# South Florida Ecosystem Restoration Task Force

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# System-wide Ecological Indicators for Everglades Restoration 2022

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Restoring America's Everglades

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# EXECUTIVE SUMMARY

This report is a digest of scientific findings about eleven system-wide ecological indicators in the South Florida Ecosystem (Table 1). These eleven indicators have been carefully selected 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 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 drivers and stressors, the stronger the signal that underlying problems are ubiquitous across the system, thus likely affecting the fundamental ecological and biological make-up of the Everglades ecosystem. Fixing these problems is key to fixing the Everglades.

The big picture findings below stem from these collective responses and were identified as common to more than one indicator over broad and important regions of the Everglades.

- **System-wide status** of indicators has not changed over this reporting period, and none have met system-wide restoration targets. This is not surprising since projects that will contribute the greatest benefits to these indicators at the system-wide scale have not yet been completed. Change in system-wide status of indicators is expected as more projects are completed.
- **Long-term tracking** of these indicators provides the information to put current responses in a broader context. Long-term trends of most indicators at system-wide scales do not indicate ecological improvement or further degradation except for Wading Birds (White Ibis & Wood Stork, increasing trend) and Lake Okeechobee Nearshore Zone Submerged Aquatic Vegetation (declining trend).
- The Wading Birds (White Ibis & Wood Stork) indicator has exhibited **continuous improvement** over the past ten years. Years when this indicator has shown the highest rate of improvement coincide with heavier rainfall and improved water conditions. This finding supports the hypothesis that restoring hydrological

conditions of the Everglades will lead to improved conditions for nesting of wading birds.

- The Lake Okeechobee Nearshore Zone Submerged Aquatic Vegetation indicator has shown a **declining trend** over the last ten years likely because lake stage has exceeded the preferred ecological stage envelop every water year since WY 2013, except WY 2020.
- **Lower funding support for monitoring since this reporting was started in 2006** has resulted in several indicators not being tracked over spatial or temporal scales as originally designed, for example, Eastern Oysters, Crocodilians, Southern Coastal Systems Phytoplankton Blooms, Juvenile Pink Shrimp, and Wading Birds (Roseate Spoonbill). Existing funding of monitoring efforts should be reviewed to determine if it is adequate to provide the needed information.
- **Invasive plants and non-native animals continue to present challenges** to Everglades restoration. While for invasive plants, large portions of the restoration footprint have been cleared and maintained at low infestation levels, populations previously under control have resurged in some areas largely due to inadequate resources for management. To control species faster than they are invading and spreading, prevention, monitoring, and control programs must be expanded. With the incorporation of CERP Guidance Memorandum 62 into CERP projects that are currently reaching the construction stage, the USACE should have an increased ability to apply invasive species management strategies into CERP projects as they are completed, allowing for a more proactive approach to managing invasive plant species.
- Although there is no indicator for non-native animals, non-native fishes are reported on under the fish and macroinvertebrate indicator. **Proportions of non-native fishes are generally high** and growing system-wide. The expansion of Asian Swamp eels and their predatory impacts are influencing expected population responses of fish and macroinvertebrates to hydrologic variation and may limit the effectiveness of hydro-restoration to enhance prey production for wading birds.

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# INTRODUCTION

## What are ecological indicators and why do we need them?

*"An ecological indicator is a metric that is designed to inform us easily and quickly about the conditions of an ecosystem."* (Bennett 2000)

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

Ecological indicators are used to communicate information about ecosystems and the impact human activity has on them. Ecosystems are complex and ecological indicators are heuristic tools to synthesize data and information and reduce complexity to ultimately help in describing ecosystems 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 that can be used to evaluate a variety of ecosystem properties, including biological, chemical, and physical variables. Due to this diversity, the development and selection of ecological indicators is a complex process. National indicators for pollution (e.g. ozone index one sees on the daily news) and the economy (e.g. daily gross domestic product reported) 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 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 to focus our ability to assess the success of the Everglades restoration program from a system-wide perspective.

These ecological indicators are plants and animals that integrate many ecological functions in their life cycles. 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 in turn affect the amount and availability of fish as food for alligators and wading birds. They are 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 cannot be measure because it would be too expensive and time consuming, or because they are too difficult to measure. Thus, observation of simpler life cycle properties of key plants and animals in turn linked to biogeochemical and environmental processes enables our understanding of how species populations, habitats, and entire ecosystems respond to drivers and stressors such as rainfall, hydrology, salinity, water management, nutrients, and invasive species.

## Purpose

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

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

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

## Goal

Any method of communicating complex scientific issues and findings to non-scientists must be: 1) developed for specific audiences, 2) transparent as to how the science was used to generate the summary findings, 3) reasonably easy to follow the simplified results back through the analyses and data to see a clear and unambiguous connection to the data and information used to roll -up the results, 4) credible and scientifically vetted without minimizing or distorting interpretation of results, and 5) objective and not a judgment call (Norton 1998, Dale and Beyeler 2001, Niemi and McDonald 2004, Dennison et al. 2007). Based on literature about science communication to non-scientists we realized that system-wide ecological indicators must be effective in quickly and accurately conveying key findings to ensure information is used effectively to support decision-making (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 scientific background, we made the underlying assumption that these indicators integrated many additional ecological and biological functions that were not or could not be measured via direct observation and thus provided an assessment of many ecological components that these indicators integrated in their life processes.

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

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

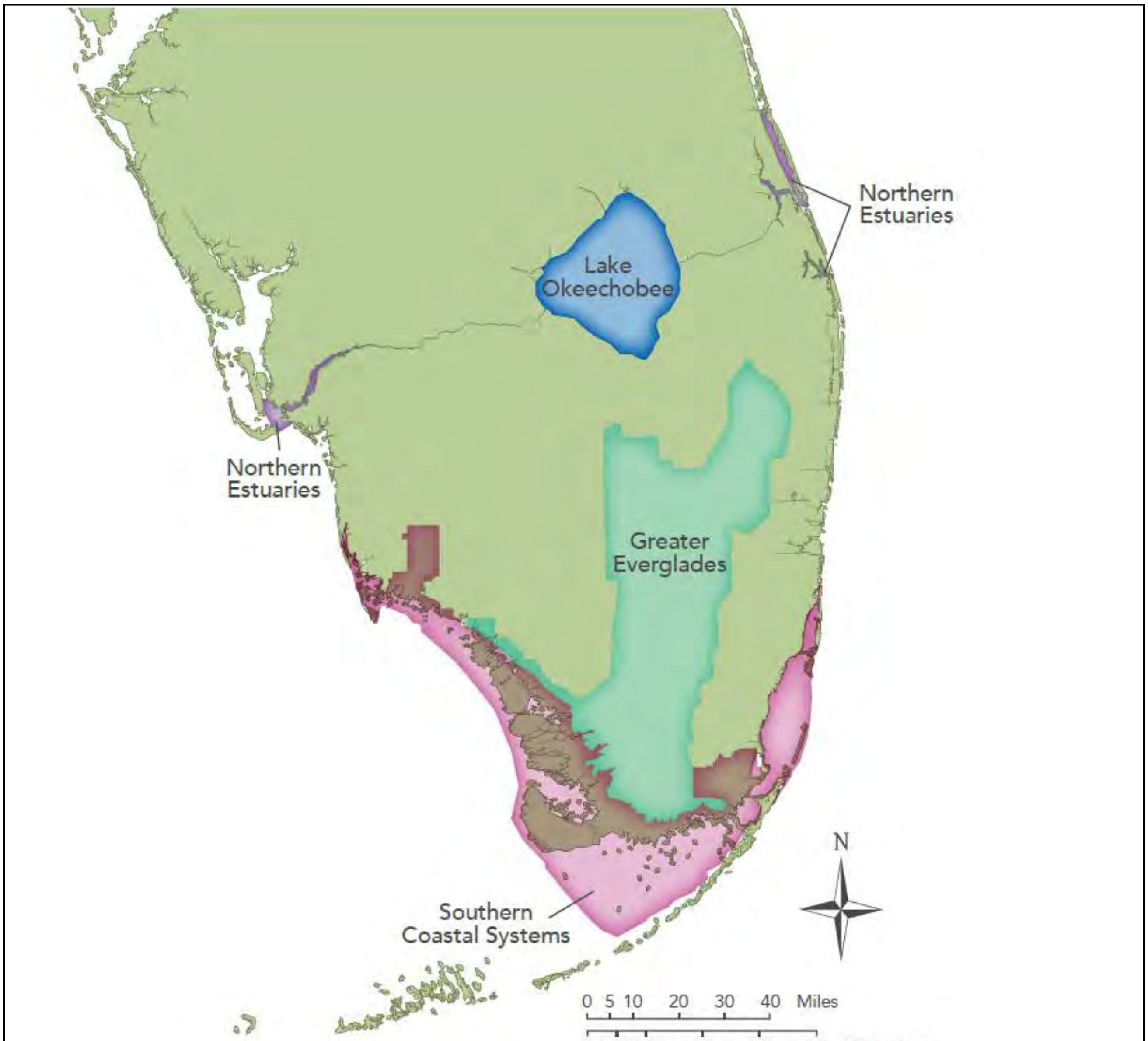


**Figure 1. Map of south Florida illustrating the boundaries of the RECOVER regional assessment modules.** Figure courtesy of RECOVER's 2019 System Status Report.

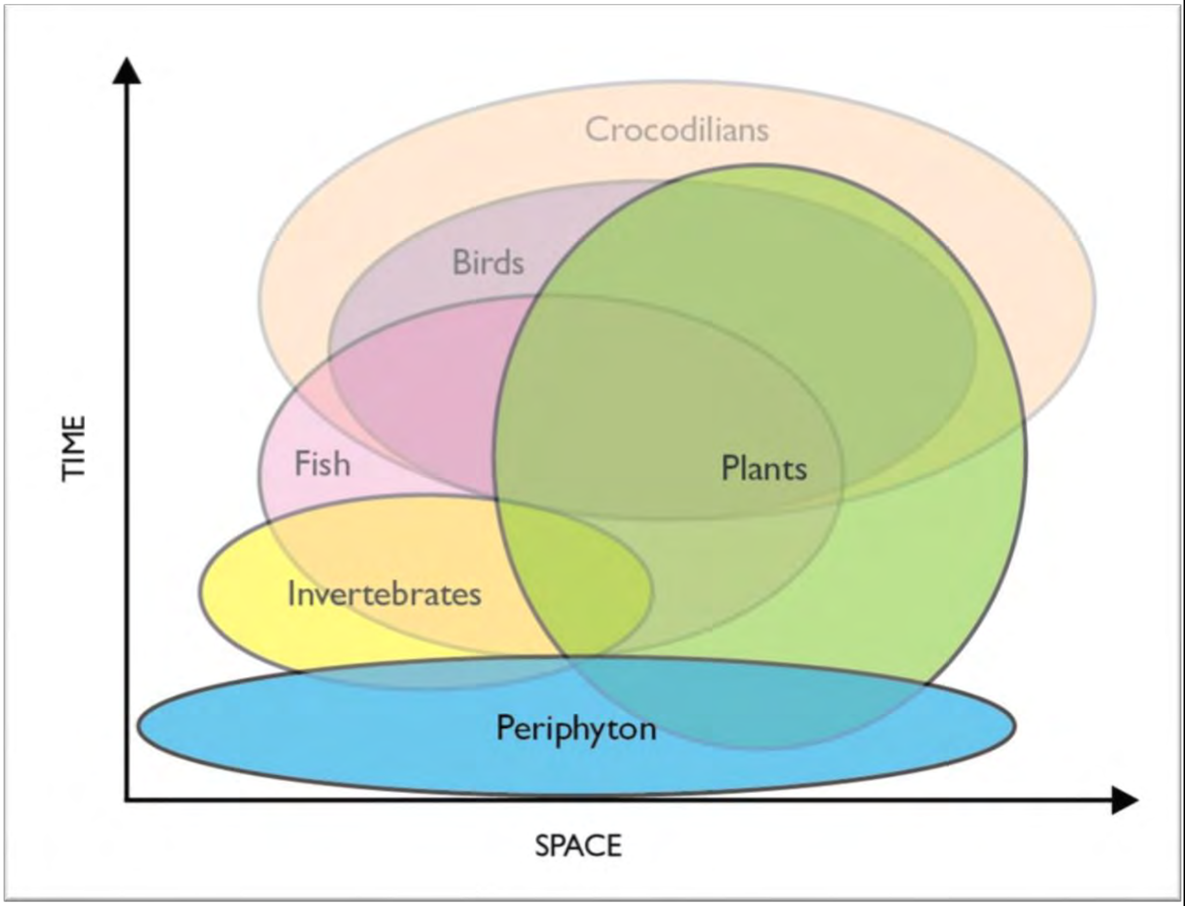


**Figure 2. Graphical representation of how the individual indicators (only 6 indicators are shown interrelate with the temporal and spatial aspects of the ecosystem).** The suite of system-wide ecological indicators was chosen based upon their collective ability to comprehensively reflect ecosystem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

# INTRODUCTION

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

Details of how stoplight colors are assigned for each indicator are available in a special issue of Ecological Indicators (2009, V9 Supplement 6). In this 2022 report, additional information on indicator calculations is provided to reflect information learned and changes in sampling.

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## HYDROLOGIC CONTEXT FOR THE SYSTEM-WIDE ECOLOGICAL INDICATORS: WATER YEARS 2020-2022

Hydrology is a major driver of Everglades ecology. In this section we provide an overview of the south Florida water cycle and a basic description of conditions during the reporting period: Water Years (WY) 2021 (May 1, 2020 to April 30, 2021) and 2022 (May 1, 2021 to April 30, 2022).

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

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

Historically, prolonged drought cycles are broken by periods of increased tropical cyclone activity (tropical depressions, tropical storms, and hurricanes). In addition, large-scale climate drivers also have a significant impact on south Florida hydrology. 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 (Figure 5).

### SUMMER WET SEASON

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

In response to these meteorological inputs, the Everglades become flooded with an ankle- to waist-deep, slow-moving pool of water through summer and fall, leaving only the high-ground tree islands and hardwood hammocks above water. The term sheet flow is used to describe this shallow and spatially expansive wetland plain that, unlike a lake or bog, flows like a stream, only much more slowly, almost imperceptibly slowly to the human eye. Spanning from horizon to horizon, this sheet of water flows south through a maze of tree-island-dotted ridges and sinuous low-lying sloughs, giving rise to the name River of Grass coined by Marjory Stoneman Douglas in 1947.

### WINTER DRY SEASON

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

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

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

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

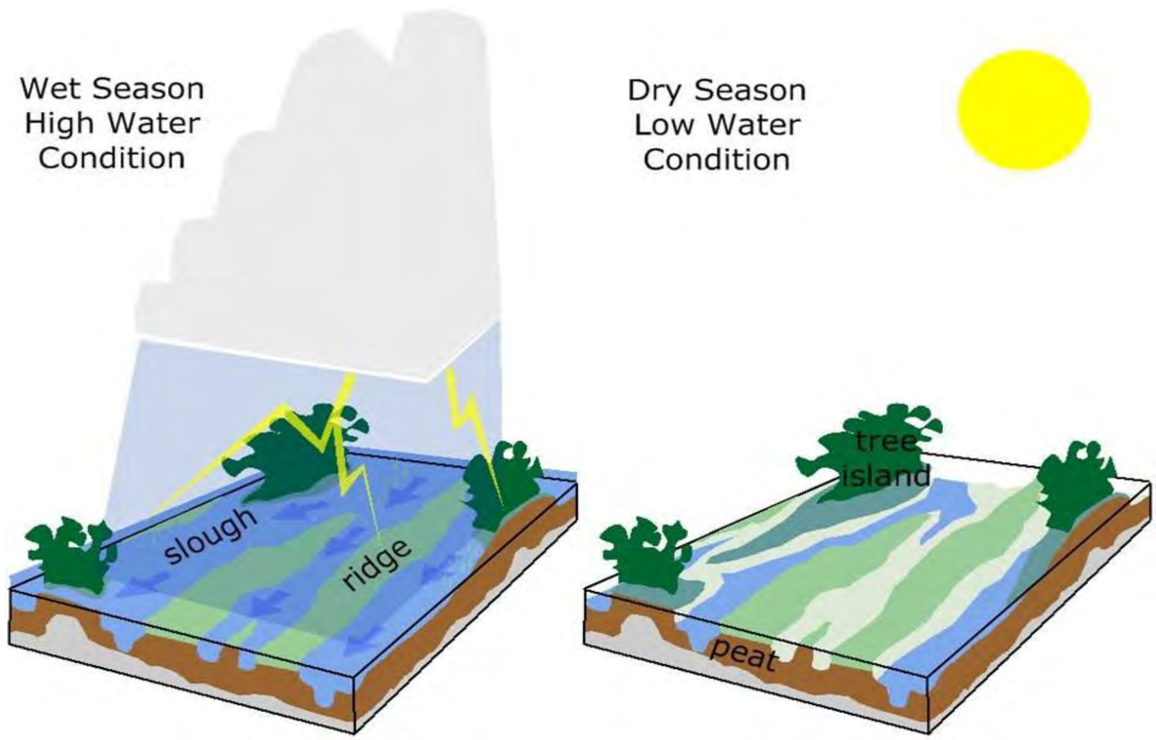



**Figure 3. Artistic representations of the Everglades during fall high water and spring low water conditions.** During the summer/fall rainy season, a shallow and slow-moving sheet of water inundates the entire ridge and slough landscape (except for the tree islands that usually remain dry). During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

