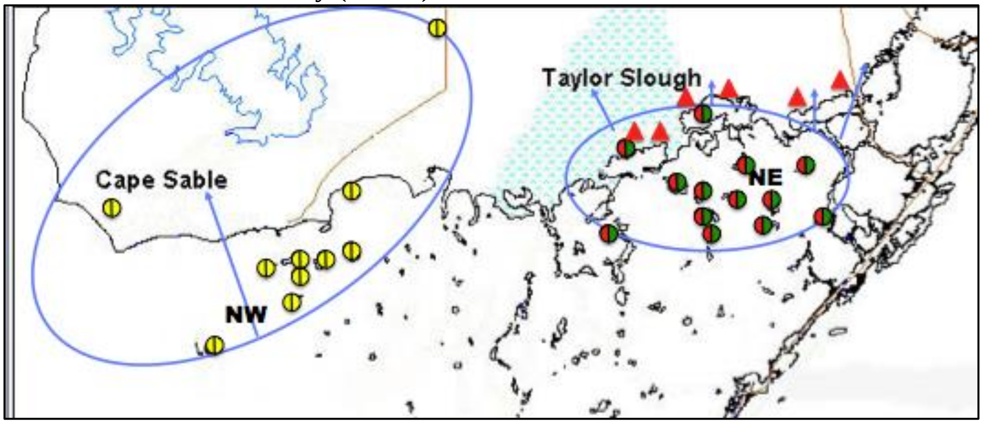

Figure 1. Map of northern Florida Bay showing approximate spoonbill nesting locations (circles) in both the northeastern and northwestern regions of Florida Bay as well as prey base sampling locations (triangles) on their foraging grounds. Right half of each circle represents the score for the nest number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

The total number of nests in Florida Bay in 2016 was 367 with a 5-year average of 344 nests. Although a great improvement over 191 nests recorded in 2014 (5-year average of 268) the number of nests is still well short of the target of 1258 nests and scores red on the stoplight (Figure 2). The overall nesting location metric was scored as red but also showed improvement since 2014 (Figure 2). Nest numbers in Northwestern Florida Bay (NWFB; Figures 1 and 2) remained below the restoration target (yellow stoplight, 5-year mean of 140 nests with a target of 210) with a slight improvement over 2014 (5-year mean of 132). Northeastern Florida Bay (NEFB; Figures 1 and 2) showed significant improvement with 197 (5-year mean 160) nests compared to 76 in 2014 (5 year mean 98) but also well short of the 688 nests target making the scoring a red stoplight and the overall location scored a red stoplight as well.

Roseate Spoonbill nesting success in Florida Bay continues the improving trend seen in recent years. We don’t think this improvement is due to restoration efforts to date, but rather to natural drought conditions that are favorable to spoonbills in the short-term because drier conditions help to concentrate their food. However, consecutive drought years such as have been experienced in 2015 and 2016 can otherwise have cataclysmic impacts on Florida Bay. (see *New Insights* section below for further details).

The prey metric for spoonbills was also well below the restoration target (red stoplight). This metric measures the percentage of freshwater fish species at spoonbill foraging locations (Figures 1 and 2). When the spoonbill prey base is dominated by freshwater species, there tend to be higher abundance of fish and they are more available to foraging spoonbills. With the drought conditions and high salinity levels, there were virtually no freshwater species collected this year resulting in a red stoplight score for this metric.

Three of the four metrics for spoonbills were well below the restoration target (red stoplight) with the forth being below the restoration target (yellow stoplight), so overall the spoonbill indicator is represented as a red stoplight.

The spoonbill indicator remains well below the restoration target.

Stoplight Table for Wading Birds (Roseate Spoonbill) for Water Year 2012-2016

ZONE/PERFORMANCE MEANSURE	WY 2012	WY 2013	WY 2014	WY 2015	WY 2016
Total Number of Nests					
Number of nests in Florida Bay (5-year mean)	**R**	**R**	**R**	**R**	**R**
Location of Nests					
Number of nests in NE Florida Bay (5-year mean)	R	R	R	R	R
Number of nests in NW Florida Bay (5-year mean)	Y	R	R	R	Y
Number of nests in SW Coastal Estuaries	B	B	B	B	B
Nesting Location Overall	**R**	**R**	**R**	**R**	**R**
Nesting Production and Success					
Chick Production in NE Florida Bay	G	G	Y	Y	Y
Chick Production in NW Florida Bay	Y	Y	R	Y	Y
Percent successful years in NE Florida Bay	Y	G	G	G	G
Percent successful years in NW Florida Bay	Y	Y	Y	Y	Y
Overall Nest Production and Success	**Y**	**Y**	**R**	**Y**	**Y**
Prey Fish Community NE Florida Bay					
Prey Community Structure NE Florida Bay	**R**	**R**	**Y**	**R**	**C**[1]
Overall Score					
Average of Nest #, Nest Location, Nest Productivity and Prey Structure[2]	**R**	**R**	**R**	**R**	**R**

Figure 2. Stoplight scores for each sub-metric, the cumulative score for each metric and the overall score for the indicator for the last five years.

