SYSTEM-WIDE ECOLOGICAL INDICATORS FOR EVERGLADES RESTORATION 2014

www. EvergladesRestoration.gov

Suggested citation: Brandt, L.A., J. Beauchamp, J.A. Browder, M. Cherkiss, A. Clarke, R.F. Doren, P. Frederick, E. Gaiser, D. Gawlik, L. Glenn, E. Hardy, A. L. Haynes, A.Huebner, K. Hart, C. Kelble, S. Kelly, J. Kline, K. Kotun, G. Liehr, J. Lorenz, C. Madden, F. J. Mazzotti, L. Rodgers, A. Rodusky, D. Rudnick, B. Sharfstein, R. Sobszak, J. Trexler, A. Volety, 2014. System-wide Indicators for Everglades Restoration. 2014 Report. Unpublished Technical Report. 111 pp.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.

- Reductions in funding for monitoring have resulted in changes in how we characterize system-wide responses. Five of the eleven indicators have had modifications made to sampling and how the indicators are calculated and as a result, what they represent. This reduction in information means that either geographic areas are no longer covered (Water Conservation Areas 2 and 3 for Crocodilians and the southwest shelf for Southern Coastal Systems Phytoplankton Blooms, for example) or that a component of the originally constructed indicator is no longer included (Periphyton composition, for example). These modifications erode our ability to detect and report on system-wide responses.

- Positive system-wide responses are not yet evident for any of the indicators; however, smaller scale, project level responses that give us a glimpse into what full restoration can bring are being seen. We present four case studies that illustrate this.

- Evidence continues to show that when water management and nature work together to provide more "natural" abundance and distribution of water, Everglades species respond positively. Lake Okeechobee is a recent example of this where climatic and operational conditions have resulted in water levels being within the ecologically desirable range resulting in positive responses to submerged aquatic vegetation.

- Where no improvements in water management operations have been implemented, species targets continued to remain low or decline. In areas of shorter hydroperiod and more frequent dry-downs both native fish biomass and alligator relative abundance show declines. In some areas abundance and diversity of non-native fishes are increasing. This may be a contributing factor to native fish biomass declines, highlighting the importance of understanding how non-native species interact with native species. Timing of water deliveries is important. Poor foraging conditions for wading birds occur when there are reversals (natural or due to water management) in water level during the dry (nesting) season. Conversely, communication resulting in fewer unnecessary disruptions in flow patterns to the foraging grounds

Executive Summary

has contributed to improved nesting success for Roseate spoonbills in Northeastern Florida Bay. In addition, timing of water flows affects phosphorus loads which is reflected in periphyton quality.

- Although concentrations have been reduced substantially, phosphorus continues to be a regional water quality concern. Yet despite this progress, elevated concentrations complicate water management operations and legal constraints and as such, constrain our ability to supply more water to the natural system. However, as indicated by periphyton nutrient content and biomass, water quality has improved since WY2012. The most impacted areas remain near water management structures or in the oligohaline ecotone that receives marine sources of phosphorus. 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.

- We are seeing effects of sea level rise in coastal areas with higher water levels in the coastal wetlands important for spoonbill foraging and in periphyton quality in oligohaline ecotone sites that are showing signs of phosphorus enrichment, likely from natural marine sources. These patterns reiterate the importance of returning more natural flow patterns to the estuaries as soon as possible so that the ecosystem can adapt.

- Invasive plant species present a serious threat to the restoration of the Everglades, and their capacity to impact the natural environment may operate independently from environmental change resulting from restoration efforts. Without control and management of invasive plant and animal species, restoration goals may not be achieved.

All of these major problems are reflected in the preponderance of red and yellow stoplights in the individual stoplight reports. These stoplights represent broadscale responses. The good news is that we are beginning to see smaller scale positive responses as a result of individual projects (see Case Studies). As more restoration projects are completed and become operational, we expect to see system-wide trends moving towards more yellow and green stoplights.

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.

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).

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)

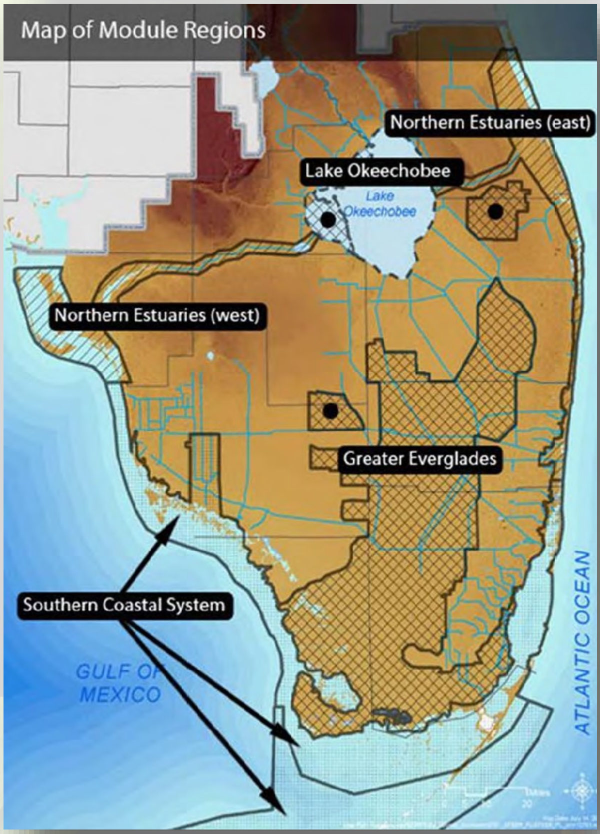


Figure 1. Map of south Florida illustrating the boundary of the SFWMD and the regional assessment modules. Figure courtesy of RECOVER's 2009 System Status Report.

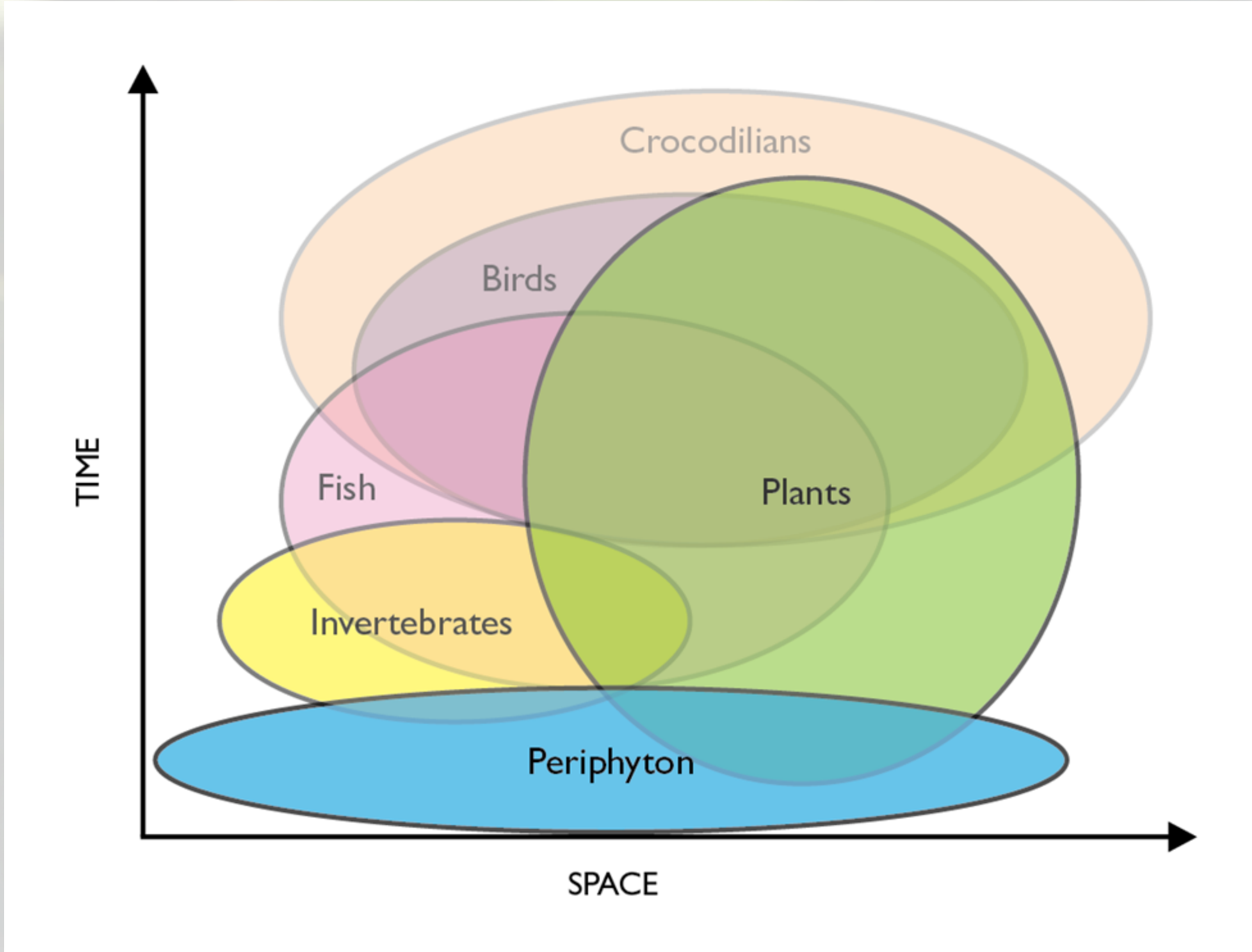


Figure 2. The suite of system-wide ecological indicators was chosen based upon their collective ability to comprehensively reflect ecosystem response in terms of space and time. For example, periphyton responds to change very rapidly at both small and large spatial scales while crocodilians respond more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

Introduction

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

Details of how stoplight colors are assigned for each indicator are available in a special issue of Ecological Indicators (2009, V9 Supplement 6). In this 2014 report, additional information on indicator calculations is provided to reflect information learned and changes in sampling.

This year we augmented the stoplight reports with four case studies that show how individual restoration projects are resulting in ecologically beneficial results. Although these responses are smaller scale than system-wide, they give us a glimpse into what we expect with full implementation of restoration.

Hydrologic Context for the System-wide Ecological Indicators Water Years 2013– 2014

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 2013 (May 1, 2012 to April 30, 2013) and 2014 (May 1, 2013 to April 30, 2014).

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).

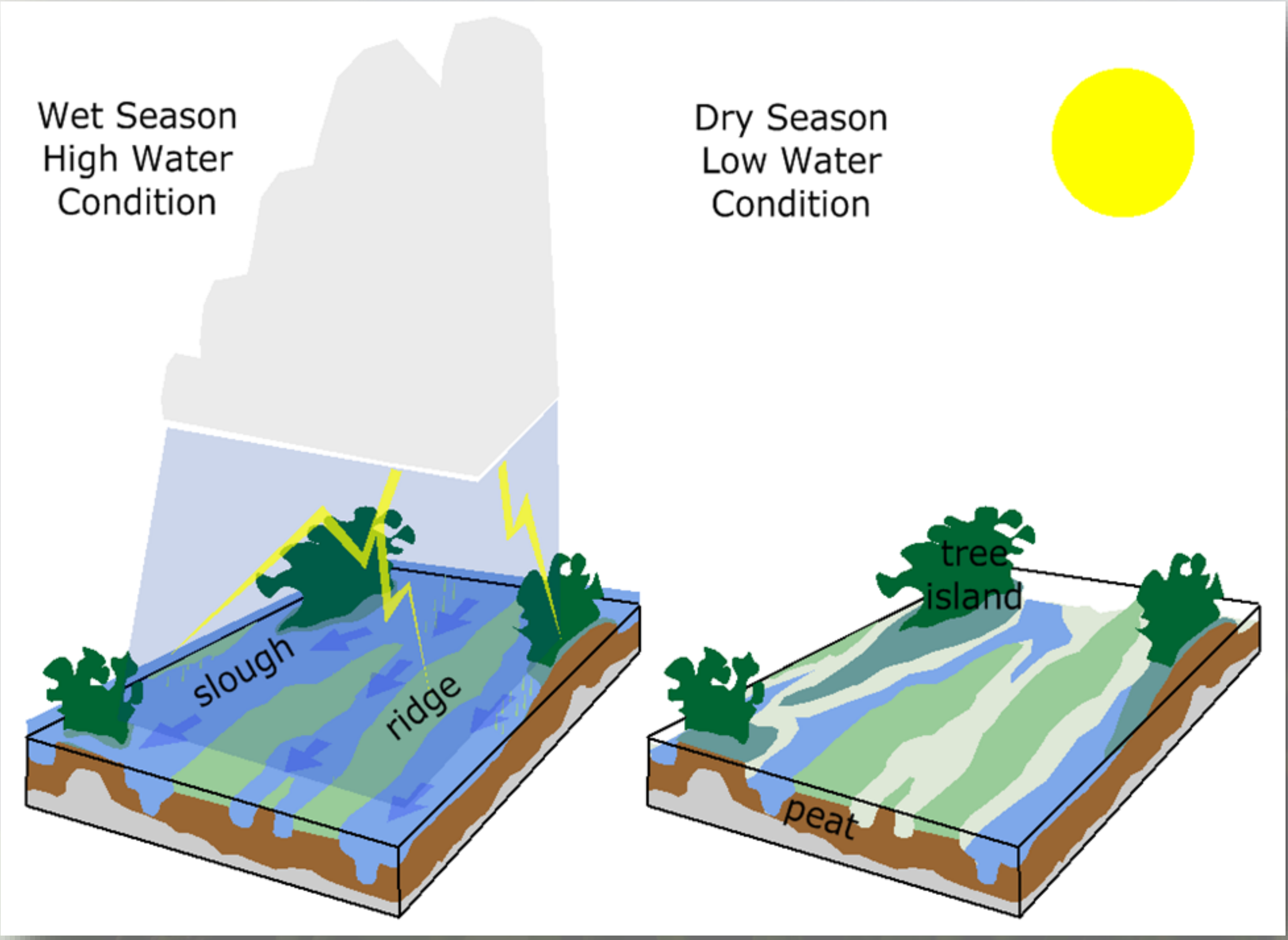


Figure 3. This diagram displays artistic representations of the Everglades during fall high-water and spring low water conditions. During the summer/fall rainy season, a shallow and slow-moving sheet of water inundates the entire slough and ridge landscape (except for the tree islands that usually remain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

Hydrologic Context for the System-wide Ecological Indicators Water Years 2013 – 2014

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).

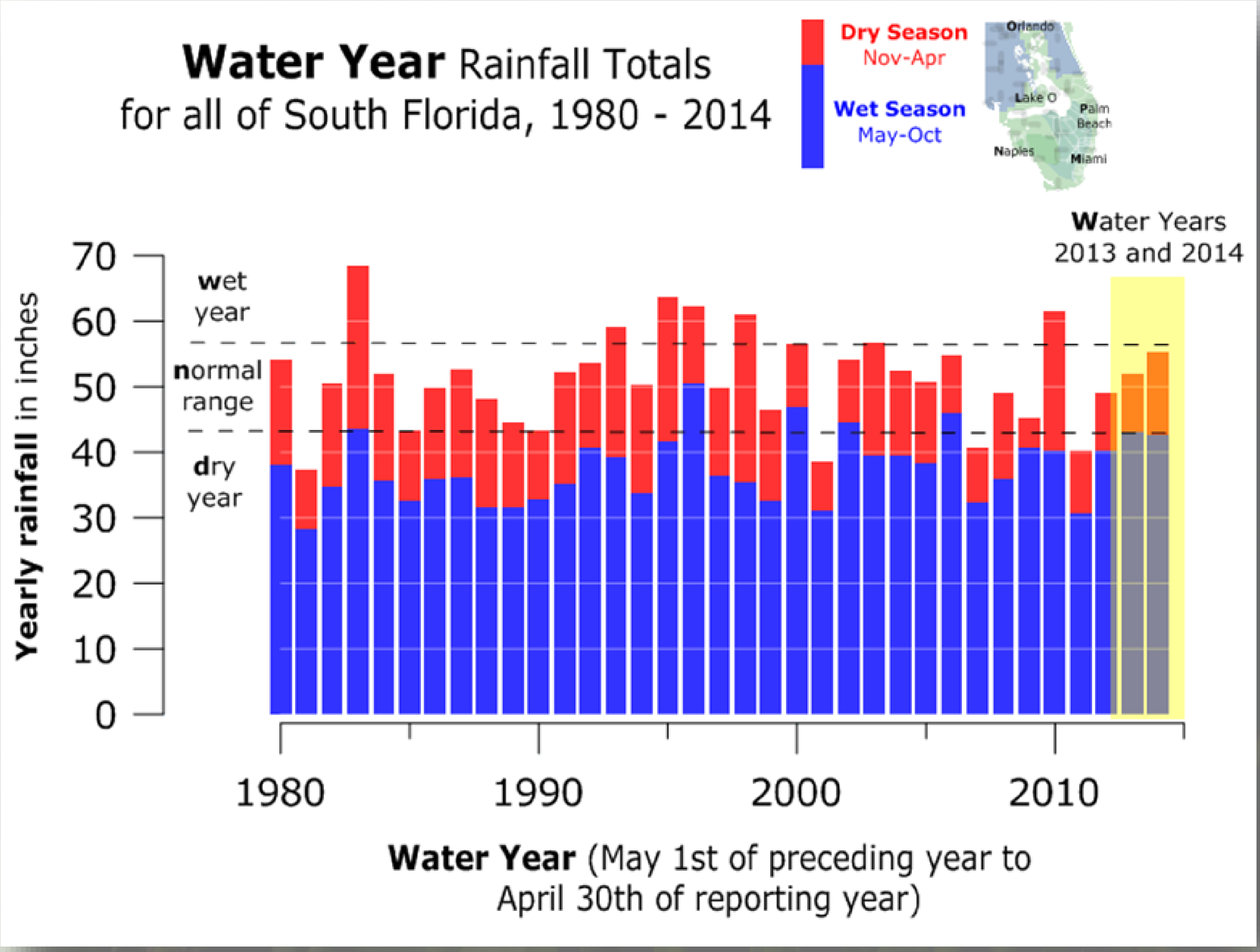


Figure 4. Yearly rainfall (inches) throughout the South Florida Water Management District. The graph was produced using daily rainfall data provided by the South Florida Water Management District. District meteorologists compute a daily rainfall value for the fourteen major basins and district wide from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

Hydrologic Context for the System-wide Ecological Indicators Water Years 2013 – 2014

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 years 2010 through 2012 were highly influenced by the El Niño-Southern Oscillation (ENSO) a climatic phenomenon caused by warming sea surface temperatures in the eastern Pacific, which strongly influences dry season rainfall variability in south Florida.

El Niño years have warmer Pacific sea surface temperatures, which translates into above average rainfall and surface water flows during the south Florida dry season. By contrast, La Niña years are associated with cooling Pacific sea surface temperatures, and conversely, dry season rainfall and water flows tend to be below-average. Water years 2013 and 2014 were not strongly influenced by El Niño or La Niña (Figure 5).

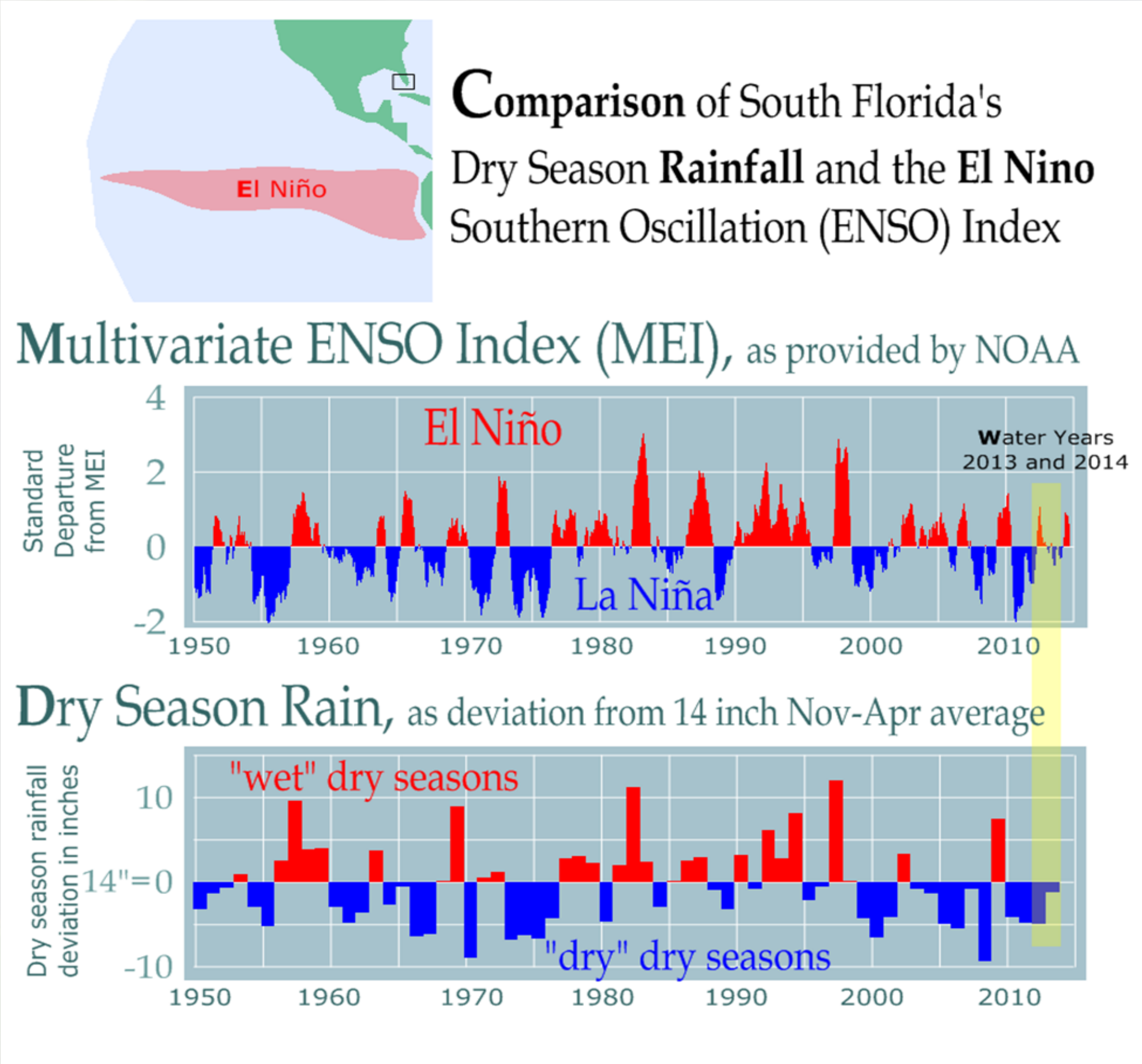


Figure 5. The graphs above show the correlation between the Multivariate ENSO Index (MEI) and winter dry season rain totals for south Florida. The top graph displays the standard departure of the MEI from 1950 to present. The bottom graph shows dry season rainfall for south Florida expressed as a departure (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.

Hydrologic Context for the System-wide Ecological Indicators Water Years 2013 – 2014

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 slow 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 pine 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.

Although south Florida is generally considered a wet area by merit of its abundant average annual rain total of 52 inches (with about 40 inches in the wet season and 12 in the dry season) and its oft-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 purposes associated with operation of the Central and Southern Florida (C&SF) project and other drainage works for:
    - 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 interannual variation – in other words, seldom do we experience average years.

Hydrologic Context for the System-wide Ecological Indicators Water Years 2013 – 2014

Water Year Summaries

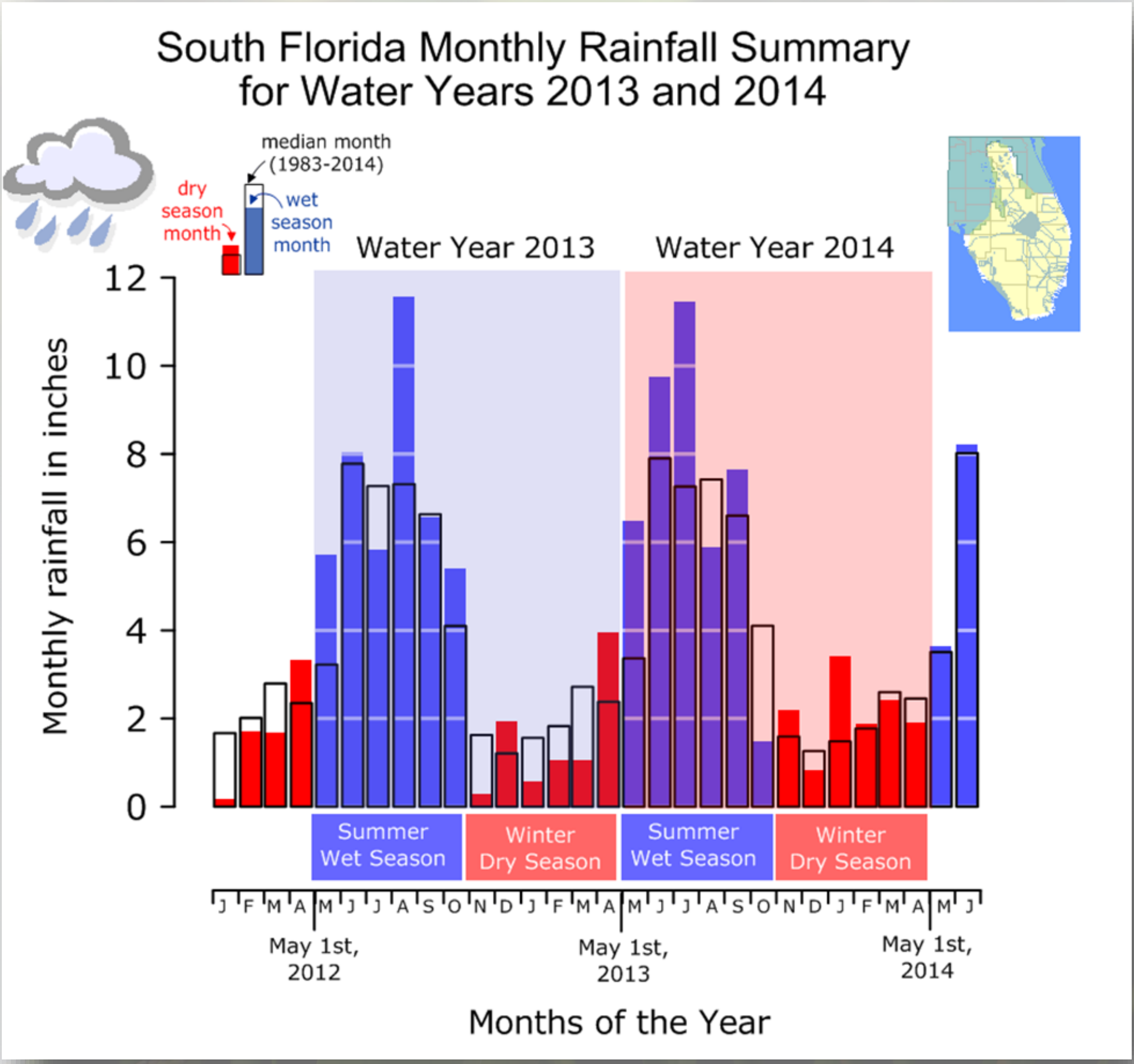


Figure 6. Monthly rainfall in water years 2013 and 2014 throughout the South Florida Water Management District. The graph was produced using daily rainfall data provided by the South Florida Water Management District. Black outlines are median (1993-2014) rainfall values. District meteorologists compute a daily rainfall value for the fourteen major basins and district wide from rain gauge measurements. See http://www.gohydrology.org/p/about.html for more information.

Water Year 2013 (May 1, 2012 to April 30, 2013)
Water Year Summaries Water Year 2013 (May 1, 2012 to April 30, 2013)

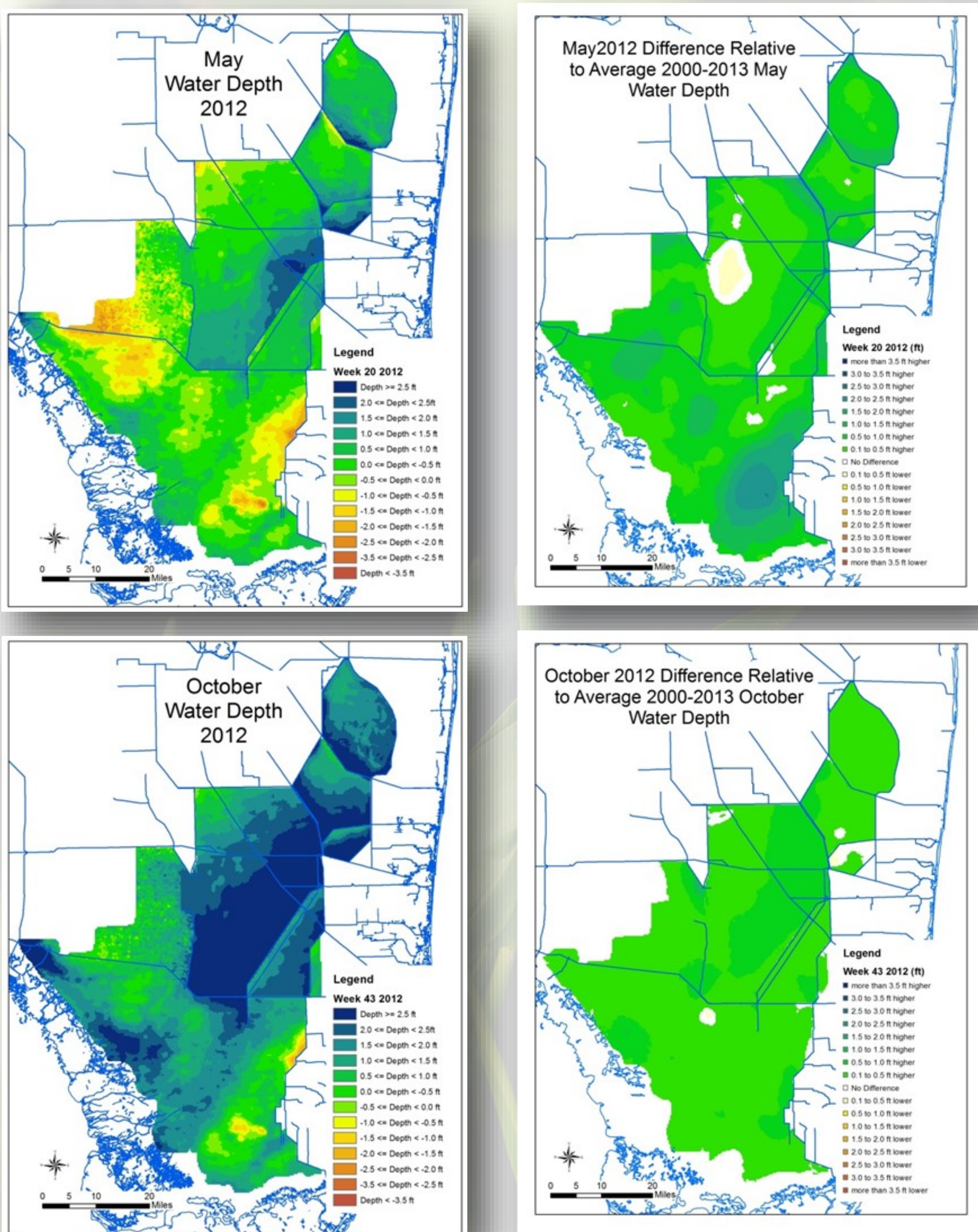


Figure 7. Water depth at the beginning of the WY2013 wet season (top left) and dry season (bottom left) and difference from the average water depth at the same time from 2000-2013 (right panels). Most areas were above the 2000-2013 at these WY2013 time snapshots.

Hydrologic Context for the System-wide Ecological Indicators Water Years 2013 – 2014

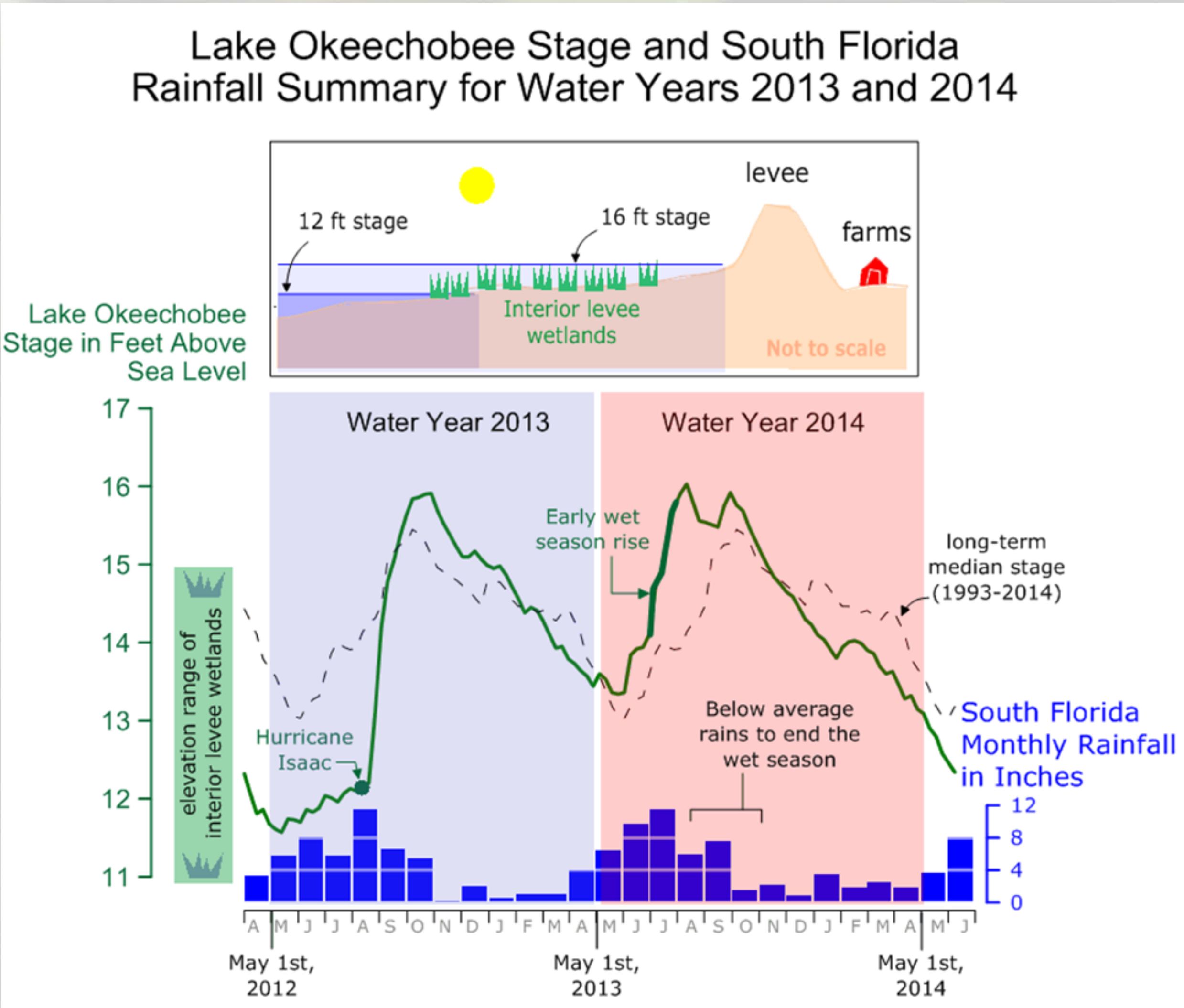


Figure 8. Lake Okeechobee stage and summary of monthly rainfall in the South Florida Water Management District in water years 2013 and 2014. Daily rainfall data provided by the South Florida Water Management District. District meteorologists compute a daily rainfall value for the fourteen major basins and district wide from rain gauge measurements. See [GoHydrology](#) for more information.