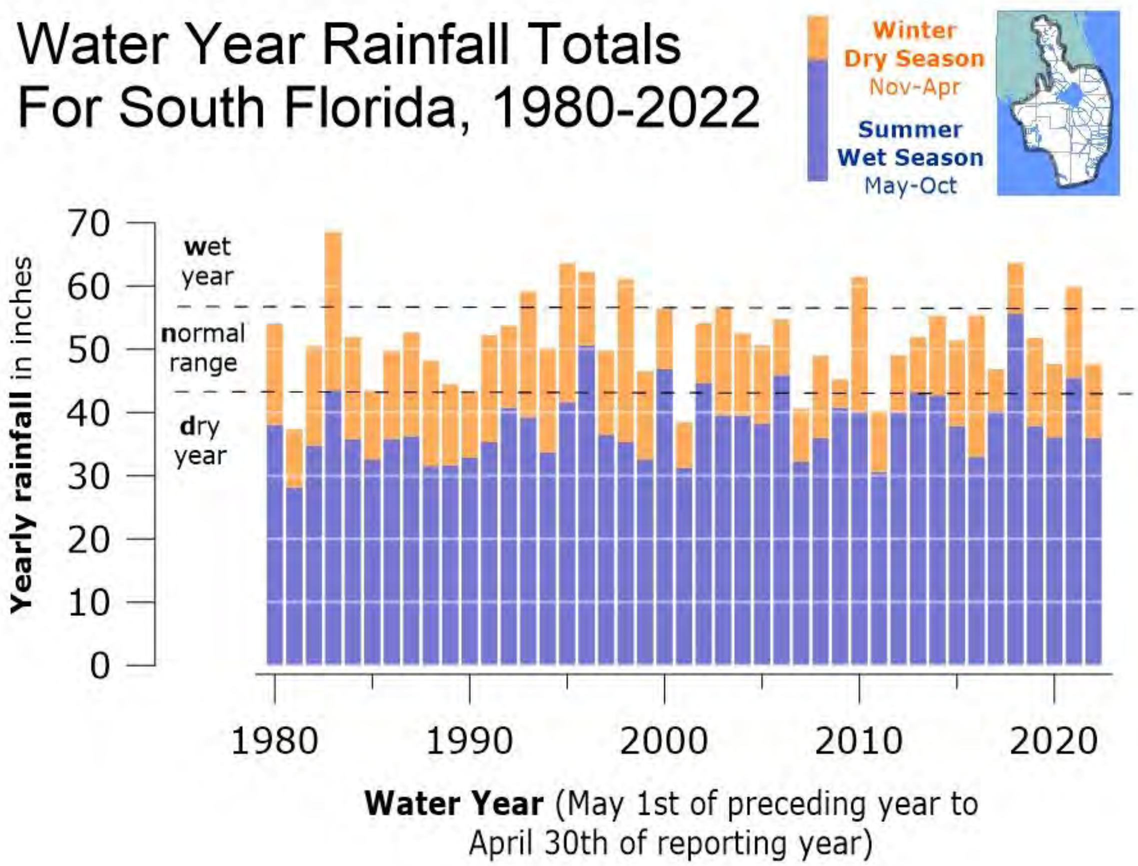



**Figure 4. Yearly water year rainfall (inches) throughout the SFWMD**. This graph was produced using daily rainfall data provided by the SFWMD. District meteorologists compute a daily rainfall value for the fourteen major basins and district-wide from rain gauge measurements. See www.Gohydrology.org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

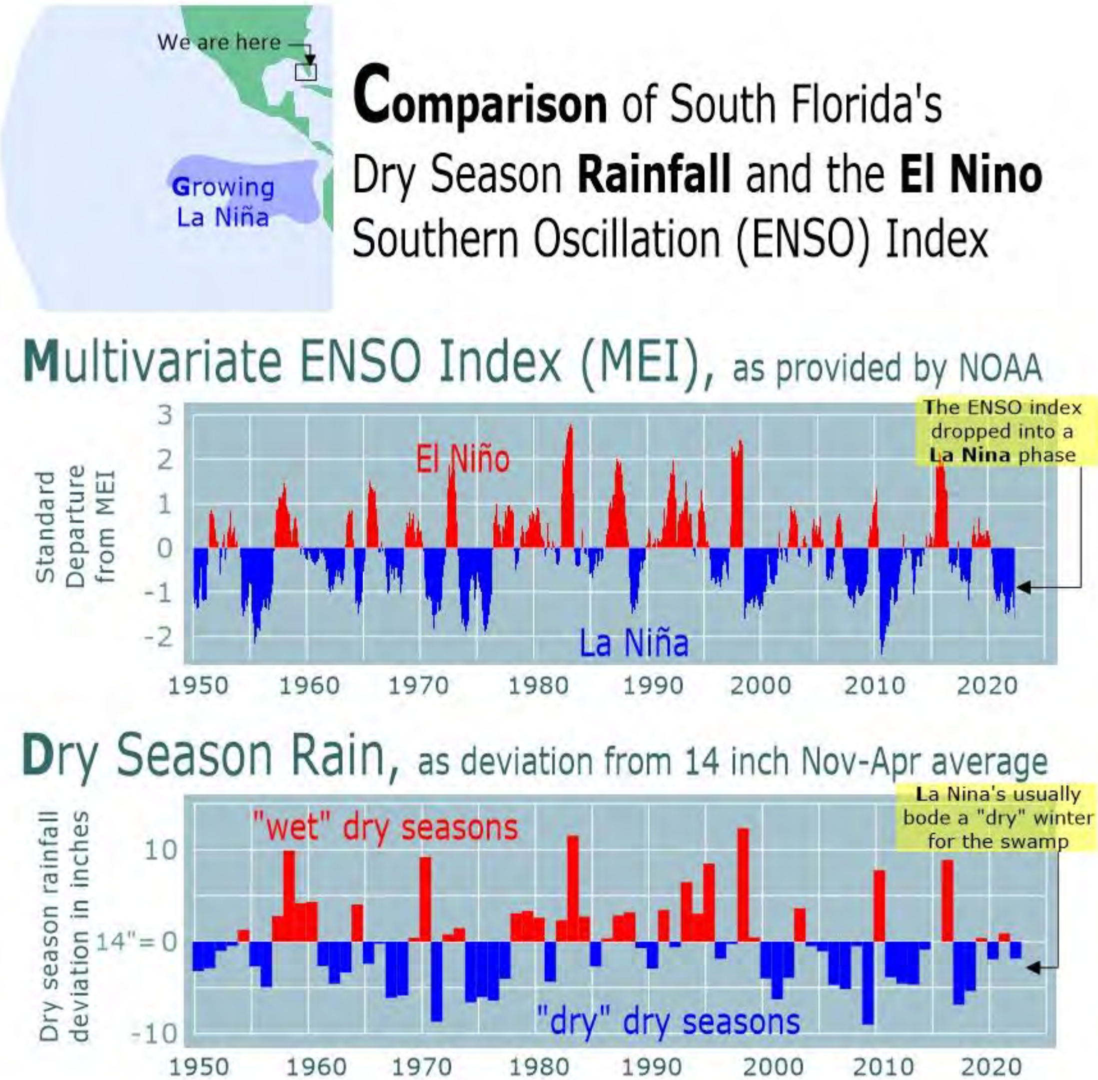



**Figure 5. Correlation between the Multivariate ENSO Index (MEI) and winter dry season rain totals for south Florida.** The top graph displays the standard departure of the MEI from 1950 to present. The bottom graph shows dry season rainfall for south Florida expressed as a departure (in inches) from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

## WATER YEAR SUMMARIES

### WATER YEAR 2021 (MAY 1, 2020 TO APRIL 30, 2021)

Water Year 2021 classified as above average in terms of rainfall, recording 46 and 14 inches of wet and dry season rainfall, respectively, for a total of 60 inches (Figure 4, Figure 6). The summer wet season started early with a June-like rain total in May (8 inches) and ended late with above average rains in October and a surprise storm in November. Of note, the early start was not enough, or rather in time, to prevent a destructive incineration of an archipelago of hardwood hammocks in the southeast Corner of Big Cypress National Preserve called the Moon Fish Wildfire. Within a week of the fire ending the May rains swept through. Near normal rainfall persisted for core four months of the summer wet season (June through September) and were supplemented by a "wet season" like October. But the real exclamation point came in November in the form of Tropical Storm Eta, filling Lake Okeechobee (Figure 6) the Everglades and Big Cypress Swamp to levels last seen in September 2017 from Hurricane Irma, only shifted forward two months to a time when water levels are usually well past their October peak. The late season highwater stand set the stage for or prolonged and steady winter recession that proved to be a boon to wading bird communities in terms of foraging and nesting. Despite expectations of a wet dry season from the bumper crop of summer and late fall rain, the Big Cypress Swamp dropped into deep drought by April's end. Although no similar wildfires occurred, Water Year 2021 proved an important restoration point: No matter how wet the wet season or the beginning of the dry season, without timely April and May rains the Big Cypress Swamp is especially prone to dropping into deep, unnatural drought due to perimeter and interior canals that stifle the spread of sheet flow and hasten its spring demise.

### WATER YEAR 2022 (MAY 1, 2021 TO APRIL 30, 2022)

Despite the previous year's bountiful rains, Water Year 2022 started slow thanks to subpar rains in May – extending drought conditions into June and even July in some area (Figure 4, Figure 6). Despite the slow start, the four core seasons of the summer wet season (June through September) and October all charted in with average rainfall. For a second year in a row, November provided an unexpected boost with twice its normal rainfall amount. Again, despite the surplus of water at the dry season's start, the Big Cypress Swamp was poised to drop into deep spring drought, imperiling the habits that so vitally depend on natural fire breaks staying wet, when a string of continental fronts at the middle and end of April and start of May boosted the water table just when it needed it most. South Florida received over 10 inches less annual rainfall and 4 inches less dry season rain than the prior year, but it is as much an issue of timing as it is the total amount. Water Year 2021 classified as low-normal in terms or rainfall, recording 36 and 12 inches of wet and dry season rainfall, respectively, for an annual total of 48 inches.

Of interest, despite the apparent disparity between Water Years 2021 and 2022, as judged by their annual rainfall of 60 and 48 inches, respectively, the first classifying in the "above normal range" and the second in the "low normal" range, the two years acted similarly in some respects, and defied the norms of previous years in several respects. The "old normal" of too much water in Water Conservation Area 3A, not enough water in downstream Everglades National Park, and a deep spring plunge of the water table below the cypress roots in the Big Cypress did not materialize for either year. Instead, three bridges along the Tamiami Trail opened the door for increased pumping into the L29 and flow of water into Northeast Shark River Slough and downstream Florida Bay, as also supplemented by the S-332 water retention barrier on the Park's east side. As a result, sloughs in the Park stayed flooded with a foot of water into May for both Water Year 2021 and 2022; whereas similar sloughs in Water Conservation 3A dropped below the one-foot depth threshold by March. Also in reprieve from previous years, timely spring rains helped keep drought in check in the Big Cypress Swamp.

Water Years 2021 and 2022 highlighted the hydrological benefits that increased operational control, afforded by the growing list of water management infrastructure projects, has made possible. Recent notables include Lake Okeechobee's strengthened levee, bridging and now raising the Tamiami Trail grade along Northeastern Shark River Slough, and opening of the C-44 Reservoir, improved seepage control along the L-31 just to name a few, with many more projects and planning initiatives in various stages the way including the Biscayne Bay Southeastern Everglades Restoration (BBSEER) and the Western Everglades Restoration Plan (WERP). Modernization of the water management infrastructure combined with availability of real-time data to inform operations was a major step forward for restoration and hydrology management.

The Everglades and Big Cypress Swamp are flood and fire adapted ecosystems in which every square inch of flora and fauna depend on a regular return interval and dosage of both flood and fire. Or as the saying goes – so goes flood and fire, so goes the swamp. As proven these past two years, operational stewardship is vital to getting both right.

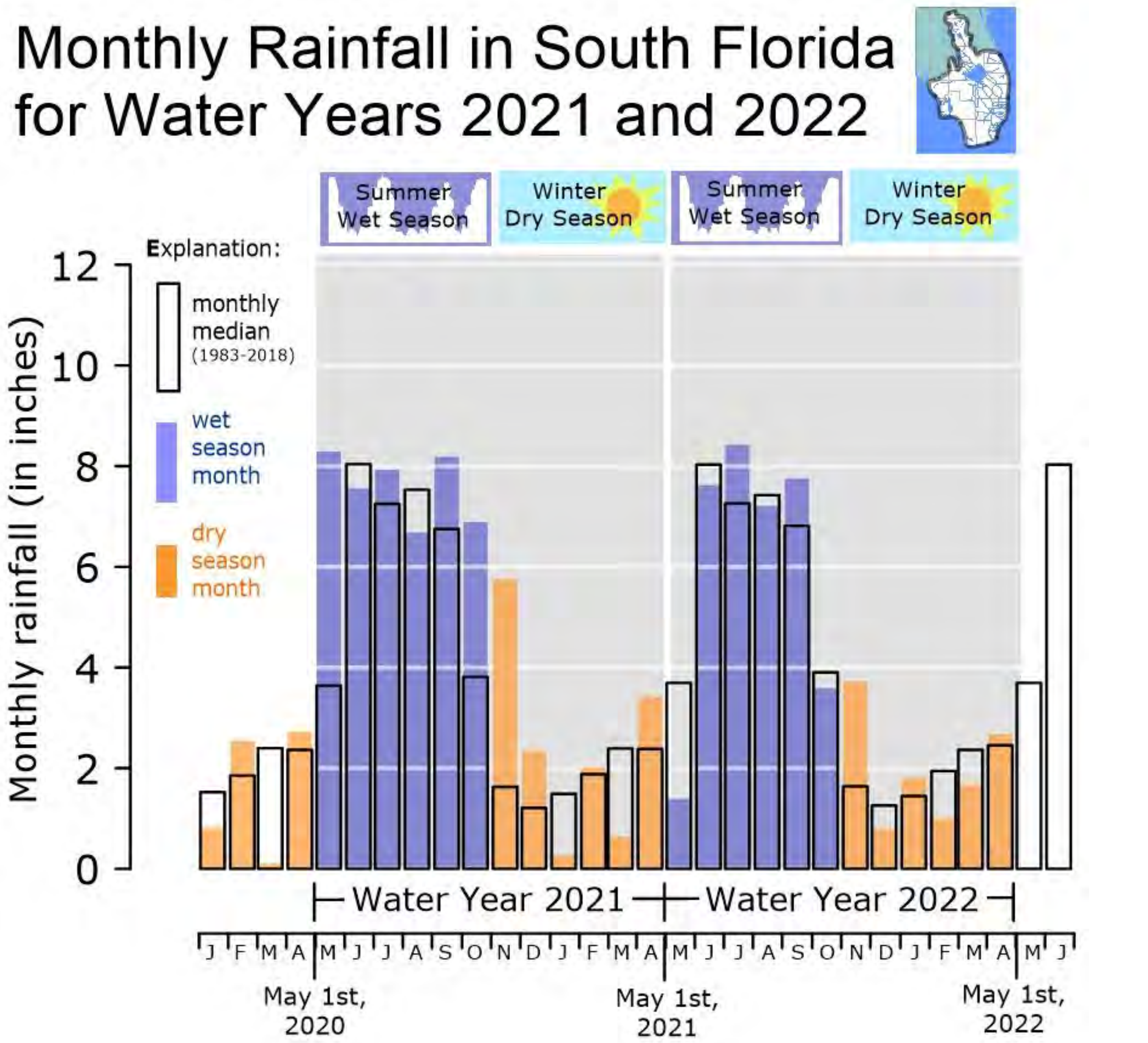



**Figure 6. Summary of monthly rainfall in Water Years 2019 and 2020 throughout the South Florida Ecosystem.** The graph was produced using daily rainfall data provided by the SFWMD. SFWMD meteorologists compute a daily rainfall value for the fourteen major basins and district-wide from rain gauge measurements. See http://www.gohydrology.org/p/about.html for more information.