[1]*Calculations for this metric are not available but preliminary examination of the data indicates a red score*

[2]*Scores for each of the 4 parameters were calculated by assigning a value of 1 for green, 0.5 for yellow and 0 for red; overall score 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*

Data and Calculations

Updates on calculation of indicator
The only change in the calculations used are that one of the prey sampling sites (7P) is no longer being monitored due to financial cutbacks in the monitoring program. The six remaining site 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. However, the importance of the 7P site should not be underestimated based on this metric alone. 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 other changes were made for the calculation of the WY2015 and WY2016 scores.

How have these data been 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 2015 (http://www.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/sfwbr_2015_final.pdf) and 2016 (not yet available) reports as well as the South Florida Environmental Reports for 2015 (http://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2015_sfer_final/v1/sfer_toc_v1.pdf) and 2016 (http://www.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2016_sfer_final/v1/chapters/v1_ch6.pdf). Information was also used in three peer-reviewed publications (Wingard and Lorenz 2014; Ogden et al. 2014a and 2014b). 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.

New insights relevant to future restoration decisions
Drought and Minimum Flows and Levels Violation
From the beginning of the wet season in Jun 2014 to the end of the wet season in Nov 2015, southern Florida was under the influence of a drought. This resulted in a Minimum Flows and Levels (MFL) violation indicating that "significant harm" was occurring in Florida Bay that would result in "temporary loss of function caused from change in...hydrology that takes more than 2 years to recover For Florida Bay the MFL rule defined an "exceedance" as salinity measured above 30 psu in central Taylor Slough (at the TR hydrostation) and a "violation" as when an exceedance occurs during each of two consecutive years, more often than once in a ten-year period. A violation occurred during the dry season of 2015. Ultimately, this resulted in hypersaline conditions and a massive seagrass die off in Florida Bay: very similar events that occurred during the 1987-1990 drought

Frederick and Ogden (2001) indicated that under current management practices wading birds nesting in the Everglades benefit from droughts and the first year following a drought. As suggested by Frederick and Ogden (2001) and experimentally demonstrated by Dorn and Cook (2015); droughts in the Everglades result in declines in abundance of larger predatory fishes. When the drought ends, the prey base species recolonize the previously dried wetlands that are relatively free of piscine predators, thereby making more prey available to nesting birds initially after the drought breaks. Beginning in Nov 2015, higher than normal rainfall during the 2016 dry season occurred thus breaking the drought just before the spoonbills began to nest. We believe the persistent drought followed by above average rainfall helps explains why spoonbills performed very well during the 2016 nesting season. Although this may appear to be favorable to spoonbills in the short term, consequences of severe droughts may actually be quite harmful in the long term. Spoonbills and other wading birds had record success rates during the 1987-1990 drought itself (Lorenz et al. 2002) resulting in population increases during and immediately following this drought (Figure 3). However, the damaging effects of that drought and seagrass die-off had long lasting negative ecological impacts on the Bay that lasted for several decades (Lorenz 2014a). These conditions ultimately led to a collapse of the spoonbill population following the 1987-1990 drought (Figure 3; also see Lorenz et al. 2002 for intervening years of 1992-93 to 1998-99) and the species represented by this umbrella indicator (Lorenz 2014a; e.g. other wading birds, game fish, marine mammals, crocodilians etc.). So in the short term it appears that spoonbills are performing well but we anticipate declines post-drought as it did following the 1987-1990 drought.