Hydrologic Context for the System-wide Ecological Indicators Water Years 2013 – 2014

In contrast to dry-season soaked Water Year 2010 and wet-season parched Water Year 2011 (61 and 40 inches annual rain, respectively), Water Year 2013 fell squarely in the normal range with 52 inches of rain, much like Water Year 2012. However, the beginning and end of the wet season were wetter than normal (Figure 6), which increased water levels early in the season and maintained them well into the fall (Figure 7).

Rain from Hurricane Isaac's feeder bands drenched the east coast of Florida in August 2012 and caused urban flooding, and also saturated the Kissimmee River, Lake Okeechobee, and Water Conservation Areas 1 and 2. Rains from Isaac elevated the stage (water level) of Lake Okeechobee 4 feet in the 5 weeks that followed (Figure 8), nearly matching the rate and height of a similar water-level rise in the aftermath of Tropical Storm Fay in Water Year 2009.

Because water levels were so low prior to August, Hurricane Isaac did not trigger appreciable flood-control releases to Florida's east or west coast. Many areas of the Everglades sustained their highest summer water levels since Water Year 2009. Benefiting from ample summer storage, the dry season saw water levels recede at a fairly steady rate—a condition initially conducive to wading bird foraging and nesting—before ending in April/May on a bit of a wet note.

Water Year 2014 (May 1, 2013 to April 30, 2014)

Rainfall in WY2014 was above average (56 inches compared to a 52 inch average) and an unusually wet spring (rains in April and May were double the average) followed by above-average rains in June and July set the stage for the quickest and highest water level start of the summer wet season south Florida had seen in years (Figure 9). Lake Okeechobee grabbed headlines by rising to just a few inches shy of its record high for August (Figure 8), a condition that prompted water managers to open the lake's flood gates for relief in anticipation of hurricane season.

Flows gushed down the Caloosahatchee and St. Lucie rivers at their highest rate since Hurricane Wilma in Water Year 2006. Totaling 2.5 and 0.7 million acre-feet in the Caloosahatchee and St. Lucie rivers, respectively, as measured at their downstream control points, these high flows, coupled with significant discharge from the local drainage basins, disrupted the delicate estuarine salinity balances and contributed to damaging algal blooms and mortality of oysters {link to oyster indicator}. It should be noted that the release volume was not commensurate with similar lake stages from a decade ago, but instead was partially reflective of recent changes in the regulatory release rules to offer added protection to the ailing perimeter levee around Lake Okeechobee, which is currently undergoing repairs.

Early concerns of tree-island and wildlife-threatening flooding in Water Conservation Area 3A abated as the second half of the wet season fizzled with subpar rains and no tropical storms. Enough water remained in the sloughs, however, to hold winter water levels in check through most of the dry season, other than in the adjacent Big Cypress Swamp to the west—a slightly higher-elevation, cypress-dominated wetland mosaic—where drought- and drainage-exacerbated wildfires ignited and spread.

Hydrologic Context for the System-wide Ecological Indicators Water Years 2013 – 2014

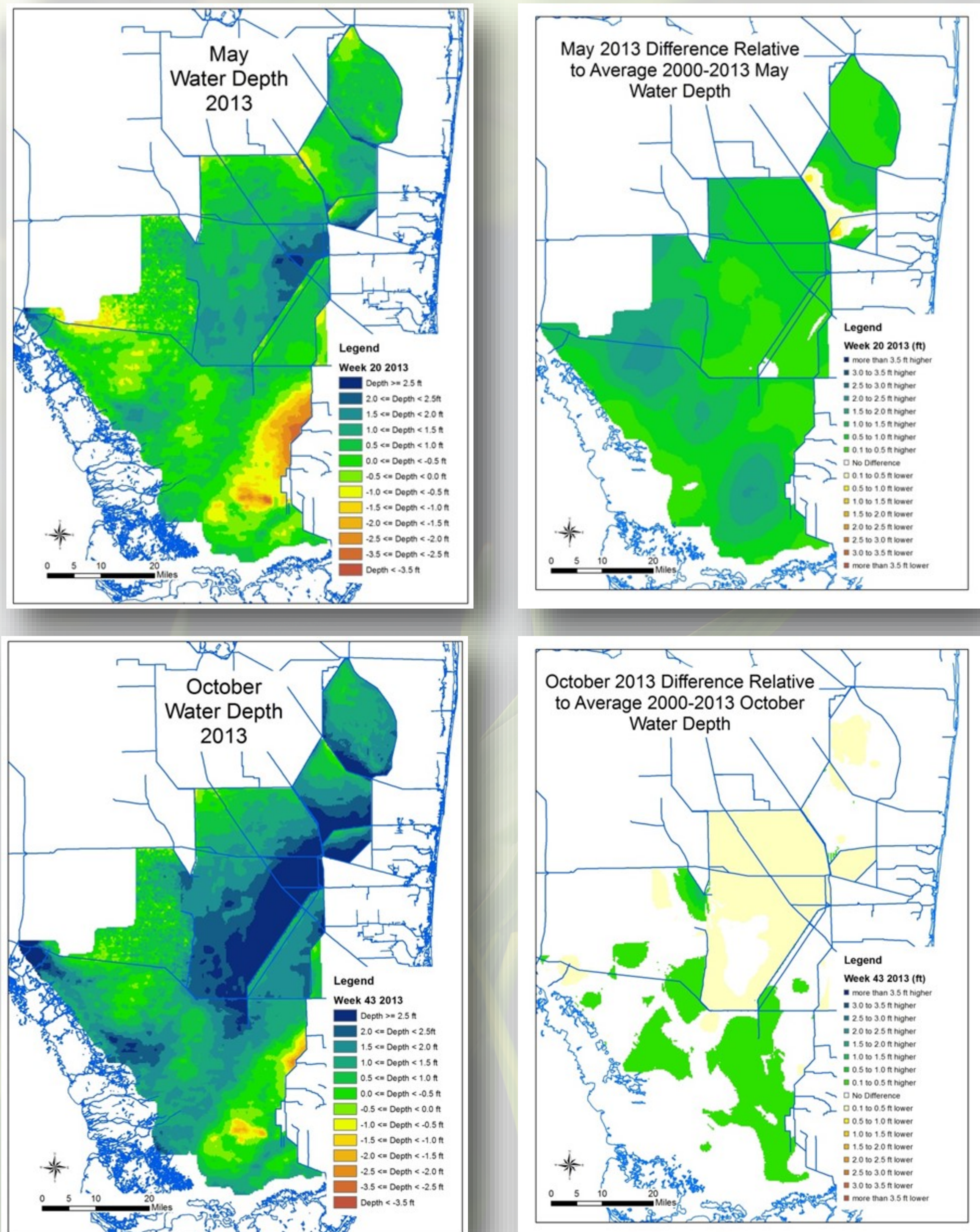


Figure 9. Water depth at the beginning of the WY2014 wet season (top left), WY2014 dry season (bottom left). Right panels show differences from the average water depth at the same time from 2000-2013.

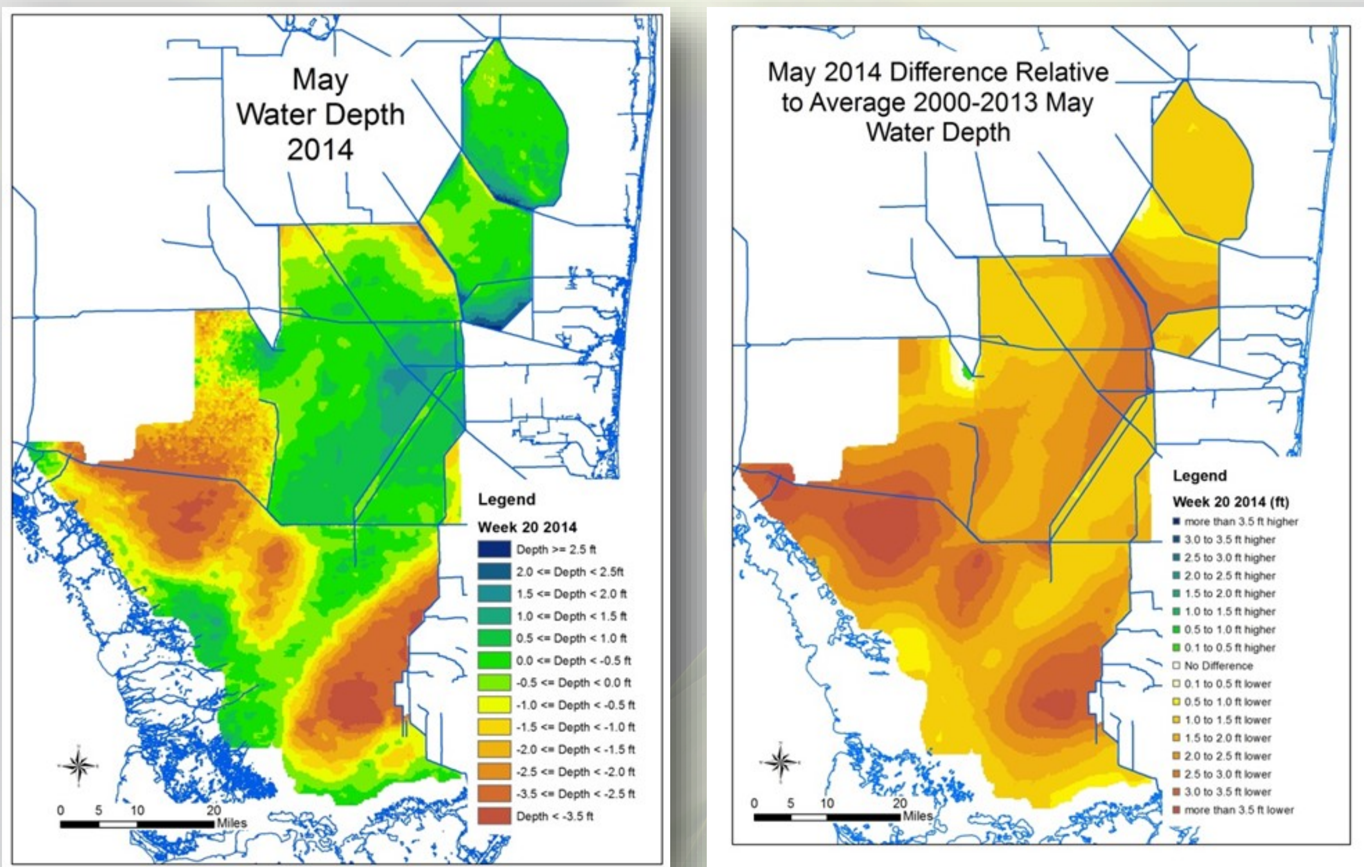


Figure 10. Water depth at the beginning of the WY2015 wet season (left). Right panel shows difference from the average water depth at the same time from 2000-2013. Most areas were above the 2000-2013 averages at the start of the WY2014 wet season but became drier than the 2000-2013 year averages during the dry season and at the start of WY2015.

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.

Stoplight Format

Further Indicator Details

This 2014 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 2012 Report , the 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.

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.

Literature cited

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 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.

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.

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 2010	WY 2011	WY 2012	WY 2013	WY 2014
Invasive Exotic Plants	Y	Y	Y	Y	Y
Lake Okeechobee Nearshore Zone Submerged Aquatic Vegetation	G	Y	R	G	Y
Eastern Oysters - **Modified (Northern Estuaries only)**	Y	Y	Y	No info provided	Y
Crocodilians (American Alligators & Crocodiles) - **Modified (DOI Lands Only)**	Y	R	Y	Y	R
Fish & Macroinvertebrates (WCA 3 and ENP only)	Y	Y	R	Y	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	Y
Florida Bay Submersed Aquatic Vegetation	Y	Y	Y	Y	Y
Juvenile Pink Shrimp - **Modified (no sampling)**	Data used as base	Y	Y	B	B
Wading Birds (Roseate Spoonbills)	R	R	R	R	R

Stoplight Legend

Red Substantial deviations from restoration targets creating severe negative condition that merits action.

Yellow Current situation does not meet restoration targets and may require additional restoration action.

Green 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.

Clear Data have been collected but not processed yet.

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

Indicators Overview

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 as far back as what was presented in the 2009 Ecological Indicators special issue (V9 Supplement 6) to directly link to the information presented there; therefore, the time series of stoplights presented in this report are not the same across all indicators. In some cases calculation of the stoplight colors has remained the same over time, in others because of new information or changes in sampling calculations have changed. Where calculations have changed scientists were ask to provide the details of those changes (updates on calculation of indicator).

Summary/Key Findings
Time series of stoplights
Map of WY2014 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

Invasive Exotic Plant Indicator

Summary Findings

The overall invasive plant indicator status did not change for any area from WY2012 to WY2014. All areas except the Florida Keys retained a yellow rating while the Florida Keys retained a green rating. All areas have control programs for most high priority invasive plant species on public and tribal lands. There is measurable progress toward region-wide control of some species such as melaleuca and Australian pine. Sustained funding, adequate control tools, and excellent coordination among land managers and researchers is yielding successes towards containment and control of these species. Unfortunately, many serious invaders remain problematic in most areas. For example, Brazilian pepper and Old World climbing fern continue to expand, presenting a significant threat to the ecological integrity of Everglades tree islands and other plant communities.

Agencies and other regional partners continue to improve coordination and focus management efforts towards newly detected, potentially invasive species. This management strategy is more likely to yield cost effective control with lower overall environmental harm. While systematic aerial monitoring programs are established for several areas, much-needed ground-based monitoring is lacking which could help land managers contain the spread of invasive species to new areas. Finally, invasive plant management on private lands remains deficient in all areas, ensuring continued invasion vulnerability to conservation lands.

As restoration proceeds, responses of invaders to changing environmental conditions will vary widely by species. For example, lengthened hydroperiods in the Kissimmee River floodplain have facilitated the rapid expansion of two invasive wetland plants—Peruvian primrose willow and West Indian marsh grass. Conversely, improved hydroperiods in the eastern Everglades are expected to slow recolonization rates of Australian pine and Brazilian pepper.

Key Findings

- The responses of invasive plants to ecosystem restoration vary strongly by species. Environmental change resulting from ecosystem restoration may inhibit the invasive potential of some species while simultaneously creating niches for new invaders.
- Most of the areas have serious invasive exotic plant problems, which are affecting natural areas and altering natural habitats and processes. Control of invasive plants is successful for a few species in some areas.
- Three biological control agents for melaleuca are well-established, and melaleuca reduction is documented. 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 spread of the lygodium gall mite from introduction sites is an encouraging development.
- 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. This is the first year of operations for the CERP Biological Control Implementation Project. The 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 area and portions of the Kissimmee River, Lake Okeechobee, and Big Cypress areas. 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.
- Insufficient funding for invasive plant control is a considerable threat to management success. As maintenance control is achieved for some priority species, other species continue to expand. As these species become more abundant and wide-spread, long-term the cost to achieve maintenance control will rise disproportionately.
- 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

Invasive Exotic Plant Indicator

LOCATION	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014
SYSTEM-WIDE	Y	Y	Y	Y	Y	Y	Y
KISSIMMEE RIVER	Y	Y	Y	Y	Y	Y	Y
LAKE OKEECHOBEE	Y	Y	Y	Y	Y	Y	Y
NORTHERN ESTUARIES-EAST COAST	Y	Y	Y	Y	Y	Y	Y
NORTHERN ESTUARIES-WEST COAST	Y	Y	Y	Y	Y	Y	Y
BIG CYPRESS	Y	R	Y	Y	Y	Y	Y
GREATER EVERGLADES	Y	R	R	R	Y	Y	Y
SOUTHEN ESTUARIES	Y	Y	Y	Y	Y	Y	Y
FLORIDA KEYS	Y	Y	G	G	G	G	G

LAKE OKEECHOBEE NEARSHORE ZONE SUBMERSED AQUATIC VEGETATION INDICATOR

SUMMARY/KEY FINDINGS

The stoplight color for the Lake Okeechobee Nearshore Submerged Aquatic Vegetation (SAV) indicator changed from red in WY2012 to yellow in WY2014 primarily because SAV coverage met the 50% or greater vascular taxa composition performance measure during WY2013 and WY2014. The other part of the measure, total SAV acreage, did not show a consistent increasing trend from WY 2012 to WY2014. Also, some sites in the nearshore region were too deep to sample during WY2014, as the lake stage was at 16 feet NGVD during the annual August SAV survey. Because lake stages during the winter and spring of WY2014 were within the ecologically beneficial zone for SAV, continued increases in SAV coverage are anticipated, barring any impacts from tropical systems or the occurrence of drought conditions.

Annual SAV coverage surveys continue. The long-term data suggest that restoration activities that provide recoverable water storage for Lake Okeechobee will allow the lake to maintain an appropriate annual hydrograph more of the time. This should enhance SAV in the nearshore region.

On the basis of annual SAV coverage data collected since 2000, maintaining lake stage within the ecologically beneficial stage envelope, both in terms of depth and temporal ascension and recession rates, provides the best conditions to maximize nearshore SAV coverage. When lake stages have been too high or low, SAV coverage has declined. However, even with better control of lake stage, periodic events such as tropical storms and droughts will continue to influence nearshore SAV coverage.

Annual changes in SAV coverage and in the proportion of the SAV population made up of vascular and nonvascular species appears to be largely determined by antecedent and/or prevailing lake stage as well as by major stochastic events such as droughts, which reduce available inundated acreage and storms and associated high lake stages which can both physically uproot plants and reduce water column light penetration to the point where SAV cannot survive.

For example, hurricanes in late summer and autumn 2004 resulted in reduced plant coverage in 2005 and 2006 (WY2006 and 2007) while droughts and attendant low water levels resulted in reduced SAV coverage in WY2002, 2008 and 2009. Moderate increases in lake stage following low water conditions resulted in excellent SAV coverage in WY2003, 2010, and 2013.

The winter and spring of WY2014 and the early summer of WY2015 have been characterized by almost ideal lake levels. Synoptic winter and spring surveys indicate that the SAV population remains in good condition. Therefore barring any major climatic events we anticipate good SAV coverage and vascular/ nonvascular ratios for the next two years.

LAKE OKEECHOBEE NEARSHORE ZONE SUBMERSED AQUATIC VEGETATION INDICATOR

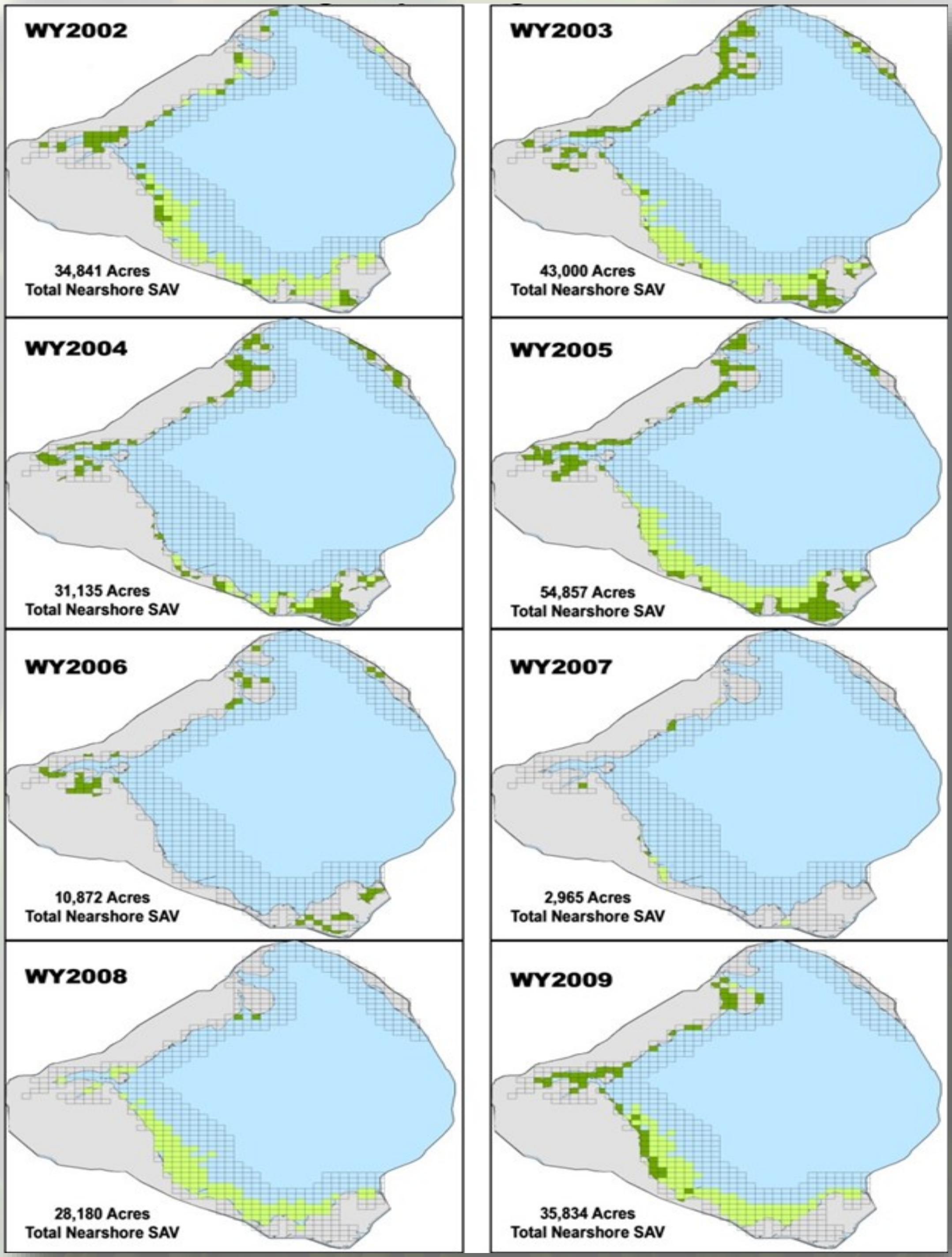
LOCATION	WY 2001	WY 2002	WY 2003	WY 2004	WY 2005	WY 2006	WY 2007
40,000 or more acres of SAV	G	R	G	R	G	R	R
Fifty percent or more vascular	R	R	G	G	R	G	R
Combined score	Y	R	G	Y	Y	Y	R

LOCATION	WY 2008	WY 2009	WY 2010	WY 2011	WY 2012	WY 2013	WY 2014
40,000 or more acres of SAV	R	R	G	R	R	G	R
Fifty percent or more vascular	R	R	G	G	R	G	G
Combined score	R	R	G	Y	R	G	Y

PERFORMANCE MEASURE: Total annual areal coverage of 40,000 acres at the end of the growing season. At least fifty (50) percent of this acreage should consist of vascular species. If both conditions are met the stoplight is green. If one or the other of the conditions is met the stoplight is yellow. If neither condition is met the stoplight is red.

LAKE OKEECHOBEE NEARSHORE ZONE SUBMERSED AQUATIC VEGETATION INDICATOR

Lake Okeechobee Submerged Aquatic Vegetation Abundance and Distribution



LAKE OKEECHOBEE NEARSHORE ZONE SUBMERSED AQUATIC VEGETATION INDICATOR

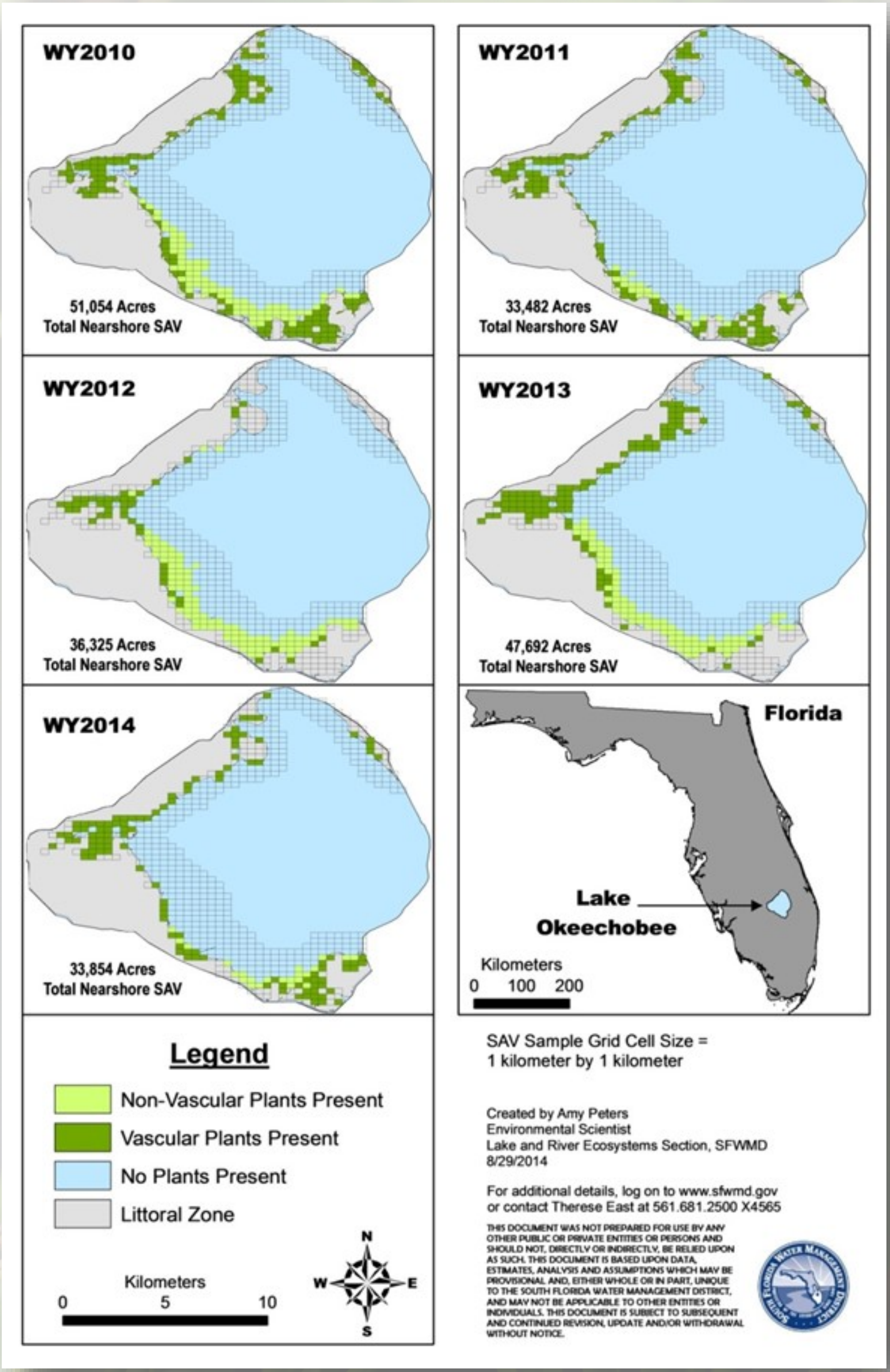


Figure 1: Distribution of SAV in Lake Okeechobee from 2002-2014

LAKE OKEECHOBEE NEARSHORE ZONE SUBMERSED AQUATIC VEGETATION INDICATOR

Updates on calculation of indicator

Although the basic practice of dividing the near shore zone of Lake Okeechobee into 1 km2 square grid cells and sampling each cell annually each August for SAV has remained unchanged since 2001, the actual sampling methodology has switched from snorkeling or diving and sampling in 0.5 m^2 quadrats to the use of an oyster-tongs like apparatus made from 2 garden rakes. Before switching methods, a study of the compatibility of the two approaches was conducted and similar results were recorded for both (Rodusky et al 2005). In WY2011, an additional set of grid cells were added to cover the lake's inner marsh (Figure 2). 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. Complete details of these changes can be found in the 2013 South Florida Environmental Report.

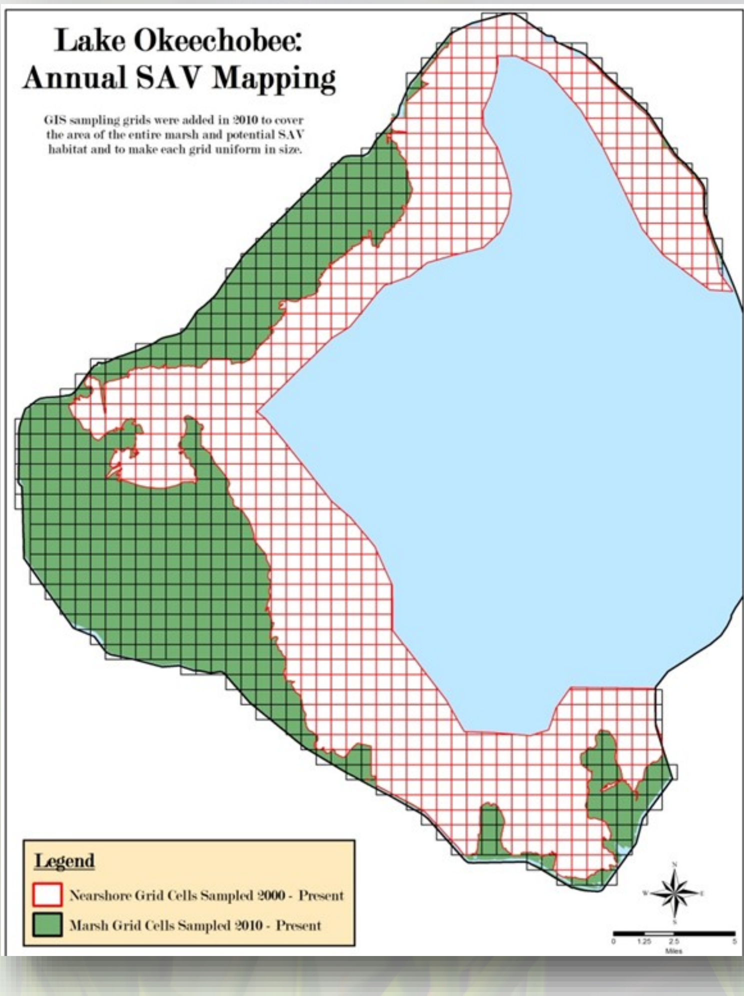


Figure 2. Map showing the extension of the annual mapping grid cells to incorporate the marsh habitat. The grid cells outlined in red are the nearshore grid cells that have been sampled since 2000 (WY 2001). The grid cells outlined in black are the marsh grid cells that were added in 2010 (WY 2011).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

LAKE OKEECHOBEE NEARSHORE ZONE SUBMERSED AQUATIC VEGETATION INDICATOR

How are these data being used?

Lake Okeechobee SAV data are used for multiple purposes. Annual 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 data is used to inform managers and stakeholders regarding short term effects of climatic variability and lake management activities 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 was recently added to the Lake Okeechobee Environmental Model (LOEM) (Jin and Ji, 2013). Similarly, this data set has recently been used to develop a performance measure relating SAV acreage to lake stage which in turn is being used along with other performance measures to evaluate, through the use of the Reservoir Storage and Operations Planning Model (RESOPS), the potential ecological benefits of various volumes of recoverable storage for Lake Okeechobee (Redfield and Efron 2015, RECOVER 2014).

New insights relevant to future restoration decisions

The Lake Okeechobee SAV data set, along with emergent aquatic vegetation data (EAV) are two of the longest continuously monitored data sets for the lake. 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 which is one of RECOVER's key Lake Okeechobee performance measures and one of the primary standards against which the ecological effects of lake operations and climatic events are measured. SAV coverage shows clear responses to lake hydrology and appears to be an excellent surrogate parameter for other important ecological components such as fish (bluegill and redear sunfish) abundance. SAV coverage over the past 14 years has clearly demonstrated the importance of structural and operational restoration strategies such as watershed storage and lower operating schedules that keep the lake in the range of 12.5-15.5 feet NGVD with annual peak elevations in autumn and minimum elevations in late spring or early summer with smooth ascension and recession rates between. 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 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. Analysis of the SAV-EAV complex has suggested new approaches to evaluating Lake Okeechobee's ecological status as a function of colonizable SAV habitat and percent utilization of this habitat as opposed to the currently used fixed acreage targets. Analysis of SAV and EAV data has also demonstrated the essential role of ongoing exotic vegetation management activities in restoration if suitably diverse native submerged and emergent plant communities are to be maintained.

Literature cited, reports, and publications

Eastern Oysters Indicator (Northern Estuaries Only)

SUMMARY FINDINGS

This summary only reports on the status of the eastern oyster (*Crassostrea virginica*) in the Caloosahatchee Estuary (Northern Estuaries). While monitoring continued in the Caloosahatchee Estuary (CRE), albeit at a reduced scope, oyster monitoring in Lostman's River was discontinued from WY2012 due to funding limitations.

On the whole, eastern oyster status remained unchanged up to 2014. Continued monitoring will yield data to make trend and status assessments in the coming years and will strengthen the confidence of the status. Current conditions in the Caloosahatchee Estuary show deviations from restoration targets, therefore restoration actions are merited. For example, relatively dry years during the past three years has resulted in higher disease prevalence and increased predation and mortality of juvenile oysters and spat recruitment. Status of oysters is expected to improve if hydrologic conditions are restored to more natural patterns. 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.

KEY FINDINGS

- While there may be occasional dry years, in general, there is too much freshwater inflow into the Caloosahatchee estuary in the summer months and too little freshwater inflow into the estuary in the winter months, disrupting natural patterns and estuarine conditions. The oysters in this estuary 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; 2010-2012 have been relatively dry years resulting in higher disease prevalence and intensity.
- Overall status of oysters in all of the Northern Estuaries is below restoration targets and requires action in order to meet restoration goals.
- 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.
- 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.

Figure 1 shows the sampling locations (past and present) in the Caloosahatchee Estuary. While this report examines oyster responses over the past 4 years in calculating stoplight indicator values, water quality data from 2000 to date were used in calculating flow targets to inform management decisions.