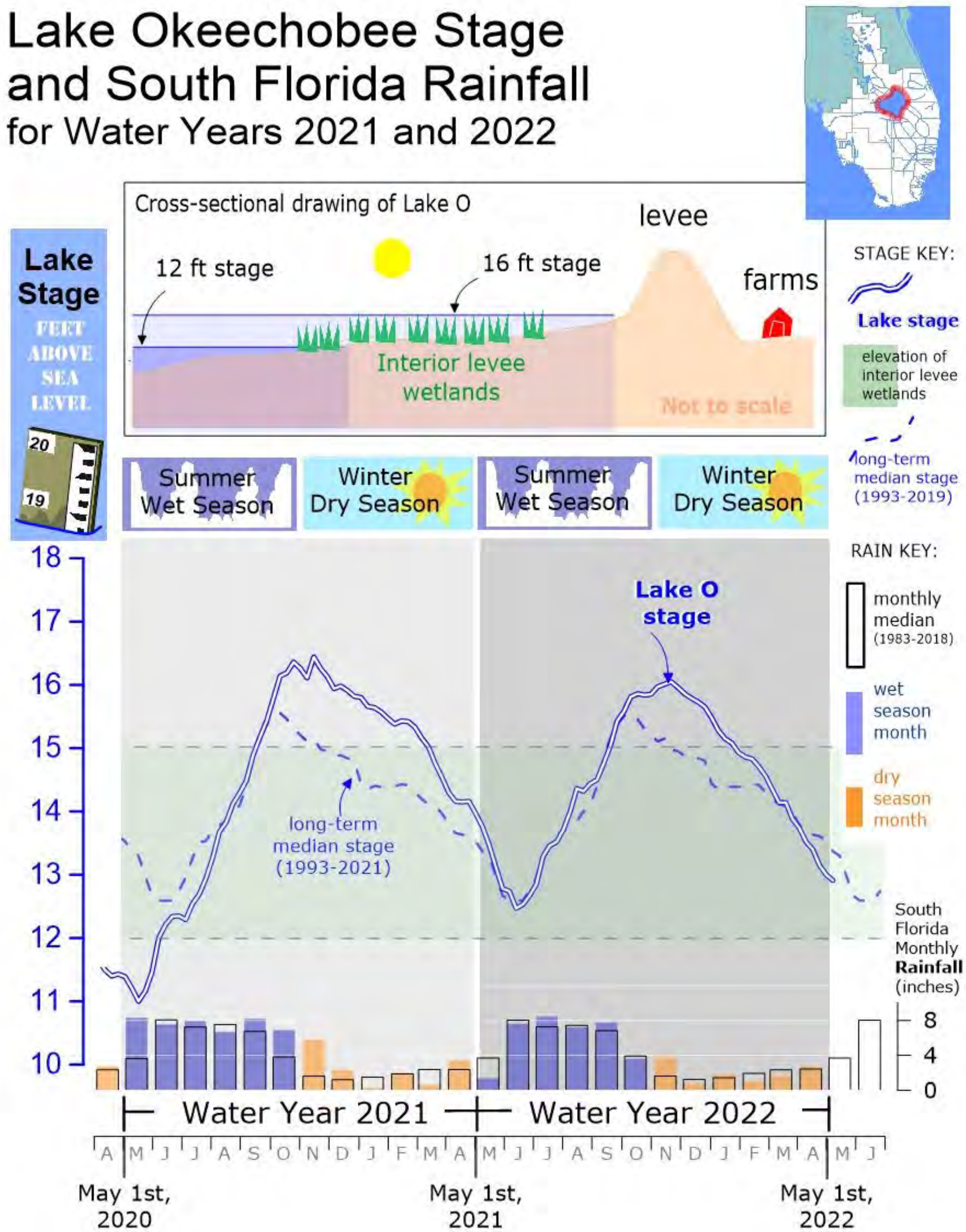



**Figure 7. Lake Okeechobee stage and summary of monthly rainfall in the SFWMD in water years 2021 and 2022.** Daily rainfall data provided by the SFWMD. District meteorologists compute a daily rainfall value for the fourteen major basins and district wide from rain gauge measurements. See GoHydrology.com for more information.

## STOPLIGHT FORMAT

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

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

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

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

This 2022 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 2020 Report, the 2022 South Florida Environmental Report, and the RECOVER 2019 System Status Report (SSR) that addresses the overall status of the ecosystem relative to system-level hypotheses, performance measures, and restoration goals.

The RECOVER 2019 SSR and 2019 Everglades Health Report Card document the measurement of ecological indicators and performance measures and their application to assess conditions in the Everglades' ecosystems for the years 2012–2017. The SSR also provides the scientific basis/foundation for the Comprehensive Everglades Restoration Plan (CERP) 2020 Report to Congress, required by the Water Resources Development Act of 2000. Produced every five years, the intent of the CERP Report to Congress is to inform the highest levels of the U.S. government on the progress made toward restoration.

Because of broad inter- governmental coordination, the SSR and Everglades Health Report Card incorporate elements of this stoplight indicator update and provides some of the detailed underlying data, theory, and analyses used in this report. The 2019 SSR and Everglades Health Report Card are available at RECOVER 2019 System Status Report 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 provides managers with information they need to adjust restoration activities at both large and small scales.

## INDICATORS OVERVIEW

Here we provide a short summary of why these plants and animals 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 plants**

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

**Lake Okeechobee Nearshore Zone Submerged Aquatic Vegetation (SAV)**

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

**Eastern Oysters**

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

**Crocodilians (American Alligators & Crocodiles)**

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

**Fish & Macroinvertebrates**

- Fish and macroinvertebrates are critical as a food for predators such as wading birds and alligators.
- Fish and macroinvertebrates density and community composition are correlated with hydrology.
- Fish and macroinvertebrates integrate the effects of hydrology in all their life stages.
- The positive or negative trends of Fish & Macroinvertebrates relative to hydrological changes permit an assessment of positive or negative trends in restoration.

**Periphyton**

- Periphyton is comprised of microbes that provide habitat for animals and energy to the rest 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 calcareous diatom taxa. For each parameter, yellow and red are indicated for values more than one and two standard deviations from mean expected values, respectively. For each wetland basin, yellow is indicated if greater than 25% of sample sites are yellow or red, and red is indicated if greater than 50% of sites are red. Expected values are calculated from the long-term average values from least disturbed sites in each wetland basin.

**Wading Birds (White Ibis & Wood Stork)**

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

**Southern Coastal Systems Phytoplankton Blooms**

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

**Florida Bay Submersed Aquatic Vegetation (SAV)**

- Florida Bay has one of the largest seagrass beds in the world, covering 90% of the 180,000 hectares of the bay.
- SAV serves many critical functions within estuarine and coastal ecosystems, such as habitat for many invertebrates, fishes, reptiles and mammals, food provision, carbon sequestration, 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 the receiving basin the South Florida Ecosystem's hydrological system.

**Juvenile Pink Shrimp**

- Pink shrimp are an important and characteristic component of the estuarine fauna of the Everglades.
- Pink shrimp abundance is correlated with 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.

**Wading Birds (Roseate Spoonbill)**

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

## ABOUT THE INDICATORS

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

This reporting cycle, in response to comments by the Working Group and Science Coordination Group we have added a "Trend" column where scientists were asked to indicate quantitatively or qualitatively over the last 10 years, are responses of this indicator moving closer or further away from what we would like to see with restoration? Because these indicators were set up to highlight System-wide responses it is not surprising that most of them have not yet shown improvement at that scale since we have not yet implemented projects that are significantly affecting the whole system.

| | **WY 2018** | **WY 2019** | **WY 2020** | **WY 2021** | **WY 2022** | **Trend** |
|---|---|---|---|---|---|---|
| Invasive Plants | Y | Y | C | Y | Y | Stable |
| Lake Okeechobee Nearshore Zone Submerged Aquatic Vegetation | R | R | R | R | R | Decreasing |
| Eastern Oysters- **Modified (Northern Estuaries only)** | R | R | R | R | R | Stable |
| Crocodilians (American Alligators & Crocodiles)- **Modified (LNWR, WCA-3, ENP, Biscayne Bay Complex)** | R | R | C | R | R | Stable |
| Fish & Macroinvertebrates (WCA-3 and ENP only) | R | R | R | R | R | Stable |
| Periphyton | Y | Y | Y | Y | C | Stable |
| Wading Birds (White Ibis & Wood Stork) | Y | R | R | R | C | Increasing |
| Southern Coastal Systems Phytoplankton Blooms- **Modified (no southwest shelf)** | R | Y | Y | Y | Y | Stable |
| Florida Bay Submersed Aquatic Vegetation | Y | Y | Y | Y | Y | Stable |
| Juvenile Pink Shrimp- **Modified (no renewed sampling)** | B | B | B | B | B | |
| Wading Birds (Roseate Spoonbill) | R | Y | R | Y | R | Stable |

# INDICATORS OVERVIEW

## Stoplight Legend

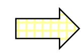
| | |
|---|---|
| R | Substantial deviations from restoration targets creating severe negative condition that merits action. ***Well below restoration target.*** |
| Y | Current situation does not meet restoration targets and may require additional restoration action. ***Below restoration target.*** |
| G | Situation is within the range expected for a healthy ecosystem within the natural variability of rainfall. Continuation of management and monitoring effort is essential to maintain and be able to assess "green" status. ***Meets restoration target.*** |
| B | No data or inadequate amount of data were collected due to reductions in funding. |
| C | Data analysis not complete or data not collected due to extenuating circumstances such as COVID 19 in 2020. |

Scientists responsible for each indicator were given an outline and asked to provide information for their indicator for each section that was relevant to them (see below). For the time series of stoplights, they were asked to provide information for the last five years. Time series from earlier years can be found in the previous System-wide Ecological Indicators for Everglades Restoration reports at Everglades Restoration Initiatives. Indicator sections received minimal editing as they were added to this document. As a way to move toward better integration with RECOVER reporting requirements scientists were asked to address how their indicator liked to RECOVER reporting on Interim Goals (see bolded section below). This will help us collectively make progress towards that reporting.

- Summary/Key Findings
- Time series of stoplights
- Map of WY 2020 stoplight colors (or WY 2019 if WY 2020 not available)
- Updates on calculation of indicator
- Description of: how have these data been used?
- New insights relevant to future restoration decisions
- **If appropriate linkage to RECOVER reporting on Interim Goals (Lake Okeechobee Nearshore Zone Submerged Aquatic Vegetation, Eastern Oyster, Crocodilians [American Alligators & Crocodiles], Fish and Macroinvertebrates, Wading Birds [White Ibis & Wood Stork], Florida Bay Submersed Aquatic Vegetation, Juvenile Pink Shrimp)**
- 
    - **What Interim Goals evaluation model(s) is used?**
    - **What monitoring data are needed to assess if the expected responses are being achieved?**
    - **Will the current modeling and modeling be sufficient to report on this indicator as an Interim Goal in 2024?**
    - **If not, what is needed?**
- Literature cited, reports and publications

# INVASIVE PLANT INDICATOR

## SUMMARY/KEY FINDINGS

| STATUS | PREVIOUSLY REPORTED (WATER YEAR 2020) | (WATER YEAR 2021) | CURRENT (WATER YEAR 2022) | Movement toward restoration target over the last 10 years |
|---|---|---|---|---|
| SYSTEM-WIDE | Sampling could not be completed because of COVID-19 restrictions | Y | Y* |  |

**2022 color based on data collected between November 2019 and March 2021.*

- Invasive plant species can cause substantial negative impacts to Everglades ecosystems, directly impeding restoration success. This Invasive Plant Indicator is used to assess the status of invasive plant species and progress in their control.
- The indicator involves numerous invasive plant species across different jurisdictions and regions. Two primary drivers affecting all invasive plants is their population status (presence and abundance) and success of control efforts. Sustained and closely coordinated control efforts will result in reductions in invasive plant populations and their impacts on native ecosystems.
- Restoration activities may affect invasive plant populations positively or negatively, depending on the characteristics of individual species and their responses to changing conditions as restoration progresses. For example, longer hydroperiods may reduce recolonization rates of Brazilian pepper in Everglades tree islands while increasing habitat suitability for Old World climbing fern.
- All agencies implement invasive plant management programs. However, landscape-level control is hampered by limited resources, remote infestations, and in some cases inadequate control methods.
- Management approaches that integrate numerous control techniques are proving useful. For example, integrating herbicide treatments, fire, and biological controls through Everglades restoration, specifically the Comprehensive Everglades Restoration Plan (CERP) Biological Control Implementation Project, is improving overall management outcomes for some invasive plant species.
- Systematic monitoring programs for established priority invasive plant species are in place for the Greater Everglades module, Big Cypress National Preserve (BCNP), Lake Okeechobee, and Kissimmee River floodplain. Similar monitoring programs are needed for remaining regions of the restoration footprint.
- The SFWMD and National Park Service (NPS) conduct routine early detection surveys along fixed routes within Everglades National Park (ENP) and Biscayne National Park (BNP), BCNP, and District/FWC-managed lands south of Lake Okeechobee. Several high priority early detection plants have been discovered and more than eleven new county records have been documented.
- While the overall distribution of many species has increased, large portions of the restoration footprint have reached “maintenance control” of priority invasive plant species. In some areas, populations previously under control have resurged, largely due to inadequate resources for management.

- Key regions where invasive plant populations remain problematic include:
  - Kissimmee River floodplain
  - Picayune Strand
  - Arthur R. Marshall Loxahatchee National Wildlife Refuge
  - Everglades National Park (northeastern region)
  - Big Cypress National Preserve
- Continued improvements in invasive plant management through strategic partnerships, coordinated planning, construction, and operational phases of restoration will reduce ecological impacts and promote more cost-effective control.
- CERP Guidance Memorandum (CGM) 062.00 (CGM 62, 2012) ensures invasive species management is included in the planning process. CEPP is the first project to incorporate the guidance, including an invasive & nuisance species management plan developed by USACE. All future CERP projects will follow this proactive approach of planning and budgeting for invasive species management, in accordance with CGM 62.

**On a system-wide scale the Invasive Plant Indicator was below the restoration target (yellow stoplight) at the end of WY 2021 and remains below the restoration target at the end of WY 2022.**

## DATA AND CALCULATIONS

**Table 1. Stoplight table for the Invasive Plant Indicator–WY 2018 – WY 2022**. Red = Substantial deviations from restoration targets creating severe negative condition that merits action. Well below restoration target. Yellow = Current situation does not meet restoration targets and may require additional restoration action. Below restoration target. 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. Meets restoration target. Black = No data or inadequate amount of data were collected due to reductions in funding. Clear = Sampling or analysis incomplete or delayed due to COVID-19 so stoplight not available. *2022 color based on data collected between November 2019 and March 2021.

| Invasive Plant Species | WY 2018 | WY 2019 | WY 2020 | WY 2021 | WY 2022 |
|---|---|---|---|---|---|
| **System-Wide** | Y | Y | C | Y | Y |
| **Kissimmee River Basin** | R | R | R | R | R |
| **Lake Okeechobee** | Y | Y | Y | Y | Y |
| **Northern Estuaries – East Coast** | Y | Y | C | Y | Y |
| **Northern Estuaries – West Coast** | Y | Y | C | Y | Y |
| **Greater Everglades** | Y | Y | C | Y | Y |
| A.R.M. Loxahatchee National Wildlife Refuge | R | R | R | R | R |
| Water Conservation Area (WCA) 2A/B | **G** | **G** | C | **G** | **G** |
| Water Conservation Area (WCA)3A | Y | Y | C | Y | Y |
| Water Conservation Area (WCA) 3B | Y | Y | C | **G** | **G** |
| Everglades National Park (ENP) | Y | Y | C | Y | Y |
| Biscayne Bay Complex | Y | Y | C | Y | Y |
| **Southern Estuaries** | B | B | B | B | B |
| **Florida Keys** | B | B | B | B | B |

**Region-wide status of the four priority invasive plant species**

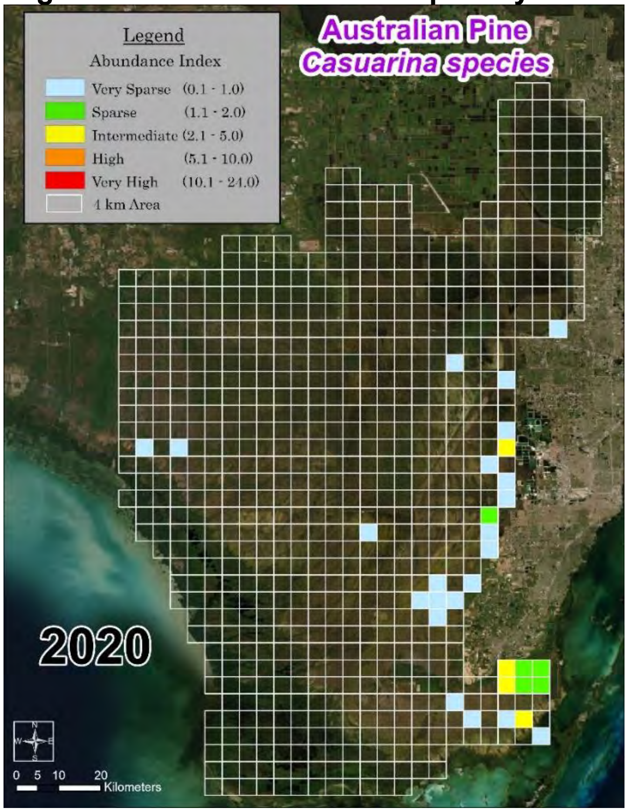



**Figure 1. Distribution and abundance index of Australian pine in the Everglades, 2020*.** Australian pine is observed infrequently within the Greater Everglades footprint and at mostly low abundance levels. *Data collected between November 2019 and March 2021.