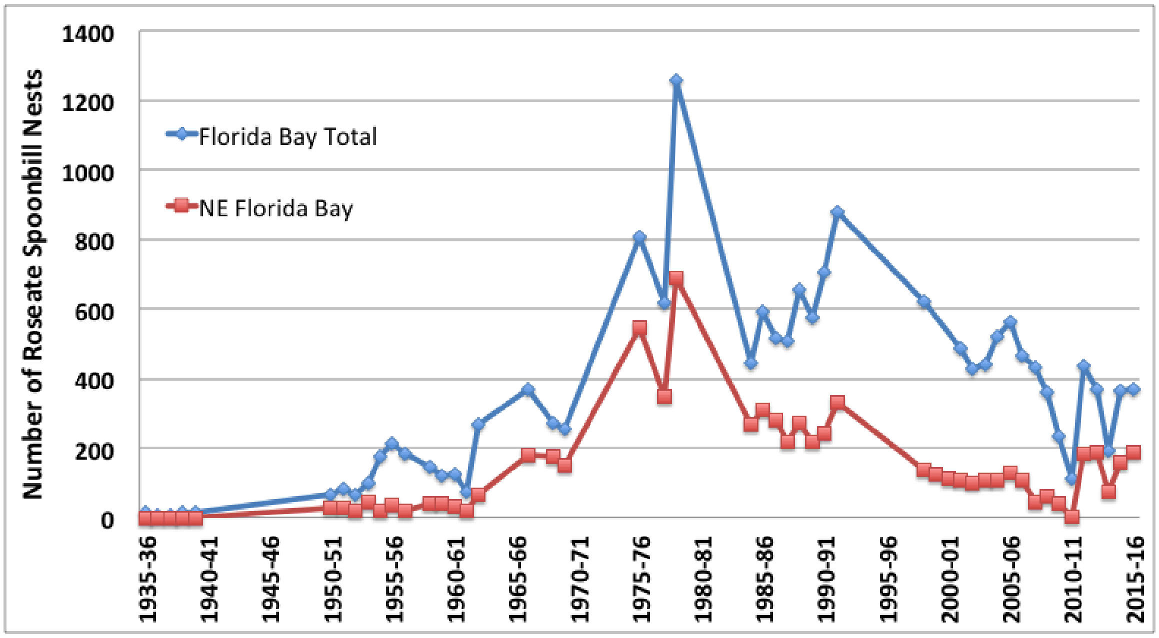

Figure 3. Total spoonbill nest numbers in Florida Bay and for the northeastern region from 1935 to present.

C-111 Spreader Canal Western Phase

The 2014-15 hydrologic-year (June to May) was the third complete year of physical and ecological data collection and analyses since the C-111SCWP project began operation in June 2012. The methods, results and discussion used to reach the following conclusions are from Robinson et al. (2016). Non-metric Multi-dimensional Scaling (NMDS) was used to justify comparison years for the three years post-project based on regional rainfall patterns. The NMDS resulted in 2012-13 being compared to 2008-09, both of which were moderately high rainfall years; 2013-14 being compared to 2003-04, both of which were low rainfall years; and 2014-15 being compared with 2010-11, both drought years. Our analyses of physical and ecological data indicate that 1) in 2012-13 with slightly above average rainfall, the project operations resulted in physical and ecological conditions that exceeded our expectations 2) in 2013-14 with below average rainfall, operation resulted in conditions that met expectations and 3) in 2014-15, during a drought, operations failed to meet any of the expectations.

Given the results of the past three years, it is reasonable to assume that when water is available via local rain, the C-111SCWP appears to be able to reflect more naturally the timing and distribution that occurred prior to modern water management practices. For the first two years post project, we provided considerable evidence that the primary goal of reducing seepage was met thereby increasing flows through Taylor Slough. Because of the drought during the third year we were unable to determine whether seepage was reduced or not. As for the secondary goal of augmenting Taylor Slough flows with a regional water source by pumping at the S-199 and S-200 structures, it appears that this was not the case.

Our conclusions are that the C-111SCWP can provide ecological benefits to the existing system under low to moderate rainfall years. We believe, based on these results, that the project would also provide benefits under above average rainfall conditions. However, under drought conditions, the project as currently operated provides little or no benefits to the ecosystem. Simply put, for the C-111SCWP to accomplish the primary goal of keeping water in Taylor Slough from seeping into the C-111 canal, there must actually be water in Taylor Slough. The secondary goal of augmenting the local water supply with a regional component is also not being accomplished under current operations. The operational plan for the C-111SCWP 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 Ac-Ft of water pumped at the two structures annually would not completely seep back into the canal (as it currently does) 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 Comprehensive Everglades Restoration Plan that provide such an overland connection between Taylor Slough and the regional water supply (e.g. Modified Water Deliveries and the Central Everglades Planning Project) must be implemented to avoid the disastrous ecological consequences that droughts currently present to Florida Bay. The C-111SCWP cannot fully perform to its potential until that hydrologic connection is made.