Eastern Oysters Indicator (Northern Estuaries Only)

	WY 2010	WY 2011	WY 2012	WY 2013	WY 2014
Caloosahatchee Estuary (Northern Estuaries)	Y	Y	Y		Y

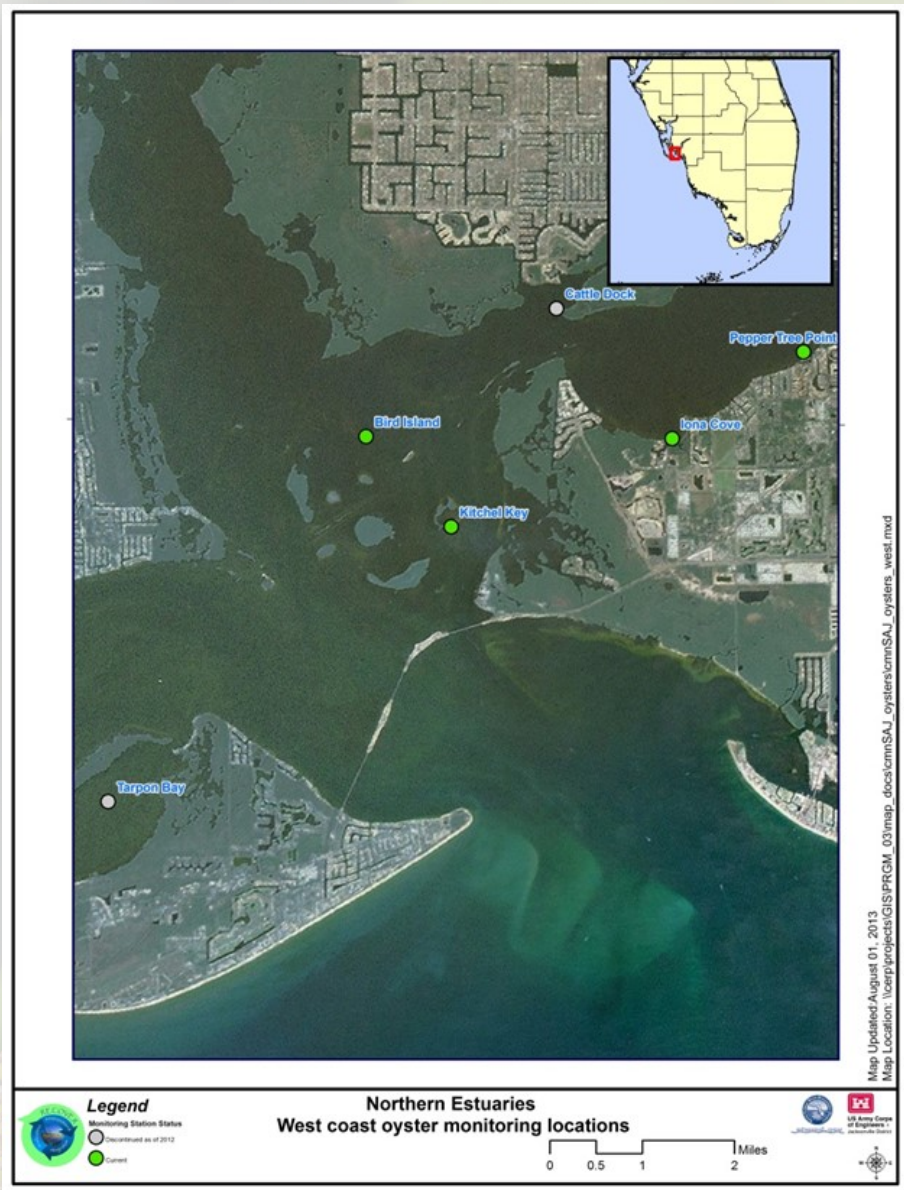


Figure 1. Oyster monitoring sites in Caloosahatchee Estuary. Green symbols denote current oyster monitoring locations. White symbols denote discontinued oyster sampling locations.

Eastern Oysters Indicator (Northern Estuaries Only)

New Insights relevant to future restoration decisions

A significant relationship exists between freshwater inflows and salinities at various points in the CRE. Flows below 3,500 cfs into the estuary from the S-79 structure will result in a salinity regime that enables oysters to survive and grow. Disease prevalence was lower at upstream locations and increased with distance downstream, suggesting that higher salinities result in increased disease incidence. In addition, disease prevalence and intensity decreased during wet years compared to dry years suggesting that freshwater releases help alleviate disease pressure. Limited freshwater releases for durations of less than two weeks will result in lower prevalence and intensity of disease in oysters and higher oyster survival. Oysters in the CRE appear to spawn actively between May and October, a period that coincides with freshwater releases and watershed runoff. While downstream locations attract higher spat recruitment due to higher substrate availability and estuarine conditions during high flow summer and fall months, growth and survival of juveniles is poor. Limiting freshwater releases to less than 3,500 cfs during these months will limit flushing of oyster larvae to downstream locations and create a favorable salinity regime for spat recruitment and survival. Low disease incidence, high condition index, sufficient spat recruitment and high growth rate at the upstream locations (e.g., Iona Cove) suggest that with the provision of suitable substrate and limiting freshwater flows during the spawning season, oyster reefs will survive and grow in the upstream locations. With CERP implementation and subsequent reduction in freshwater flows, it is anticipated that oyster reef development will be shifted upstream compared to current locations.

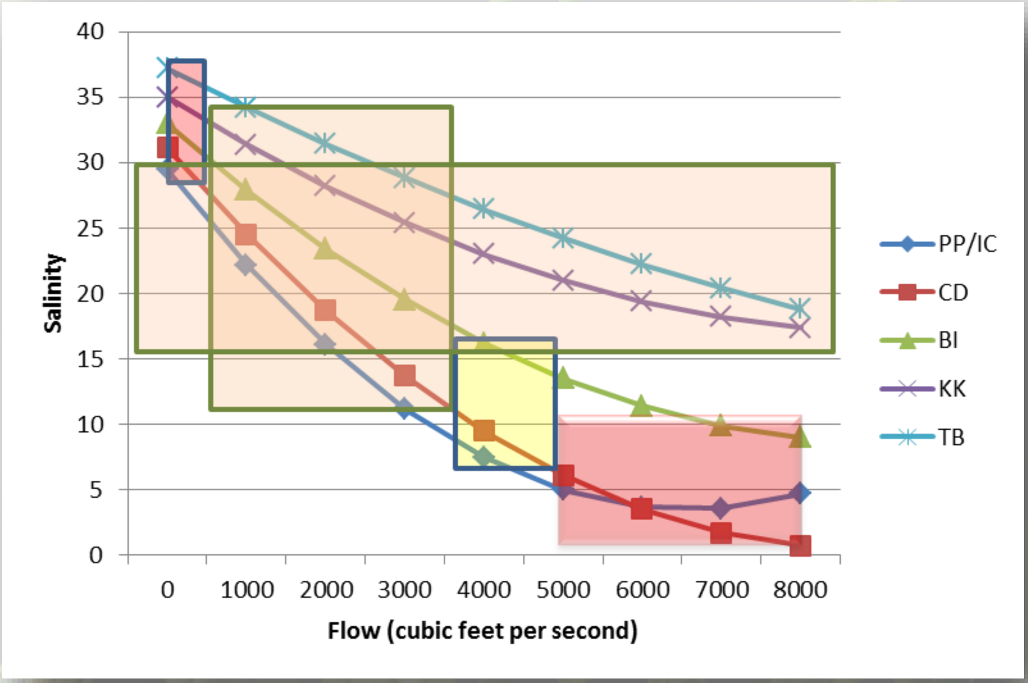


Figure 2. Relationship between monthly mean of the 30-day moving average freshwater inflows at the S-79 structure and salinity at various oyster sampling locations taken during monthly oyster sampling in the CRE. Green color indicates flows that would yield salinities that are favorable to juvenile and adult oysters. Yellow denotes “caution” or potential harm. Red denotes severe mortality at these flows/salinities. Salinities between 15 and 30 are favorable for oyster growth and survival. (Note: PP/IC – Pepper Tree Point/Iona Cove, CD – Cattle Dock, BI – Bird Island, KK – Kitchel Key, and TB – Tarpon Bay.

Eastern Oysters Indicator (Northern Estuaries Only)

The oysters in the Caloosahatchee Estuary are still being impacted by too much fresh water in summer and too little fresh water in the winter. While conditions in WY2013 were relatively stable, WY2014 witnessed large amounts of freshwater releases into the Caloosahatchee Estuary. Although oysters at downstream locations survived, oysters at the upstream locations (e.g. Iona Cove) encountered total mortality. 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. Disease levels were moderate and living densities good in WY2012, while disease levels were low and living densities low due to low salinities prevailing in the Caloosahatchee estuary during early summer / Fall months.

Some refinements in the monitoring program, development of predictive tools, and further knowledge of all factors effecting the reestablishment, health and long-term survival of the oyster communities are needed. At this time, the oyster hypotheses do not need to be refined, but some gaps in knowledge, such as the effect of contaminants on oysters and how varying salinities impact oysters need to be studied. The existing sampling design and sampling frequency can adequately assess the direction and magnitude of change in oyster metrics. The limited data set over the recent drought shows that predation may be a substantial stressor as salinities increase. Given that predation pressure is significant in some locations, such information is necessary and a longer data set will enhance the oyster habitat suitability index by strengthening the predictability of potential suitable habitat.

Combining salinity tolerance targets and larval supply with a particle transport model will offer resource managers locations where oyster larvae are expected at a given flow rate. Since substrate is critical for settlement of oyster larvae and subsequent development of reefs, combination of field monitoring and particle transport models can inform resource managers about managing freshwater inflows that are favorable to oysters (and other biota) as well as ensuring adequate substrate is present for larval settlement at the right places for development of reefs.

Creation of storage in the Caloosahatchee estuary basin to store excess freshwater discharges from Lake Okeechobee, thereby minimizing huge fluctuations in salinity may enable oyster populations to survive and result in increased population densities in the Caloosahatchee Estuary. Current conditions do not meet restoration criteria, signifying that this area needs further attention.

Literature cited, reports, and publications for more information

Crocodilians (American Alligators & Crocodiles) Indicator–Modified (DOI Lands Only)

SUMMARY/KEY FINDINGS

A full system-wide status for crocodilians for WY2012–WY2014 cannot be provided because system-wide funding was suspended in 2012. However, sampling has 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 overall crocodilian indicator status on Department of Interior (DOI) lands dropped from "yellow" to "red" from WY2012 to WY2014. Each management unit remained consistent with the corresponding WY2012 assessment except for crocodiles in the Biscayne Bay Complex, which dropped from "yellow" to "red." None of the managements units meet restoration targets; therefore restoration actions are merited. The status of alligators and crocodiles are expected to improve when hydrologic conditions are restored to more natural patterns.

The current status on DOI lands is well below restoration targets. From WY2008 to WY2011 the overall crocodilian index score hovered around 0.4, which is the cutoff from below restoration target "yellow" to well below restoration targets "red." In WY2012 and WY2013 the index score improved to 0.431 and 0.457, respectively. These values were still below restorations targets, but showed positive gains. In WY2014 there were declines in both alligator and crocodile component scores and this was reflected in the overall crocodilian index score dropping to 0.346 ("red").

Alligator overall status remains the highest in South Florida at the A.R.M. Loxahatchee National Wildlife Refuge (LOX), which peaked in WY2012 with a management unit score of 0.75 very near to meeting restoration targets. Since then the LOX score has dropped to 0.58 and 0.5 for WY2013 and WY2014, respectively. This drop reflects a declining trend in body condition in WY2013 and low body condition and a declining trend in relative density in WY2014. A hypothesis is that these results are a lag effect of extreme dry conditions in WY2011 which may have both reduced available prey and resulted in mortality of alligators of all size classes.

Alligator management unit scores at Big Cypress National Preserve (BICY) and Everglades National Park (ENP) have fluctuated just under 0.4. Within ENP the Shark Slough area is the only subunit with a positive long-term trend in the score (though it is still well below restoration targets). Management unit scores for crocodiles have remained constant in ENP at 0.5, while management unit scores for crocodiles in the Biscayne Bay Complex have fluctuated between 0.5 and 0.25.

Crocodilians (American Alligators & Crocodiles) Indicator –Modified (DOI Lands Only)

American Alligators and Crocodile	WY 2008	WY 2009	WY 2010	WY 2011	WY 2012	WY 2013	WY 2014
System-wide	Y	Y	R	R	B	B	B
DOI Lands	Y	Y	Y	R	Y	Y	R

American Alligator	WY 2008	WY 2009	WY 2010	WY 2011	WY 2012	WY 2013	WY 2014
A.R.M. Loxahatchee National Wildlife Refuge	Y	Y	Y	Y	Y	Y	Y
Water Conservation Area 2A	R	R	R	R	B	B	B
Water Conservation Area 3A	Y	Y	Y	Y	B	B	B
Water Conservation Area 3B	R	R	R	R	B	B	B
Everglades National Park	R	R	R	Y	R	R	R
Big Cypress National Preserve	Y	R	Y	R	Y	Y	Y
American Crocodile							
Everglades National Park	Y	Y	Y	Y	Y	Y	Y
Biscayne Bay Complex	R	Y	R	R	Y	Y	R

Figure 1. Stoplight colors for WY2014 for crocodilian indicator.

Crocodilians (American Alligators & Crocodiles) Indicator (Modified DOI Lands Only)

Updates on calculation of indicator

Initial calculation of stoplight values was presented in a special issue of Ecological Indicators in 2009 (Mazzotti et al. 2009). Since then several changes have been made that incorporate information learned and changes in sampling due to funding limitations. The time series of stoplight colors presented in this report reflect the updated calculations.

The crocodilian indicator was developed as a System-wide indicator spanning the Greater Everglades, from the LOX in the north through Water Conservation Areas 2 and 3 to the southern estuaries in ENP. It also includes BICY to the west, and Southern Coastal Systems from the Biscayne Bay Complex to the southwest coast, including Crocodile Lake National Wildlife Refuge (CLNWR) in the south.

The overall index combines scores for both alligators and crocodiles in different management units and thus incorporates aspects of both the freshwater and estuarine areas. Calculations are done by species and management unit and then combined. Calculations of the index for each management unit includes components that incorporate the current status (alligator relative density, alligator body condition, alligator hole occupancy in ENP, juvenile crocodile growth, and hatchling crocodile survival), a longer-term status (5 years for alligator relative density and hatchling crocodile survival, and 3 years for alligator body condition, and crocodile growth), and a recent trend assessment (5 or 3 years as above). Since 2012 when sampling was reduced due to funding limitations the alligator hole occupancy metric has not been included in the ENP calculation. In addition, all sampling sites in WCA2 and WCA3 were suspended, so the calculation for alligators includes only sampling on the following DOI lands: LOX, BICY, and ENP.

Additional changes were made to calculation of the index based on information learned. In Mazzotti et al. 2009, stoplight thresholds for alligator relative abundance and body condition were based on available data from 1999-2006 (Rice and Mazzotti 2006). In 2010 the thresholds were updated using data from 2004-2009 which is a more representative sample across areas (Hart et al. 2012).

Sampling for alligator body condition was changed to include animals greater than 1.25 m total length (TL) rather than 1.0 m TL to allow for direct comparison of body condition and abundance trends by size class (1.25 m is the cutoff between small and medium size classes). In addition, variability of body condition of smaller animals is greater than larger animals thus requiring larger samples to detect changes. We also updated our calculation of body condition to use snout-vent length instead of head length to allow us to compare body condition of crocodilians in the Everglades to crocodilians sampled elsewhere around the world where SVL (but not HL) is routinely measured (Webb et al. 1978, Verdade 2001, Santos et al. 1994, Dalrymple 1996, Seijas 1998, Fujisaki et al. 2009). Size of crocodiles used to assess growth was updated to include all juveniles up to 1.5 m.

Crocodilians (American Alligators & Crocodiles) Indicator (Modified DOI Lands Only)

How have these data been used?

Data collected as a part of this project were used to refine an Alligator Production Index Model (Shinde et al. 2013) that was used as an ecological tool in development of the Comprehensive Everglades Planning Project (CEPP) and to finalize the RECOVER Greater Everglades Performance Measure for American Alligator Abundance, Body Condition, Hole Occupancy, and Production Suitability Index.

Data also contributes to several reports and case studies {Cape Sable and C-111 Case studies} related to the restoration of Everglades systems and to threatened species monitoring. Annual updates are provided to the Fish and Wildlife Service, where they track the status and recovery of federally listed species such as the American crocodile. Information was provided to RECOVER via an annual assessment update for the project: American alligator density, size and hole occupancy and American crocodile juvenile growth and survival. These data can be used in an analysis designed to distinguish between effects of the Comprehensive Everglades Restoration Plan (CERP) and those of non-CERP events such as hurricanes or droughts. Information also was used for the annual System Status Report (SSR), whose goals are to evaluate current monitoring data and to determine if the objectives of CERP are being met (RECOVER 2014)

Data are currently being used to assess restoration projects in the Greater Everglades such as Tamiami Trail Modification Project where the goal is to restore hydropatterns in ENP to near historic flows. We expect to see increases in alligator relative density and body condition. Additionally we are evaluating the effects of the Decomp Physical Model (DPM), a CERP project designed to address uncertainties associated with Everglades restoration. Here we are evaluating the responses of alligators to a more natural flow of water through the system.

New insights relevant to future restoration decisions

Analysis of alligator relative density data of six survey areas from WY2003-2012 showed that areas with longer hydroperiods with less frequent and intense dry-downs have higher, more stable alligator relative densities, while areas with shorter hydroperiods and more frequent and intense dry-downs have lower alligator densities with declining trends. In addition, an analysis of 10 years of data for LOX examined the effect of dry years on alligator relative density and found that negative population growth corresponded to years with extremely low water levels (Waddle et al. in review). These results support our hypotheses that multi-year hydroperiods are important for maintaining alligator populations in the Everglades. Repeated and intense dry-downs affect both the ability of alligators to reproduce if they occur during April/May and the survival of hatchling and juvenile alligators regardless of when they occur. Based on the information presented in the SSR, areas that experience dry-downs that last longer than two months (60 days) or repeatedly occur at intervals more frequently than once every five years are not likely to support populations of alligators that are at or approaching restoration targets.

Both alligator and crocodile movement patterns have been examined to better understand movement dynamics in relation to environmental factors such as temperature and salinity. Rosenblatt et al. (2013; accepted) and Fujisaki et al. (2014) found that alligators in the estuary exhibited individual specialization for habitat use and movements and they respond to changes in salinity and water temperature. Crocodiles exhibit different spatial use patterns in different salinity environments, have large home ranges and daily movements greater than 1km (Beauchamp 2014).

In addition, Cherkiss et al. (accepted) reported on the remarkable movements of an individual *Crocodylus acutus* (American Crocodile) as it moved over a 14-year period. The crocodile was originally marked in Homestead, Florida as a young of the year in 1999 and later recaptured multiple times more than 388 km away along the southwest coast of Florida. After several relocations and numerous sightings, this individual who has become known as "Yellow Number 1" was found back within the same canal system in which it was first captured. This information will be helpful in understanding changes in patterns of distribution of alligators and crocodiles as more natural freshwater flows to the estuaries are restored.

We have continued to refine our understanding of the effects of salinity and other environmental factors on growth, survival, relative density, nesting, and body condition of crocodiles by taking advantage of both the long-term dataset going back to 1978 and more recent surveys.

Using linear regression analyses, we investigated the effects of year, area, habitat, salinity, air and water temperature on relative growth as measured by change in total length. Growth rate of crocodiles showed a decrease over time. In addition, growth rate differed among areas with NE Florida Bay having the lowest growth rate. Habitat type (i.e., canal, cove, etc.,), air and water temperatures did not have a significant effect on growth rate; however, growth rate significantly decreased with increases in salinity (Table 1, Mazzotti et al. 2014). With restored salinity patterns we expect to see an increase in crocodile growth rate in all of these areas (see Cape Sable Restoration and C-111 Spreader Canal Western Project sections).

Crocodile survival within ENP between 2004-2013 was also assessed. During that time a total of 5,227 hatchlings were marked in the three ENP nesting areas of NE Florida Bay, Flamingo/Bear Lake and East Cape/Homestead Canal (Table 2; Figure 2). Of this, 2.66% of hatchlings are known to have survived at least six months. Survival rates were different amongst the nesting areas (ANOVA $F_{2, 27} = 6.946$, $p = 0.004$). During the survey period, most hatchling crocodiles (65.5%) were caught in the East Cape/Homestead Canal area, but fewer hatchlings survived beyond six months ($\chi^2 = 19.06$; $p < 0.001$). In contrast, fewer hatchlings were caught in the Flamingo/Bear Lake area, but a greater number of these hatchlings survived beyond six months ($\chi^2 = 729.0$; $p < 0.001$). Flamingo/Bear Lake area also had the highest post-six month survival rate. Fewer hatchlings survived than expected by chance in NE Florida Bay ($\chi^2 = 4.76$; $p < 0.05$). We expect to see increases in crocodile survival in the Cape Sable and NE Florida Bay areas in response to restoration.

Comparisons have been made of relative density of non-hatchling crocodiles among survey routes nearest the Buttonwood and Cape Sable canal plugs (Buttonwood Canal and Cape Sable/Lake Ingraham [including Homestead canal]) to Joe Bay/Little Madeira Bay in NE Florida Bay). There were higher crocodile encounter rates in both Buttonwood Canal and Cape Sable/Lake Ingraham relative to Joe Bay/Little Madeira Bay ($F = 36.677$, $df = 2$, $p < 0.001$; see Figure 2 of Cape Sable Restoration section). Buttonwood Canal also had the highest non-hatchling crocodile abundance during a single survey (2.54 crocodiles/km). Encounter rates of non-hatchling crocodiles were highly correlated with survey areas ($r = 0.766$, $p < 0.001$) but were not correlated with year ($r = -0.057$, $p = 0.776$). On average, there was a decrease in crocodile relative density in Joe Bay/Little Madeira Bay ($\beta = -0.0137$; $p = 0.00021$) and Cape Sable/Lake Ingraham ($\beta = -0.0285$; $p = 0.0070$), but an increase in Buttonwood Canal ($\beta = 0.03017$; $p = 0.059$).

Because we have a long-term dataset going back to 1978 we have been able to track changes in crocodile nesting over time and locations. The total number of crocodile nests observed in ENP has increased from 11 in 1978 to 117 in 2014, with a maximum of 138 in

Crocodilians (American Alligators & Crocodiles) Indicator (Modified DOI Lands Only)

2008 (R^2 = 0.6406; $p < 0.0001$; nests = 1261; Figure 3). Nesting increased in the historical core area of NE Florida Bay at an annual rate of 3.4% from 1978 to 2014 (R^2 = 0.6619, $p < 0.0001$). However, most of the increase in crocodile nesting occurred in the relatively new Cape Sable/Flamingo nesting area, where nests increased from 2 in 1986 to a high of 109 nests in 2008, an annual rate of increased nesting of 16.3% (R^2 = 0.8091, $p < 0.0001$). Prior to 1995, 86% of crocodile nests (N = 174) were located in NE Florida Bay. Since 1997, 65% of crocodile nests (N = 688) were located in the Cape Sable/Flamingo nesting area (see Mazzotti et al. 2014).

Body condition is currently being used as a performance measure for alligators and as one of the metrics used for calculation of the alligator stoplight scores. To date we have not used body condition in a similar way for crocodiles. We now have enough data to conduct preliminary analysis and assessment of how we can use body condition in a similar way for crocodiles using data from 1978-2013. Females were found in greater body condition relative to males (Table 3). There was an overall significant difference when body condition was compared among size classes, with juveniles (0.65 to <1.5 m TL) showing the lowest body condition (2.01±0.43SD) relative to hatchlings (<0.65 m, 2.40±0.43), sub-adults (1.5 to <2.25 m TL, 2.28±0.36) and adults (≥ 2.25 m TL, 2.39±0.35), all $p<0.001$. Values for body condition for sub-adult (2.25) and adult (2.39) crocodiles are higher than average values for sub -adult and adult alligators (2.10, Hart et al. 2012).

Body condition was compared by locations in ENP for each size class (Table 4). NE Florida Bay registered the leanest crocodiles with the lowest body mass or each size class. Juvenile and adult crocodiles in NE Florida Bay had the poorest body condition of the three areas while sub-adults did not differ significantly across sites (Table 4). Additional body condition analyses are underway and we will develop quartiles for red, yellow, and green stoplight values as has been done with alligators.

Literature cited, reports, and publications for more information

Crocodilians (American Alligators & Crocodiles) Indicator (Modified DOI Lands Only)

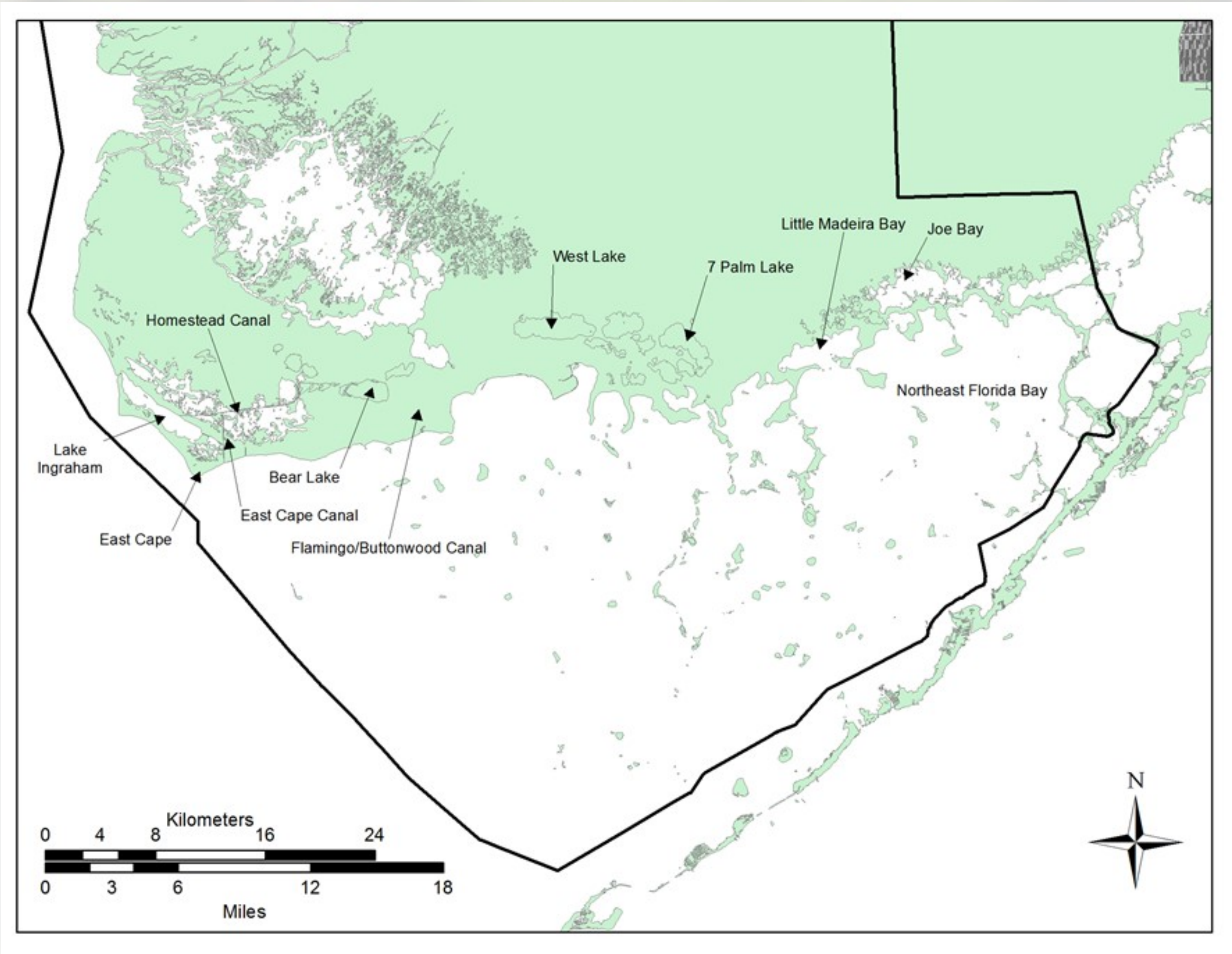


Figure 2. Florida Bay with locations of key crocodile survey areas mentioned in the text.

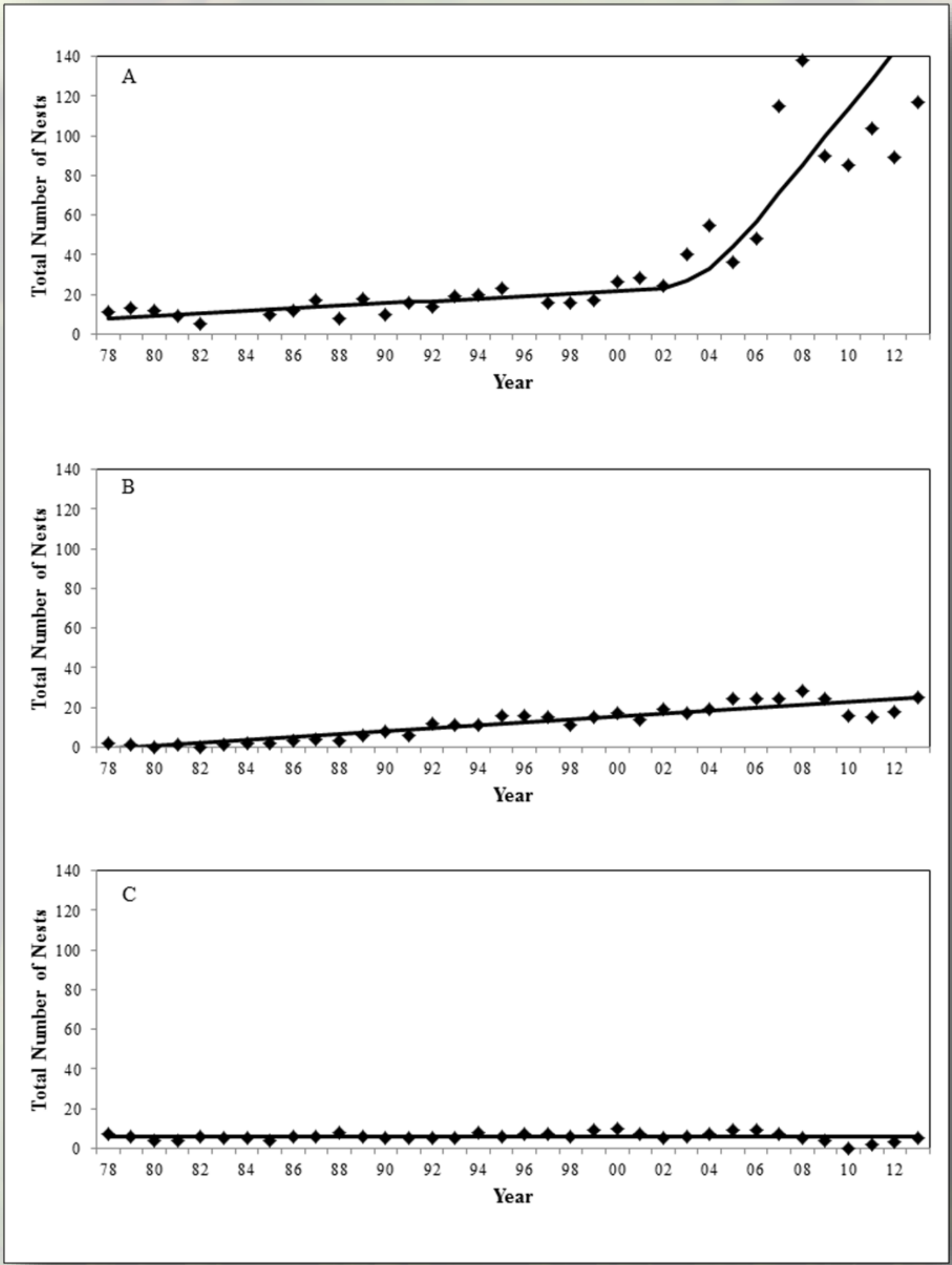


Figure 3. Summary of total number of American Crocodile nests found between 1978 and 2013 in the three primary nesting areas (A) Everglades National Park ($R2 = 0.6406$; $p < 0.0001$; nests = 1261), (B) Turkey Point Power Plant ($R2 = 0.8515$; $p < 0.0001$; nests = 430) and (C) Crocodile Lake National Wildlife Refuge ($R2 = 0.0067$; $p = 0.6363$; nests = 209) (Graphs modified from Mazzotti et al. 2007 with addition of 2005-2013 data and analysis from 1978-2013).

Crocodilians (American Alligators & Crocodiles) Indicator (Modified DOI Lands Only)

Table 1. Linear regression analyses testing association of location, habitat, year of capture, salinity, and air and water temperatures on growth rate of non-hatchling crocodiles within ENP from 1978-2013.

1978-2013 Total Length Change (cm/day)

	N	*β*	*SE*	*p*
Year	344	-0.006	0.002	0.002*
Area (ref 3)				
Area 3		--	--	--
Area 3.5		0.096	0.035	0.007*
Area 4.0		0.075	0.030	0.013*
Habitat (ref 1)				
Habitat 1		--	--	--
Habitat 2		-0.001	0.025	0.973
Habitat 3		0.012	0.126	0.924
Habitat 4		-0.001	0.035	0.979
Salinity PSU		-0.002	0.001	0.039*
Water Temp °C		0.003	0.005	0.555
Air Temp °C		-0.005	0.005	0.317

Salinity is measured in practical salinity units. *β* is an unstandardized coefficient of regression.

Area/Location codes are: 3 = NE Florida Bay, 3.5 = West Lake/7Palm Complex, 4 = Flamingo/Cape Sable. Habitats are: 1 = canal, 2 = cove, 3 = pond, 4 = creek/river. Area 3 (ref 3) and habitat 1 (ref 1) are points of reference in analyses. **p* <0.05.

Table 2. Survival of hatchling crocodiles from the three nesting areas within ENP. Captures are from 2004-2013.

Nesting Site	Hatchlings marked N	# Survived ≥ 6 months N (%)	Mean survival rate ± 1SD ≥ 6 months
NE Florida Bay	1316	17 (1.29%)	0.34±0.24
East Cape/Homestead	3424	32 (0.93%)	0.40±0.15
Flamingo/Bear Lake	487	90 (18.48%)	0.69±0.26
Total	5227	139 (2.66%)	0.48±0.19

Crocodilians (American Alligators & Crocodiles) Indicator (Modified DOI Lands Only)

Table 3. T-test results of body measures when compared between male and female non-hatchling crocodiles captured in Everglades National Park from 1978-2013.