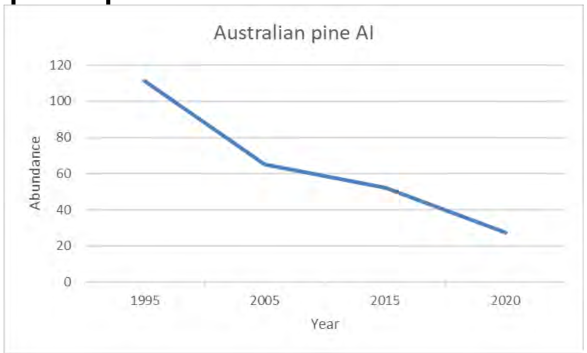



**Figure 2. The region-wide abundance index of Australian pine has steadily declined over the last 25 years.** Data represent the summed abundance index scores for the Everglades monitoring footprint.

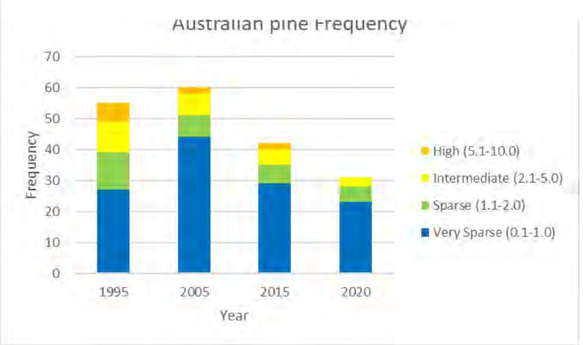



**Figure 3. The frequency of Australian pine has decreased since 2005.** The proportion of high and intermediate abundance classes has also decreased.

Australian pine (*Casuarina* spp.) is the least abundant of the four tracked invasive species in the project area (Figure 1). Since 1995, the region-wide abundance index has decreased 75% (Figure 2) and its distribution (frequency of occupied cells) has decreased 44% (Figure 3). Where Australian pine was detected, it is typically at very sparse levels and, in some cases, only one or two trees are present in a four-kilometer grid cell. Much of the observed decline over the 25-year monitoring period occurred in the northeastern reaches of ENP and parts of the Southern Glades Wildlife Management Area, where Australian pine once occurred at high-levels. These declines in abundance are attributed to systematic and repeated control efforts by federal, state, and county agencies. Most of the remaining Australian pine infestations are located on private lands and in remote regions of sawgrass marsh and mangrove forest. ENP is addressing Australian pine infestations in remote mangroves using helicopters to transport herbicide applicators for precision treatments. Ongoing maintenance of this species across public lands will likely result in continued declines. In addition, recolonization rates of Australian pine in areas where this species historically existed will decrease as restoration proceeds, due to the plant's intolerance of extended hydroperiods.

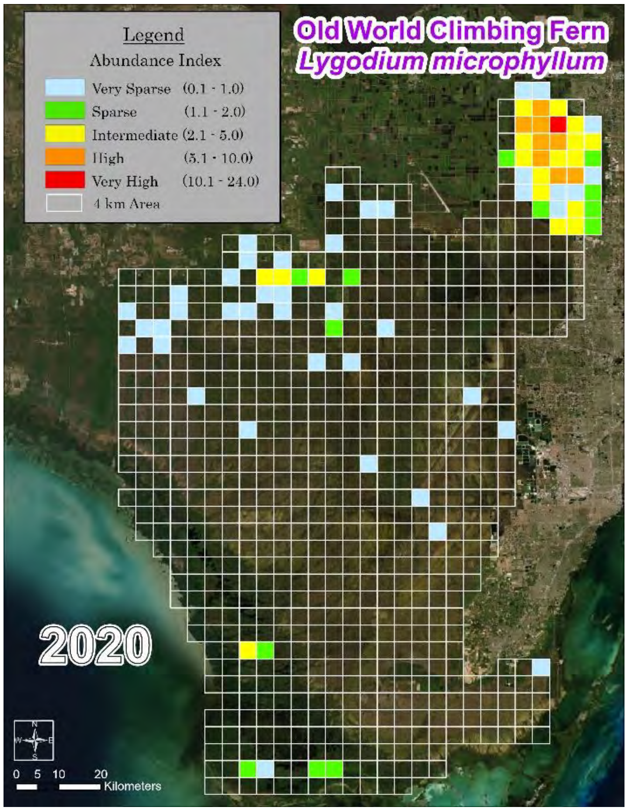



**Figure 4. Distribution and abundance index of Old World climbing fern in the Everglades, 2020*.** Old World climbing fern distribution is characterized by high-level localized infestations and scattered sparse occurrences. *Data collected between November 2019 and March 2021.

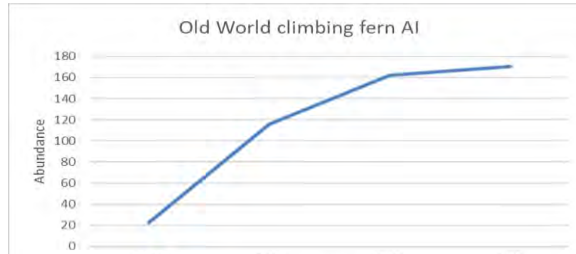



**Figure 5. The region-wide abundance index increased substantially over the last 25 years.** Data represent the summed abundance index scores for the Everglades monitoring footprint.

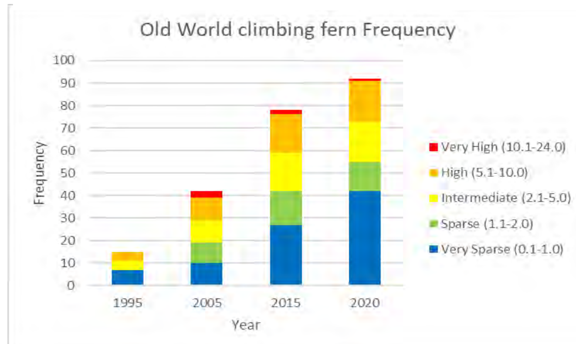



**Figure 6. The area of occurrence (grid cell frequency) for Old World climbing fern steadily increased during the 25-year sampling period.**

Old World climbing fern (*Lygodium microphyllum*) occurs throughout the monitoring footprint, but its distribution is most concentrated in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (LNWR), located in the northeastern section of the Everglades (Figure 4). However, low-level infestations in other areas have expanded since 2005. The region-wide abundance index score for Old World climbing fern (OWCF) increased by roughly 640% since 1995 (Figure 5), reflecting the rapid spread of this highly invasive plant across the landscape and its aggressive dominance in localized areas. However, the rate of increase has declined over the 25-year monitoring period, suggesting that ongoing efforts to contain this invasive plant's spread is dampening the invasion rate. Several agencies have made this plant a priority for rapid response control when it is first detected in new management areas. While the area of occurrence (grid cell frequency) continues to increase, the number of cells containing very high and high infestation levels decreased between 2015 to 2020 (Figure 6). Interestingly, OWCF abundance decreased substantially in the southwest region of ENP between 2015 and 2020. Herbicide treatments were not conducted in the area and it is not clear what factors contributed to this decline. Potential but unconfirmed factors include prescribed fire, tidal surges, and biological controls. The continued increase in abundance and distribution across the project area demonstrates that while control efforts and potentially other disturbances are limiting the level of infestation in some areas, OWCF continues to expand its range. Hydrologic restoration may reduce invasion rates in some low-lying coastal graminoid marshes but is not likely to contribute to OWCF reductions systemwide.

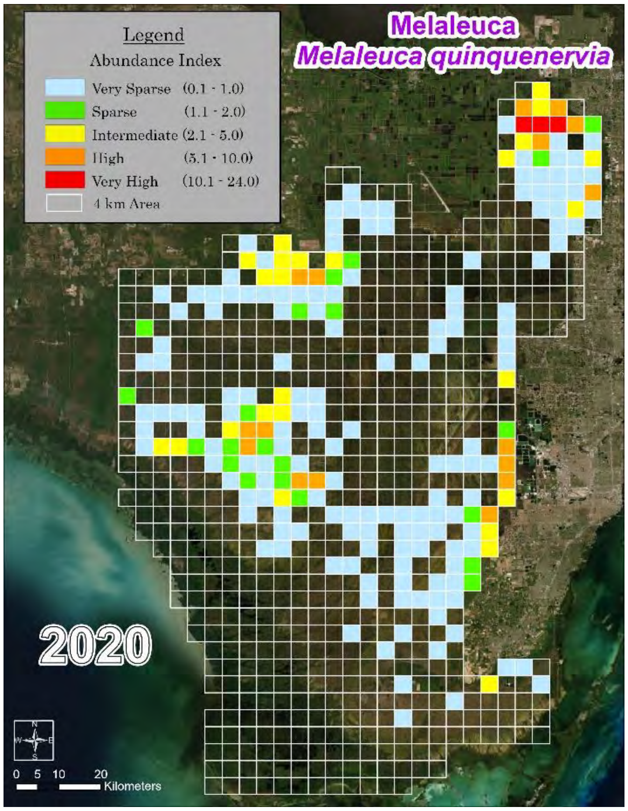



**Figure 7. Distribution and abundance index of melaleuca in the Everglades, 2020*.** Low level melaleuca is widely distributed across the project area and multiple areas of localized heavy infestations remain. *Data collected between November 2019 and March 2021

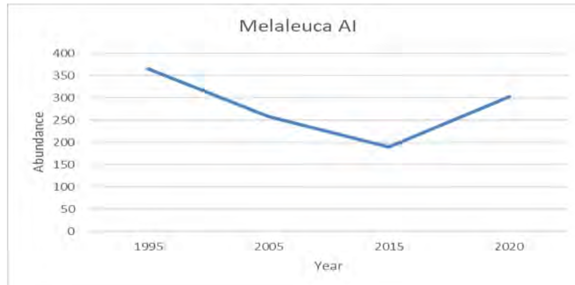



**Figure 8. Melaleuca abundance increased in the last five years but remains lower than it was in 1995.** Data represent the summed abundance index scores for the Everglades monitoring footprint.

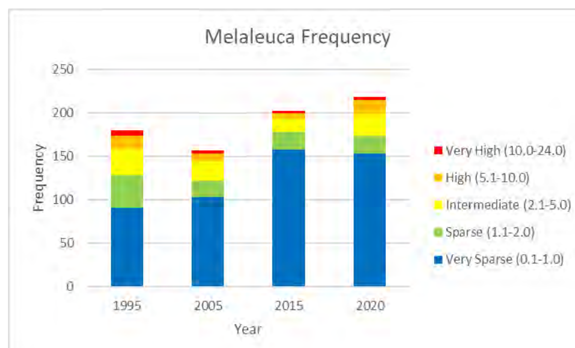



**Figure 9. Melaleuca's area of occurrence (grid cell frequency) increased slightly since 1995.** The relative proportion of high-level infestations increased since 2005.

Distribution of melaleuca (*Melaleuca quinquenervia*) across the project area has increased in the last five years. Despite this increase in frequency, the species remains less abundant than it was when the monitoring project began (Figure 8). Ongoing control work in southern portions of LNWR, parts of ENP and in WCA 2 and 3 has prevented large resurgences in historically impacted areas. Roughly three quarters of all melaleuca mapped in 2020 was in the very sparse cover class. Much of this low-level melaleuca is found scattered across open expanses of sawgrass marsh and in some cases, only one seedling was documented across a four-kilometer grid cell (Figure 7). This widespread but sparse distribution demonstrates the need for continued frequent and thorough sweeps to ensure that trees are removed from the landscape before they begin to produce seeds.

There was a notable increase in intermediate and high-level melaleuca between 2015 and 2020 (Figure 9). This reflects localized increases in infestation levels, particularly in untreated regions of LNWR and in areas that experienced recent wildfires in BCNP. The post-fire resurgence of melaleuca was anticipated by land managers who have begun control work on the densely growing seedlings in the fire footprint. Biological control agents appear to be slowing the maturity rate of the trees, giving more time for treatment prior to seeding.

It is expected that as hydroperiods lengthen through restoration, melaleuca recolonization rates may decline. This effect is predicted to be most pronounced in WCAs 2 and 3 and eastern ENP.

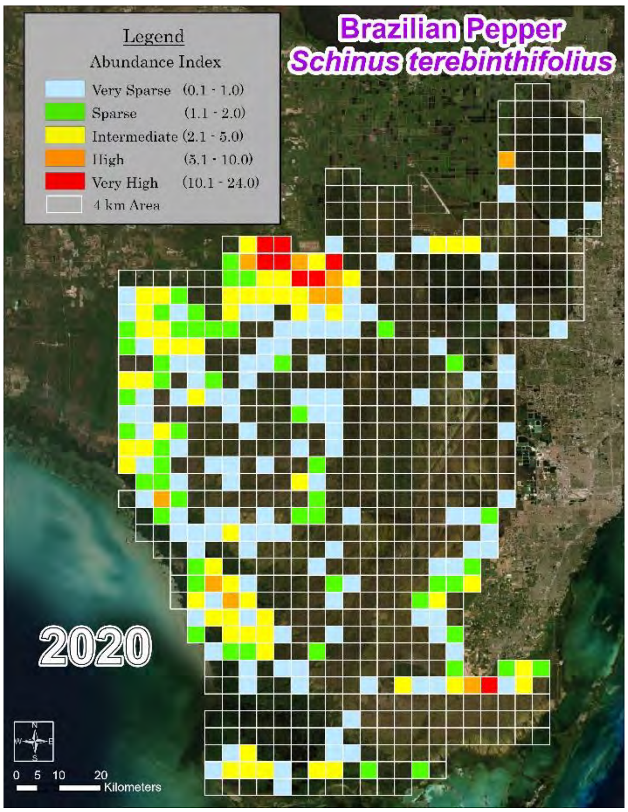



**Figure 10. Distribution and abundance index of Brazilian pepper in the Everglades, 2020*.** Brazilian pepper remains abundant in the west and parts of the southeast project area. *Data collected between November 2019 and March 2021.


**Figure 11. After two decades of increasing abundance, Brazilian pepper has begun to decline.** Data represent the summed abundance index scores for the Everglades monitoring footprint.

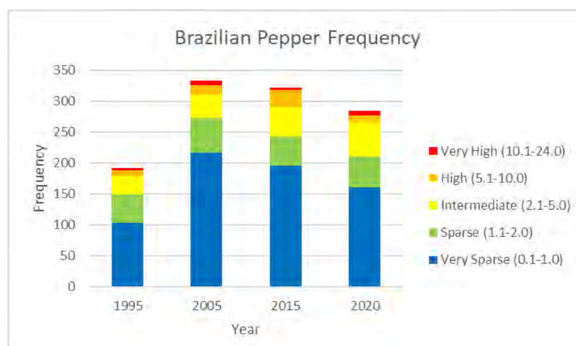



**Figure 12. Brazilian pepper's area of occurrence (grid cell frequency) increased since 2005.**

Brazilian pepper (*Schinus terebinthifolia*) abundance increased 41% since monitoring began in 1995 but has decreased 10% in the past five years (Figure 11). Low distribution levels in 1995 may be attributed to small plants going undetected. Despite the historic trend of increasing abundance, the overall distribution across the project area has been steadily declining since 2005. In the WCAs, Holeyland and LNWR, sustained Brazilian pepper control efforts are evident by its low level, sparse distribution (Figure 10). Brazilian pepper abundance has increased in the central north portion of the project area where no treatment program is in place and hydroperiods are reduced. It is expected that as hydroperiods lengthen through restoration, Brazilian pepper recolonization rates will decline. This effect is predicted to be most pronounced in WCA 2 and 3 and eastern ENP.

### Updates on calculation of indicator

The indicator calculation continues to follow Doren et al (2009), which assesses the status of invasive plant species populations, number of new invasive species present, and availability of monitoring programs and control tools. This indicator is assessed for each RECOVER assessment module, including sub-management units within the Greater Everglades module. Species level assessments are reported for regions within the CERP footprint in the 2022 South Florida Environmental Report (SFER) (Rodgers et al. 2022).

To assess population status and new species introductions, data is collected from several monitoring protocols as described in Rodgers et al. (2018). Budget constraints and expanded monitoring objectives resulted in reductions in system-wide monitoring using systematic reconnaissance flights (SRF) from a two-year to five-year interval and is limited to the Greater Everglades, Lake Okeechobee, and Kissimmee River modules. These modules are monitored using the SRF methodology in separate years. The 2022 report includes population status data collected between November 2019 and March 2021 for the Greater Everglades module and Big Cypress National Preserve. Kissimmee River and Lake Okeechobee will be assessed in 2023 and 2024, respectively. The SRF methodology is based on aerial assessments by trained mappers. Invasive plant abundance measurements (based on canopy cover) are collected within a 4 km grid system. An abundance weighted frequency score is calculated for each 4 km grid cell, allowing for broad-scale assessments of distribution and abundance over time. Systematic early detection monitoring remains limited to the Greater Everglades module. The status of the invasive plant indicator (Doren et al. 2009) remained below the restoration target (yellow stoplight) at the end of WY 2022.