<u>Delays in Nesting Timing and Sea Level Rise</u>

Alvear-Rodriguez (2001) estimated Roseate 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 Nov 1 and Dec 31 in all years except 2 (one in Oct and one in Jan). 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 Jan 1 to Jan 10. Last year the date was Jan 24 and this year it was Feb 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 suggests 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 2014). The delay in nesting and the fact that the majority of nesting occurred in two mainland colonies (Madeira Hammock and Paurotis Pond) suggest that conditions have deteriorated for nesting spoonbills within Florida Bay.

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 4) and has resulted in higher water levels on the foraging grounds (Lorenz et al. 2011) likely causing reduced prey availability (Lorenz et al. 2011) resulting in delayed nesting in Florida Bay's spoonbill population. This also likely explains the low nesting effort, asynchronous nest initiation, and changes in nesting location of Roseate Spoonbills in since 2010. This may ultimately change the way Spoonbills will be used as an indicator for Everglades restoration going forward.

<u>Cape Sable Canal Restoration</u>

As detailed in the 2014 System Wide 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. Currently, Everglades National Park has identified a preferred alternative to plugging the canals in an Environmental Assessment (https://parkplanning.nps.gov/document.cfm?documentID=72374) that may ameliorate some of the impacts of the canals on those foraging grounds, however, one of the major tidal exchanges between the Gulf of Mexico and the interior foraging grounds (East Side Creek) remains unaddressed in the EA preferred plan.

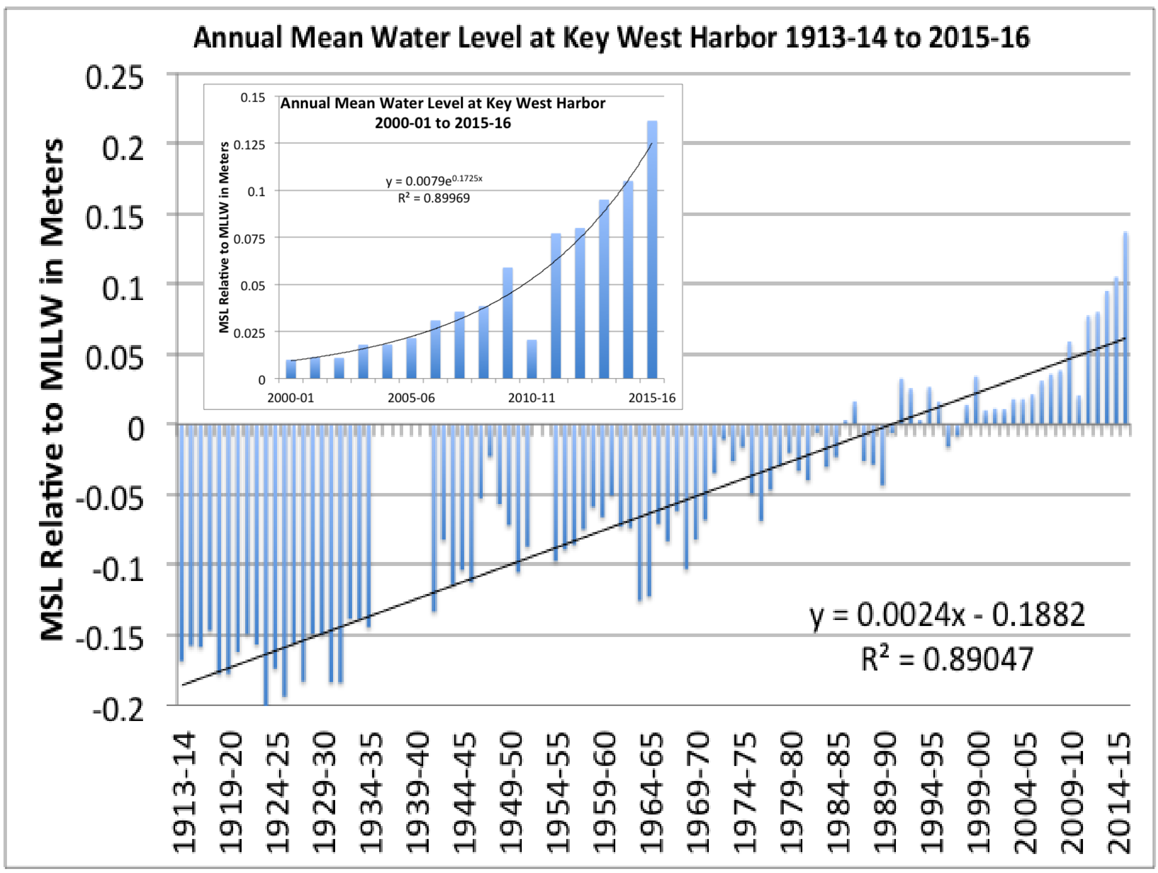

Figure 4. Mean sea level in relation to Mean Low Low Water for Key West Harbor 1913 to present. Inset is the same data from 2000 to present indicating an exponential increase in sea level rise as predicted by many climatologists.