Sex	Female		Male			
	N	Mean ± SD	*N*	Mean ± SD	*t*	*p*
Condition	280	2.28±0.38	250	2.09±0.38	5.475	<0.001**
SVL	319	105.58±33.69	272	76.40±42.48	9.139	0.001*
TL	319	197.38±61.54	272	144.66±78.16	8.999	<0.001**
Mass	280	30696.54±26254.44	250	11856.10±21723.36	9.034	<0.001**

**p* is significant at the α = 0.05, ** *p* < 0.0001

Table 4. Body condition of crocodiles captured within Everglades National Park (1978-2013) with associated univariate comparisons between areas of the park grouped by size classes.

Measure	NE Florida Bay		West Lake/7Palm Complex		Flamingo/Cape		*F*	*p*
	N	Mean ± SD	*N*	Mean ± SD	*N*	Mean ± SD		
Condition								
Juvenile	92	1.74±0.50	47	2.18±0.30	155	2.14±0.38	28.684	<0.0001**
Subadult	77	2.21±0.41	37	2.33±0.28	64	2.34±0.33	2.426	0.091
Adult	43	2.29±0.42	13	2.36±0.26	42	2.51±0.23	4.535	0.013*

**p* is significant at the α = 0.05, ** *p* < 0.000

Fish & Macroinvertebrates Indicator (WCA3 and ENP only)

SUMMARY FINDINGS

The stoplight color for the fish and macroinvertebrates assessed in ENP (Shark and Taylor Sloughs) and WCA 3A and WCA 3B remains red for WY2014. This summary is based on the density of all small fish and crayfish collected in monitoring programs using a 1-m2 throw trap in these areas. This method effectively captures aquatic animals between 0.06and 3.2 inches (0.15 and 8 cm) in length, which is representative of key food species for apex predators in the region. Production of these animals is affected by hydrology, nutrient status, and abundance of their predators, but they are particularly impacted by marsh drying events (hydrology). They are assessed by comparison of observed densities to densities predicted based on rainfall for that year. Stoplights are assigned based on how many times densities are above or below rainfall-based values after accounting for key aspects of model uncertainty. This stoplight also incorporates assessment of non-native fish species.

In WY2013-2014, three of six monitoring sites in central Shark River Slough (SRS) did not meet restoration targets for fish density (red), but only one was drier than expected based on rainfall1. These conditions resulted from fewer fish that prefer wet conditions than expected, but levels of drought-tolerant species (e.g., flagfish and Everglades crayfish) were consistent with or above expectations. Water management is causing drier conditions than would be expected based on the amount of rainfall and water depth patterns in our baseline hydrological period of 1993 through 1999. It is possible that re-current drying has altered the fish community composition to favor fast-recovering species that sustain lower biomass over time. Taylor Slough has returned to yielding fewer fish than expected based on rainfall at two sites (red) and fewer than expected at two others (yellow). Fish preferring wetter conditions were less abundant than expected, while short-hydroperiod taxa were at or near targets. Results were mixed in Water Conversation Areas 3A and 3B, yielding a yellow for both regions. In WCA 3A, two sites yielded fewer fish than expected based on rainfall, one yielded slightly more than expected, but all others were within desired ranges. There were fewer fish than expected in southern WCA-3B (red). The long-term monitoring program indicates that water management was closer to targets in 2007 through 2010 than in years 2001 through 2006, but then appeared to over-dry the Southern Everglades in water years 2011-2013. Monitoring data indicate that non-native taxa continue to be most common at edge habitats, though widespread in Everglades marshes. As reported in 2012, the frequency and species diversity of non-native fishes is increasing in Shark River Slough, Taylor Slough, and the ENP Panhandle following a drop in 2010. This trend should receive further attention.

KEY FINDINGS

All but one of the sites coded red for fish density resulted from fewer fish than expected based on observed rainfall, and most were in Shark River and Taylor Slough. Taylor Slough was scored as not meeting targets (red) overall.

- Taylor Slough showed an improvement in 2007 through 2010 compared to previous years (2001-2006), but has deteriorated since 2011. Overall, Taylor Slough is assigned a red light and warrants continued attention.
- Shark River Slough yielded red for half of the sites, including the site in Northeast Shark River Slough. Only one of these areas dried when it was not expected to by our rainfall-driven predictions. The low fish may be from a recent history of repeated drying events that is limiting the pool of fish available to initiate recovery.
- Results were mixed in WCA 3A, and the overall assessment is caution (yellow). There was evidence of more frequent drying than expected from observed rainfall in the western area. Everglades crayfish are seldom collected in WCA 3A, so they are not assessed there.
- WCA 3B yielded fewer fish than expected based on rainfall.
- Non-native fish are generally 2% or fewer of the fishes collected at all monitoring sites. However, higher numbers, particularly of Mayan cichlids and jewelfish have been noted at the mangrove edge of Shark River Slough and Taylor Slough, in the Rocky Glades, and near canals in general. Non-native species were knocked back by the cold months in January, 2010, but have returned to previous levels. Also, several new species are becoming common in the Taylor Slough and Panhandle areas of ENP.

[1]The target hydrological years for this assessment include 1992-1999. Forecasting models (statistical models derived by cross-validation methodology) that link regional rainfall to surface water-depth at our monitoring sites were used to model hydrology. Alternative hydrological model outputs, such as those derived by the Natural System Model, generally yield longer target hydroperiods than used here leading to more frequent impacts.

Fish & Macroinvertebrates Indicator (WCA3 and ENP only)

Performance Measure	WY 2010	WY 2011	WY 2012	WY 2013	WY 2014
Overall	Y	Y	R	Y	R
Shark River Slough					
Total Fish	Y	Y	Y	Y	Y
Non-Native Fish	Y	Y	Y	Y	Y
Bluefin Killifish	Y	G	R	Y	Y
Flagfish	Y	G	Y	Y	Y
Easter Mosquitofish	Y	Y	Y	Y	Y
Everglades Crayfish	C	Y	G	G	C
Taylor Slough					
Total Fish	G	G	Y	Y	R
Non-Native Fish	Y	G	Y	Y	Y
Bluefin Killifish	G	G	Y	Y	R
Flagfish	G	G	G	G	Y
Easter Mosquitofish	G	G	Y	Y	R
Everglades Crayfish	G	G	Y	Y	R
Water Conservation Area 3 A					
Total Fish	G	Y	Y	Y	G
Non-Native Fish	Y	G	G	Y	Y
Bluefin Killifish	G	G	G	G	G
Flagfish	G	Y	Y	Y	Y
Easter Mosquitofish	G	Y	G	G	Y
Water Conservation Area 3 B					
Total Fish	G	G	Y	R	R
Non-Native Fish	Y	Y	G	Y	Y
Bluefin Killifish	Y	G	R	R	R
Flagfish	Y	Y	Y	R	R
Easter Mosquitofish	G	G	G	Y	G

Fish & Macroinvertebrates Indicator (WCA3 and ENP only)

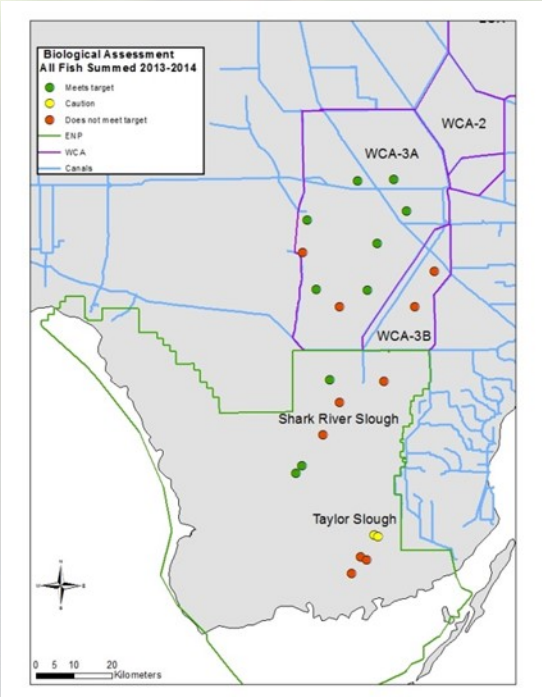


Figure 1. Stoplight color at sampling sites for total fish in WY2014.

Updates on calculation of indicator

As in past indicator reports, we used a model-based approach to set targets for aquatic fauna based on expected density based on rainfall. This approach uses the relationship of water-level fluctuation and regional rainfall between 1992 and 1999 at long-term monitoring sites to project the expected water-level fluctuation at those sites from 2000 through the 2014 water year (May 2013 through April 2014). The 1992 through 1999 period was used to parameterize our rainfall model because it included several very rainy years with hydropatterns similar to those expected under the Natural System Model (NSM) hydrological model (Trexler and Goss 2009). We used our complete aquatic fauna database (July 1996 through May 2014) to establish functional relationships between selected performance measures (PM) and hydrological metrics, which were then used to project the expected PM values based on the target hydrology. These projections were compared to the observed values for each PM to determine the relative match of observed and projected target conditions, which was used to assign stoplight values. This procedure is described in detail in Trexler and Goss (2009). In this section of the report, we provide results for selected sites and two PMs to illustrate the process leading to this stoplight report.

We used data from 19 long-term monitoring sites to conduct the assessments (Figure 2). With two exceptions, each study site has three plots that are separated by sawgrass-dominated ridges; two sites in Taylor Slough are bridged by two additional plots (one to the east and one to the west) to capture the abrupt hydroperiod gradient in that area. Thus, a total of 61 plots with data from 18 water years (1997 through 2014) were used to produce this report. Assessments were conducted separately for each study plot and the plot results were averaged to yield a site stoplight. For each PM, a predicted value was calculated based solely on the target hydrology (Figure 3, blue line). Two example PMs are shown in Figure 3, the density of all fish summed (Total Fish), which was best modeled by a simple linear model (PM = intercept + Days Since Last Dry), and the density of bluefin killifish, which was best modeled with a polynomial model (PM = intercept + Days Since Last Dry + Days Since Last Dry2). We used this simple model to place all variance not directly correlated with hydrology in the error term of the model and calculated a confidence interval (+/- 2 standard errors) for each prediction to accommodate model uncertainty. The mean and standard error of the difference between observed values (Figure 3, red line) and predicted values were calculated for each plot for each year. These plot-level deviations were aggregated to yield a mean deviation for a site for each year. With this information for each study site, we then compared the deviation from the range of predicted values (Figure 4, black hash marks +/- 1.5, 2, and 3 standard errors) with the model confidence interval (Figure 4, red and black asterisks). We assigned red stoplights when the 3 standard error interval of the observed deviations from predicted did not overlap with the model confidence interval, or when the 2 standard error intervals failed to overlap the model confidence interval for two years in succession, or when the 1.5 standard error intervals failed to overlap for four of five consecutive years. Yellow lights were used to indicate caution and correspond to years where the mean of the target was above or below the 1.5 standard error model interval. Finally, green stoplights were reported for years when the target fell within the 1.5 standard error control limits. These assessments were conducted for each site and PM (Total Fish, Figure 5; Bluefin Killifish, Figure 6) and stoplights were produced. The abridged report presented in the first section of this document provides regional average stoplights, taken by giving the stoplights for each site a score of 1 to 3 and averaging the scores.

We used rain and water stage data from 1992 through 1999 as our target period because this period includes some dry years early and very wet years later, creating a range of rainfall and surface water depths to parameterize the model without extrapolation beyond the observed conditions. Also, important changes were made in operations of water delivery late in 1999 for the goal preserving Cape Sable Seaside Sparrows (S332D period in Kotun and Renshaw 2014), with possible effects on hydropattern and marsh drying both in and upstream of Everglades National Park (Sikemma et al. 2005). With the addition of new data each year, we re-parameterize the model linking hydrological parameters to PM values. This approach makes our assessment conservative because it incorporates any acclimation of PM response to changing hydrological regimes into the assessment. This approach also means that past assessments may change as new data are obtained. We have opted to update the PM models with each new assessment, but not hydrological targets, because of limitations in PM data during the years before 2000. This is well illustrated in Figure 3 for the bluefin killifish PM; note that the number of days passed since the preceding drying event were already high at the start of the study (July 1996). Thus, a model of bluefin killifish and hydrological parameters would have to be extrapolated well beyond the data used to generate it in order to apply in in the years after 2000. In addition to the problem of extrapolating the assessment model beyond the data, the coefficient of determination (R2) are relatively low when only the first four years of study are employed. Banet and Trexler (2014) concluded that a minimum of six years of data was needed to produce these management models.

Major construction related to ecosystem restoration has recently been completed, or is nearing completion. These projects seek to benefit the northeastern region of Shark River Slough, Taylor Slough, and the Panhandle region of Everglades National Park. These projects give a reason to anticipate an improvement in the aquatic fauna performance measures in the next biennial report.

Fish & Macroinvertebrates Indicator (WCA3 and ENP only)

New insights relevant to future restoration decisions

How do the current assessments fit into long-term trends of the fish and crayfish biomass in the Everglades? We have been working on that question through the use of time-series analyses of the data used to make these assessments, as well as use of much longer time series available for two of the long-term monitoring sites (Full report: Trexler et al. 2013). The focus of these analyses was biomass of wading bird prey (small fish and crayfish) to ask if trends (consistent directional change over time) were present after accounting for climatic variability. The bi-annual assessments of these aquatic animals include many yellow and red lights, indicating deviations from rain-fall based expectations on a year-by-year basis. Are these annual results supported by a systematic time series analysis?

We analyzed hydrological data collected in the Shark River Slough (SRS), Taylor Slough (TSL), and Water Conservation Areas (WCA) 3A and 3B between 1977 and 2012 to evaluate long-term trends at 19 study sites (Map of sites in Figure 2 of this report). Analysis focused on fishes and crayfish within the size range consumed by wading birds to evaluate dynamics of wading bird prey. The actual length of the time series analyzed varied among the study sites and ended the year before the data used for this assessment. Nineteen sites provided 16-year time series from 1996 through 2012; three of those sites in SRS (6, 23, and 50) provided 27-year time series starting in 1985; two sites in SRS (6 and 23) provided 33 years of data beginning in 1977. Marsh drying reduces local biomass of aquatic animals in the Everglades through death by desiccation or predation or by forcing them to move across the landscape to seek hydrological refuges (Trexler et al. 2005). The recovery of aquatic animal biomass following marsh drying in long-hydroperiod areas can take several years and may not be complete before a subsequent drying event resets the recovery process. The concentration of aquatic animals, particularly fishes and crayfish, caused by periodic drying is a key process in sustaining high numbers of nesting wading birds. Management to recover historical nesting populations of wading birds must include spatially structured dynamics created by seasonal cycles of rainfall and inter-annual variation in the severity of marsh drying.

Fish biomass declined at five of six long-term study sites in the SRS, three of three sites in TSL, five of eight sites in WCA 3A, and two of two sites in WCA 3B (Table 1; Figure 7). The rate of decline varied among sites, in part related to their location within each study region, but on average, an 11.2% decline was noted in TSL, 9.5% in SRS, and 13.2% in WCA 3A and 3B between 1996 and 2012. The steep decline in WCA was largely the result of large biomass reductions at sites north of Alligator Alley. The modest drop in SRS was influenced by increasing biomass between 1978 and 2000 at one site in northeast SRS (SRS 23), consistent with a past report on benefits from Water Delivery Tests 1-7; however, biomass at that site has declined since 2000. The long-term decline in biomass noted overall in SRS began before the start of widespread sampling in 1996. One plot at site 6 was sampled continuously beginning in 1978 (SRS 6). Over this 33-year time period, fish biomass at SRS 6 exhibited a decreasing trend with a 14.1% overall drop, despite a temporary increase in the late 1990's likely associated with an unusually high amount of precipitation (Figure 8). In many cases, fish species composition has changed to reflect an increase in the relative abundance of species that thrive in short-hydroperiod conditions. Crayfish biomass has also declined since 2000, though in more of a step-wise change because of a switch in species dominance. Prior to 2000, slough crayfish (*Procambarus fallax)* dominated SRS collections and was the most common species in TSL. The slough crayfish species is indicative of long hydroperiods, in contrast with the short-hydroperiod Everglades crayfish (P. alleni). Since 2000, the Everglades crayfish has become the most common crayfish in both regions, where it maintains lower biomass populations than the slough crayfish. As a result, crayfish biomass has decreased over the study period at several sites in SRS and TSL. In WCA 3A and 3B, the biomass of Slough crayfish has also declined at several sites, while Everglades crayfish remains scarce in these regions.

The effects of management control of hydrology on these patterns were evaluated using a two-step analysis. First, flow from upstream water structures was determined to explain the majority of variation in water depth at our long-term monitoring sites in SRS (flow from the S-12 structures) and TSL (flow metered at the Taylor Slough Bridge). Water flows from upstream structures showed long-term trends toward lower flows, particularly in the January through March dry-season months. Though variable, rainfall did not display consistent trends over the course of the study (e.g., one or more rainy years were followed by one or more dry years, to yield no net trend) and rainfall explained very little of the observed variation in depth. Also, over the period of record for EDEN data (1992-2012), a general trend toward an increased probability that the marsh surface would dry for some period each year was found at fish-crayfish monitoring sites. This pattern could not be explained by rainfall changes, which was a covariate in the analysis. In summary, the operation of structures upstream from our monitoring sites appeared to result in a greater frequency of marsh drying between 1992 and 2012 than would be expected by rainfall.

The second step in evaluating the source of trends in fish and crayfish biomass was to incorporate hydrological parameters from the study sites into models of biomass. For fishes, the parameters were: 1) days since the site was last dry; 2) water depth at the time of sampling; 3) rate of change in water depth from 30 days prior to sampling (water expansion/ recession rate); and 4) season (coded from wet season to dry season; 1 for July, 2 for October, 3 for December, 4 for February, and 5 for April). Fish biomass generally increased to an asymptote as time passed after a drying event, decreased (slightly) as water depth increased, decreased if water expansion rate increased and increased if water recession rate increased, and varied seasonally from a low in July (many of the fishes were small recruits at this time and were excluded from this analysis) to a high in February and April. Declining trends in fish biomass remained at all but one site after accounting for these local hydrological factors known to affect fish biomass. The results suggest that in addition to the immediate effect of increasing the frequency of marsh drying, forcing fish communities into a perpetual recovery condition, emergent harmful effects on biomass were also present.

Two possible explanations for this emergent effect have been identified. First, changes in fish community composition from species favored in long-hydroperiod marshes to species favored under short-hydroperiod conditions may be favoring species that maintain lower biomasses. This is also the case with the crayfish, in which long-hydroperiod slough crayfish are typically found at higher density than short-hydroperiod Everglades crayfish. Second, it is possible that each drying event forces a lottery of survival that requires some minimal period of recovery; if these high-mortality lotteries occur with too little intervening time, populations may not be able to recover adequately to have enough individuals to fare well in the next event. Therefore, each successive drying event further depletes the pool of survivors. It seems likely that there is a minimal return-time between system-wide drying events that can sustain a highly productive aquatic community.

The changes in fish biomass we observed could result from a change in fish density or a change in the size distribution of individuals of the same species, or both. For example shortening the life expectancy of fish would shift the age-distribution to younger individuals and decrease biomass. We evaluated these sources of biomass change in analyses reported in Trexler and Catano (2014). Based on evaluations of multiple statistical models, we found that change in fish density was the most influential contributor to changes in fish biomass over time at most sites. In most cases, fish density explained two to three (and as high as ten) times the variation in fish biomass compared to fish size. Average fish length was an equivalent or larger determinant of biomass change than density in only two sites (SRS 6 and SRS 23). In SRS 6, the effects of size and density in shaping biomass were relatively equal, but with more evidence for average fish size. SRS 23, however, demonstrates far more support for the effect of average fish size on biomass than density. Also, this was the only site from our set of long-term monitoring sites across the southern Everglades that demonstrated an appreciable increase in average fish biomass for a portion of the time series. Therefore, it appears that the efforts to restore freshwater flows into Northeast Shark River Slough in the 1990's and early 2000's, either permitted individual fish to reach larger sizes or shifted the species composition to include more individuals of species that reach larger terminal sizes. Both could lead to higher overall biomass.

This project examined the standing crop of fishes and crayfish with the focus on key prey items for wading birds. The CERP trophic hypothesis proposes that food availability for predatory birds is limited by the pattern of water recession and is the inclusion of aquatic fauna in the bi-annual indicator report. Water recession patterns determine how potential prey are provided in high-quality patches at water depths that allow birds to feed efficiently at key times in the nesting cycle. The trophic hypothesis proposes that the abundance of potential prey is a necessary antecedent to making prey available, but alone is not sufficient to assure abundant prey needed to sustain nesting. It is possible that the increased frequency of drying in SRS and TSL makes prey more available in the short term, while simultaneously depleting the store of prey region-wide and in subsequent years. Under such a scenario, wading bird consumption of prey resources could outpace the rate of prey replenishment. Wet-season prey biomass contributes to, but does not alone explain, the formation of high-quality prey patches. However, low prey abundance may hamper the formation of high-quality dry-season prey patches. At present we may only hypothesize that multi-decadal, slow declines in prey biomass will adversely affect dry-season prey availability. Continued monitoring of prey biomass in sloughs and in drying pools where birds forage is warranted to better understand the implications for these long-term trends.

The long-term trends reported here are consistent with bi-annual stoplight report-card assessments indicating annual patterns of lower density of species used as performance measures for Everglades restoration. The general trend for yellow and red stoplights in Shark River Slough and Taylor Slough are indicative of long-term trends with marked cumulative impacts. Several major construction projects may soon yield hydrological benefits. Construction of bridges and increased upstream connectivity of the Shark River Slough and L-29 canal seeks to lengthen hydroperiods in the northeastern region of the Slough. Construction of hydrological barriers along the eastern boundary of Everglades National Park, and other amenities of the C-111 Basin project, seek to improve hydrology in Taylor Slough and the eastern Panhandle region of Everglades National Park. The benefits of these efforts should be seen in the next several years of monitoring data.

Non-native Fishes

Non-native fish persist below 2% of the fish fauna, on average, at our long-term monitoring sites used for this report (Figure 9, A-C). However, the distribution and abundance of these fishes are changing and it is possible that some of the long-term sites will pass this benchmark in the next biannual report. Also, areas within the Everglades, but near the edges, and not included in this assessment protocol, are showing marked non-native invasions with no physical barriers to stop expansion into the core wetlands of the ecosystem. The Panhandle Region of Everglades National Park is an example of this (Figure 9, PHD region). A number of authors have suggested that periodic cold weather events and frequent drying have kept invasive fishes from making apparent impacts on the native fauna (e.g., Trexler et al. 2000). This limitation may be relaxing with continued introduction of species, either because of selection favor cold-hardy species or genotypes within species or because of multi-species impacts (so-called invasional meltdown, e.g., Simberloff 2006).

We have always focused on the relative abundance of non-native fishes in making assessments as an indicator of their likely impact in the absence of direct evidence. To date, few data analyses from freshwater wetlands have indicated correlated responses between native species and non-native fishes (but see Kobza et al. 2004; Harrison et al. 2013). However, a number of studies have demonstrated the potential for marked impacts by predatory invasive species that have yet to reach high densities in the majority of the freshwater wetlands (e.g., jewelfish in Schofield et al. 2014).

Non-native fishes continue to be most abundant at the ecotone of the mangrove zone and the freshwater Everglades in Taylor Slough and Shark River Slough, Everglades National Park. Mayan cichlids remain the most common non-native species there (Figure 10). However, jewelfish have increased in frequency in data collected during the 2013 and 2014 water years, particularly in Shark River Slough (Figure 10). The jewelfish has been expanding its range in the Everglades since 2000; by 2002 it was commonly collected along the eastern border of the Park (Kline et al 2014). Short-hydroperiod habitats along the eastern border of Everglades National Park, called the Rocky Glades, has been home to elevated frequency of non-native fishes for some time (Trexler et al. 2001; Kobza et al. 2004). However, jewelfish has become the dominant non-native fish in that region (Kline et al. 2014) and has been shown to have potential to create impacts on native fauna (Rehage et al. 2009; Dunlop-Hayden and Rehage 2011; Schofield et al. 2014).

We have illustrated the changing patterns of non-native fish density in Shark River Slough with data from the Northeast Shark River Slough study site (Site 23: see map Figure 2 this report). The density of all fish there has been declining gradually since 2002 (Figure 11, top panel) and the density of non-native species has displayed four small peaks since 2000 (Figure 11 middle panel: 2004; 2006-7; 2009; 2012-13). Non-native fish exceeded 2% of the fish collected at this site for at least two consecutive sampling events three times (Figure 11 C: 2004, 2006-7, and 2012-13). The

Fish & Macroinvertebrates Indicator (WCA3 and ENP only)

most recent time was the most persistent, with 7 sampling events in two water years (2012-13) exceeding this arbitrary benchmark. Mayan cichlids accounted for the peaks prior to 2012, but the most recent (and persistent) peak has been from jewelfish.

These results illustrate why non-native fishes have been consistently assigned a yellow light in the stoplight indicator reports, including this one. A yellow for non-native fishes indicates that non-native species are present in a region, but less than 2% of the total fish catch. This level is an arbitrary benchmark set because more impact-based metrics are not currently possible for monitoring at the landscape scale. It is possible that both Taylor Slough and Shark River Slough will cross the 2% benchmark in coming assessments. More work is needed to develop a causal understanding of the ecology of these non-native species to better interpret their impacts. Are non-native fishes creating an imbalance in the fauna of the Everglades by disrupting ecological processes that maintain key functions of the ecosystem, or are they simply supplementing existing communities and possibly adding biomass to a naturally disturbed ecosystem? Ultimately a value-based assessment may be required to size up the impacts of non-native fishes.

We have incorporated the value of preserving the native aquatic-community structure of Everglades ecosystems in our assessment by coding regions as yellow when non-native fishes are detected. However, an ecosystem function-based value system may lead to a more universally agreed upon negative assessment; we are not yet able to make such an assessment based on data.

Recent restoration efforts have sought to increase connectivity and sheet flow into the Everglades National Park. These benefits may have unintentional consequences for invasion on non-native aquatic species. Expansion of jewelfish from the eastern edge of Everglades National Park, and invasion of swamp eels to the Panhandle region at the C-111 canal interface, may illustrate these consequences (discussed in Kline et al. 2014). Ongoing efforts at restoration and operation of new and coming restoration projects suggest that future biannual assessments will document some red stoplights for the non-native fish performance measure.

Literature cited, reports, and publications for more information

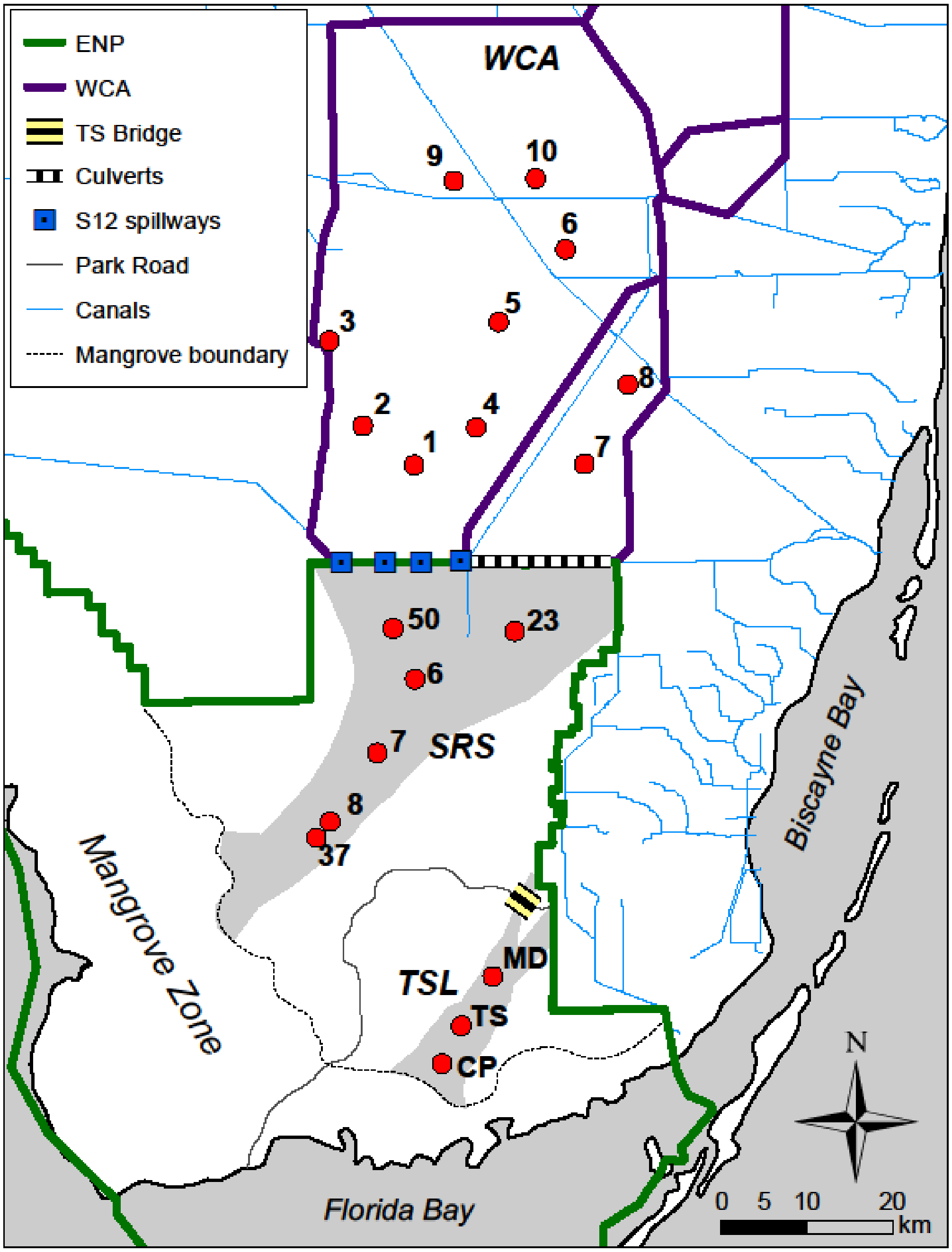


Figure 2. Map of study sites showing management structures (S12 spillways, culverts, and the Taylor Slough Bridge). Approximate boundaries of the Shark River Slough (SRS) and Taylor Slough (TSL) are shown in gray.

Fish & Macroinvertebrates Indicator (WCA3 and ENP only)

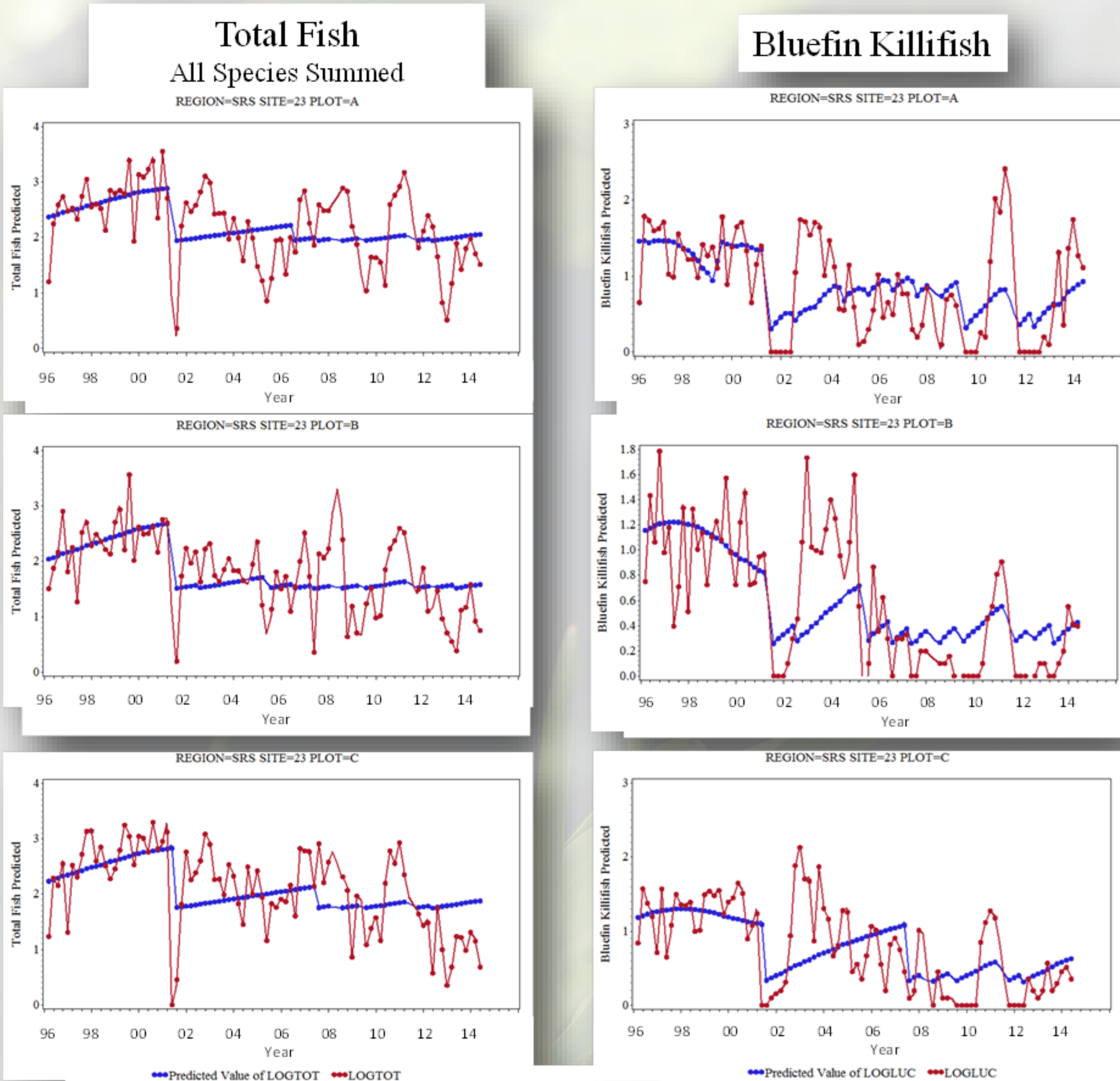
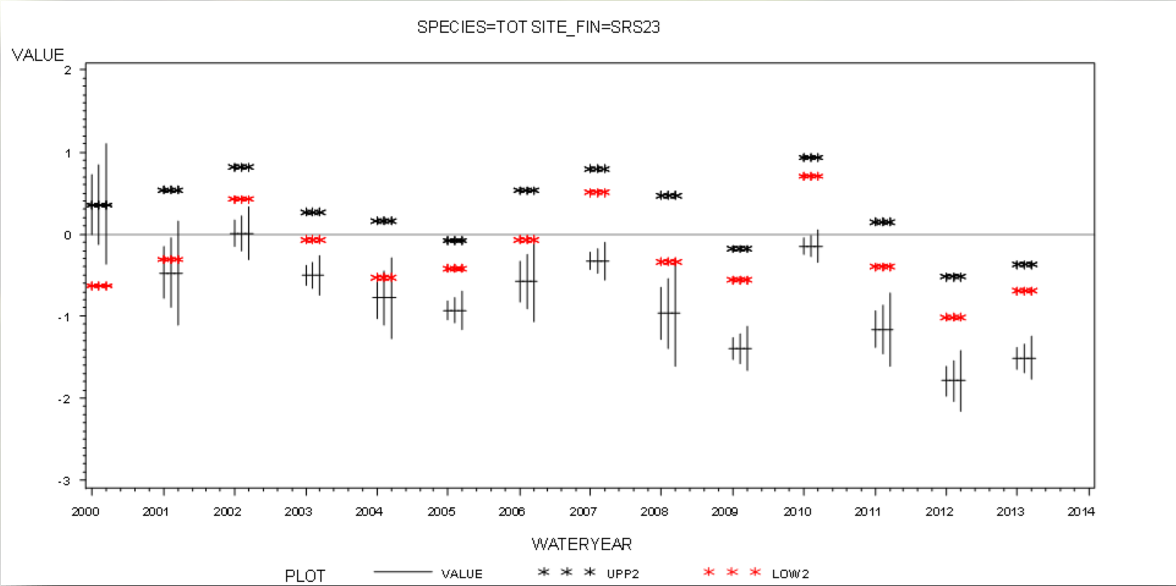


Figure 3. Plots of observed plot means (red) and target predicted values from three plots (A, B, and C) from our Northeast Shark River Slough monitoring site (Region = SRS, Site = 23). Data for all fish summed (total fish) are reported in the left column, and for bluefin killifish are in the right column. Data begin in July, 1996 (96) and continue with five samples per water year. Year 00 is July 2000. All data are the natural log of density of fish (ln(#/m2)). Note that a simple linear model (PM = intercept + Days Since Last Dry) best fit the Total Fish PM, while a polynomial model (PM = intercept + Days Since Last Dry + Days Since Last Dry 2) best fit bluefin killifish.