### How have these data been used?

Data were used to update the RECOVER System Status Report sections on invasive species. The System-wide science report covers many drivers and stressors affecting changes in the South Florida Ecosystem. Invasive species are a driver of change that has significant implications for several Monitoring and Assessment Plan (MAP) ecosystem indicators. Data provided in the report is utilized to elucidate how invasive species, as ecosystem engineers, may alter restoration outcomes as CERP progresses. These data are also used to report on the status of invasive species and progress towards their management in the SFER to meet mandated reporting requirements pursuant to Chapter 2005-36, Laws of Florida, and Section 373.036(7), Florida Statutes (F.S.). Additionally, monitoring data is used to inform land managers of invasive plant expansion or reestablishment, to respond to newly detected invasive plant species, and to assess program-level progress as management efforts continue.

### New insights relevant to future restoration decisions

Most of the regions continue to have substantial invasive plant infestations, though many areas have active monitoring and control programs. Large sections of the Everglades region show consistent decreases in invasive plant abundance due to sustained integrated management strategies. However, documented increases in abundance of melaleuca and OWCF in localized areas are a concern and reflect the challenges of achieving sustained maintenance control of some species over large, remote landscapes.

There are now 80 Category I Invasive Plant Species (FLEPPC 2019) established in the CERP footprint (Rodgers et al. 2022). These species are known to alter native plant communities by displacing native species, changing community structure or ecological function, or hybridizing with natives. Early detection monitoring resulted in the detection of two invasive species in management units not previously documented. Repeated follow up herbicide treatments and biological control in WCA 2A/B and WCA 3B have finally yielded maintenance control conditions for all priority invasive plant species as indicated by the green stoplight color in WY 2021 and 2022. In addition, a multi-scale monitoring program is in place and funded, and no new invasive plants were recently reported for these areas. These conservation areas once had very large melaleuca infestations, and many wondered if the plant could ever be sufficiently controlled there. The melaleuca strategy that relied on integrated pest management, consistent and sufficient management funding, monitoring, regulatory and research support all contributed to this success. Numerous invasive plant species continue to persist in high densities within the Kissimmee River floodplain. OWCF, creeping water primroses (*Ludwigia* spp.), and several invasive grass species—paragrass (*Urochloa mutica*), limpograss (*Hemarthria altissima*), and West Indian marsh grass (*Hymenachne amplexic*aulis) are common and aggressive invaders in this region. Land managers and restoration scientists are developing management strategies for these species and some control has been achieved. Significant resources will be required to achieve maintenance level control of these species.

In addition to the invasive species in the Kissimmee River, invasive floating aquatic vegetation (water hyacinth and water lettuce) on Lake Okeechobee remains a high management priority. Recently, feathered mosquito fern (*Azolla pinnata*) is becoming a more recent sighting in the northwestern side of the lake. With relatively low water levels, tropical American water grass (*Luziola subintegra*) has become a common invasive grass species for managers to address. This species has encroached in multiple areas throughout the lake and surrounding tributaries. Lake managers have developed aggressive treatment management plans to address the spread of Tropical American Luziola subintegra in these areas to help prevent spread and establishment. Biological control of several invasive plants is showing promising outcomes. biological control agents for melaleuca are well-established, and melaleuca reduction is documented (Rayamajhi et al. 2019). Two agents for Old World climbing fern are now established. One of these, the brown lygodium moth, is now widespread and exerting localized pressure on the invasive fern. The recent expansion of the lygodium gall mite from introduction sites is an encouraging development and the pest has shown some localized damage to Old World climbing fern, particularly following fire events. The CERP Biological Control Implementation project continues rearing and releasing approved agents at the United States Department of Agriculture's Agricultural Research Service biological control laboratory in Davie, Florida. During 2021, the program continued releases of biological control agents for OWCF and water hyacinth and ramped up rearing and release of a recently approved agent for Brazilian pepper. A second agent for air potato (*Dioscorea bulbifera*) was approved this year and releases are expected to begin within months. Since the project's inception in 2013, there have been 3,115 release events resulting in the release of over 9.2 million biological control agents.

Monitoring that would identify new invasive species or new distributions for existing species covers the Greater Everglades region (Rodgers et al. 2018) and portions of the Kissimmee River, Lake Okeechobee, and Big Cypress regions. These efforts are providing insight into landscape scale distribution and abundance changes for some species, but the ability to identify where and when new species establish is limited. In many cases, invasive plant populations are not being systematically monitored. Overall, the picture remains mixed for invasive plants. Although progress has been made on a number of species, we are still unable to control many species faster than they are invading and spreading. To control species faster than they are invading and spreading, prevention, monitoring, and control programs must be expanded. With the incorporation of CERP Guidance Memorandum 62 into CERP projects that are currently reaching the construction stage, the USACE should have an increased ability to apply invasive species management strategies into CERP projects as they are coming online, allowing for a more proactive approach to managing invasive plant species.

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# LAKE OKEECHOBEE NEARSHORE ZONE SUBMERGED AQUATIC VEGETATION (SAV) INDICATOR

## SUMMARY/KEY FINDINGS

| STATUS | PREVIOUSLY REPORTED (WATER YEAR 2020) | (WATER YEAR 2021) | CURRENT (WATER YEAR 2022) | Movement toward restoration target over the last 10 years |
|---|---|---|---|---|
| SYSTEM-WIDE | R | R | R | ⇩ |

- Submerged aquatic vegetation (SAV) provides habitat for fish and wildlife, stability for sediments, and improves water quality. A healthy SAV community directly corresponds to healthy Lake Okeechobee conditions. The SAV community is directly influenced by water levels and light conditions so restoration activities that maintain optimal lake stages (height of the water above mean sea level) and decrease turbidity are key.
- SAV coverage should expand with completion of Everglades Restoration projects that provide watershed storage and subsequently improve Lake Okeechobee stages. Without these projects, rapid inflows from a channelized watershed will continue to drive high lake stages, especially during wet conditions, inhibiting growth and development of SAV and essentially drowning emergent vegetation. Everglades Restoration that creates storage capacity in the watershed will also prevent dry conditions that drive lake stages down and expose SAV beds, converting open water areas to emergent marshes and/or terrestrial habitats. Additionally, it will stabilize lake stages, thereby reducing interannual variability which should help SAV flourish beyond the 50,000-acre RECOVER annual restoration target (interim goal of ≥35,000 acres) and allow for more frequent favorable water levels that benefit lake ecology.
- While several Everglades Restoration projects, specifically CERP, will affect lake stages to some degree (e.g., C-44, C-43, and Everglades Agricultural Area (EAA) reservoirs), only one upstream project, the Lake Okeechobee Watershed Restoration Project (LOWRP), will directly affect inflows to the lake and lake ecology. Through installation of Aquifer Storage and Recovery wells and wetland restoration in the watershed, lake stages are expected to remain within desired ranges more frequently, particularly under dry conditions.
- Over the long-term, additional storage will be needed in the watershed as was originally envisioned in LOWRP and CERP. Such improvements to lake stages should increase coverage of SAV to established targets. The Kissimmee River Restoration project, authorized in 1992 (pre-CERP), may have incidental nutrient load reduction benefits to Lake Okeechobee and provide seasonal changes to inflow patterns, but will not significantly alter inflow volumes to the lake. This project is expected to reduce total phosphorus loads to Lake Okeechobee by 30 metric tons.
- To date, no projects have been completed that will directly impact lake stages. The C-44 Reservoir and associated Stormwater Treatment Area (STA) has been completed but this eastern watershed storage project was formulated to improve estuary conditions with minimal and/or indirect impacts to lake stages. Watershed storage and downstream storage remains minimal to non-existent, and stages continue to deviate wildly from desired ranges, particularly during wet and dry events.
- SAV areal coverage declined 77% from WY 2021 to WY 2022, going from just over 16,000 acres of total SAV to approximately 3,700 acres. This was the lowest areal coverage since WY 2007 when three successive hurricanes reduced the spatial extent of SAV to less than 2,000 acres. Most of the decrease was due to the loss of the non-vascular *Chara spp.*, which declined by 97% while the vascular species declined by 54%. This loss of SAV coverage essentially negated the significant recovery of over 20,000 acres that occurred in WY 2020

after the seiche, rapid water level rise, and combined wind and wave energy from Hurricane Irma in WY 2018 resulted in a decline to just over 5,000 acres of total SAV in WY 2019. The recovery was aided by lake levels being within or below the optimal lake stages for nearly a full year, improving light penetration and encouraging reestablishment of SAV. In contrast to this recovery period, water levels for nearly a full year prior to the WY 2022 SAV growing season were above or at the top of the threshold of optimal levels.

- The interim goal of ≥35,000 acres of total SAV has only been achieved once in the past decade (WY 2013) and although WY 2014, WY 2015, and WY 2016 were within 2,000 acres or less of the interim goal, SAV coverage has been less than 30,000 acres in six of the past ten water years, averaging just over 24,000 acres, or just 69% of the ≥35,000 acres.
- WY 2021 and WY 2022 achieved only 47% and 11% of the interim goal, respectively. Additional water storage north of the Lake is needed to store water during wet times to reduce high lake stages and later be released into the lake to reduce the impacts of low stages during dry times, thus maintain optimal lake stages more frequently.

**The SAV indicator was well below the restoration target (red stoplight) at the end of WY 2021 and remained well below the restoration target at the end of WY 2022 (Table 1).**

Lake stages were high in late WY 2021 compared to recent years, which likely affected SAV coverage in sampling efforts of WY 2022. While WY 2021 continued a three-year trend of moderate increase in the abundance of vascular SAV after Hurricane Irma, WY 2022 saw a decline of 78%, reaching the lowest level of slightly over 3,700 acres of total SAV since several hurricanes decimated habitats over 15 years ago (Figure 1). The interim goal of 35,000 acres of SAV during the late summer / early fall peak growing season has not been met since WY 2013, and SAV coverage has been less than 20,000 acres in three of the last five water years. The CERP projects currently under construction are unlikely to benefit the SAV community because they are not intended to improve water quality or quantity into Lake Okeechobee.

**Table 1. Stoplight table for Lake Okeechobee Nearshore Zone Submerged Aquatic Vegetation for WY 2018 - WY 2022.** Red = less than intermediate goal of ≥35,000 acres and well below restoration target. Yellow = coverage ≥35,000 and < 50,000 acres and above intermediate goal but below restoration target. Green = coverage ≥50,000 acres and meets or exceeds the restoration target.

| | WY 2018 | WY 2019 | WY 2020 | WY 2021 | WY 2022 |
|---|---|---|---|---|---|
| ≥50,000 SAV acres restoration target | R | R | R | R | R |
| ≥35,000 SAV acres intermediate goal | R | R | R | R | R |

# LAKE OKEECHOBEE NEARSHORE ZONE SUBMERGED AQUATIC VEGETATION (SAV) INDICATOR

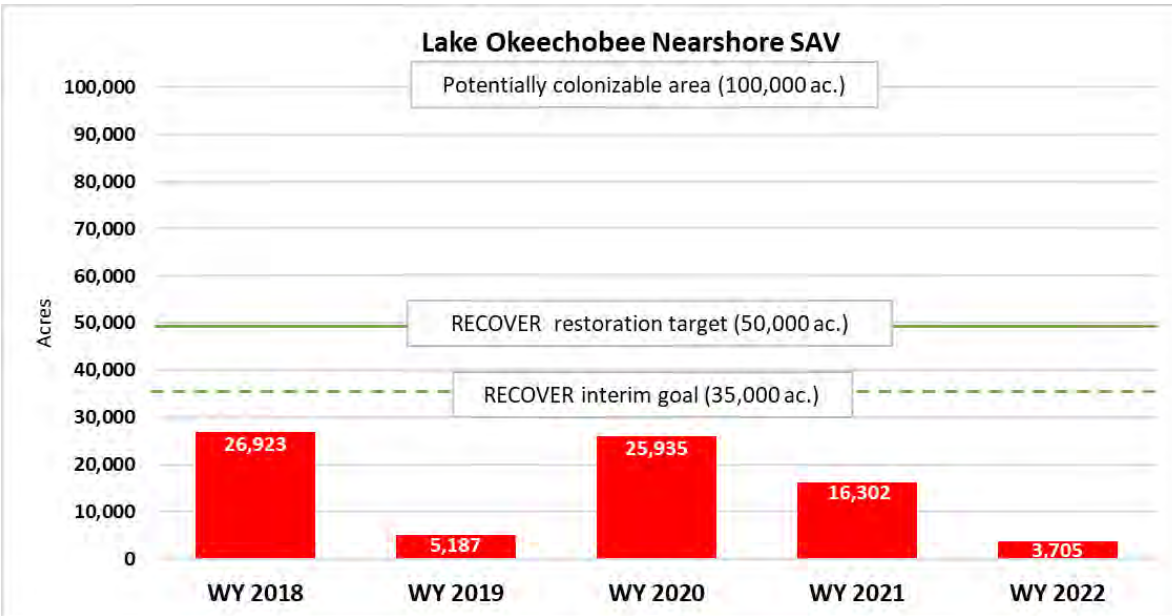


**Figure 1. Annual nearshore SAV mapping results for WY 2018 – WY 2022.** SAV is sampled during peak growing season (July / August / September) on a yearly basis.

## DATA AND CALCULATIONS

### Updates on calculation of indicator

No updates since 2016. In 2016 the SAV Indicator was revised and approved by RECOVER as a performance measure. The indicator for this performance measure is the annual peak percent cover of SAV relative to the potentially colonizable nearshore area (100,000 acres) and includes an interim goal of at least 35,000 acres (35% of colonizable area) annual areal coverage of SAV. Anything less than 35,000 acres receives a red stoplight. Values ≥ 35,000 and <50,000 acres receive a yellow stoplight and values ≥50,000 acres meet the target and receive a green stoplight.

### How these data are being used

SAV is a key indicator of a lake's overall ecological health and is a critical resource in shallow lakes (Havens et al. 2004). SAV is monitored on Lake Okeechobee to track responses to environmental conditions using a systematic grid method (Sharfstein and Zhang 2017). In late summer/early fall, during the peak growing season, the entire nearshore region of the lake is mapped to determine the total area of each SAV species and coverage and distribution maps are developed. Results from this annual SAV mapping effort are reported in the annual SFER, published by the SFWMD, and in the RECOVER Systems Status Report. The data are being used to help assess habitat conditions for nearshore fish and wildlife, to demonstrate changes in water quality, and to inform short-term water management operations. This information also can be used in the context of interim goals.

## New insights relevant to future restoration decisions

Lake level and turbidity act as external forcing functions to drive changes from an SAV / clear water state to a phytoplankton / turbid water state. Thus, the nearshore zone switches between an SAV / clear water state when water levels and turbidity are low to a phytoplankton / turbid water state when there are periods of prolonged high-water levels with accompanying sediment resuspension (Havens et al. 2001, 2004, James and Havens 2005).

Even under the 2008 Lake Okeechobee Regulation Schedule (LORS), the lake stage has exceeded the preferred ecological stage envelope (varies seasonally between 11.5 to 15.5 ft above sea level) every water year since WY 2013, except for WY 2020. While the spring of WY 2017 and most of the WY 2018 summer had lake stage below or at the lower end of the ecological stage envelope and SAV increased, Hurricane Irma passed over the lake and its watershed in the fall of WY 2018, pushing lake stage to a max of 17.2 ft: the highest stage since October 2004. Lake stage remained above 16 ft for nearly 2.5 months and stayed above the preferred ecological envelope for nearly 3.5 months, reducing SAV coverage. At the end of WY 2019 and during the growing season of WY 2020, lake stages went below the ecological stage envelope and SAV rebounded. However, during the spring of WY 2021, stage quickly increased, going from approximately 11.3 ft to 13.3 ft by the beginning of the SAV sampling in August WY 2021, adding more stress to an already stressed SAV community and coverage declined. Lake stages continued to increase during the fall and winter of WY 2021, reaching nearly 16.5 ft in mid-November, nearly a foot above the top of the ecological envelope. Stages stayed above the ecological envelope until the beginning of WY 2022, when rapid decreases in water levels brought stage to 12.5 ft just over a month before the WY 2022 SAV sample. Despite having stages near or at the top of the preferred ecological range just prior to sampling, the prolonged stages above 16 ft likely affected SAV at lower elevations and those communities with lower height in the water column, reducing coverage to below 4,000 acres in WY 2022.

On the basis of annual SAV coverage data collected since WY 2002, maintaining lake stage within the ecologically beneficial stage envelope, both in terms of water depth and temporal ascension and recession rates, provides the best conditions to maximize nearshore SAV coverage. When lake stages have been significantly above or below the envelope, SAV coverage has declined (at least temporarily, in the case of lower water). Restoration activities that provide a significant increase in water storage in the Lake Okeechobee watershed, thereby allowing the lake to more closely follow the timing and depths of an ecologically beneficial stage envelope, should enhance SAV coverage and density in the nearshore region. However, even with better control of lake stage, periodic events such as tropical storms and droughts will continue to influence nearshore SAV coverage. The damage caused by Hurricane Irma significantly decreased coverage, to the second lowest levels since multiple hurricanes impacted the lake in WY 2005-2006; taking several years for the SAV to recover (and aided by significant droughts and low lake stages afterwards). SAV coverage was already low prior to Hurricane Irma after a string of years with relatively high lake stages but subsequent stages at and below the bottom of the ecological stage envelope allowed for the recovery of the SAV community. The recovery was short lived as higher lake stages in the two most recent water years negated the post Hurricane Irma recovery.