Synthesis

Summarizing the results of the 2016 breeding season was difficult given the varied perturbations and confounding results of restorations efforts. It appears that the over-riding influence resulting in the unusually high nesting success was the end of the 2 year drought of 2015-16. The late nesting, asynchrony and mass movement of nesting to inland locations appear a response to sea level rise throughout the Bay, while the ineffectual nature of the C-111SCWP Project under drought conditions and the delay in Cape Sable Canal Restoration activities seem to be negatively influencing the northeastern and northwestern colonies respectively. What is apparent is the value of multi-year continuous studies such as this one. If only a single year was assessed, the data for 2016 alone would suggest that spoonbills were recovering at some level. By using multi-year parameters (such as the five year average used for nesting success metrics), false positive or negative results can be avoided such as would have happened if only a single year were used as the metrics. The power of multiyear continuous data collection allows for placing data in context that makes a more comprehensive evaluation possible. If taken in a vacuum, it would appear that the best thing for Florida Bay, based on this indicator, would be droughts. This is not the case given the multiyear data collection following the 1987-1990 drought that allow the 2015 and 2016 data to be placed in a broader context and allow for the buffering of single positive (2015-16) and negative (2010-11) years through the use of multiyear metrics that smooth out these patchily distributed responses. The one clear result is that through long term, continuous data collection we are able to correctly recognize that as an ecological indicator for Florida Bay, spoonbills nesting patterns suggest that Florida Bay still needs the planned restoration activities that will bring closer to historic freshwater flows from the Everglades to Florida Bay.

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LEAD SCIENTISTS FOR INDICATOR REPORT

First Name	Last Name	Agency	Indicator
Joan	Browder	National Oceanic Atmospheric Administration	Pink Shrimp
Peter	Federick	University of Florida	White Ibis and Wood Stork
Evelyn	Gaiser	Florida International University (FIU)	Periphyton
Chris	Kelble	National Oceanic Atmospheric Administration	Florida Bay Algal Blooms
Jerry	Lorenz	Audubon of Florida	Roseate Spoonbill
Chris	Madden	S FL Water Management District	Florida Bay SAV
Frank	Mazzotti	University of Florida	Crocodilians
LeRoy	Rodgers	S FL Water Management District	Invasive Exotic Species
Andy	Rodusky	South Florida Water Management District	Lake Okeechobee Nearshore
Joel	Trexler	Florida International University	Fish and Macroinvertebrates
Aswani	Volety	University of North Carolina Wilmington	Oysters

LEAD SCIENTISTS FOR INDICATOR REPORT

Others involved in indicator sections for this report or Biennial Report to Congress

Marsha	Bansee Lee	Office of Everglades Restoration Initiatives	Document Compilation
Laura	Brandt	U.S. Fish and Wildlife Service	Crocodilians, Document Coordination
Micheal	Cherkiss	U.S. Geological Survey	Crocodilians
Dale	Gawlik	Florida Atlantic University	White Ibis and Wood Stork
Steve	Geiger	Florida Fish and Wildlife Conservation Commission	Oysters
Jeff	Kline	National Park Service	Fish & Macroinvertebrates
Melaine	Parker	Florida Fish and Wildlife Conservation Commission	Oysters
Dave	Rudnick	National Park Service	Southern Coastal Systems Phytoplankton Bloons
Bruce	Sharfstein	South Florida Water Management District	Lake Okeechobee Nearshore
Bob	Sobczak	National Park Service	Hydrology
Jessica	Spencer	US Army Corps of Engineers	Invasive Exotic Species

For further information on this document please contact:

South Florida Ecosystem Restoration Task Force
U.S. Department of the Interior - Office of Everglades Restoration Initiatives (OERI)
c/o NOVA University
3321 College Avenue
Davie, FL 33314
Telephone: 954-377-5971

For more information on the South Florida Ecosystem Restoration Program
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