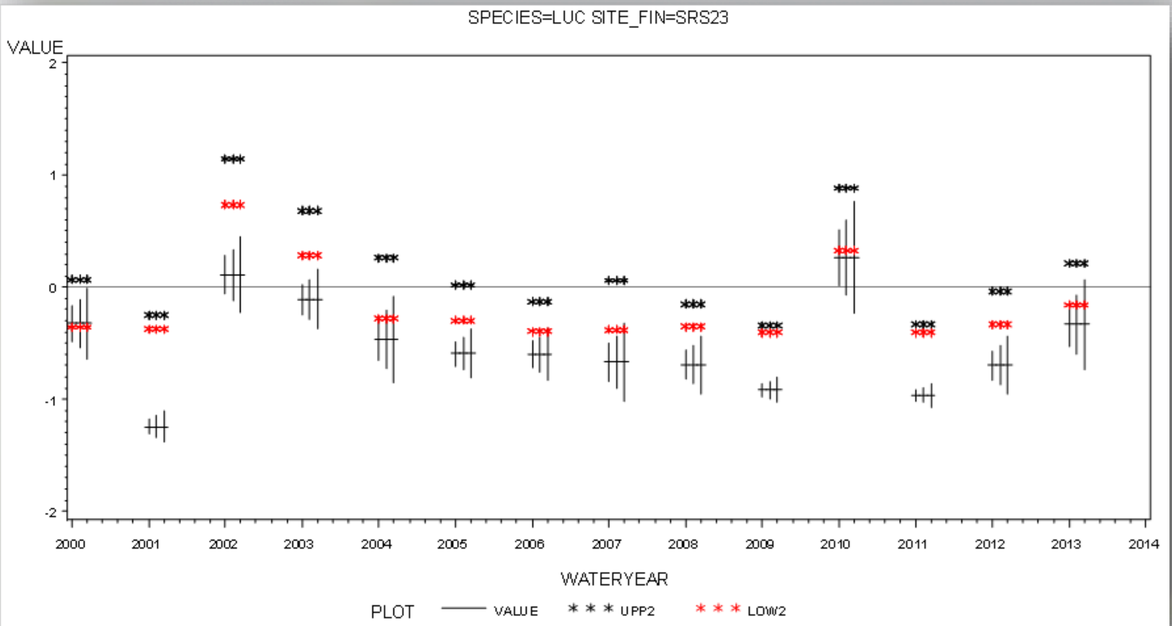


Figure 4. Example of site-level assessment for two PMs, Total Fish (top) and Bluefin Killifish (bottom). Plots report model confidence intervals (asterisks upper [black] and lower [red] bounds) and mean deviation of observed data from model predictions (hash marks: horizontal line is mean, vertical lines are +/- 1.5, 2, and 3 standard errors). Stoplights are assigned based on the amount of overlap of the vertical hash marks and the model confidence interval. Ideally, model confidence intervals would span the zero line on the graph, however, even good models may be biased in given years (tend to over or under predict data). Use of these confidence intervals adjusts for these systematic deviations and empirical aspects of model uncertainty. Note that the graph is labeled by calendar year (year at the start of each assessment period), rather than water year (year at the end of an assessment period).

Fish & Macroinvertebrates Indicator (WCA3 and ENP only)

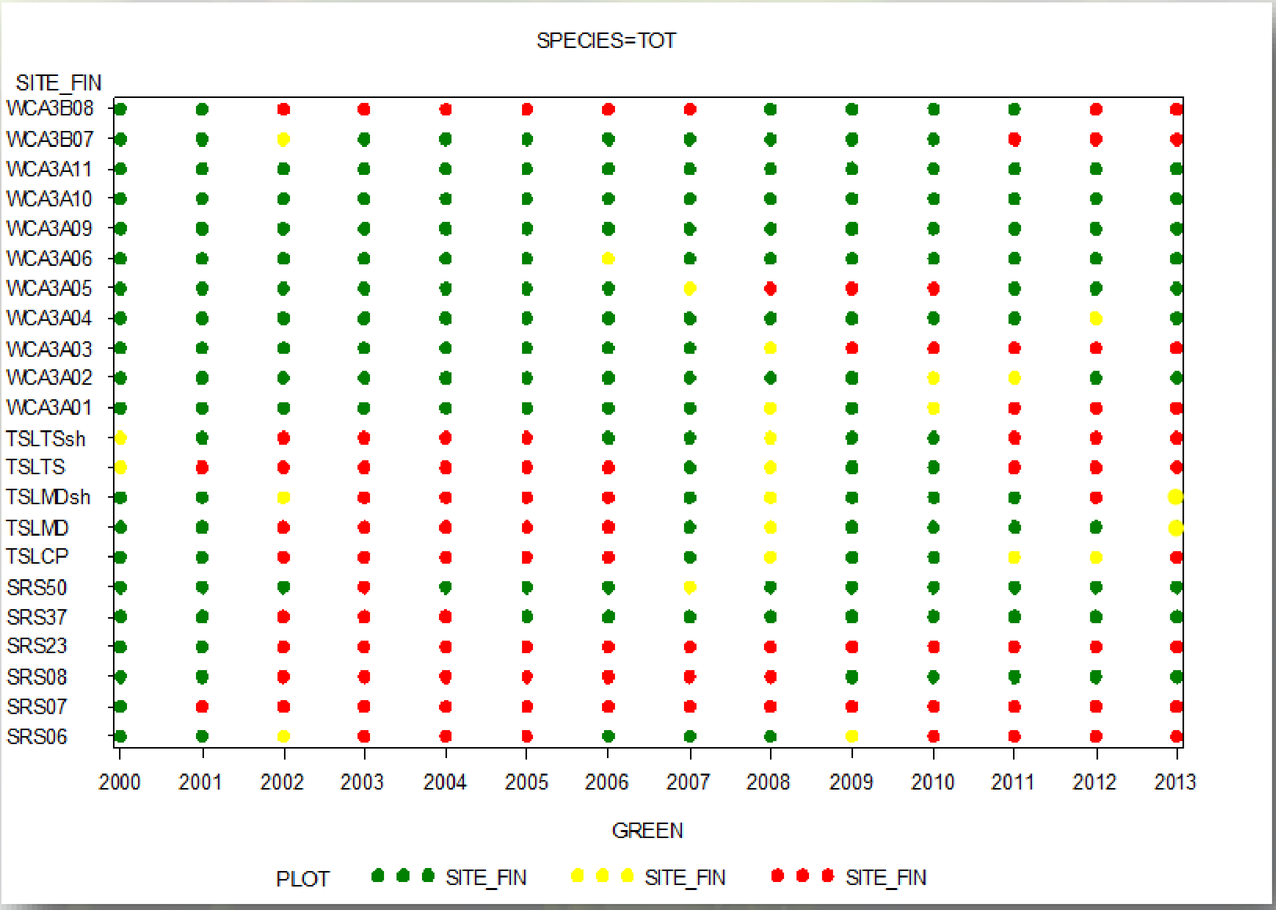


Figure 5. Example of the aggregation process used to produce stoplights for the Total Fish PM. The top panel illustrates results for each site for the 2014 water year (the graph is labeled by calendar year [year at the start of each assessment period], rather than water year [year at the end of an assessment period]). See text and Figure 3 for details on this type of graph. The lower panel illustrates the stoplights for each site by year. These results were aggregated by region to produce the overall assessment.

Fish & Macroinvertebrates Indicator (WCA3 and ENP only)

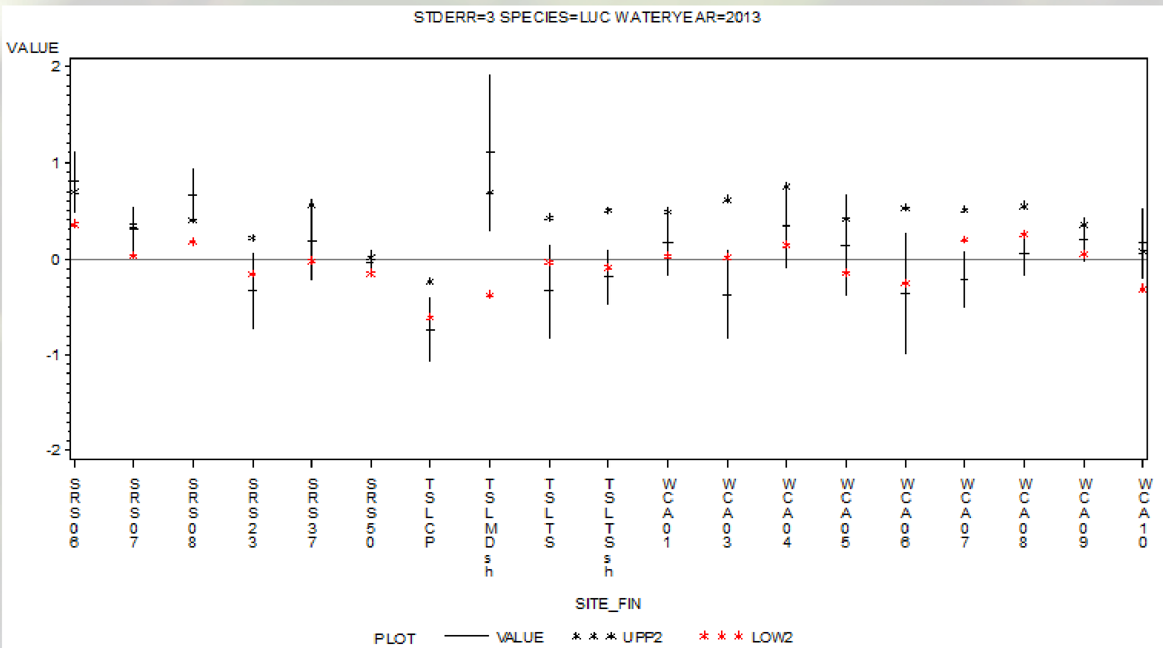


Figure 6. Example of the aggregation process used to produce stoplights for the Bluefin Killifish PM. The top panel illustrates results for each site for the 2014 water year (the graph is labeled by calendar year [year at the start of each assessment period], rather than water year [year at the end of an assessment period]). See text and Figure 3 for details on this type of graph. The lower panel illustrates the stoplights for each site by year. These results were aggregated by region to produce the overall assessment.

Fish & Macroinvertebrates Indicator (WCA3 and ENP only)

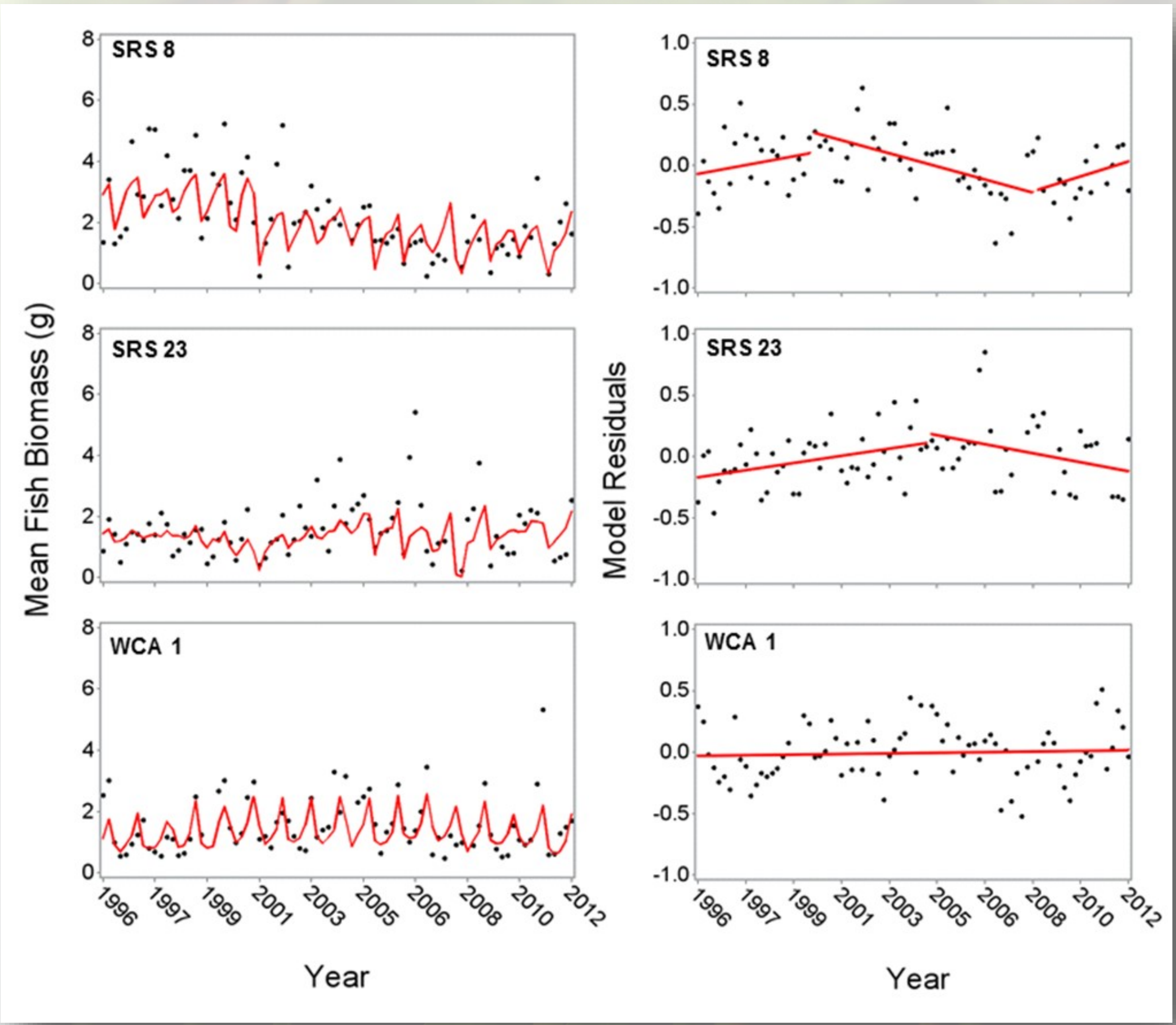


Figure 7. Fish biomass time series from February 1996 - April 2012 for three example monitoring sites. Column 1: Observed values (black dots) and model predicted values (red line) of total fish biomass (g/m²) for Shark River Slough sites 8 & 23 (NESS) and WCA 3A Site 1. Predicted function is from the full model including all hydrologic variables. Column 2: Fish biomass model residuals (black dots) and piecewise regression functions (red lines) fit to unexplained variation in each time series. SRS 8 and 23 are in different spatial areas of SRS where hydrologic conditions were modified during the time series. WCA 1 is north of the Tamiami Trail where hydrological conditions have remained relatively stable.

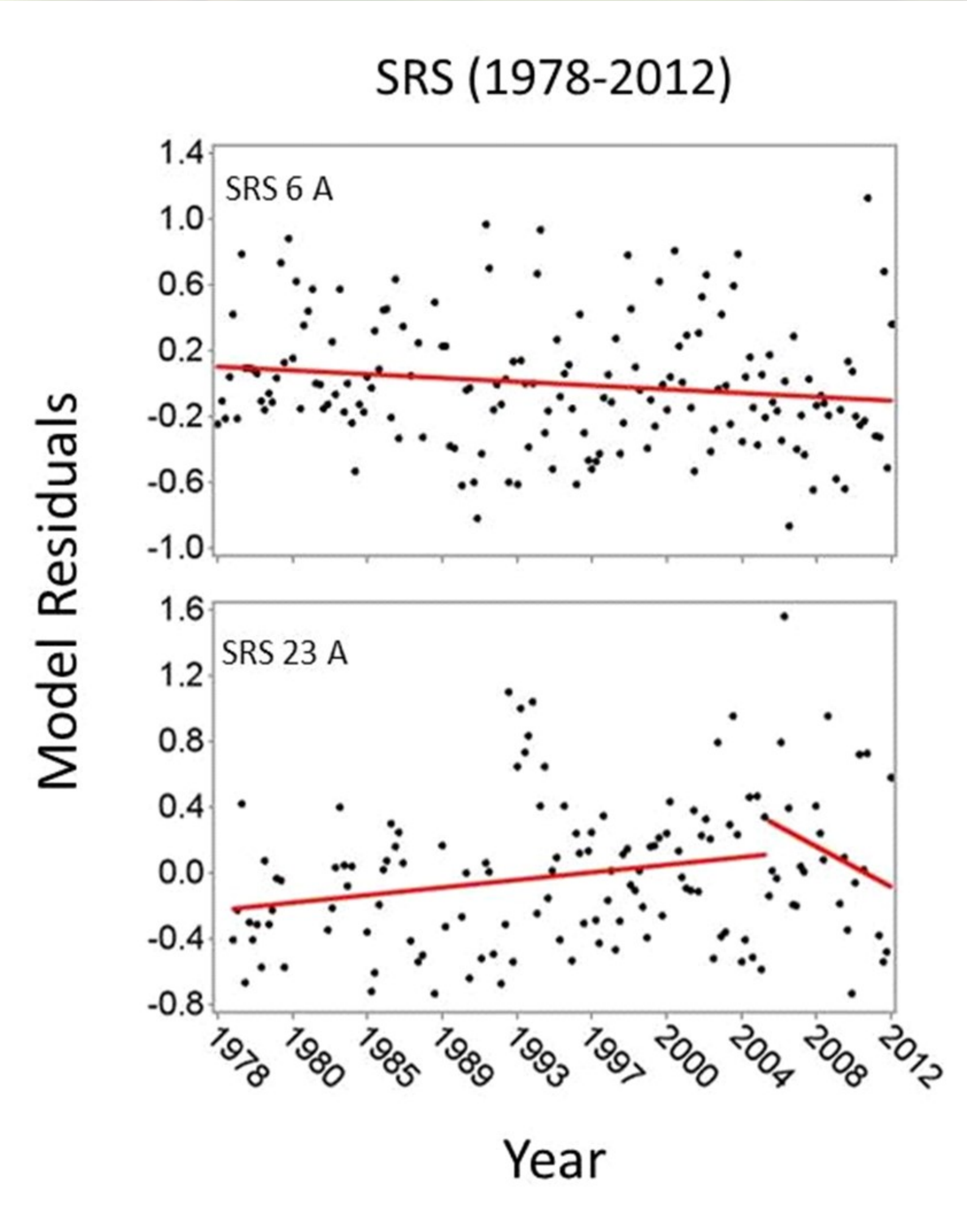


Figure 8. Fish biomass model residuals (black dots) and piecewise regression functions (red line) fit across the time series (1978 – 2012) for SRS sites.

Fish & Macroinvertebrates Indicator (WCA3 and ENP only)

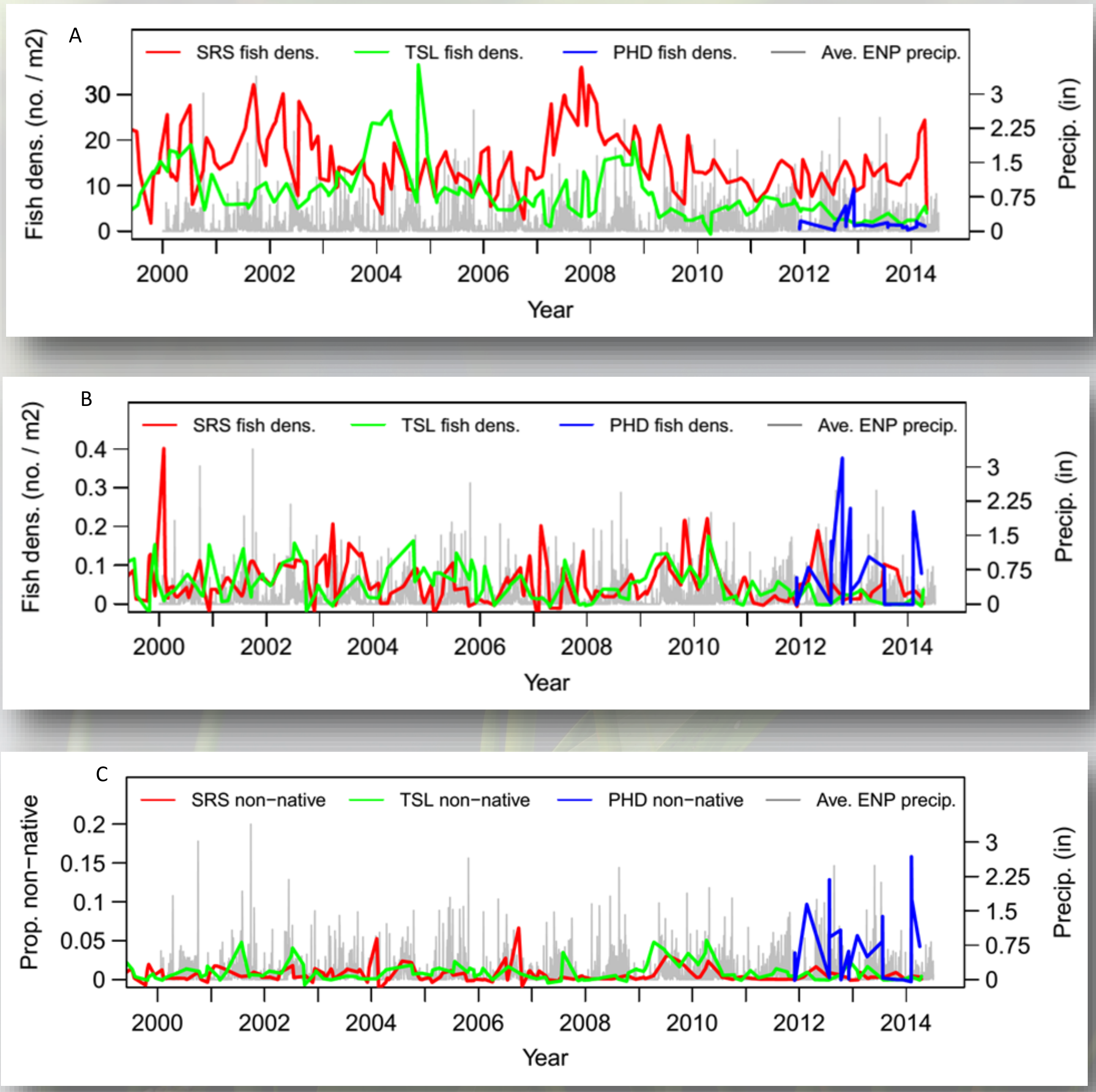


Figure 9. Time series of total (A) and invasive (B) fish densities in the SRS, TSL, and PHD regions of ENP. Proportion of total fish density represented by non-native species is reported in (C).

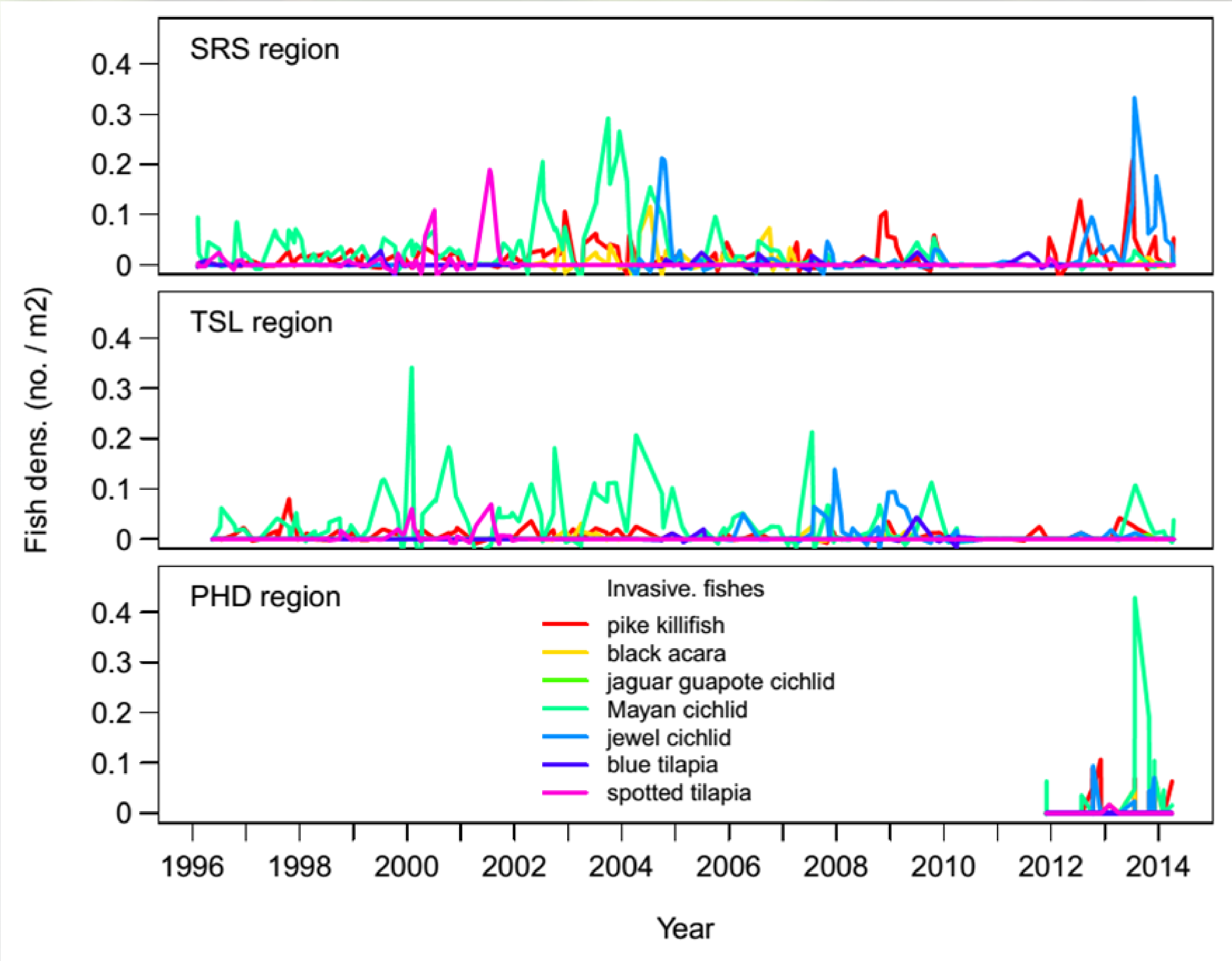


Figure 10. Temporal trends in densities of non-native fish species in the SRS, TSL, and PHD regions of ENP.

Fish & Macroinvertebrates Indicator (WCA3 and ENP only)

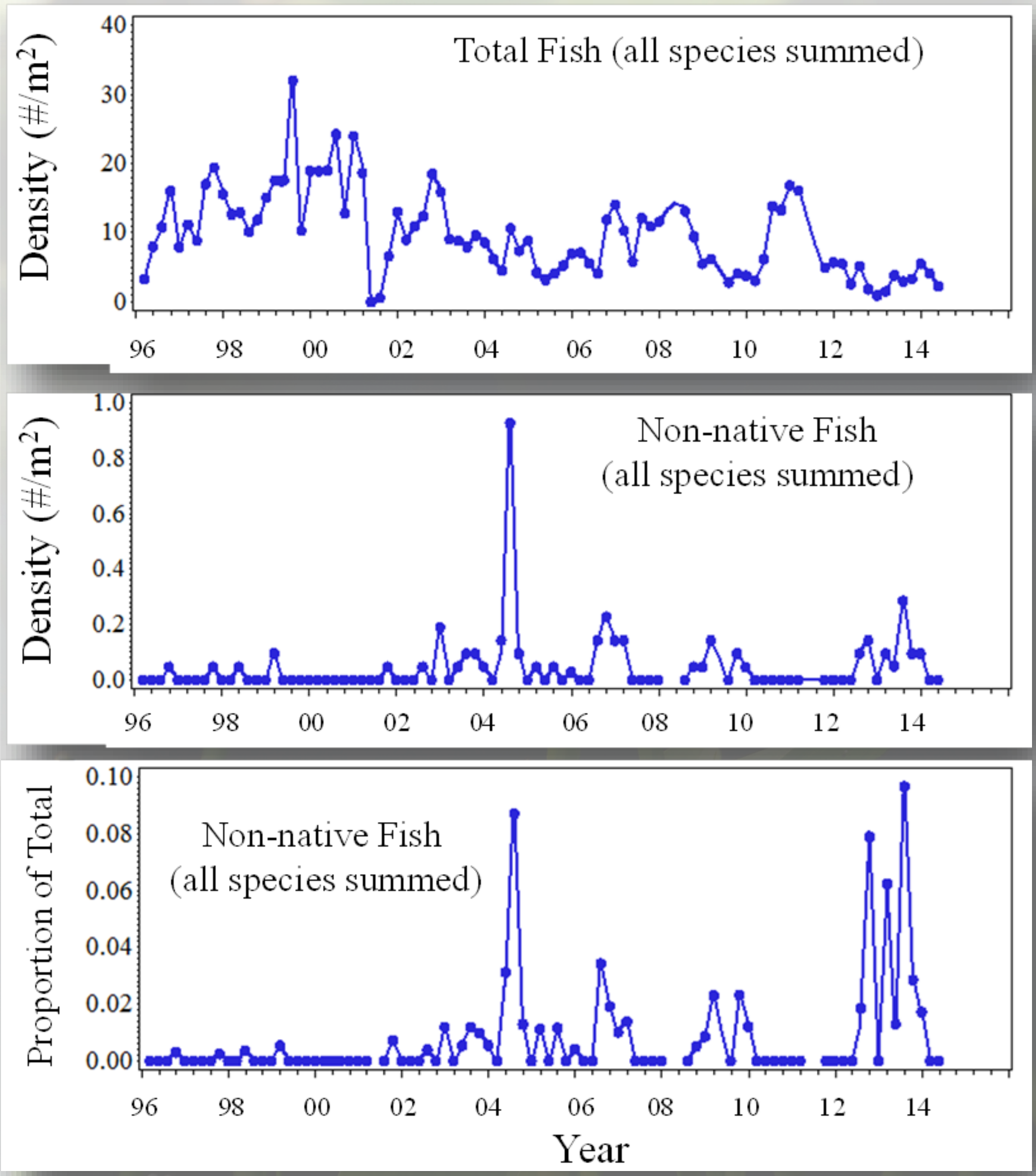


Figure 11. Time series of non-native fishes in northeast Everglades National Park (site 23). All data are from throw-trap samples. Peaks in years before 2012 are from Mayan cichlids; peaks in 2012-2014 are primary from jewelfish.

Fish & Macroinvertebrates Indicator (WCA3 and ENP only)

Table 1. Mean fish biomass (g/m²) in 1996 and 2012, difference, and percent change reported for each site.

Region	Site	1996	2012	Total Change	% Change
SRS	6	1.88	1.54	-0.34	-18.05
SRS	7	2.02	1.97	-0.05	-2.37
SRS	8	2.01	1.76	-0.25	-12.48
SRS	23	1.26	1.39	0.13	10.21
SRS	37	4.14	3.21	-0.93	-22.52
SRS	50	0.87	0.77	-0.10	-11.83
TSL	CP	0.95	0.82	-0.13	-13.29
TSL	MD	1.71	1.63	-0.08	-4.61
TSL	TS	1.19	1.00	-0.19	-15.77
WCA	1	1.30	1.35	0.05	3.48
WCA	2	1.81	1.59	-0.23	-12.48
WCA	3	2.03	1.60	-0.43	-21.11
WCA	4	1.46	1.47	0.01	0.68
WCA	5	2.11	2.06	-0.05	-2.20
WCA	6	1.35	1.48	0.12	9.02
WCA	7	2.10	1.93	-0.17	-8.04
WCA	8	1.96	1.50	-0.46	-23.47
WCA	9	2.54	1.77	-0.77	-30.44
WCA	10	2.46	1.30	-1.16	-47.26

Periphyton Indicator (Modified No Composition)

SUMMARY FINDING

WY 2014 showed improvements in periphyton quality (total phosphorus -TP) values relative to prior years. Problem locations were clustered near the L-67 extension canal in Shark River Slough (SRS), the central WCA 3A flowpath and near-canal boundaries of WCA 1 and 2A. Several enriched values near the oligohaline ecotone are thought to be caused by marine sources of phosphorus. An early onset of the 2014 wet season may have resulted in an earlier flushing of P into the system that was not captured by our late wet season sampling. Periphyton abundance was also higher throughout the system, with only 3-4% of sites showing altered or cautionary conditions. An improved indication of water quality problems provided by species composition data was not possible again in WY 2014.

Periphyton quality and biomass values showed improvements in WY 2014 relative to previous years even though water flow into the system (and, consequentially, phosphorus (P) loading) was greater. A total of 6% of sites showed altered quality in WY2014, compared to 21% in WY2013 and 15% over the 9-year record. Over the duration of record, there is a strong correlation between annual indicator values and P loads delivered through canal input structures. The high correlation between inflow concentration and condition status across each wetland is surprising, since it includes locations well to the interior. 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. Analysis at the PSU level may resolve interpretation of sources for impairment.