## LINKAGE TO RECOVER REPORTING ON INTERIM GOALS

### What Interim Goals evaluation model(s) is used?

Lake stage is used as an evaluation measure for Lake Okeechobee interim goals. Increasing the frequency of time that lake water levels remain within the recommended ecological envelope should create conditions that are favorable for the establishment of the desired SAV community. However, we do not have a model for predicting changes in average annual coverage associated with the model outputs.

### What monitoring data are needed to assess if the expected responses are being achieved?

Lake stage data and SAV monitoring that is currently being conducted. Since 2001, the entire nearshore SAV community of Lake Okeechobee is mapped during the peak growing season (August) with an intensive program that includes 631 sites around the shoreline. The total spatial extent, species distribution, and acreage of SAV in the nearshore is calculated and maps of the dominant species are developed. Estimates from this effort will determine whether peak SAV coverage is more than the interim target of ≥35,000 acres (14,165 ha), which would be indicative of success.

### Will the current modeling and modeling be sufficient to report on this indicator as an Interim Goal in 2024?

No. There is no current modeling effort for SAV; however, the current monitoring strategy measures the SAV while it is at its theoretical maximum abundance and is sufficient to measure progress. Continuing the annual monitoring of SAV will provide data to determine the potential impacts of past, present, and future CERP projects on both the transient and more permanent SAV communities. Although there are no CERP projects currently underway that will benefit the lake's SAV communities, future projects that maintain ecologically suitable lake stages should make the SAV interim goals of ≥35,000 nearshore acres (14,165 ha) achievable in most years.

### If not, what is needed?

Potentially, modeling to relate expected or achieved lake stage to area of SAV; however, there are targets for desired conditions so additional modeling may not be necessary.

## Literature Cited, Reports, and Publications for More Information

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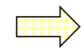
# EASTERN OYSTERS INDICATOR

## SUMMARY/KEY FINDINGS

| STATUS | PREVIOUSLY REPORTED (WATER YEAR 2018) | (WATER YEAR 2020) | CURRENT (WATER YEAR 2022) | Movement toward restoration target over the last 10 years |
|---|---|---|---|---|
| **SYSTEM-WIDE Modified Northern Estuaries Only** | R | R | R |  |

- Eastern oysters are a natural component of estuaries in south Florida that provide water quality benefits, habitat and food for many species, shoreline stabilization, and important commercial, recreational and economic resources for coastal communities.
- Eastern oysters are frequently used as indicators of water quality because they are a dominant species in the estuarine community and their sedentary nature allows for development of cause-and-effect relationships between environmental conditions and oyster population health and abundance.
- Restoration of more natural freshwater flows to the estuaries will reduce occurrences with abrupt changes in estuarine salinity and temperature and will stabilize oyster population health and abundance. Additionally, successfully restored freshwater flows will allow for reestablishment of oysters at estuarine locations that are currently uninhabitable.
- Eastern oysters will benefit most from the following Everglades Restoration projects: the Indian River Lagoon-South project, the Caloosahatchee C-43 Basin Storage Reservoir, the Central Everglades Planning Project (CEPP) including the EAA Reservoir and STA, and the LOSOM update. These projects will improve conditions on both coasts of Florida by providing water storage, reducing detrimental freshwater flows, and maintaining the right amount of essential freshwater flow.
- Eastern oyster status was below the restoration target for WY 2021 and WY 2022 in the Northern Estuaries (Caloosahatchee River Estuary, St. Lucie Estuary, Loxahatchee River Estuary and Lake Worth Lagoon).
- In WY 2021, the values of the metrics used to assess oyster populations in both the St. Lucie and Caloosahatchee River estuaries declined despite moderate conditions.
- In WY 2022, oyster densities and juvenile recruitment rates continued to remain below restoration targets. One of the highlights was that even though the overall score for the St. Lucie Estuary remained below restoration targets, live oysters were again present at all nine sampled stations. Salinities were low enough to reduce predation and disease but not too low, for too long, to cause oyster mortalities.

**On a system-wide scale, the Eastern Oyster indicator remains well below the restoration target (red stoplight) because the majority of projects that will benefit the species have not yet been completed.**

Stoplight scores for the Northern Estuaries and each individual estuary for WY 2018 – WY 2022 are provided in Table 1. Locations of monitored Northern Estuaries and sampling stations within each estuary are shown in Figure 1.

**Table 1. Stoplight Table for Eastern Oysters Indicator (Northern Estuaries Only) for Water Years 2018 –2022.** Red = biological parameter scores substantially lower than restoration targets. Yellow = biological parameter scores are below restoration targets. Green = biological parameter scores are within the expected range for Eastern oysters in the Northern Estuaries.

| Eastern Oyster | WY 2018 | WY 2019 | WY 2020 | WY 2021 | WY 2022 |
|---|---|---|---|---|---|
| **Northern Estuaries** | R | R | R | R | R |
| St. Lucie Estuary (SLE) | R | R | Y | Y | Y |
| Loxahatchee River Estuary | R | G | Y | Y | R |
| Lake Worth Lagoon | R | Y | R | Y | Y |
| Caloosahatchee River Estuary (CRE) | R | Y | R | R | R |

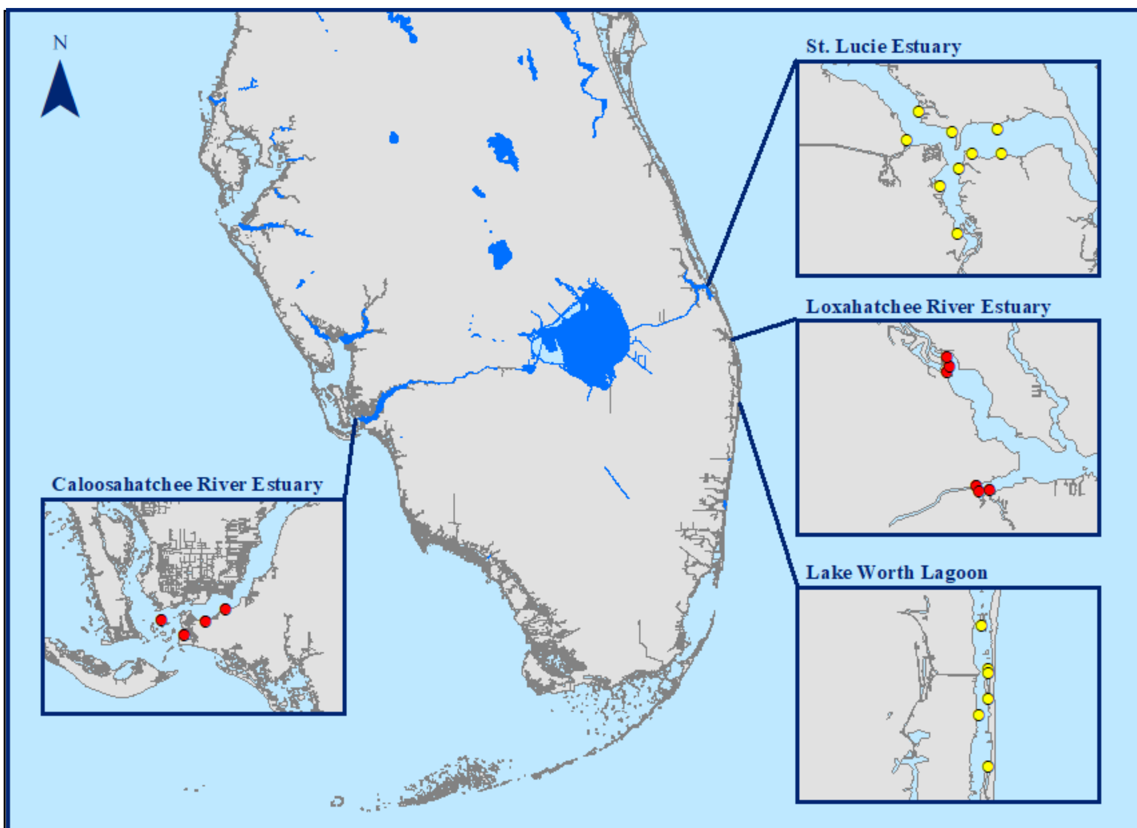



**Figure 1. Stoplight colors for Eastern oyster indicator by estuary for WY 2022**. Circles represent sampled stations in each estuary. Red circles = biological parameter scores substantially lower than restoration targets. Yellow circles = biological parameter scores are below restoration targets. Green circles = biological parameter scores are within the expected range for Eastern oysters in the Northern Estuaries.

## DATA AND CALCULATIONS

### Changes in the calculation of the indicator

For the SRE, Loxahatchee River Estuary, Lake Worth Lagoon and Caloosahatchee Estuary, oyster density, larval settlement rates, and prevalence of infections by the parasitic protozoan *Perkinsus marinus* (dermo) were used to calculate scores for each estuary (Table 2)

**Table 2. Values for the metrics used to evaluate oyster population status**. Abundance is expressed in oysters per $m^2$. Dermo prevalence is expressed a s a percentage of the oysters sampled. Settlement is expressed as spat per shell. Abundance criteria are unique to sites. Dermo and settlement are consistent for all sites.

| Metric | Red | Yellow | Green |
|---|---|---|---|
| Abundance | | | |
| St. Lucie Central | < 100 | 100 – 500 | > 500 |
| SL North and South | < 20 | 20 – 100 | > 100 |
| Loxahatchee | <100 | 100 – 500 | > 500 |
| Lake Worth | <100 | 100 – 500 | > 500 |
| Caloosahatchee | < 500 | 500 – 1000 | >1000 |
| Dermo | > 60 % | 20 – 60% | < 60 % |
| Settlement | < 1 | 1 – 5 | >5 |

### How have these data been used?

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

### Insights relevant to future restoration decisions

- Freshwater inflows into the Northern Estuaries have been altered from a natural state to one in which inflows are more variable and extreme. This altered salinity regime has adversely affected oyster populations by exposing them to high freshwater inflows during the wet season, which leads to acute declines in oyster abundances, and by allowing too little freshwater inflow during the dry season or drought periods, which leads to gradual increases in predation, disease and mortality rates. While there may be occasional dry years, or years when conditions are wet during the dry season, there is generally too much freshwater inflow into the SLE and CRE in the summer months and too little freshwater inflow in the winter months. In the LRE and LWL, there is too little freshwater inflow throughout the year in most years.
- Oyster responses and population abundances in the Northern Estuaries are below targets and are frequently experiencing declines under the current variable salinity conditions. Recovery rates of oyster abundances suggest that oyster index scores could be expected to increase if natural hydrologic conditions are restored.

- Restoration of natural hydrologic freshwater inflow patterns along with substrate enhancement (addition of cultch) after water conditions improve is essential for improving the health and abundance of oysters in the Northern Estuaries.
- Current conditions do not meet restoration criteria, signifying that the Northern Estuaries need further attention.
- If hydrological conditions remain the same, there will not be an improvement in oyster abundances or responses in the Northern Estuaries.
- Continued monitoring of oysters in the Northern Estuaries will provide an indication of ecological responses to ecosystem restoration and allow for differentiation between responses to restoration efforts and natural variations.

## Estuary Specific

### *St. Lucie Estuary (SLE)*

Oyster abundance increased in summer 2019 and remained stable in spring 2020. A large freshwater event in the fall of 2020 resulted in reduced salinities that caused a decline in settled oyster density, but by the end of the event there were still oysters present at The SL Central, North, and South sites, though not all stations. High flows occurred again in June through December of 2020, causing a minor decline in oyster density and loss of oysters at some upstream stations in the north and south fork, but not from the entire estuary. In 2021, flows were consistently high, but rarely extreme and when flow exceeded 1500 cfs, the duration was short. By spring 2022, settled oysters were present at all stations in the March survey, albeit below restoration target densities.

Peak reproductive development and spawning activity typically occurs between April and September and is usually greater in the months during or after a period with moderate or higher salinities. In 2020, peak settlement of oysters occurred in May with a second peak in October and November in the central estuary. Similarly, peak settlement occurred in June in 2021, with some settlement throughout the summer. In 2021, a second, smaller peak in settlement occurred in November-December at almost all stations throughout the estuary. These high recruitment rates continued through the end of the year with some settlement persisting until February 2022 and a new spring peak beginning again in April. Analysis of reproductive development in adult oysters showed that during wet periods, most oysters still completed gametogenesis and spawned. During the 2021 and 2022 water years, periods of increased flow to the estuary, mainly from the watershed, reduced salinity below optimal but were also not extreme enough to eliminate settlement of larvae and recruitment of oysters to a size detectable during settled oyster density surveys.

Disease prevalence from the parasitic protozoan Perkinsus marinus (dermo) was low, typically 20% or lower at most stations, with a mean for water year 2021 of 7.47 % of sampled oysters showing infections. Through 2021 dermo prevalence increased such that on some sample trips, prevalence at some stations reached 80% during the August and December (SL-N) and November (SL-C). The overall mean for the estuary remained below 20% in water year 2022 (18.12%) but was tending upwards. Moderate salinities such as those that occurred in WY 2022 allow for the spread of the dermo parasite, but infection intensities remained very low. Oyster populations in the SLE continue to be negatively affected by the highly variable freshwater inflows that are a result of the altered local hydrology. Extended periods of high salinities can result in gradual increases in disease infection rates that lead to compromised oyster health and survivorship. In water years 2021 and 2022, salinities in the St. Lucie Estuary remained largely benign or beneficial for oysters. Extended periods of extremely low salinities that result in acute damage to oyster populations were not observed.

***Loxahatchee River Estuary (LRE)***

The density of live oysters was higher in the Northwest Fork than in the Southwest Fork of the LRE during WY 2021 and WY 2022. Freshwater inflow to the estuary exceeded 1000 cfs in June, November and December of 2020 but did not do so in WY 2022. There were more suboptimal salinity days in the Northwest Fork than the Southwest fork, but the duration of those conditions was short. Those lower salinities likely reduced predation and disease pressures on resident Northwest Fork oysters thus allowing them to survive and thrive, ultimately resulting in the greater densities mentioned above. Live oyster densities in the Northwest Fork were as expected in WY 2021 but fell slightly below expectations in WY 2022 (496 oysters per $m^2$). Density was consistently below restoration targets in the Southwest Fork.

The timing of reproductive development and larval recruitment in the LRE is similar among oysters in the two forks. Reproductive development and spawning activity generally occurred between March and October. Settlement of larvae typically occurred in May or June with additional pulses of settlement throughout the fall. In WY 2022 a small number of spat were observed in each month through the winter. There were few, but still some spat in every month from January through March and settlement began to increase rapidly in April and May.  Recruitment rates were generally higher in the Northwest Fork than the Southwest Fork.

Disease prevalence from the parasitic protozoan Perkinsus marinus (Dermo) was higher in the Southwest Fork than the Northwest Fork.  In WY 2021, the average prevalence in the Southwest Fork was 59.4% and in WY 2022 it increased slightly to 67.7 %. By comparison, in the Northwest Fork the prevalence was 14.0 % in WY 2021 and 22.6% in WY 2022. Salinities in the Northwest Fork are commonly within the optimal range for oyster health whereas salinities in the Southwest Fork are typically above the optimal range for oyster health. The high infection rates in the Southwest Fork and average rates of dermo prevalence within the estuary that is above the target threshold (20% or lower) indicate that freshwater inflows into the estuary have generally not been of sufficient magnitude or duration to provide prolonged relief from disease pressure.

Oyster populations in the LRE have been negatively impacted by the pattern of freshwater inflows that are a result of the altered local hydrology. Oysters are naturally adapted to variable salinities as long as the duration of excursions above and below the optimal range are brief.  Extended periods of high salinities result in gradual increases in disease infection rates that lead to compromised oyster health and survivorship. If salinities rapidly decrease to suboptimal levels, as occurred in WY 2022, the opportunity for acclimatization to new conditions is reduced or eliminated and the local oysters are more susceptible to predation and disease. The shift from dry conditions to wet conditions in WY 2022 was not extreme, and salinities were only briefly below optimal. High salinities are a persistent problem in the LRE but there is evidence that brief excursions to optimal salinities, or even suboptimal salinities, can substantially reduce disease rates and increase reproductive capacity.

***Lake Worth Lagoon (LWL)***

The density of live oysters in LWL continued to decline during WY 2021 and WY 2022. Beneficial water flow in the fall of 2021 reduced salinity briefly in LWL, but salinity in all of WY 2022 was above optimal in the estuary.  Reduced salinities reduce predation and disease pressures on resident LWL oysters and would allow those them to better survive and thrive.