Only 6% of sites suggested a cautionary status in WY2014, compared to 20% in WY2013 and 12% over the 9-year record. These sites were clustered near canal boundaries and in the oligohaline ecotone that receives a natural marine source of P. A much greater number of sites (44%) indicated cautionary or altered biomass in WY 2014, which was similar to the average across years of 43%, primarily due to lagged response of biomass to prolonged P enrichment near canal boundaries and due to higher water depths in central WCA 3A. The 3-year exclusion of species -based analysis precluded accurate assessment of water quality concerns, particularly in water conservation areas where the species stoplight is most sensitive. Improvements indicated in WY 2014 may have resulted from the very early onset to the 2014 wet season. Typically nutrients oxidized in surface sediments during the dry season are flushed into the system during the first wet season rains, which are often captured in our wet season sampling. Restoration planning should take into account timing of water movement through the system as it will influence phosphorus concentrations and loads and periphyton quality. Importantly, flow restoration may also reduce phosphorus enrichment associated with sea level rise along the ecotone which has persistently been observed throughout the period of record.

Periphyton Indicator (Modified No Composition)

	2006	2007	2008	2009	2010	2011	2012	2013	2014
SYSTEM-WIDE									
Quality (TP)	Y	Y	G	Y	G	G	Y	Y	G
Biomass	Y	Y	Y	Y	Y	Y	Y	Y	Y
Composition	R	Y	Y	Y	Y	Y	N	N	N
WCA 1									
Quality (TP)	Y	G	G	Y	G	G	Y	Y	G
Biomass	G	G	G	G	G	G	G	G	G
Composition	R	Y	Y	Y	Y	Y	N	N	N
WCA 2A									
Quality (TP)	Y	Y	Y	G	G	Y	Y	Y	G
Biomass	R	Y	Y	Y	Y	Y	Y	Y	G
Composition	R	R	R	Y	Y	Y	N	N	N
WCA 3A									
Quality (TP)	Y	Y	Y	Y	G	G	Y	Y	G
Biomass	Y	Y	Y	Y	Y	Y	R	Y	Y
Composition	R	G	Y	Y	Y	Y	N	N	N
SRS									
Quality (TP)	Y	Y	G	Y	G	G	G	Y	G
Biomass	Y	Y	Y	Y	Y	Y	Y	Y	Y
Composition	Y	G	Y	Y	G	Y	N	N	N
TS									
Quality (TP)	G	Y	G	G	G	G	G	G	Y
Biomass	G	G	Y	G	G	G	G	Y	G
Composition	Y	G	G	G	Y	Y	N	N	N

Periphyton Indicator (Modified No Composition)

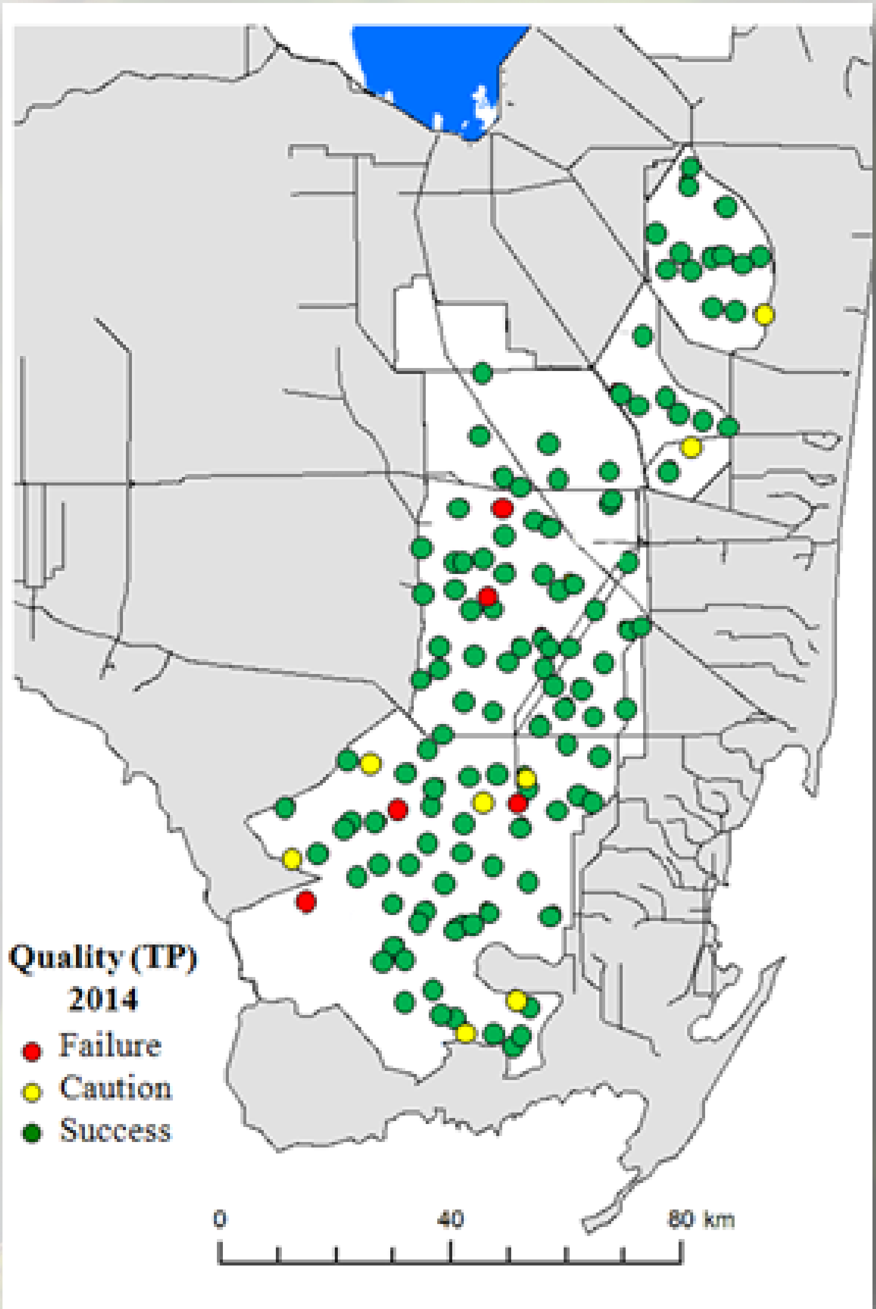


Figure 1. Stoplight colors for periphyton sampling sites for WY2014.

Periphyton Indicator (Modified No Composition)

Updates on calculation of indicator

Now that almost a decade of data are available from the periphyton mapping program, a sophisticated analysis was conducted to compare the utility of the quality, biomass and composition metrics and determine relationships to P loading from boundary canals (Gaiser et al. In Press). The analysis suggested refined cutoffs for quality and biomass metrics that were applied to the current stoplight report. For periphyton quality (in µg TP g-1), cutoffs for baseline and cautionary status are now <540 and 650 (WCA 1), <220 and 270 (SRS and WCA 2A), <170 and 230 (TS) and <300 and 400 (WCA 3). For periphyton biomass (in g ash-free dry mass m-2), cutoffs for baseline and cautionary status are now <10 and 20 (WCA 1), >50 and 0 (SRS and WCA 2A), >120 and 0 (TS) and 25 and 0 (WCA 3). The ratio of weedy to native diatoms was shown to be the most sensitive metric to changes in TP concentration exposure. The species compositional metric, dropped in WY 2012, improves detection of water quality improvement or impairment more than 20%. Wet season compositional values for the 6 years of record are highly correlated with flow-weighted mean TP concentrations at inflow structures. The compositional metric was also the key meaningful metric in an analysis of edibility for key aquatic prey species (Trexler et al. In Press). More details are included in a case study in the biennial report. These data and findings were also reported in the 2014 System Status Report (Section 3 B) and are being used to support models for synthesis efforts.

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 generally show greater impairment than dry years. In addition, absence of species data from WY 2012-2014 suggest ~20% are being misinterpreted.

[Literature cited, reports, and publications for more information]

Wading Birds (Wood Stork & White Ibis) Indicator

SUMMARY/ KEY FINDINGS

Conditions for nesting were generally poor for wading birds in 2013 with wet conditions preceding the nesting season and frequently interrupted drying trends during the nesting season. Numbers of nest starts were mediocre and nest success was among the lowest seen in the last ten years, and abandonments were common particularly at colonies of Wood Storks. The 2014 nesting season was preceded by favorably long hydroperiods and high stages. However, nest initiations and nest success were negatively affected by a strong reversal in February throughout the system. Late season nesters (ibises and small herons) fared relatively well, but early season nesters (storks and great egrets) had poor success. All wading bird indicators showed little change in trend or degree in 2013 and 2014. Although one indicator (ibis super colony nesting) now routinely exceeds the target, the other three seem stuck in a stable area and remain numerically distant. Although proportion of nesting that occurs in the coastal zone has improved in recent years, (14 – 21%), it remains far from the 70% typical of the predrainage period. Nonetheless, storks seem committed to an increased tendency to nest in the coastal zone. The ratio of tactile foragers (storks and ibises) to sight foragers (Great Egrets) has shifted little in the past five years and is very far from the 30:1 ratio typical of predrainage colonies. Finally, during the last two years, storks have not initiated nesting until early March, some of the latest initiations on record. This practically guarantees that stork reproduction will continue into the wet season, when foraging opportunities disappear with rising water, and nests are routinely abandoned.

During the last two years, we have seen marginally earlier nesting (late January) by storks, with an overall trend that is fairly stable over the past 7 years. Little progress is being made in this indicator, with no years in which early January or December nesting's have occurred, and the indicator is not approaching the target of nesting dates earlier than December 30th. This trend does not meet the restoration target.

The proportion of nesting birds occurring in the headwaters/ecotone in 2013 and 2014 was 19.8% and 17.6%, respectively, and the 5-year running average for this measure now stands at 21.9%. This measure does show promise, with a markedly upward trend over the past ten years, suggesting that the coastal ecosystem has better carrying capacity. However, the goal of 70% or greater of the birds nesting in the coastal zone remains distant and there has been no progress in the last four years towards this restoration target.

The 5 year running average ratio of ibis+stork nests to Great Egret nests in 2013 and 2014 (2.6, 2.5 respectively) is still far below the 30:1 characteristic of predrainage conditions. In addition, there has been no upward trend over the last ten years in this measure.

In 2013 the frequency of large ibis nesting events criterion was met, but was not met in 2014. However, because this indicator is measured as an interval, it is only meaningful as expressed over a multi-year period. More generally, the frequency of exceptionally large ibis nesting events has improved dramatically since the late 1990s, and the mean interval between these events has changed from over 40 years to less than three in most recent years. The 5-year running average remains at 1.4 years, a considerable improvement and well within the restoration target of 1.45 years. This indicator of restored conditions therefore appears to have been met for every one of the last nine years.

With the exception of large ibis nesting's, trends for wading bird indicators are stable (proportion in headwaters, ratio of tactile to nontactile feeders, timing of stork initiation). This suggests that progress in the wading bird indicators has stalled, and that little functional progress has been made in restoration of these indicators in the last five years.

Literature cited, reports, and publications for more information

Wading Birds (Wood Stork & White Ibis) Indicator

	WY 2008	WY 2009	WY 2010	WY 2011	WY 2012	WY 2013	WY 2014
Wading Bird Indicator Summary	R	R	R	R	R	R	R
Ratio of Wood Stork + White Ibis nests to Great Egret nests	R	R	R	R	R	R	R
Month of Wood Stork nest initiation	R	Y	R	R	R	R	R
Proportion of nesting in headwaters	R	R	Y	Y	Y	R	R
Mean interval between exceptional Ibis nesting years	G	G	G	G	G	G	G

How have these data been used?

Wading bird nesting information is used in real-time to help guide operations on a weekly basis during the nesting season. In addition, the projects comprising wading bird monitoring contribute to the annual Wading Bird Nesting Report (widely read by managers, the public, and used by the media), and sections on wading bird nesting and contamination are a regular feature of the annual SFER and System Status Reports.

New insights relevant to future restoration decisions

Past field data have been used to develop models relating hydropattern to fish density and availability, and now to nesting effort and success. The annual reproductive information is now being used to validate forecasting by these models, with surprising success being shown. These modeling tools have also been used to forecast the likely effects of restoration scenarios of CEPP. The existence of an annual monitoring program allows 1) annual refinement of model results under different conditions, and 2) an ability to detect departures from predicted responses to large modifications to the system. The partnership of modeling and validation is proving extremely useful in furthering understanding about the hydrology-fish-bird reproduction system, and in reducing uncertainty about responses to specific components of CERP and CEPP.

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

SUMMARY FINDING

The status of Phytoplankton Blooms throughout the majority of the Southern Coastal System (an indicator of water quality) remained consistently above the baseline from water years 2012 through 2014. The slightly elevated yellow status of phytoplankton blooms in the areas of the SCS outside of Biscayne Bay (Florida Bay and the southwest Florida coastal zone) is likely a function of increased rainfall and runoff in these regions and not a cause for concern. Florida Bay, in particular, has phytoplankton blooms that are either decreasing or remaining steady suggesting that water quality is not degrading. However, these findings are confounded by the fact that Florida Bay experienced a widespread, ecologically damaging phytoplankton bloom in the mid-1990s (Butler et al. 1995), which is the beginning years for the time period used to investigate trends. While all sub-regions had degraded water quality relative to baseline conditions, only Biscayne Bay experienced a widespread, unprecedented phytoplankton bloom during the summer of WY2014. This bloom resulted in all sub-regions of Biscayne Bay having an undesirable, red status for WY2014. Moreover, there is a significant increasing trend in phytoplankton blooms in Biscayne Bay, as well as on the west coast of the Everglades indicating that water quality has been steadily degrading in these areas over the past 20 years.

It should be a top priority to investigate the underlying causes of the increased phytoplankton blooms in Biscayne Bay. There was an unprecedented phytoplankton bloom in Biscayne Bay in WY2014 causing all sub-regions to receive a red score and there are significant linear increases in phytoplankton throughout Biscayne Bay over the past 20 years. Moreover, there is an increase 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 likely necessary to improve water quality and return phytoplankton blooms in this area to their baseline conditions.

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 no 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.

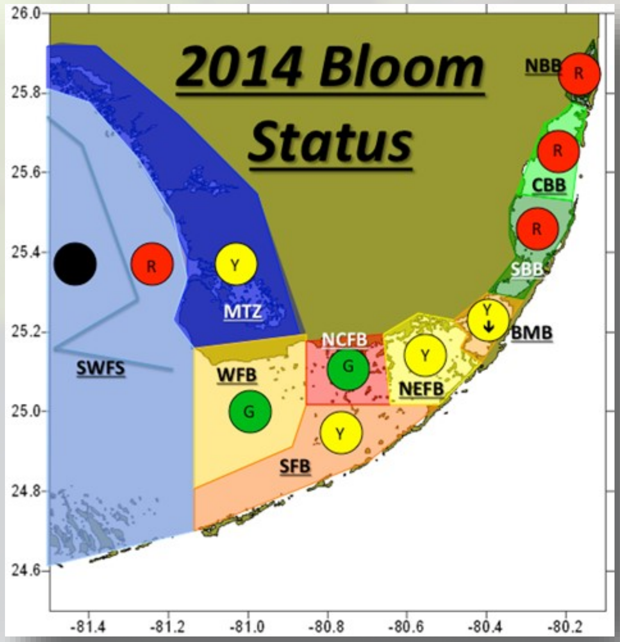


Figure 1. Stoplight colors for phytoplankton bloom indicator by subregion for WY2014. Trend arrows indicate significant 5-year trends of degrading () or improving () water quality in that sub-region.

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 WY14. 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 (Briceno et al. 2009).

Other uses of this Indicator:

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.

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

CHLOROPHYLL A INDICATOR	WY 2005	WY 2006	WY 2007	WY 2008	WY 2009	WY 2010	WY 2011	WY 2012	WY 2013	WY 2014
System-wide	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Southwest Florida Shelf (SWFS)	Y	Y	G	G	Y	Y	Y	R	B	R
Mangrove Transition Zone (MTZ)	G	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)	G	R	R	R	G	Y	Y	Y	Y	Y
North-Central Florida Bay (NCFB)	G	Y	Y	G	G	G	G	G	Y	G
Northeast Florida Bay (NEFB)	Y	Y	Y	G	G	G	Y	Y	Y	Y
Barnes, Manatee, & Blackwater Sounds (BMB)	G	R	R	R	G	G	Y	Y	Y	Y
South Biscayne Bay (SBB)	Y	R	R	Y	Y	Y	R	Y	Y	R
Central Biscayne Bay (CBB)	Y	R	Y	Y	Y	Y	Y	Y	Y	R
North Biscayne Bay (NBB)	Y	Y	Y	Y	Y	Y	Y	Y	Y	R

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 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 decision 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.

Literature cited, reports, and publications

Florida Bay Submersed Aquatic Vegetation Indicator

Summary Finding

A baywide composite score of yellow (fair) summarizes the overall system status for Submersed Aquatic Vegetation (SAV) in Florida Bay for the WY13-14 period, unchanged from the previous period of WY11-12. The SAV Indicator for individual zones of the bay remained at good in the Northeast, Central and Western zones, and fair in the Southern zone for both years (Figure 1). The SAV Indicator for the Transition zone (the mangrove ecotone, embayments, creeks and lakes in the southern Everglades wetland) was fair in WY13 and improved to good in WY14 yielding an average two-year score of fair.

The overall SAV Indicator score combines underlying scores for the Abundance Index, which measures spatial coverage and density of SAV, and the Diversity Index, which measures species diversity and presence of desirable species. The Abundance Index was good in the Northeast zone, fair in the Transition, Central and Western zones and poor in the Southern zone for both WY13 and WY14 (Table 1). The score of fair in the Western zone represents a decline from good in 2012 for Abundance while all other zones were unchanged from 2012 for the Abundance Index. The spatial extent component of the Abundance Index expresses the proportion of bay bottom area covered by seagrass and it reflected good SAV cover all zones of the bay for WY13-14 (Figure 2). No significant die-off events occurred during the assessment period.

Despite good areal cover, the Abundance Index was reduced in some zones due to low density component scores reflecting sparseness of SAV in several areas (Figure 3). This included a reduction to fair in the Western zone in both WY13 and WY14, continuing fair in the Transition and Central zones and a continuing poor score in the Southern zone. Notably, density remained poor in Madeira Bay, Long Sound and Joe Bay in the Transition zone and Twin Key Basin in the Southern zone. Density dropped to fair in Rankin in the Central zone and remained fair in Rabbit in the Western zone. As a result, the rolled-up Abundance Index was good only in the Northeast zone, the others being fair or in the case of the Southern zone, poor.

The Diversity Index, which combines indicators for species dominance and presence of desirable target species, showed continued good status in the Northeast, Central and Western zones. The Transition zone Diversity Index continued at fair status in WY13 then improved to good in WY14, reflecting improvement from poor to fair species dominance (Figure 4) and recovery of SAV habitat leading to *Ruppia* expansion. Increased *Ruppia* was responsible for an improvement of the target species score from fair in WY12 to good in WY13 and WY14 (Figure 5). The Southern zone maintained its fair Diversity Index status through WY2013-2014, reflecting excessive dominance by *Thalassia* for a fair species dominance score of fair (Figure 4). Lack of community diversity yielded a continuing fair target there as well (Figure 5).

Florida Bay Submersed Aquatic Vegetation Indicator

	WY 2010	WY 2011	WY 2012	WY 2013	WY 2014
OVERALL	Y	Y	Y	Y	Y
NORTHEAST ZONE					
Abundance	G	G	G	G	G
Diversity	G	G	Y	G	G
TRANSITION ZONE					
Abundance	Y	Y	Y	Y	Y
Diversity	Y	Y	Y	Y	G
CENTRAL ZONE					
Abundance	Y	Y	Y	Y	Y
Diversity	G	G	G	G	G
SOUTHERN ZONE					
Abundance	R	R	R	R	R
Diversity	Y	Y	Y	Y	Y
WESTERN ZONE					
Abundance	G	G	G	Y	Y
Diversity	G	G	G	G	G

Florida Bay Submersed Aquatic Vegetation indicator

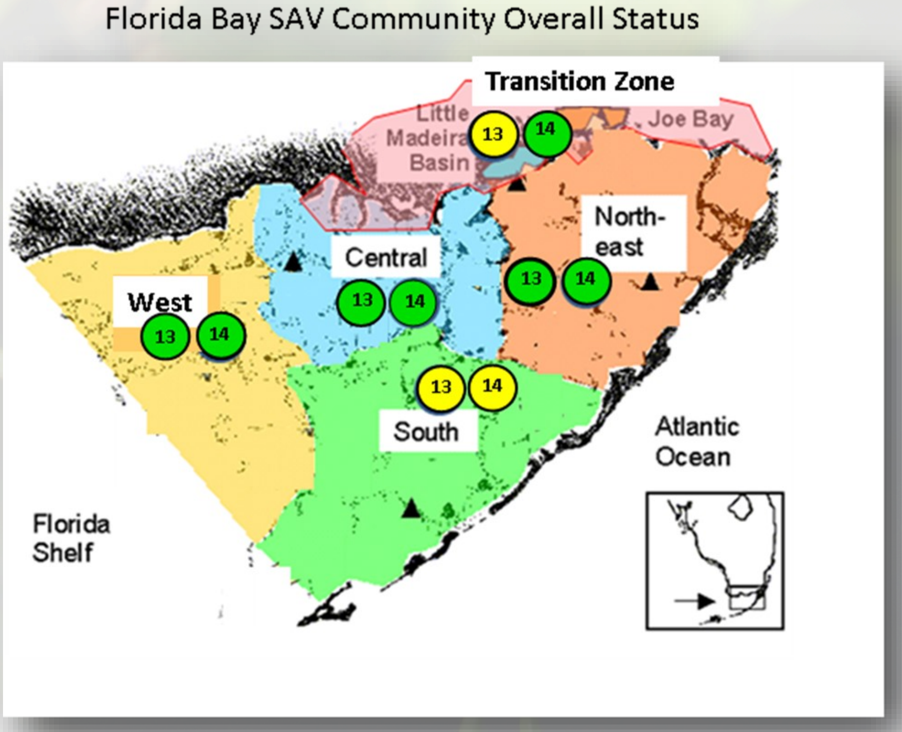


Figure 1. SAV Indicator scores for WY 13 and FY14 for each of five indicator zones in Florida Bay. Indicator stoplights combine Abundance and Diversity Indexes. All zones remain unchanged from 2012 except the Transition zone, which improved to good in 2014 from fair in 2013.

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 developed for this document. This change calls for the additional step of rolling up the annual scores from each two year reporting period for each sector 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. The rounding down step is based on the fact that managers want to 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.

Clarification and streamlining of official terminology is also made in this document. The rolled-up zone and baywide scores determine the SAV Indicator which is the highest level of the status hierarchy (previously called the “carrying capacity” index and Index C). The two Indexes that comprise the SAV Indicator occupy the next hierarchical level, herewith entitled the Abundance Index (unchanged, but sometimes previously 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 are used in a variety of ways: 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

Several insights have been gained from use of the indicators in terms of both how the system is functioning through time and of how the indicators should be interpreted. In general, the Florida Bay seagrass system has been in fair condition in recent years reflecting cause for concern in some areas as well as showing signs of improvement in some areas. There are longstanding deficits in SAV abundance in the Transition (fair), Central (fair) and especially the Southern (poor) zones and the Western zone has turned from good to fair in recent years. In contrast, diversity in the Northeast and Transition zones has improved from fair to good in the past one or two years and has a long history of good scores for diversity in the Western and Central zones. Only in the Southern zone has diversity remained problematic, with scores of fair for many years.

The underlying components of the indicator give some important clues as to conditions in the SAV community. Low abundance scores are almost entirely due to low density– the spatial extent scores are universally green indicating that SAV is persistent and ubiquitous in the bay. It is the density of beds that is driving the abundance score down in all cases, again most notably in the Southern zone. Examination of the range cutoffs for the stoplights shows that there are expectations for higher density in the Southern than in the other zones, a consequence of higher densities in the past. Only in the nutrient-poor Northeast zone are density targets consistently being met, but the threshold for a good score is the lowest in that zone.

Florida Bay Submersed Aquatic Vegetation indicator

On the diversity score, there has been modest improvement in nearly all zones in terms of species dominance. Within the past eight years, the Diversity Index component has moved from poor to fair and maintained fair status to date. The Western zone has already been at fair status throughout the history of the use of the indicator. Target species component scores have been at or improved to good status for all zones except the Southern, which improved from poor to fair several years ago and has maintained that status.

After nine years of analysis of SAV status via the indicator method, several patterns are emerging: it is clear that the spatial extent and target species goals are being met relatively easily in nearly all basins. The density and species dominance parameters are much more intransigent. However, species dominance gains (mostly indicating reductions in Thalassia monoculture and greater diversity) are being made slowly throughout the bay and now, for the first time, scores have improved to stand at fair for all zones. The density component of abundance has been mostly static for many years, though with a troubling backsliding to fair in the Western zone for WY2013 and WY2014.

Overall in Florida Bay, the SAV status has either remained steady or improved, notably with improvement in the Transition zone. Trends in the underlying components of the Northeast zone also have been positive, reflecting continued improvement since the mid-2000's when hurricanes and a prolonged algal bloom negatively impacted the SAV community. Although the Western zone remains in good overall condition, there are declines in some component scores that bear watching and improvement is required in the perennially fair status of the overall score in the Southern zone. It is expected that with continued improvements to hydrology via restoration, improvements in these parameters will occur in the near- or mid-term.

Literature cited, reports, and publications for more information

Florida Bay Submersed Aquatic Vegetation indicator

				Water Year								
Zone	Zone ID	Red-Ylw	Ylw-Grn	2006	2007	2008	2009	2010	2011	2012	2013	2014
Northeast	NE	0.4	0.65	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Transition	TR	0.4	0.6	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Central	C	0.6	0.75	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Southern	S	0.6	0.75	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Western	W	0.6	0.8	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢

Figure 2. Spatial Extent component of Abundance Index per zone of Florida Bay by Water Year; threshold values for poor, fair and good ranges are indicated.

				Water Year								
Zone	Zone ID	Red-Ylw	Ylw-Grn	2006	2007	2008	2009	2010	2011	2012	2013	2014
Northeast	NE	0.1	0.3	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Transition	TR	0.1	0.5	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡
Central	C	0.4	0.6	🔴	🔴	🟡	🟡	🟡	🟡	🟡	🟡	🟡
Southern	S	0.5	0.7	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴
Western	W	0.45	0.65	🟡	🟡	🟢	🟢	🟢	🟢	🟢	🟡	🟡

Figure 3. Density component of Abundance Index per zone of Florida Bay by Water Year; threshold values for poor, fair and good ranges are indicated.

				Water Year								
Zone	Zone ID	Red-Ylw	Ylw-Grn	2006	2007	2008	2009	2010	2011	2012	2013	2014
Northeast	NE	0.2	0.55	🔴	🟡	🟡	🟡	🟡	🟡	🔴	🟡	🟡
Transition	TR	0.3	0.7	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🟡
Central	C	0.2	0.55	🔴	🔴	🟡	🟡	🟡	🟡	🟡	🟡	🟡
Southern	S	0.1	0.45	🔴	🔴	🔴	🔴	🟡	🟡	🟡	🟡	🟡
Western	W	0.25	0.5	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡

Figure 4. Species Dominance component of Diversity Index per zone of Florida Bay by Water Year; threshold values for poor, fair and good ranges are indicated.

				Water Year								
Zone	Zone ID	Red-Ylw	Ylw-Grn	2006	2007	2008	2009	2010	2011	2012	2013	2014
Northeast	NE	0.1	0.3	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Transition	TR	0.1	0.5	🟢	🟢	🟢	🟢	🟢	🟢	🟡	🟢	🟢
Central	C	0.1	0.4	🟡	🟡	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Southern	S	0.1	0.4	🔴	🔴	🔴	🟡	🟡	🟡	🟡	🟡	🟡
Western	W	0.1	0.3	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢

Figure 5. Target Species component of Diversity Index per zone of Florida Bay by Water Year; threshold values for poor, fair and good ranges are indicated.

JUVENILE PINK SHRIMP INDICATOR (MODIFIED NO SAMPLING)

SUMMARY/KEY FINDINGS

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. 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 (Robblee et al. 2014), but a full system-wide status report for WY2013 and WY2014 cannot be produced because FIAN funding was suspended after 2011.

This report provides a view of the status of pink shrimp in WY2013 and WY2014 for southern Biscayne Bay only, near a couple of locations previously reported 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.

Pink shrimp abundance in the western alongshore nursery ground of southern Biscayne Bay, Shoal Point to Turkey Point, has been monitored at the same 47 sites since January 2007. Two collections annually, dry season (January-March) and wet season (July-September), are made. The monitored location is the alongshore area immediately shoreward of the North Black Point and South Black Point Biscayne Bay monitoring locations reported in FIAN. Both FIAN areas were given red stoplights for WY2010 and yellow stoplights for WY2011 in the 2012 ecological indicators report.

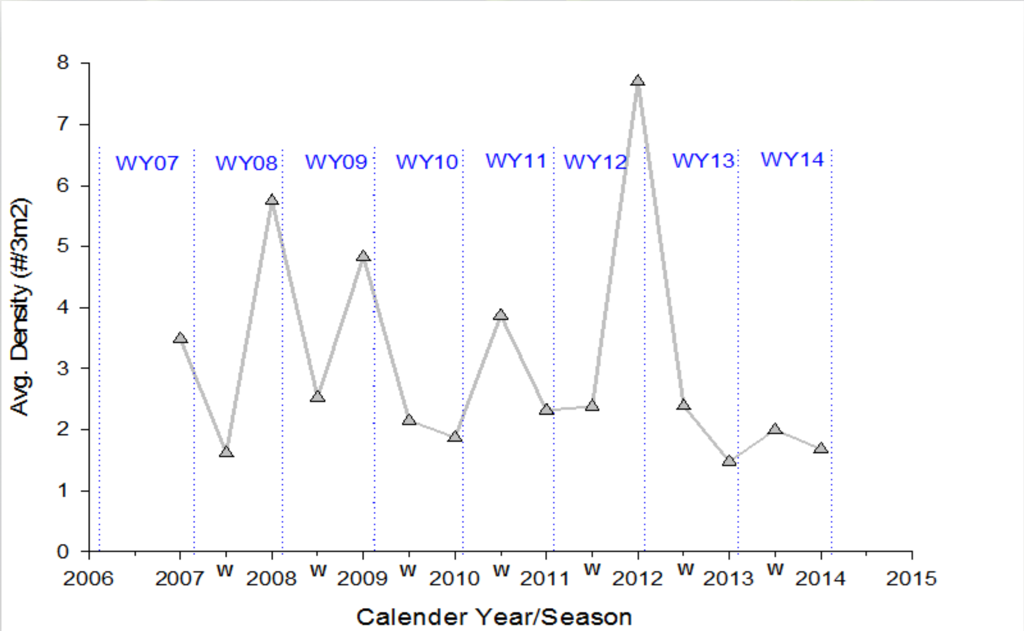


Figure 1. Pink shrimp density, by year-season, Dry 2007 through Dry 2014, from IBBEAM. Each data point represents spatially averaged density, dry (year tick) or wet (W tick), of a given year. Data-point pairs corresponding to Water Years are enclosed within vertical dotted lines, and Water Year is indicated between those dotted lines at the top of the graph. (Density values must be divided by 3 to be compared to FIAN density values.)

Juvenile Pink Shrimp Indicator (Modified No Sampling)

Density of pink shrimp from IBBEAM data is plotted by season and year in Figure 1. Density follows a general seasonal pattern of highest values in the dry season and lowest values in the wet season, but departs from this pattern in Dry 2010 and Dry 2011. The low density in Dry 2010 may have been due to the January 2010 cold snap, which occurred immediately prior to IBBEAM sampling; however, Dry 2011 density was similarly low without ready explanation. The high-dry, low-wet seasonal pattern returned in Wet 2012. Density in Dry 2012 was the highest in the period of record.

Figure 2 gives a poor stoplight score to pink shrimp density in spring 2010 in North Black Point and South Black Point and fall 2010 in South Black Point. Poor, low neutral, or neutral scores are given for both spring and fall density in both 2010 and 2011 in both locations. The previous years used in determining the percentiles for creating the stoplight background are plotted for perspective on where these previous years fell on the background and also to demonstrate temporal patterns such as trends. No patterns are apparent other than that the only green years were the earliest years, 2005 or 2006.

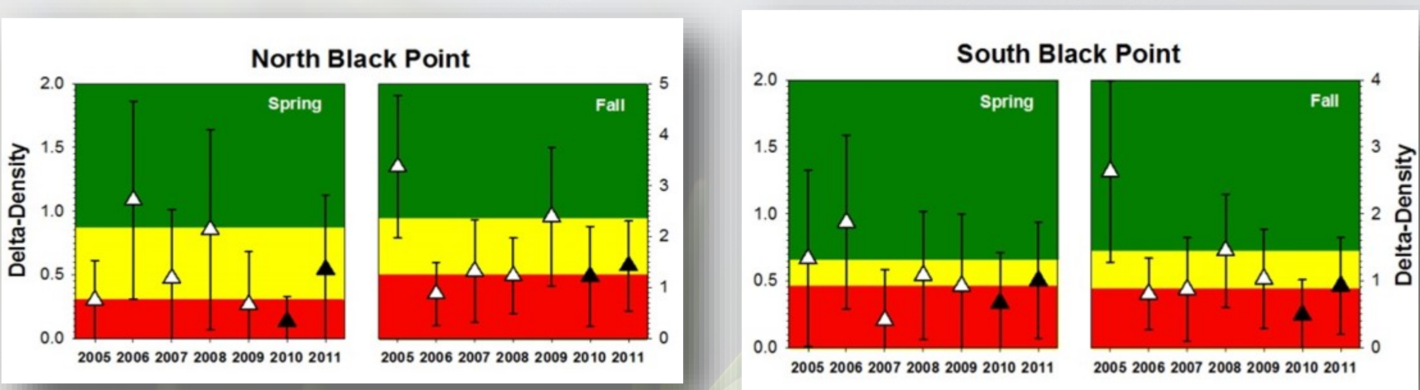


Figure 2. Stoplight pink shrimp status plots from FIAN work for the 2012 Ecological Indicators Report. Points are annual spring and fall density, by year, for 2005 through 2011, with 95% confidence limits (as vertical bars), plotted against a "stoplight" background based on percentile distributions of annual seasonal density from 2005 through 2009 (white triangles; Robblee et al. 2014). Boundaries between red, yellow, and green are the 25%th and 75%th percentiles of the distribution of annual density for the season. The status of pink shrimp density for 2010 and 2011 (black triangles) can be evaluated as poor (red), neutral (yellow), or good (green) against this background.