Reproductively active oysters are present in most months in the LWL, as temperatures rarely fall below 20°C. The proportion of active oysters is greatest between April and October. Settlement of oyster larvae was highest between August and November (WY 2021) and August through November (WY 2021) though some spat were observed in almost every month samples were collected in WY 2021 and WY 2022. Recruitment rates were above the target threshold (5 spat per shell) in WY 2021 and fell slightly below that threshold in WY 2022.

Disease prevalence from the parasitic protozoan Perkinsus marinus (Dermo) fell slightly in WY 2021 and remained moderate in WY 2022. Infection rates greater than the target rate of 20% prevalence indicate that freshwater inflows into the estuary have generally not been of sufficient magnitude or duration to provide relief from disease pressure.

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

***Caloosahatchee River Estuary (CRE)***

The density of live oysters at sampled stations in the CRE is highly variable and greatly influenced by freshwater inflows and the resultant salinity fluctuations along the upstream to downstream gradient. Water year 2021 began with an extended period when flow exceeded 5000 cfs and a brief excursion above 10,000 cfs entering the estuary. WY 2022 had high flow but rarely had extreme flow. Mean settled oyster density in the estuary varied but has generally trended downward since WY 2014. While the trend is not consistent, no single stations reached the restoration target for the estuary (1000 oysters / $m^2$) in either WY 2021 or WY 2022. Ideally, upstream stations would improve during dry years, and downstream stations would improve during wet years.

Reproductive development and spawning activity can be protracted in the CRE, with ripe and spawning individuals present between March and October. While spawning appears protracted, peak settlement of spat tends to occur in September each year. Settlement rates generally begin increasing in June or July and continue at some level through November with some spat present during any month. Unfortunately, the rate of settlement has declined since WY 2014, and is often below the restoration target of 5 spat per shell.

Disease prevalence from the parasitic protozoan Perkinsus marinus (Dermo) was moderate to high, ranging from 30% to 89% in CRE oysters between WY 2014 and 2022. Despite episodes of inflow rates that moderate salinity, dermo was persistently present in the estuary. Dermo prevalence is rarely below the target threshold (20%) and is commonly above 50%, even at the most upstream station. As with other sites in Florida, dermo infection intensity typically remains very low.

Oyster populations in the CRE continue to be negatively affected by the highly variable freshwater inflows that are a result of the altered local hydrology. Extended periods of high salinities result in gradual increases in disease infection rates that lead to compromised oyster health and survivorship. Periods of extremely low salinities that can result in in acute damage to upstream oyster populations were not observed in WY 2021 or WY 2022, and most low-salinity events were brief. However, the rapid transitions between high and low salinity regimes compound the effects of the salinity extremes by reducing the opportunity for acclimatization to new conditions. The timing and duration of extreme low salinity events can greatly affect the severity of the damage to oyster populations. Extended periods of above optimal or below optimal salinities are a persistent problem in the CRE, and the very narrow geographic region of the river that currently supports oyster habitat is an impediment to a healthy oyster population. Moderation of flows and moderation of the rapid changes in flow might allow the oyster the population to expand both upstream and downstream in the estuary.

## LINKAGE TO RECOVER REPORTING ON INTERIM GOALS

### What Interim Goals evaluation model(s) is used?

Habitat Suitability Indices (HSI) have been created for Eastern oyster (*C. virginica*) in the Caloosahatchee River Estuary and St. Lucie River. The existing GIS-based HSI model integrates spatial layers of three environmental variables: salinity, temperature, and bottom type (adapted from Barnes et al. 2007). Relevant environmental variables affecting the extent and health of oysters in the Northern Estuaries can then be incorporated into an index. The HSI models create composite maps incorporating these variables and scores of suitability from 0–1.0, with 0 being unsuitable, and 1.0 being most-suitable. Assessment of biological metrics that can be used to inform HSI's occurs in all four estuaries include density, size, settlement, reproduction, and disease. Estuary-wide substrate surveys that include oysters and oyster shell have been conducted of Caloosahatchee and St. Lucie River at irregular intervals of 5-10 years between surveys.

### What monitoring data are needed to assess if the expected responses are being achieved?

HSI have not been created for Eastern oyster (*C. virginica*) in the Loxahatchee River nor Lake Worth Lagoon. Hydrodynamic models of Caloosahatchee and St. Lucie River exist need to be incorporated to HSI to inform areas that exclude oyster bar creation. Some locations have currents that exceed the ability of reefs to form, but hydrodynamic models do not exist for all estuaries.

This work is funded through SFWMD for Caloosahatchee River, St. Lucie River, and Loxahatchee River and by Palm Beach County for Lake Worth Lagoon. To continue evaluation of the oyster metric, continued funding is required. Three of the four estuaries are mapped on an irregular basis as funding allows, but no such funding nor project has occurred in Lake Worth Lagoon.

### Will the current monitoring and modeling be sufficient to report on this indicator as an Interim Goal in 2024?

No.

### If not, what is needed?

Continued monitoring of all four estuaries and repeated mapping efforts of all four estuaries will be needed to link existing monitoring to changes in the total acreage and health of oyster habitat.

Additional metrics in the HSI's should include bathymetry, fetch and distance to the Intercoastal Waterway (wave energy), and seagrass distribution (to exclude any future oyster restoration projects). Updated and finalized HSI's for each estuary should be adopted. Interim goals for oyster habitat acreage for Loxahatchee River and Lake Worth Lagoon. No monitoring, models nor metrics exist for oyster reef or worm reef (similar but unique type of molluscan habitat historically present in the 10,000 Islands area) in the southern estuaries; therefore if the desire is to have the oyster interim goal reflective of the entire system modeling and monitoring will be needed in the southern estuaries.

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## SUMMARY/KEY FINDINGS

| STATUS | PREVIOUSLY REPORTED (WATER YEAR 2019) | (WATER YEAR 2021) | CURRENT (WATER YEAR 2022) | Movement toward restoration target over the last 10 years |
|---|---|---|---|---|
| SYSTEM-WIDE - Modified (LNWR, WCA-3, ENP, Biscayne Bay Complex) | R | R | R | ⇨ |

- Crocodilians (alligators and crocodiles) are iconic, keystone species of the Florida Everglades. As essential ecosystem engineers, crocodilians create both high ground (nests) and low areas (alligator holes, trails) that promote species diversity in the ecosystem.
- Crocodilians are ecological indicators in the Everglades whose survival and population dynamics are directly connected to regional hydrology and estuarine salinity.
- Crocodilian responses are tightly linked to patterns of freshwater flow through the Everglades and to the southern estuaries that influence water depth, salinity regimes, and ultimately resource availability.
- We expect positive responses in crocodilian growth, survival, body condition, and estimated abundance in marsh areas where Everglades Restoration projects (i.e., Mod Waters, Tamiami Trail bridge, C-111 South Dade and C-111 Spreader Canal Western projects) are now beginning to restore multi-year hydroperiods, more natural fluctuations in water depths, and more natural water deliveries to critical estuaries and ecosystems.
- We continue to observe declines in American alligator estimated abundance in the Everglades system where key projects such as the CEPP have not yet been completed, particularly in areas that are consistently drier earlier in the year, such as in northern WCA 3A. Consecutive dry years have negative impacts on alligator abundance, and alligator body condition is related to range in water depth and fall water depths. Projects such as CEPP will improve conditions for alligators, thus positively affecting abundance and body condition.
- Long-term monitoring of American crocodiles has demonstrated that metrics such as body condition, relative density, growth, and survival respond positively to patterns of increased freshwater flow and reduced salinity on short, medium, and long-term intervals. This new knowledge provides us with insights that allow us to better assess crocodile responses to areas where freshwater flow and salinity patterns are the target of restoration efforts, such as northeastern Florida Bay.
- Although the overall stoplight color for crocodilians for WY 2021 and WY 2022 is red and is well below the restoration target, we have seen improvement in Northeastern Shark River Slough likely because of restoration efforts associated with Mod Waters and the Tamiami Trail Bridge project.
- Over the last 10 years the crocodilian indicator has remained well below the restoration target (Table 1; Figure 1) with the overall index score remaining constant. In some areas some of the metrics continue to decline; however, in areas such as Northeastern Shark River Slough where restoration actions have been taken, we are starting to see improvement in alligator populations. In addition, we expect that lower salinity values in areas like Northeastern Florida Bay will have a positive influence on crocodile abundance and body condition.

**The crocodilian indicator remains well below the restoration target (red stoplight).**

## CROCODILIANS (AMERICAN ALLIGATORS AND CROCODILES) INDICATOR

**Table 1. Stoplight table for the Crocodilian (American Alligator & Crocodile) Indicator WY 2012 – WY 2022**. Red = Substantial deviations from restoration targets creating severe negative condition that merits action. Well below restoration target. Yellow = Current situation does not meet restoration targets and may require additional restoration action. Below restoration target. 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. Meets restoration target. Black = No data or inadequate amount of data were collected due to reductions in funding. Clear = Sampling or analysis incomplete or delayed so stoplight not available.

| **American Alligators and Crocodiles** | **WY 2012** | **WY 2013** | **WY 2014** | **WY 2015** | **WY 2016** | **WY 2017** | **WY 2018** | **WY 2019** | **WY 2020** | **WY 2021** | **WY 2022** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| System-wide (Modified) | B | B | B | B | R | R | R | R | C | R | R |
| DOI Lands (Modified) | R | R | R | R | R | R | R | R | C | R | R |
| **American Alligator** | | | | | | | | | | | |
| A.R.M. Loxahatchee National Wildlife Refuge | Y | Y | Y | Y | Y | Y | Y | Y | C | Y | Y |
| Water Conservation Area 2A | B | B | B | B | B | B | B | B | B | B | B |
| Water Conservation Area 3A | B | B | B | B | B | B | B | B | B | Y | R |
| Water Conservation Area 3B | B | B | B | B | B | B | B | B | B | R | R |
| Everglades National Park | R | R | R | R | R | R | Y | R | C | Y | R |
| Big Cypress National Preserve | R | R | R | R | Y | R | B | B | B | B | B |
| **American Crocodile** | | | | | | | | | | | |
| Everglades National Park | R | Y | Y | Y | R | R | R | G | Y | R | R |
| Biscayne Bay Complex | R | R | R | R | R | R | R | R | C | R | R |

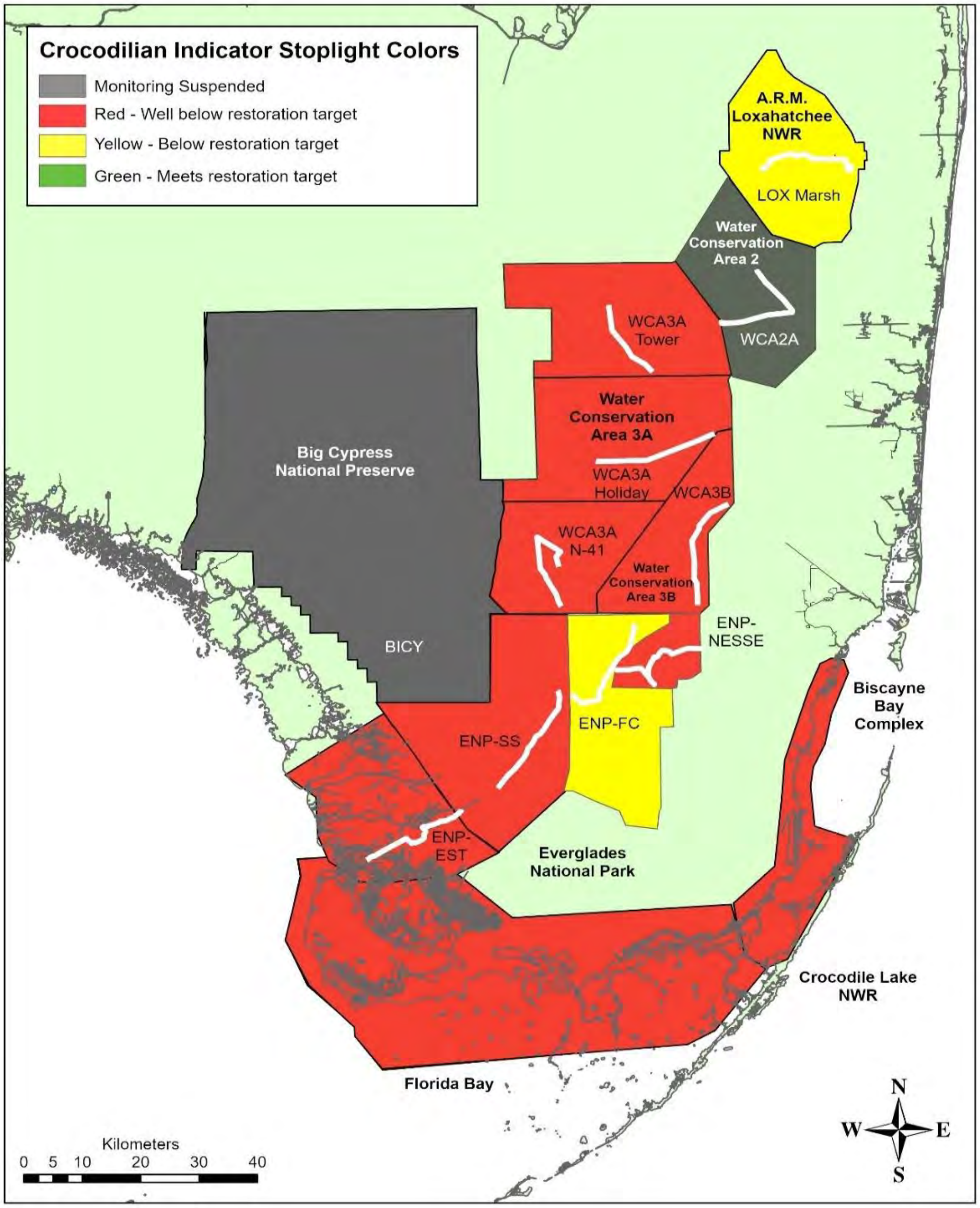


**Figure 1. Stoplight colors for crocodilian indicator by management unit for WY 2022**. Red = Substantial deviations from restoration targets creating severe negative condition that merits action. Well below restoration target. Yellow = Current situation does not meet restoration targets and may require additional restoration action. Below restoration target. 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. Meets restoration target. Black = No data or inadequate amount of data were collected due to reductions in funding. Color for WCA and interior ENP are for American alligators (*Alligator mississippiensis*) only. Color for southwest coastal ENP are American alligators and American crocodiles (*Crocodylus acutus*). Color for Biscayne Bay is for crocodiles only. Alligator survey routes are highlighted in each area by a white line.

## DATA AND CALCULATIONS

### Updates on calculation of indicator

For alligators, several changes have occurred in sampling since 2004 and hence in how we calculate the indicator. Originally, we had 10 marsh routes. With funding cuts in 2011, we only continued sampling on DOI lands including LNWR, ENP, and BCNP (a total of 5 routes).

In 2016, funding was restored to sample in WCA3A&B and now that we have 5 years of data, we can again incorporate those routes into the overall stoplight calculation. Currently, there is only partial funding for routes on DOI lands and sampling in the BCNP was paused in 2018. Calculation of overall stoplight scores have taken these changes in routes into account.

### How these data are being used

Some of the data presented here are a part of the monitoring program for the Mod Waters project. Crocodile data continue to provide foundational science for U.S. Fish and Wildlife Service documents such as the crocodile 5- year review and biological opinions. Results from continued long-term crocodile monitoring also benefit multi-agency efforts (C-111 Spreader Canal Western, Tamiami Bridge, L-31 Seepage Barrier).

### New insights relevant to future restoration decisions

*Alligators*

In addition to the 5-year trends used in the stoplight calculation, we calculated long-term trends in American alligator abundance for 10 of our Everglades routes using data available for the period 2004-2017 using the dynamic N-mixture binomial model described in Farris et al. (2021) for spring and fall data separately. Almost all routes showed a decline in abundance in both spring and fall (Farris et al. 2022). Using data simulation, we revisited our power to detect a trend in 5 years using the results from the abundance modeling and realistic starting alligator abundances. If the change in alligator abundance over 5 years is relatively large or the starting density was high with an alpha value of 0.25 and at least 3 surveys per season there is adequate power to detect a trend in abundance. Where starting abundance is low additional measures such as presence absence along routes may be more appropriate.

The above analysis coupled with the challenges we have faced in surveying Northeast Shark River Slough East (NESSE) and Tower in spring because of dry conditions (could not survey 2 of the last 5 years; Figure 2) is further solidifying the need to develop alternative metrics to help evaluate route responses as well as alligator responses to restoration in drier areas that have low alligator abundance. With restoration, we should be able to complete our surveys and captures in most of spring seasons with the exception being in low rainfall years when sloughs would naturally dry out. Therefore, we will be tracking our ability to complete spring surveys and captures as a way show progress towards restoration.