Juvenile Pink Shrimp Indicator (Modified No Sampling)

Figure 3 uses same the analytical framework as presented in 2012 Ecological Indicator reporting to determine the status of pink shrimp along the Biscayne Bay shoreline. The base years are 2007 -2012, and 2013 and 2014 are the years being evaluated. Spring density is in the red (poor) zone for both years being evaluated. The reports for 2012 and 2014 overlap somewhat in their periods of coverage and the latter report extends the evaluation for additional years. They differ somewhat in their spatial coverage, so it is not surprising that they do not match each other in the overlap years. The biggest difference is in fall(wet) 2010, which can be seen as a high point in density in the later graph, but a low point in the earlier graph. Difference areal coverage and different segment of spatial data may be reasons for the lack of agreement. Nevertheless, the IBBEAM data allow a continued view of pink shrimp abundance in at least the alongshore southern Biscayne Bay nursery area.

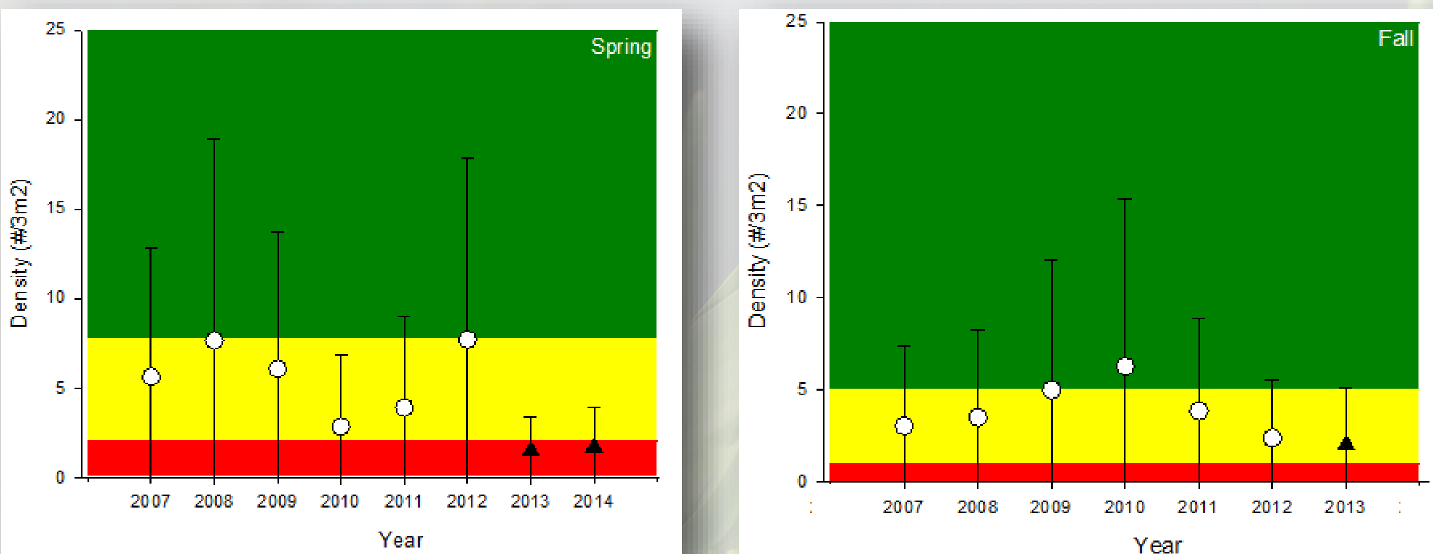


Figure 3. Stoplight pink shrimp status plots from IBBEAM. In this case, spring or fall density for the years 2007 through 2012 are used to calculate the 25th and 75th percentiles used to demarcate the red (poor), yellow (neutral), and green parts of the background used to evaluate the status of pink shrimp density in the years 2013 and 2014 (Wet 2014 data not yet available).

Juvenile Pink Shrimp Indicator (Modified No Sampling)

Habitat Suitability Models

IBBEAM has developed Habitat Suitability Models that can be used in RECOVER evaluations of the potential status of various components of the Biscayne Bay alongshore ecosystem under alternative proposed management scenarios. The pink shrimp model, graphically represented in Figure 4, 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 20 and a Halodule cover of about 50%.

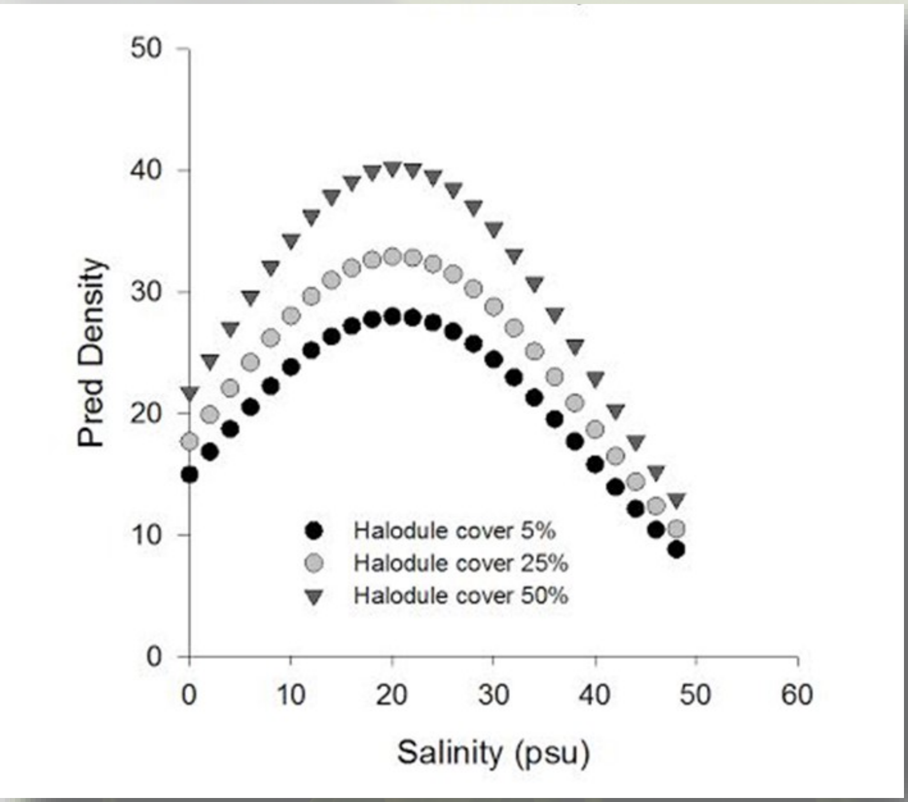


Figure 4. Habitat Suitability Model for pink shrimp, developed from data collected by IBBEAM and previous projects in the alongshore area of Biscayne Bay, 2005-2013. Sampling was extended from 47 to 72 sites (south to Manatee Bay) from 2007 to 2012 (dry only), then, due to funding reductions, reduced back to 47 sites from 2012 Wet forward. (Units of density are number of shrimp per 3 square meters.)

IBBEAM also has produced Habitat Suitability models for several other taxa. IBBEAM has four components: epifauna (including pink shrimp), mangrove fish, submerged aquatic vegetation, and salinity. See the 2014 IBBEAM Report (Lirman et al. 2014) for details and additional information.

[Literature cited, reports, and publications]

Wading Birds (Roseate Spoonbill) Indicator

Summary Findings

The overall score for the Roseate Spoonbill Indicator remained red in 2014. It has been red since 2010 reflecting a decrease in nest numbers and nesting success primarily in Northwestern Florida Bay (NWFB).

Bay-wide nest numbers

Nest numbers bay wide in 2014 (176) were lower than in 2012 (348) and 2013 (376) (including Madeira Hammock; see "Updates on calculation of indicator" section below) likely due to extremely high water in the adjacent marine environment that kept foraging grounds flooded until late in the year (see "New insights relevant to future restoration decisions" section below). These numbers were higher than the critically low number of 87 nests in 2011 (although this did not include known spoonbill nesting at Madeira Hammock; see "Updates on calculation of indicator" section below). 2011 had the lowest number since Florida Bay became part of Everglades National Park in 1949. Although this finding was very alarming, nest numbers have increased since then. It is believed that this increase is the result of chicks fledged successfully from 2005 to 2009 reaching sexual maturity and entering the breeding population. Spoonbills normally begin nesting in November or early December. In 2014, the average nest initiation date was December 29, 2013 and nesting at Madeira Hammock did not begin until late April. This delay was likely due to the high water levels on the foraging grounds (see "New insights relevant to future restoration decisions" section below). Although the recent increases in overall nest number are encouraging, they are well short of the target of 1258 (all spoonbill targets are based on pre-1984 conditions because that was when the South Dade Conveyance System was completed and began to heavily impact Taylor Slough and Florida Bay).

Nest location

Conditions in Northeastern Florida Bay (NEFB) appear to be improving while those in Northwestern Florida Bay (NWFB) are declining. Nest numbers increased from 3 in 2011 (Madeira Hammock was not counted in 2011 so this is an underestimate) to 183 and 188 in 2012 and 2013 but then fell to 76 in 2014. These recent increases are, again, encouraging, but well short of the target of 688 for NEFB. In contrast to NEFB, nest numbers in NWFB have declined from 2009 to present going from green for the 25 years prior to 2010 (a five year mean of greater than 210 nests), yellow (five year average between 130-210 nests) in 2010, 2011, 2012, and red (a five year mean of less than 130 nests) in 2013 and 2014. Aerial surveys have detected the presence of spoonbills nesting in significant numbers in several of the Shark River Slough estuary colonies: a target location for this indicator. However, these colonies are prohibitively difficult and costly to survey so no nesting estimates can be made.

Nesting production and success

Similar to the nest location metrics, nest production and success metric indicates modest increases in NEFB with the opposite trend in NWFB. The 5-year mean of NEFB production was 1.05 chicks fledged per nest attempt (c/n) in 2014, the lowest it has been in the last five years and putting it in the yellow category (<1.38 c/n). Although nest numbers and nest production dropped from 2013 (1.39 c/n) to 2014, we do not attribute this to water management practices but rather to higher water levels in the surrounding marine environment (see "New insights relevant to future restoration decisions" section below). In NEFB spoonbills have been successful in 7 of the prior 10 years for both 2013 and 2014 (green threshold is 7 of ten years). Nesting success in NEFB has improved greatly in recent years, probably due to favorable climatic conditions and to communication between the author and his colleagues with operations mangers at the South Florida Water Management District during nesting season that began in 2005. This communication results in fewer unnecessary disruptions in flow patterns to the foraging grounds in NEFB, leading to greater success. The chicks fledged over this 9 year period of high production are now coming into sexual maturity and appear to be reversing the declining trend in in nest numbers in NEFB.

Nesting failed in NWFB in 4 of the last 5 years, which has never happened before and dropped below the red threshold of less than a 5 year mean of 1 c/n for the first time ever. Between1984 and 2010, there have only been 8 years in which NWFB colonies have failed. Beginning in 2012, the number of successful years out of the last 10 fell to six and has remained there since. The threshold for green is 7 of ten years successful. The cause for the decline in NWFB is not known but two highly speculative reasons can be put forth. One is that the Homestead and East Cape canals have degraded the interior wetlands of Cape Sable (the primary foraging grounds of NWFB birds) to the point that they are no longer as productive in prey base fishes. These canals have since been plugged but a third canal (Raulerson Brothers Canal) has become an uncontrolled tidal canal continuing the degradation started by the Homestead and East Cape canals {Cape Sable Case Study}. The second possibility is that we have observed much more nest predation from crows over the last few years. This generally occurs in relatively close proximity to Flamingo where crows have ample subsidies from human carelessness: crows regularly raid peoples unattended food parcels and trash. This also has been observed to be more frequent in recent years.

Prey community structure

Water management operations appear to be having a positive affect not only on NEFB spoonbills but also on their prey base. The C-111 Spreader Canal West project became operational in 2013 and lower salinities were observed on the foraging grounds ({C-111 Case Study}, {Lorenz et al. 2014 Annual Report}; salinity data for the nearby Trout Creek, Little Madeira Bay and McCormick Creek at {Link to GoHydrology} at http://www.gohydrology.org/p/about.html), however, it can take up to 3 years for the fish community to change to being dominated by freshwater species. There was an increase in the percentage of freshwater species from less than 1% in 2012 to 4.4% in 2013 but this was still shy of the threshold for a yellow score (5% freshwater species). Data for 2014 have not been processed at the time of this report.

Wading Birds (Roseate Spoonbill) Indicator

ZONE/PERFORMANCE MEASURE	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014
TOTAL NUMBER OF NESTS						
Number of nests in Florida Bay (5-year mean)	Y	R	R	R	R	R
LOCATION OF NESTS						
Number of nests in NE Florida Bay (5-year mean)	R	R	R	R	R	R
Number of nests in NW Florida Bay (5-year mean)	G	Y	Y	Y	R	R
Number of nests in SW Coastal Estuaries	B	B	B	B	B	B
Nesting Location Overall	Y	R	R	R	R	R
NESTING PRODUCTION AND SUCCESS						
Chick production in NE Florida Bay	Y	Y	G	G	G	Y
Chick production in NW Florida Bay	G	G	Y	Y	Y	R
Percent successful years in NE Florida Bay	Y	Y	Y	Y	G	G
Percent successful years in NW Florida Bay	G	G	G	Y	Y	Y
Overall nest production and success	Y	Y	Y	Y	Y	R
PREY FISH COMMUNITY NE FLORIDA BAY						
Prey community structure NE Florida Bay	R	R	Y	R	R	C
OVERALL SCORE						
Average of nest #, nest location, nest productivity and prey structure	Y	R	R	R	R	R

[1] c/n is a unit of nest production that indicates the average number of chicks raised until they leave the nest per nesting attempt i.e. 1c/n indicates that on average a colony produced 1 chick for every nest that spoonbills initiated.

[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

Wading Birds (Roseate Spoonbill) Indicator

Updates on calculation of indicator

Since the publication of this indicator, a significant discovery was made that makes it appear that there was a rapid increase in nesting numbers from 2011 to 2012. There was a real increase in nest numbers from 2009 to 2014, however, some of the intervening years may have been under-counted do to the colonization of spoonbills nesting at Madeira Hammock in 2010. Although aerial surveys cannot be used to estimate spoonbill nest numbers, they can be used to determine the presence of spoonbill nesting at colonies that are otherwise inaccessible. Beginning in 2010, spoonbills were observed nesting at the Madeira Hammock colony (this was the first time any wading birds nested at this colony for several decades). This colony is located approximately 3km north of Little Madeira Bay in NEFB and is very difficult to access; however, biologist began to make periodic checks in 2012. There were 164 nests in 2012, and about the same number in 2013. Both years had a high degree of nesting success although no quantification could be made. In 2014 there were an estimated 50 nests and Madeira Hammock was one of the only colonies in Florida Bay to have successfully fledged chicks. These birds were observed flying toward active foraging grounds in NEFB and several birds that were marked as chicks in Florida Bay were observed nesting at this colony. We, therefore, considered this colony as part of the NEFB population. It should also be pointed out the 2010 and 2011 estimates of 223 and 87 total nests respectively (41 and 3 in NEFB) were biased and artificially low estimates since the Madeira Hammock colony was active but not surveyed. Even though this discovery is highly promising, spoonbill numbers both bay-wide and in NEFB are still dangerously low (red stoplight for both).

Application of these data to other uses

The spoonbill metrics will be used to evaluate planned operational changes of the C-111 spreader canal project {Link to C111 Case Study}. This evaluation will not include spoonbills or their prey from NWFB since the project is designed to benefit northeastern and central Florida Bay through increased flow through Taylor Slough. The plugging of the Raulerson Brothers canal is in the planning stages and NWFB spoonbills will be used to evaluate the effects of this canal before and after the plan is completed {Link to Cape Sable case study}.

Based on spoonbill prey data collected from 1990 to 2013, we understand that prey productivity is increased with longer hydroperiods and lower salinity in the mangrove wetlands. The C-111 spreader canal project is expected to lengthen wet season hydroperiods and lower salinity. Prey availability is dependent on low water levels in the wetlands where spoonbills feed during the dry season. It is not fully understood what effect the C-111 spreader project will have on this metric but with currently increasing sea level, there may be adverse responses to prey availability leading to spoonbill nesting failure. We will continue to monitor spoonbill prey to evaluate this uncertainty.

Also based on prey studies in the Cape Sable interior wetlands performed since 2005, we found that the plugging of the Homestead and East Cape Canals had a positive effect on both spoonbills and their prey. This was a short-lived response (about 2 years) because of the breaching of Raulerson Brothers canal from the 2005 hurricane season and the subsequent size and tidal flow increases from this canal into the interior wetlands that are on-going today. As the size and tidal exchange through this canal gradually increased over the last several years, it has largely masked the beneficial results of the plugging of the other two canals.

The reports and publication that developed from the spoonbill monitoring and assessment efforts have been used not only in creating this spoonbill spotlight report but also to, wholly or in part, to set the Minimum Flows and Levels Criterion for Florida Bay, contributed to the System Status Report, were used to develop the C-111 Spreader Canal and Cape Sable Case Studies.

Wading Birds (Roseate Spoonbill) indicator

New insights relevant to future restoration decisions

Mean sea level in the Gulf of Mexico has a profound impact on water levels on the spoonbills foraging habitats north of Florida Bay. As cooler temperatures prevail in the dry season, the Gulf waters cool and contract thereby lowering water levels in the Gulf. This contraction draws water out of the coastal wetlands, lowering water levels and concentrating fish into the remaining wetted habitat. This makes them highly available to spoonbills who time their nesting cycle with the low water and high fish concentration period. In recent years, higher mean sea level in the Gulf has resulted in higher water levels on the foraging grounds causing reduced and delayed nesting in Florida Bay's spoonbill population. Evidence of this increase in mean sea level for the Gulf is apparent in the 100 yr. sea surface record from the Key West Harbor (Figure 1) and it appears that the increase has become more rapid since about 2000. Evidence that this recent rise in sea level has affected dry season (spoonbill nesting season) water levels in Florida Bay can be seen in the water level records from the Peterson Key, Bob Allen Key, Butternut Key and Little Madeira Bay hydrostations {http://www.gohydrology.org/}. Figure 2 shows the mean daily water level at Audubon's Taylor River hydrostation that is centrally located in Taylor Slough where spoonbills feed. It compares the last two hydrologic years with the mean from 1986-87 to 2011-12. It also compares these to 1994-95 which was an El Nino event that notoriously held water levels at record heights throughout the Everglades landscape. These data clearly indicate that the last two years had extraordinarily high water levels in Taylor Slough. Although not presented here, similar data were collected at Audubon's nine other hydrostations found throughout the spoonbills foraging grounds. Higher water levels were not as pronounced if at all discernable at hydrostations throughout the interior Everglades but was much more pronounced in the coastal habitats thereby indicating the influence of sea level rise on these habitats. This likely explains the low nesting effort, delayed nesting and overall low productivity of roseate spoonbills in 2013-14. This may ultimately change the way spoonbills will be used as an indicator for Everglades restoration going forward.

Literature cited, reports, and publications for more information

Wading Birds (Roseate Spoonbill) indicator

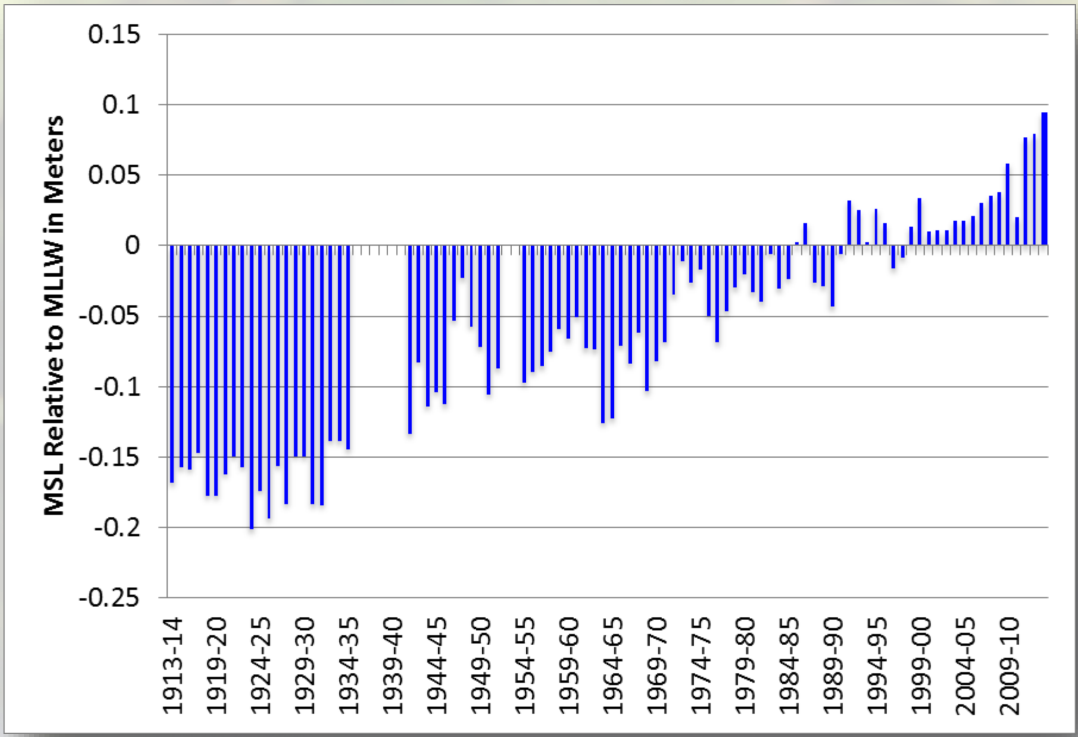


Figure 1. Mean annual sea level at Key West Harbor from 1913-14 to 2013-14.

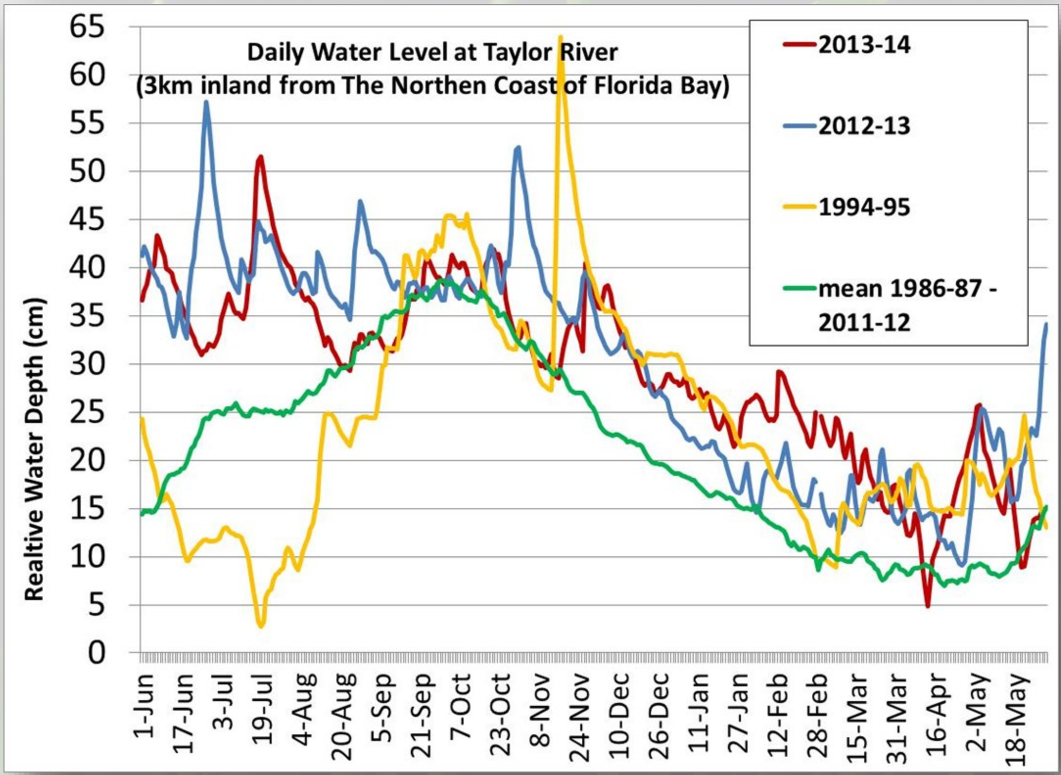


Figure 2. Annual water level cycle relative to the surface of the wetland at the Taylor River hydrstation. Note that 2013-14 was much higher than mean except for a few days in April and that they were also higher for most of the dry season than in 1994-95 a notoriously high water year attributed to El Nino cycle.

Case Studies

A fundamental premise of Everglades restoration is that the ecosystem must be managed from a system-wide perspective. The suite of system-wide ecological indicators was chosen based on their collective ability to reflect the ecosystem in terms of response to restoration over space and time. Their purpose is to report on the general status of the ecosystem as a whole and show how the key ecological components respond to implementation of restoration projects.

The stoplight colors shown in this report for each indicator integrate across all of the areas where that indicator is monitored. This includes both areas where restoration actions have occurred and where they have not occurred, thus representing a system-wide view. Because many restoration actions to date have been fairly small-scale, or focused on just one component of the ecosystem, we have not yet seen collective positive trends in the suite of indicators (see indicators at a glance). There are, however, examples where local restoration actions have resulted in the type of positive ecological responses that we expect to one day see system-wide. We have selected four case studies that illustrate how some ecological indicators are responding to smaller-scale operations or early stages of larger restoration actions. Arranged geographically from the north to south, they are as follows:

- Kissimmee River Restoration Project
- Lake Okeechobee Restoration
- C-111 Spreader Canal Western Project
- Cape Sable Canals Restoration Project

Case Studies: The Kissimmee River Restoration Project—A Long Term Project Shows Promising Interim Results

The Kissimmee River Restoration Project (KRRP) is one of the largest and most ambitious river restoration projects in the world. Restoration of the Kissimmee Basin, located at the northern extent of the greater Kissimmee-Okeechobee-Everglades watershed, will have positive impacts on water bodies far downstream. Scheduled for completion in 2019, the project will restore a full suite of ecosystem values to more than 40 square miles of river channel and floodplain habitats at a total cost of approximately $800 million.

The restoration approach underway includes backfilling more than 22 miles of the simplified, straight-line flood conveyance canal that replaced the once naturally meandering, complex river channel. The result will reconnect approximately 40 miles of historical river channel into one continuous, often braided, stretch of river. Following completion of construction, inflows to the river will be allowed to mimic natural conditions, inundating floodplain habitats in response to season and rainfall.

Typically, restoration projects of this magnitude are completed in phases, due to budgetary and other resource constraints. The KRRP uses this phased approach and two of four phases of canal backfilling have been completed to date. Incremental construction and implementation of an intermediate inflow regime has allowed for monitoring of environmental response of important ecological indicators within completed construction phases, in advance of full project completion. And, even though hydrologic conditions at this interim phase of the project do not fully reflect those of the historical system, they have already induced dramatic response in important ecosystem components.

Monitoring of environmental response is a crucial aspect of the KRRP project, necessary to assess whether or not the project successfully meets its goal of restoring ecological integrity to the river-floodplain ecosystem. To evaluate response, a monitoring plan was developed that investigates a suite of 25 performance measures covering physical, chemical, and biological aspects of the ecosystem. Measuring response by more than one type of environmental variable helps evaluators determine if critical ecosystem processes that drive response and sustain riverine and floodplain biota have been reestablished. Examples of environmental metrics included in KRRP performance measures include, but are not limited to: (1) number of days the river channel experiences flow, (2) rates at which water drains off the floodplain, (3) concentration of dissolved oxygen in the river channel, (4) spatial coverage and composition of wetland plant communities on the floodplain, and (5) densities of wading birds using floodplain habitats during the breeding season.

Interim monitoring results in the Phase I project area, since reintroduction of flow in 2001, indicate that restoration targets for some performance measures have been met. For example, the density of winter wading birds is showing tremendous response to interim restoration. The restoration target value for wading bird density is 30.6 birds/km^2, when averaged over a three-consecutive-year moving window of time. The target value has been achieved in most three-year periods, although the lower error bound brings the average below 30.6 in most of the latter year averages (Table 1). Variability in wading bird use of floodplain habitats since 2001 is due mostly to low use during extreme drought.

While the wading bird results are encouraging, it is very important not to prematurely declare success on the KRRP project when only two of four phases have been completed and only a small group of performance measure targets have been achieved to date. The response of two KRRP floodplain vegetation targets provides an instructive example. Vegetation communities of the floodplain are being evaluated by comparisons of vegetation maps created through interpretation of aerial photographs taken at 5-year intervals. Plants are placed into both large-scale (wetland vs. terrestrial) and smaller scale (i.e., wet prairie vs. broadleaf marsh) groupings based on their hydrologic requirements (i.e., water depth tolerance and duration of inundation). The large-scale metric target indicates that wetland plants will cover greater than or equal to 80% of the floodplain when restoration is complete. One part of the smaller-scale metric states that broadleaf marsh (the wetland community type requiring the greatest inundation depths and longest inundation period) will cover greater than or equal to 50% of the floodplain post-restoration. While the large-scale wetland plant target has been met, the small-scale wetland plant target has not (Figures. 1 and 2). This result is not surprising since floodplain inundation depths and frequencies mimicking the historical condition have not been achieved under interim conditions, thus not producing the finer-scale vegetation change that is expected to occur with implementation of historical hydrologic conditions at the end of project construction.

Demonstrating the interim success of a project of this physical scale and time-frame is vital to maintaining forward momentum both within the technical team and at management and policy level. The interim progress simultaneously illustrates the effectiveness of the investment of resources to date and makes clear that achievement of the full suite of anticipated benefits is dependent on a continued commitment to project completion and performance measure monitoring.

Period	Three-year Running Average ± S.E.
2002–2004	65.4 ± 5.1
2003–2005	74.3 ± 3.5
2004–2006	76.4 ± 4.8
2005–2007	58.9 ± 8.8
2006–2008	49.3 ± 27.4
2007–2009	21.4 ± 7.0
2008–2010	33.9 ± 8.6
2009–2011	29.0 ± 9.8
2010–2012	37.6 ± 9.0
2011–2013	31.0 ± 7.2

Table 1. Post-restoration abundance as three-year running averages (± Standard Error [S.E.]) of long-legged wading birds excluding cattle egrets during the dry season (December–May) within the Phase I, IVA, and IVB restoration areas of the Kissimmee River.

Case Studies: The Kissimmee River Restoration Project–A Long Term Project Shows Promising Interim Results

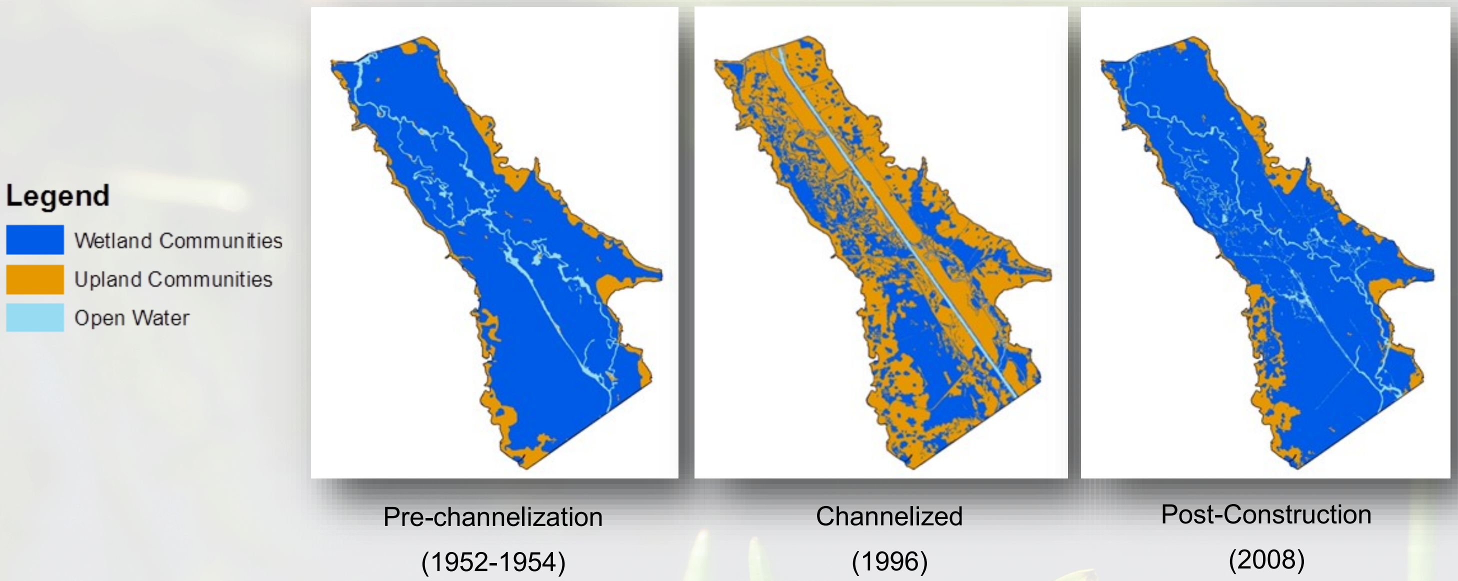


Figure 1. Coverage of wetland versus upland vegetation in the Phase I area of the Kissimmee River Restoration project.

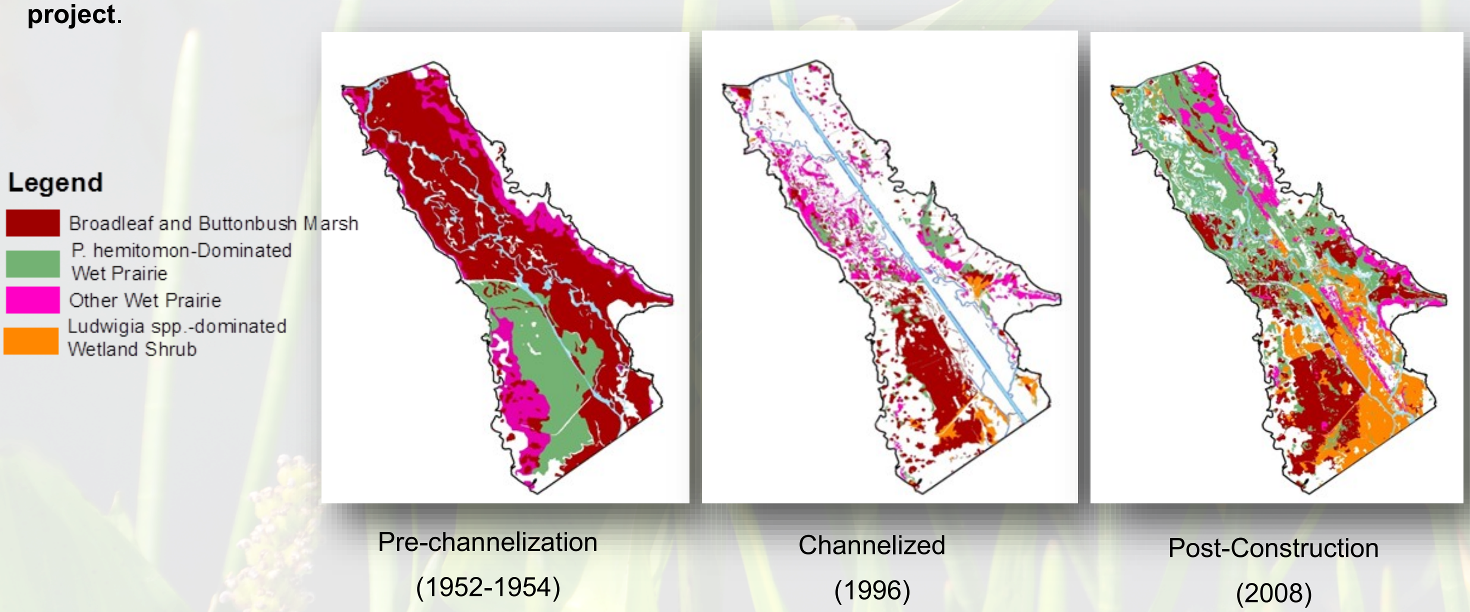


Figure 2. Coverage of major wetland vegetation communities in the Phase I area of the Kissimmee River Restoration project.

Case Studies: Lake Okeechobee–Lowered Lake Reveals Important Ecological Lessons

Lake Okeechobee and its surrounding wetlands lie at the center of the Greater Everglades watershed that stretches from the Kissimmee River through the Everglades and finally into Florida Bay (see map). Lake Okeechobee provides natural habitat for fish, wading birds and other wildlife, and is also a key component of south Florida's water supply and flood control systems. The lake's health has been threatened in recent decades by excessive inflow of nutrients from agricultural and urban activities and also by harmful high and low water levels. Restoration of the lake is a priority within Everglades restoration efforts. A recent period of lower Lake Okeechobee water levels provides an opportunity to see how a hydrologically restored lake might function.

Since 1999 we have had the opportunity to see how ecological conditions in Lake Okeechobee respond to a variety of lake stages, hurricanes, and drought. The period between August 2000 and August 2001 was characterized by a managed drawdown of the lake for water control purposes, followed by a major drought. Between August 2004 and August 2005, the lake was impacted by several hurricanes, raising water levels while in 2007 another major drought affected the lake; followed by a rapid rise in lake stage and a return to more typical lake stages in 2008. Also, in April 2008, a new and lower lake regulation schedule was implemented for Lake Okeechobee, primarily in response to concerns about the stability of the aging Herbert Hoover Dike. The new schedule was designed to keep the water level of the lake approximately one foot lower compared to the previous schedule, which itself was an improvement over its predecessor which had aimed to keep the lake level even higher. As a result, for most of the past 6 years, the water level of Lake Okeechobee has remained either within or below an ecologically preferred range of 12.5 to 15.5 feet above sea level. Because lake levels for this recent period reflect what anticipated post-restoration conditions are expected to be like, examining the recent ecological status of the shoreline and nearshore zones provides insight into the ecology of a hydrologically restored Lake Okeechobee.

Although long-term baseline data sets exist for many species of Lake Okeechobee flora and fauna, the acres covered by, and species composition of, emergent aquatic plants in the marsh and submersed aquatic vegetation in the nearshore zone are considered to be the best indicators of habitat quality in a hydrologically restored lake (see, Lake Okeechobee Nearshore Zone Submersed Aquatic Vegetation indicator). Generally speaking, the total extent of vegetated acres is a good proxy for environmental conditions of Lake Okeechobee.

To assess these conditions, marsh plant data, both emergent and submersed, for 2003 (the last year prior to the lower lake-level conditions for which data are available), 2007, and 2012 were examined. Under lower lake-level conditions, the area of the southern and western shoreline zone colonized by emergent aquatic plants expanded, as did the area colonized by submerged aquatic vegetation, resulting in an increase in total vegetated acres in the shoreline and nearshore zones, suggesting an improvement in available habitat (Figure 1).

Submerged aquatic vegetation coverage is more ephemeral than emergent aquatic plant coverage and more sensitive to random, unpredictable events such as droughts and hurricanes. However, the influence of lower lake levels on submerged vegetation can be seen by comparing 1999 conditions (high lake levels) to the improvements achieved following the managed drawdown and drought of 2000–2001, the recovery from the hurricanes that decimated the submerged aquatic vegetation community between the August 2005 and August 2006 sampling, and conditions since the implementation of new regulation schedule in 2008 (Figure 2). Submerged aquatic vegetation has responded positively whenever lake levels have been in an appropriate range.

Other taxonomic groups, including periphyton, sport fish, and wading birds are also showing increased abundance under the lower lake-level conditions, and the incidence of detrimental

Case Studies: Lake Okeechobee–Lowered Lake Reveals Important Ecological Lessons

cyanobacterial blooms appears to have declined as well. As encouraging as the ecological response to lower lake levels has been, achieving these levels by simply draining large volumes of water from Lake Okeechobee when needed, as has been done under the 2008 lake regulation schedule, entails serious negative consequences for both water supply and for the east and west coast estuaries that consequently receive environmentally damaging high flows from the lake. Therefore, a regional restoration solution is required that will both permanently improve the lake level and protect the estuaries. Watershed storage and treatment capabilities, that will ultimately allow excess water to once again flow southward through the Everglades ecosystem, are important goals of both the Comprehensive Everglades Restoration Plan and the Central Everglades Planning Project.

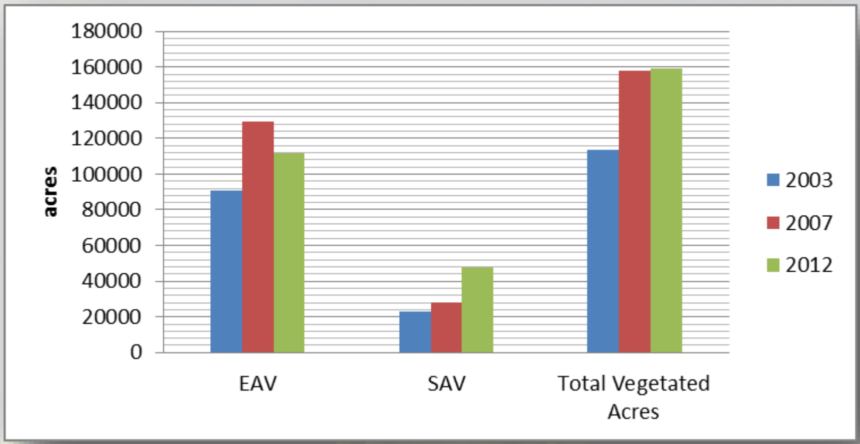


Figure1. Acres of emergent aquatic vegetation (EAV), submerged aquatic vegetation (SAV), and total vegetated acres in 2003, 2007, and 2012. Emergent vegetation is not sampled annually, hence the choice of years used for this analysis.

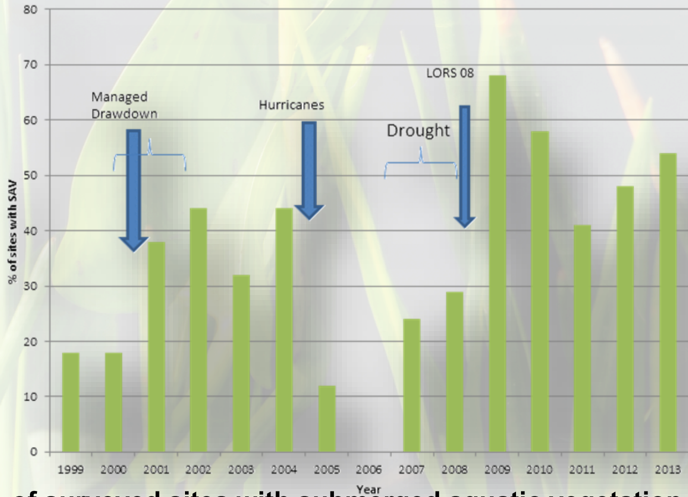


Figure 2. Percentage of surveyed sites with submerged aquatic vegetation (SAV) on transects conducted quarterly during the peak of the growing season (August, 1999-2013). 42 sites were sampled 1999-2010 and 54 from 2011 on.

Case Studies: C-111 Spreader Western Project: Single Project promises benefits to many species

The C-111 Spreader Canal Western Features Project (Project) was developed to protect the values of Everglades National Park (ENP). The Project is intended to create a nine-mile hydraulic ridge oriented north-south adjacent to ENP that will keep more of the rainfall and natural water flows within Taylor Slough and also begin restoration of the Southern Glades and Model Lands (Figure 1; http://www.evergladesplan.org/pm/projects/proj_29_c111.aspx). These areas form a contiguous habitat corridor with ENP, Biscayne National Park, Crocodile Lake National Wildlife Refuge, the North Key Largo Conservation and Recreational Lands (CARL) purchases, John Pennekamp State Park, and the Florida Keys National Marine Sanctuary. It is estimated that about 252,000 acres of wetlands and coastal habitat may be affected by the Project.

In February 2012, the South Florida Water Management District (SFWMD) completed construction of the Project as part of its program of expedited restoration projects. The Project includes the Frog Pond Detention Area, Aerojet Canal features, plugs in the C-110 canal, a plug at the S-20A structure, and incremental operational changes at the S-18C structure (Figure 1). The Project became operational in late June 2012.

Anticipated outcomes of the Project include increased flow in Taylor Slough as measured at Taylor Slough Bridge, and decreased discharge out of the C-111 canal through the S-197 structure. The increase in flow through Taylor Slough is expected to result in higher water levels in the Taylor Slough watershed, lower salinities in northern Florida Bay, an expansion of brackish and freshwater submerged aquatic vegetation, greater growth and abundance of the emergent aquatic vegetation community, increased abundance of the freshwater prey-based fish communities, increased nesting success rate for spoonbills (number of chicks per nest), increased growth and survival of juvenile crocodiles, increased crocodile relative abundance, and increased crocodile nesting. Decreased discharge through the S-197 structure will reduce the impacts of this point-source out-flow into Biscayne Bay. In the past these large point-source discharges into the estuarine habitat have devastated sessile marine organisms by rapidly lowering salinity below their lethal tolerances.

Water Years (WY) 2013 & 2014 (for definition of Water Year, see Hydrology Context in this report) provided the first opportunities to assess the effect of the Project by examining flows, water levels, and downstream salinity. Flows at Taylor Slough Bridge in 2013 averaged almost 60 percent greater than the historical average (134 cubic feet per second [cfs] compared to 84 cfs from 1992 to 2012), wet season flows were the highest recorded in the last 20 years, and the ratio of C-111 discharge to Taylor Slough flow was the lowest it has been in 20 years. This increase may be partly attributed to the benefits of the Project, however, hydrologic conditions in the previous year also contributed to the increase in Taylor Slough Bridge flows. Precipitation in WY2013 was above average regionally compared to annual averages from 2000-2012 and was variable across the Project area, confounding this assessment.

To further examine potential effects of the Project, conditions were compared to conditions in WY2008 and 2009, a period when regional rainfall patterns were spatially and temporally similar to WY2012 and 2013. Nonetheless, higher localized rainfall in the Project footprint in WY2013 and the timing of that rainfall (rehydrating the area earlier than normal) make it challenging to conclusively link downstream effects to the Project. Water levels were significantly higher in the Taylor Slough, C-111, and Southern Biscayne Bay Watersheds in 2012-13 than in 2008-09. The Project may have contributed to these higher levels but local precipitation and sea level rise possibly played a role in this as well.

Salinity levels, an important determinant of ecological condition, were assessed in Florida Bay, downstream of Taylor Slough to see if salinity declined after Project implementation. If so, this would suggest that ecological conditions may also have been improved. An analysis was performed using hourly salinity values from two ENP marine monitoring network stations, one at the mouth of Little Madeira Bay just downstream from Taylor Slough and a control from Butternut Key further south in the bay proper, well away from Project impacts. This analysis revealed that salinities in Little Madeira Bay were significantly lower by 1.50 - 1.76 practical salinity units (psu) after February 2012. A similar analysis using water quality data from NOAA found no significant difference in chlorophyll a, a proxy for water quality (see Southern

Case Studies: C-111 Spreader Western Project: Single Project promises benefits to many species

Coastal Systems Phytoplankton Blooms indicator), before and after the completion of the Project.

Submerged aquatic vegetation, an important ecological indicator, is integral to the ecological function of Florida Bay, providing a large nutrient sink, binding sediments and thereby reducing turbidity, and providing a food source and habitat for many species including prey fish. In WY2013, submerged aquatic vegetation was more abundant than in 2008-2009, an encouraging result that requires additional observation to validate.

The abundance of freshwater prey fish is expected to increase in response to lower salinities. This may take 1-3 years because the freshwater species take time to immigrate into the estuarine habitat and become established. The total abundance of prey fish was not higher in WY2013 compared to 2008-2009; however, there was an encouraging increase in the number of species of freshwater fish at the Taylor Slough sites, consistent with our hypotheses about shifts in abundance and community structure of prey fish.

Abundance of prey fish, coupled with appropriate water level fluctuations, and salinity, can contribute to nesting success of spoonbills (see Wading Birds (Roseate Spoonbill) indicator) and increases in growth and survival of juvenile crocodiles and crocodile nesting (see Crocodilian indicator and Cape Sable Case study). The success rate of 1.29 chicks per nest (c/n) in 2012-13 marks the sixth time in the last seven years that spoonbills produced more than1.0c/n. This increase, compared to the 1982 to 2005 period when more than 1.0c/n was produced in only 7 of 20 years, coincides with increased communication between the water management operations team at the SFWMD and Audubon scientists and highlights the importance of ecologically-based flow patterns.

It is too soon to evaluate changes in growth and survival of juvenile crocodiles in the Taylor Slough basin; however, crocodile abundance in that area from June 1, 2012 – May 31, 2014 was slightly higher (0.054 crocodiles/km) than for June 1, 2008 – May 31, 2010 (0.036 crocodiles/km).

A variety of ecological indicators is expected to respond favorably to longer hydroperiods, higher water levels and flows, and reduced salinities. With only 1-2 years of post-project data, it is only possible to describe correlations between ecological responses, changes in hydrology, and project implementation; however, initial results are consistent with our conceptual ecological models and what was predicted in advance of project implementation. While this is a positive indication, it is too soon to be able to separate the direct contribution of the Project from that of other environmental factors. Additional years of monitoring covering years with different environmental conditions, such as drought, will be required to determine Project contribution to changing ecological indicators, verify cause-effect relationships, and allow us to more effectively use this information as feedback to Project operations.

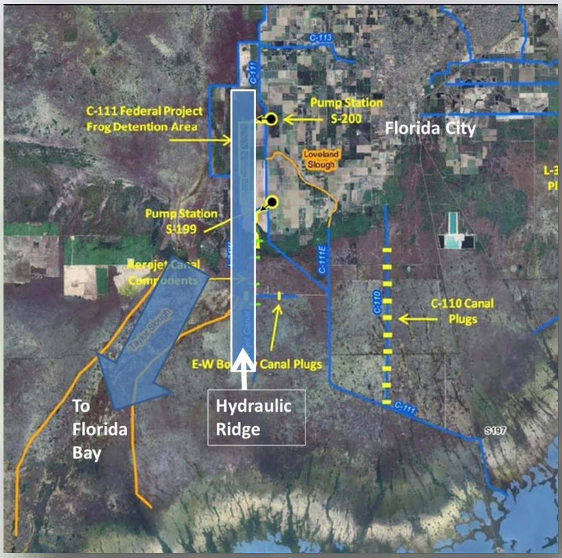


Figure 1. C-111 Spreader Canal Western Features Project (Project) The Project is intended to create a nine-mile hydraulic ridge oriented north-south adjacent to ENP that will keep more of the rainfall and natural water flows within Taylor Slough and also begin restoration of the Southern Glades and Model Lands .

For more information see: Audubon fact sheet, RECOVER 2014 System Status Report, and Lorenz et al 2014.

Case Studies: Cape Sable Canals Restoration: Crocodiles and Spoonbills Suggest Ecological Response

Restoring more natural patterns of freshwater flow and salinity in coastal estuaries is an important goal of Everglades restoration. As restoration projects are completed, freshwater from upstream areas will be delivered southward through the system. In the meantime, there are opportunities for restoration projects at the downstream end of the system as well. In Everglades National Park, a canal restoration effort plugs canals that have allowed saltwater to intrude into areas where it did not historically occur and gives us a glimpse into a future where ecological improvements will result from restoration actions.

The Cape Sable peninsula and the Flamingo area of Everglades National Park (ENP) are located at its southwestern tip, extending into the Gulf of Mexico and Florida Bay (Figure 1). The area remained relatively untouched by humans until the early 20th century. At that time, a network of canals was dredged through a marl ridge from the coastline into the freshwater interior to drain the area for agriculture and cattle grazing. The canals triggered substantial changes in the area, exposing interior marshes and lakes to the sea and altering salinity, deposition of sediments, and erosion patterns over the entire area. Constant movement of water, driven by the tides, widened the canals over time, altering the environment for species such as the American crocodile (Crocodylus acutus), a species very sensitive to salinity levels, and Roseate Spoonbills (Ajaia ajaja), two of our system-wide ecological indicators (see Crocodilian indicator and Wading Birds (Roseate Spoonbill) indicator).

Park managers, recognizing the need to address the changes created by the canals, plugged the East Cape, Homestead, and other interior canals in 1956 with earthen dams along the marl ridge to prevent further salt water intrusion and loss of freshwater to tide. Many of these dams eventually failed and a series of restoration efforts using stronger materials has followed over the decades. For example, an initial plug in the East Cape canal failed but was closed once again in the mid-1980s. It remained closed until 1992 and was plugged again in 1997 with sheet pile. By the early 2000s, East Cape canal was open once again. In contrast, the Buttonwood canal in the Flamingo area was plugged with a concrete structure in the mid-1980s and has remained closed. Most recently, the East Cape and Homestead canals were repaired in 2011 in a project funded by the American Recovery and Reinvestment Act.

Now, many years after the canals were first dug, we have studied crocodiles and spoonbills at Cape Sable and Flamingo, where canal restoration actions were implemented, and compared the results to northeastern Florida Bay. The mangrove coasts of northeastern Florida Bay once provided the core habitat of the American crocodile in Florida, but now suffer from high salinity levels due to the shortage of freshwater flow through the altered system. Juvenile crocodiles are very sensitive to high salinity and their growth and survival is very low in this area.

Data collected within ENP from 1978-2013 were used to evaluate effects of year, area, habitat, and salinity on crocodile growth. Growth rates of crocodiles in northeastern Florida Bay showed a decrease, while those in the central and western areas, which include the Buttonwood Canal and Cape Sable portions of Florida Bay, showed increases. Growth rates significantly decreased with increases in salinity.

Survival of hatchling crocodiles was assessed using data collected from 2004-2013 in northeastern Florida Bay and from the western portion of Florida Bay, which includes Buttonwood, East Cape and Homestead Canals, and differences were found among areas. The proportion of hatchlings surviving was higher in the Buttonwood nesting locations than in the East Cape and Homestead Canals. Northeastern

Case Studies: Cape Sable Canals Restoration: Crocodiles and Spoonbills Suggest Ecological Response

Florida Bay had the lowest six month survival rate relative to the other areas.

Over the period 2004-2012, crocodiles were encountered at higher rates per kilometer during night-time spotlight surveys in Buttonwood Canal, while a decrease was observed in northeastern Florida Bay and at Cape Sable (Figure 2). Since 2006, the abundance of crocodiles observed in Buttonwood Canal has been greater than in Cape Sable. Declines in encounter rates for crocodiles in Cape Sable after 2005 may be a response to Hurricanes Katrina and Wilma during which storm surge overran and compromised an already damaged plug in East Cape Canal. This would have resulted in increased salinity and avoidance of the area by crocodiles, explaining the decrease in encounter rates. The plug in Buttonwood Canal was not compromised by these hurricanes and benefits of a restored salinity regime continued.

Following the plugging of the East Cape and Buttonwood Canals in the 1980s, nesting was observed along the canal banks and increased faster in these areas than in freshwater starved northeastern Florida Bay. Crocodile nesting began to increase rapidly at Cape Sable in 2002, about 15 years after 1980s-era restoration activities were undertaken (Figure 3). Crocodiles occupy areas with improving salinity conditions relatively quickly (2 to 3 months), but an increase in the number of animals nesting is dependent on the time it takes a surviving hatchling to mature and enter the breeding population (10 to 20 years).

The higher relative abundance and rapid increase in crocodile nesting in areas where restoration of canal systems is underway (Cape Sable), compared to an area where an altered salinity regime remained uncorrected until recent efforts to restore more natural flow (northeastern Florida Bay), lends preliminary support to the hypothesis that restoring the hydrology of an area can result in ecological improvements.

These findings are also consistent with those of a study performed by Audubon Florida scientists. They found that Hurricanes Katrina and, especially, Wilma in 2005, as noted above, had a major impact on the canal system, both widening the East Cape and Homestead Canals and breaching the Raulerson Canal plug. Subsequent to these events, an inland hydrostation began to show evidence of strong tidal influence and fish collections at the site indicated that the habitat had become less productive and prey less available, presumably due to increasing salinity levels. Once the East Cape and Homestead canals were re-plugged in 2011, the tidal influence was greatly reduced at the inland sites. Prey availability increased and low salinity species became more prevalent. A control hydrostation, unaffected by the damaged canals and their repair, never showed tidal influence. Roseate spoonbills nest and feed near these sites and nesting success is dependent on prey abundance and availability. Spoonbill numbers plummeted following the 2005 hurricane season and began to increase again after the canals were dammed, restoring more natural conditions.

The canal plugging project in Everglades National Park serves to illustrate that even relatively small restoration efforts may produce meaningful results and can serve to inform larger restoration projects. Because crocodiles and spoonbills in Everglades National Park have been monitored for many years, data needed to analyze response to canal restoration were available. Long-term monitoring of salinity, crocodiles, spoonbills, and their prey in these areas is necessary to allow us to continue to assess and fine-tune the restoration process.

Case Studies: Cape Sable Canals Restoration: Crocodiles and Spoonbills Suggest Ecological Response

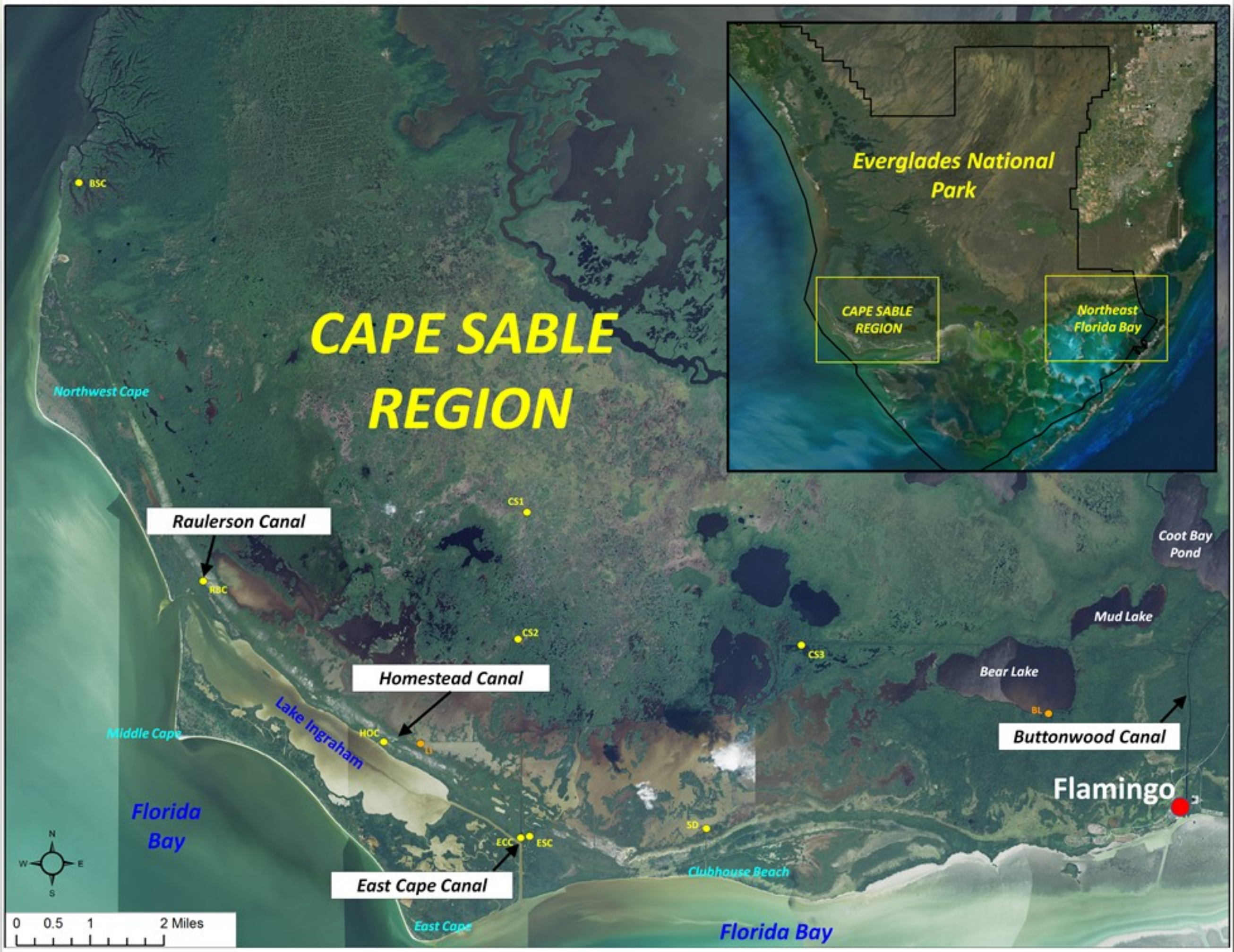


Figure 1. Cape Sable and the Florida Bay region.

Case Studies: Cape Sable Canals Restoration: Crocodiles and Spoonbills Suggest Ecological Response

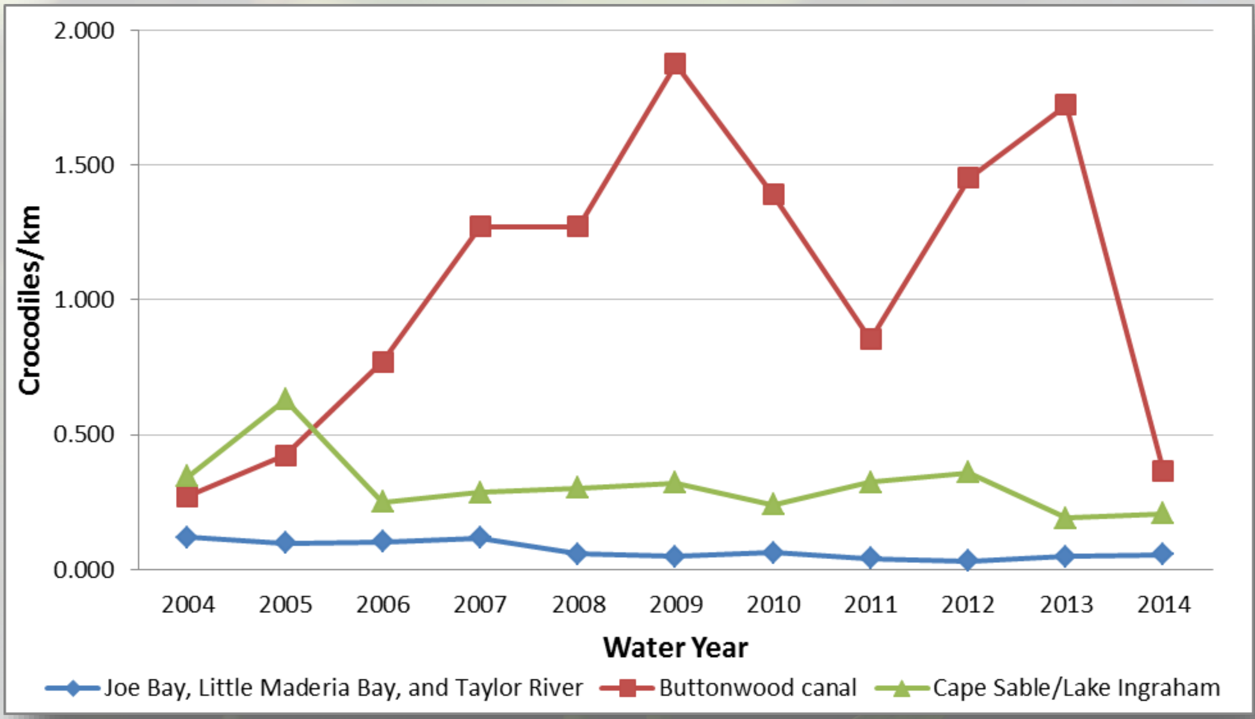


Figure 2. Non-hatchling crocodile density calculated as encounter rate per kilometer of route surveyed from 2004-2014.

Case Studies: Cape Sable Canals Restoration: Crocodiles and Spoonbills Suggest Ecological Response

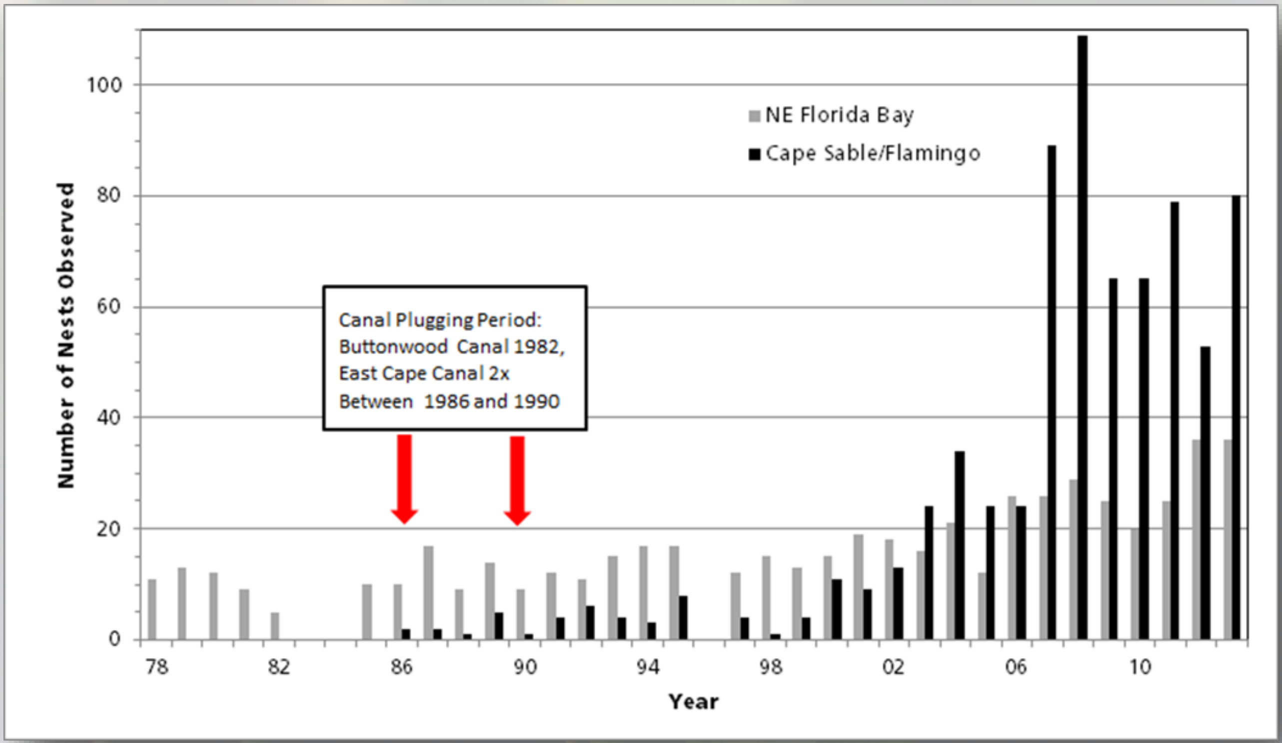


Figure 3. Number of American crocodile nests per year found in northeastern Florida Bay and the Flamingo/Cape Sable area (Buttonwood, East Cape and Homestead canals) during 1978 through 2013. Crocodile nests were first discovered in the Flamingo/Cape Sable area after Buttonwood and East Cape Canals were plugged in the early 1980s. Since then, the number of nests per year has increased more rapidly in the Flamingo/Cape Sable area.

Scientists for indicator report

Lead Scientist for Indicator Report

First Name	Last Name	Agency	Indicator
Joan	Browder	NOAA	Pink Shrimp
Peter	Frederick	UF	White Ibis and Wood Stork
Evelyn	Gaiser	FIU	Periphyton
Chris	Kelble	NOAA	Florida Bay Algal Blooms **
Jerry	Lorenz	Audubon of Florida	Roseate Spoonbill **
Chris	Madden	SFWMD	Florida Bay SAV **
Frank	Mazzotti	UF	Crocodilians
LeRoy	Rodgers	SFWMD	Invasive Exotic Species **
Andy	Rodusky	SFWMD	Lake Okeechobee Nearshore **
Joel	Trexler	FIU	Fish and Macroinvertebrates
Aswani	Volety	FGCU	Oysters

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

Jeff	Beauchamp	UF	Crocodilians
Laura	Brandt	FWS	Crocodilians **
Michael	Cherkiss	USGS	Crocodilians **
Alice	Clarke	NPS	Technical Editing
Dale	Gawlik	FAU	White Ibis and Wood Stork
Lawrence	Glenn	SFWMD	Kissimmee Case Study
Ellen	Hardy	NPS	Technical Editing
Lesli	Haynes	FGCU	Oysters
Angie	Huebner	ACOE	Invasive Exotic Species **
Steve	Kelly	SFWMD	Southern Coastal Systems Phytoplankton Blooms **
Jeff	Kline	NPS	Fish & Macroinvertebrates
Gladys	Liehr	NOAA	Pink Shrimp
Peter	Ortner	RSMAS	Southern Coastal Systems Phytoplankton Blooms
Melanie	Parker	FWC	Oysters
Dave	Rudnick	NPS	Southern Coastal Systems Phytoplankton Blooms **
Bruce	Sharfstein	SFWMD	Lake Okeechobee Nearshore **
Bob	Sobczak	NPS	Hydrology