Our expectation is that in areas like NESSE and Tower that are drier and generally have fewer alligators we will first be able to complete our spring surveys and captures more consistently with no more than 1 year out of 5 when we cannot. We should also begin to see more subadult and adult alligators (3 years) along these routes followed by evidence of successful reproduction in the form of hatchlings (5 years). To date, we have been using non-hatchling abundance as our metric for tracking trends. It may be informative to also look at size class distribution including number of pods of young. Pods of young will allow us to tie more directly to what is being modeled in the Alligator Production Suitability Index.

**Figure 2. Examples of terrain at the stopping points along the NESSE (left) and Frog City (right) survey routes during Spring 2020, wherein it became too shallow or completely dry to safely continue.** The water depths were 8.25 cm (~3.5 inches) at the NESSE stopping point and 3.81 cm (~1.5 inches) at the Frog City stopping point.

*Crocodiles*

Our long-term American crocodile capture-recapture study has produced 10,040 capture events of 9,865 individuals allowing us to calculate growth and body condition under different salinities and over time (Briggs-Gonzalez et al. 2021). Mean crocodile body condition in this study was 2.14 ± 0.35 SD across the South Florida population. Crocodiles exposed to hypersaline conditions (> 40 psu) during the dry season maintained lower body condition scores and reduced growth rate by 13% after one year, by 24% after five years, and by 29% after ten years (Figure 3). Estimated hatchling survival for the South Florida population was 25% increasing with ontogeny and reaching near 90% survival at year six. Hatchling survival was 34% in NE Florida Bay relative to a 69% hatchling survival at Crocodile Lake National Wildlife Refuge and 53% in Flamingo area of ENP. Hypersaline conditions negatively affected survival, growth and body condition and was most pronounced in NE Florida Bay, where the hydrologic conditions have been most disturbed (Briggs-Gonzalez et al. 2021).

We have also used the long-term data to examine trends in crocodile nesting in relation to climate change and anthropogenic factors. Over the 37-year period of 1980-2016, hatching dates are shifting 1.5 days earlier every two years in ENP and about half that at the Florida Power and Light Company Turkey Point Power Plant (Turkey Point) with every 1˚C increase in sea surface temperature. The result is that hatching is occurring approximately 10 days earlier in ENP and 6 days earlier at Turkey Point (Cherkiss et al. 2020). Because crocodile hatching in Florida is timed with the middle of the rainy season, which allows hatchlings to take advantage of lower salinities resulting from rainfall, changes in timing of nesting may affect crocodile growth and survival.

The data from 3,013 nests recorded across South Florida from 1970-2020 were used in a paper by Mazzotti et al. (2022) that documents trends in number of nests and nesting success in relation to natural and anthropogenic factors. More crocodiles are nesting in more places than they were in the 1970s, including on artificial substrates such as levees, canal berms, and ditches. Minimum temperature and rainfall during the summer season are correlated with increased nesting success. Understanding the nesting ecology of crocodiles in Florida helps us to understand how crocodiles may respond to changing environmental conditions.

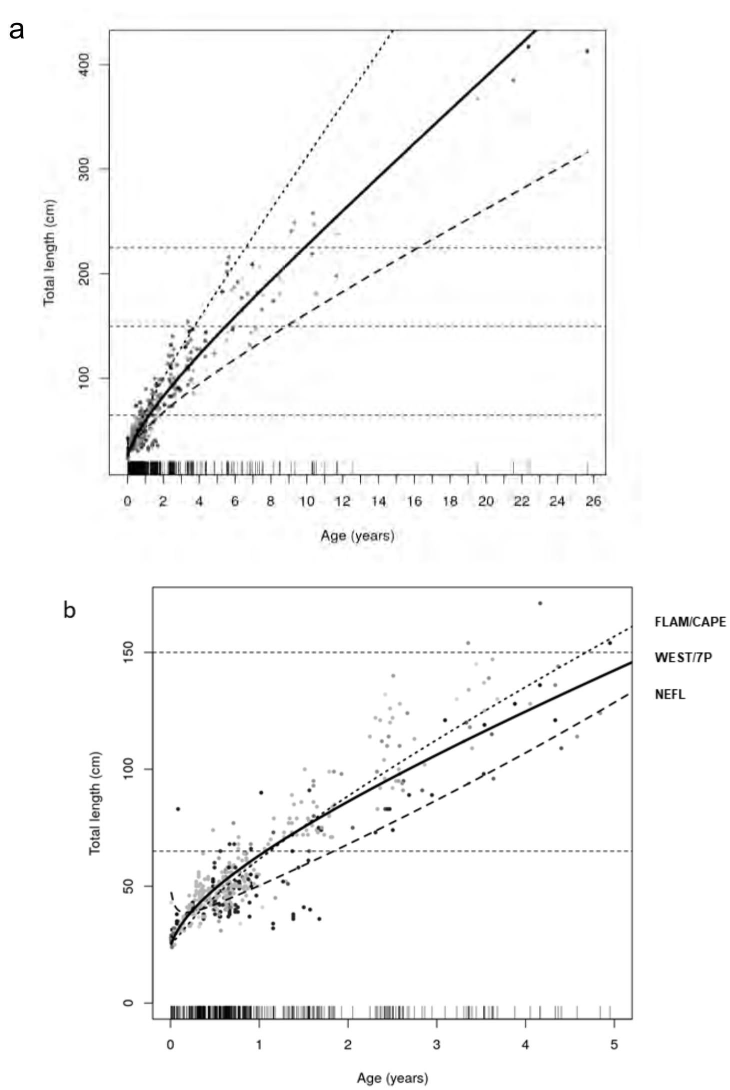


**Figure 3. Growth curves for American crocodiles in response to salinity conditions in south Florida captured between 1978–2015**. a) Solid line is average growth at mean salinity during the dry season, dotted line represents growth rate under low salinity conditions, and the dashed line is growth rate under high salinity conditions. b) Solid line is the average growth at the West Lakes and 7Palms area, dotted line is average growth rate at Flamingo and Cape Sable area, and dashed line is average growth rates in NE Florida Bay. From Briggs-Gonzalez et al. 2021.

## Linkage to RECOVER Reporting on Interim Goals

### What Interim Goals evaluation model(s) is used?

The RECOVER interim goals for American alligators are evaluated using the Alligator Production Suitability Index Model (APSI, Shinde et al. 2014) which estimates an overall suitability index using five components of alligator production: (1) land cover suitability, (2) breeding potential (female growth and survival), (3) courtship and mating, (4) nest building, and (5) egg incubation.

The RECOVER interim goal for American crocodiles is evaluated using a growth and survival index. Progress towards this interim goal is measured by comparing crocodile growth, survival to restoration targets.

### What monitoring data are needed to assess if the expected responses are being achieved?

The most direct way to link alligator responses to model output would be to consistently measure nest numbers and nest success. Doing this throughout the Everglades is logistically challenging and time consuming (Brandt 2019) and the only place nest surveys are regularly conducted is in ENP. However, monitoring abundance and body condition can be linked to the overall APSI. The number of pods of young (counted during abundance surveys) is a direct indicator of alligator production. Body condition is hypothesized to be an important contributor to alligator production through the breeding potential portion of the APSI. An assumption of the breeding potential index is that water depths that existed prior to the breeding season influence body condition which influences successful breeding (better body condition more successful breeding). The expectation is that if the APSI shows that there should be an increase we should see more pods of young. Likewise, when the breeding potential index shows an increase, we should see an increase in body condition.

### Will the current monitoring and modeling be sufficient to report on this indicator as an Interim Goal in 2024?

No.

### If not, what is needed?

Current monitoring is not adequate for a full system-wide assessment of interim goals as was envisioned in the 2009 Monitoring and Assessment Plan. To assess progress toward interim goals for American alligators and American crocodiles, spotlight survey data are needed to calculate estimated abundance and capture data are needed to calculate body condition. The continuation of American crocodile nesting surveys is also essential in supporting the determination of crocodile growth, survival, and distribution. Additionally, continuing to monitor salinity throughout Southern Coastal Systems will allow us to link crocodile responses to changes in salinity.

The current modeling is insufficient to fully report on progress towards interim goals as we ideally will need modeling that shows the expected model output given actual conditions as the inputs. In addition, we do not have sufficient data from all management units as was outlined in MAP 2009 to report on this indicator at a system-wide level.

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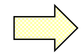
# FISH AND MACROINVERTEBRATES INDICATOR

## SUMMARY/ KEY FINDINGS

| STATUS | PREVIOUSLY REPORTED (WATER YEAR 2020 | (WATER YEAR 2021) | CURRENT (WATER YEAR 2022) | Movement toward restoration target over the last 10 years |
|---|---|---|---|---|
| SYSTEM-WIDE - (WCA-3 and ENP only) | R* *qualified by lack of April 2020 data (COVID-19 | R | R |  |

- Fish and macroinvertebrates are important indicators in the Everglades because their abundance provides food for wildlife like wading birds and alligators.
- Fish and macroinvertebrate densities are correlated with hydrologic variation across their life stages.
- Positive or negative trends in fish and macroinvertebrate densities relative to hydrological changes are correlated with the restoration of the Everglades ecosystem.
- With the completion of restoration projects associated with CEPP we expect to observe increases in the density of most fish in areas where hydrological conditions have been historically drier than target conditions because they should become wetter (e.g., ENP Shark River Slough [SRS] and Taylor Slough [TS]), whereas we expect little change or even a decline in numbers in other places that have been ponded with too much water (e.g., SE WCA-3A).
- The time between drying events is a key driver of fish and macroinvertebrate density and species composition. We anticipate improvement in this indicator where projects that deliver more freshwater have been implemented.
- Water quality (total phosphorus concentration) can also impact the fish and macroinvertebrate indicator. Maintaining historical concentrations of total phosphorus in areas receiving new water deliveries will thus also improve this indicator.
- Invasion and growth of non-native fish populations, most recently predatory freshwater eels, are presenting new challenges to the restoration benefits and the assessment thereof, and will require increased attention in future assessments.
- Over the past 10 years responses of the fish and macroinvertebrate indicator have not moved closer to targets because recent water management actions do not appear to have reduced drying over the majority of the southern Everglades and because non-native fish species are expanding.

**The Fish & Macroinvertebrates indicator remains well below the restoration target (red stoplight).**

# FISH AND MACROINVERTEBRATES INDICATOR

**The fish and macroinvertebrate indicator remains outside the overall restoration target (red stoplight) with some slight regional improvements or declines over the past couple years.** The status of individual fish and macroinvertebrate indicators used collectively to assess status in ENP (SRS and Taylor sloughs) and WCA 3A and WCA 3B, were markedly or moderately inconsistent with the rainfall-based restoration target in WY 2022 (assessed from July 2020 through April 2022).

In ENP SRS the fish and macroinvertebrate indicators remained moderately (most individual responses) or markedly (total fish; Table 1) outside the restoration target because the majority of Everglades Restoration projects that will benefit aquatic animals have not been fully implemented (e.g., CEPP) or were just recently implemented (e.g., Combined Operating Plan [COP] in Sep 2020). The densities indicate too few total fish and too much recent drying (e.g., WY 2021) in most parts of SRS. Total fish are still scoring as a red stoplight in SRS including in NE SRS (Figure 1) even though that site stayed flooded in WY 2022. Fish density responses will take up to 3 years to regrow and respond to increased water depths (and decreased drying frequency) in NE SRS (NE SRS; Trexler et al. 2005). Most other total fish scores in SRS are red on the stoplight map indicating that improvements are not yet being realized in most of SRS (Figure 1). The site in NW SRS (Figure 1) dried even in WY 2022 when the other SRS sites did not and rainfall-projections suggested it should have stayed wet. Non-native fish proportions in Shark River Slough have remained from 0.4-1.1% for the past three years, giving the region a yellow score (Table 1). African Jewelfish densities in SRS, which peaked in 2015-2017 have remained low in this assessment.

The condition of the fish and macroinvertebrate indicator in ENP TS has moved towards a yellow stoplight (caution status) and has fluctuated between green and yellow for the past three years with total fish densities hitting target levels or exceeding targets at most sites in response to increased water depths (Figure 1). The red stoplight at the southern end of TS indicates one site was producing more total fish than expected based on our rainfall targets (Figure 1), and a more detailed hydrological analysis will be necessary to identify if the hydrologic change was the result of recent hydrological management, rainfall/flood-control-driven emergency operations, sea-level rise, or a combination. Nevertheless, several taxa, summed over the region had yellow stoplight scores (Table 1) while Everglades crayfish have consistently had a red stoplight for at least six years. The consistent red stoplight score for the Everglades crayfish has occurred through both dry and wet years and the lack of response is problematic. Hydrologic responsiveness of the ecological indicators is a major assumption of hydrological restoration and our performance measure assessments (Trexler and Goss 2009, Beerens et al. 2017), and we interpret the lack of response (lack of crayfish) as caused by the spread of the predatory Asian Swamp Eel (*Monopterus albus/javanensis*). The need to consider potential adverse impacts of non-natives on restoration goals was advised in the CERP Guidance Memorandum 062.00 (2012).

Both the Everglades crayfish and the Flagfish have been nearly eliminated from TS since approximately 2014 and the disappearances were coincident with the widespread establishment of non-native Asian Swamp Eels (establishment based on long-term electrofishing data).

Our recent paper (Pintar et al., 2023) argues that the Asian Swamp Eel is having strong top-down impacts on crayfish and some of the small fishes in TS and nearby areas. Without a regular monitoring record of invasions by large fish predators we would not understand how to reconcile the mismatches between densities and realized depth variation. To fully quantify the degree of losses of these indicator taxa, if they are caused by eels, will require an amended model and targets that project the densities using only the pre-eel data.

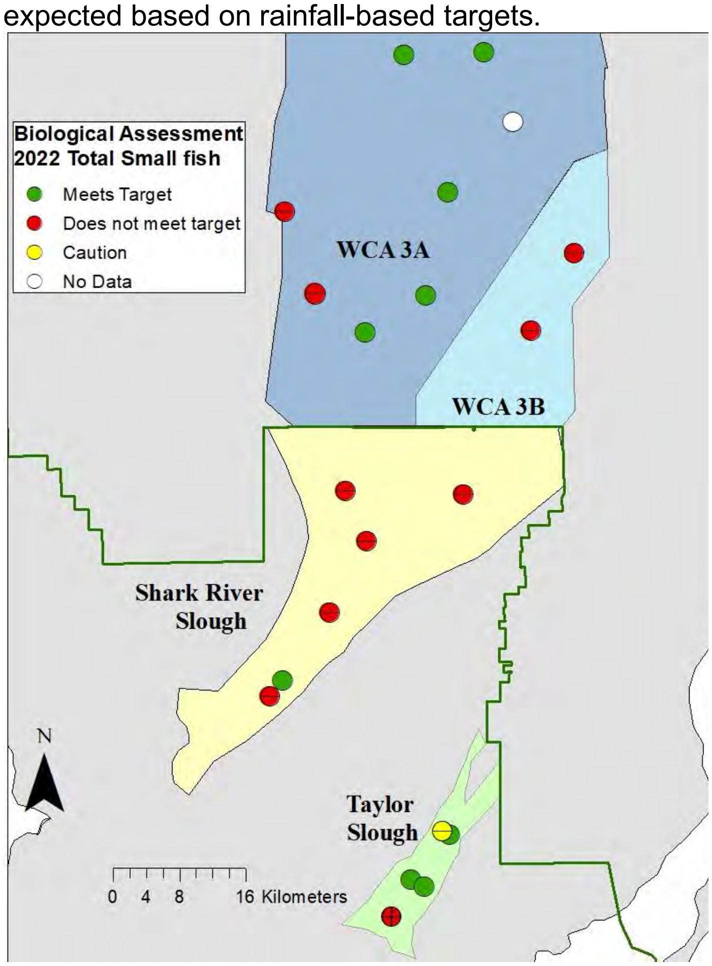
In sum for ENP, this indicator contains multiple components (total fish density, density of indicator fish species and Everglades crayfish, and non-native fish relative abundance) and those in Shark and Taylor sloughs in ENP that are sensitive to hydrological drying have been below rainfall-based expectations at most long-term monitoring sites extending back to WY 2013. The slight improvement in TS over the past few years, associated with infrequent drying, has been accompanied by no improvement in SRS and a recent red stoplight scores in NW SRS (Figure 1) because of repeated drying (i.e., in the previous assessment the score was green). Improved scores driven by water levels in this assessment are difficult to attribute to recent changes in deliveries versus emergency operations or even sea-level rise.

**Table 1. Stoplight Table for Fish and Macroinvertebrates Indicator (ENP and WCA3 only) for WY 2018- WY 2022**

| Performance Measure | WY 2018 | WY 2019 | WY 2020 | WY 2021 | WY 2022 |
|---|---|---|---|---|---|
| Overall | R | R | R | R | R |
| **Shark River Slough** | | | | | |
| Total Fish | R | Y | Y | Y | R |
| Non-Native Fish | Y | Y | Y | Y | Y |
| Bluefin Killifish | Y | Y | Y | R | Y |
| Flagfish | Y | Y | Y | G | Y |
| Eastern Mosquitofish | R | Y | Y | Y | Y |
| Everglades Crayfish | Y | G | G | Y | Y |
| **Taylor Slough** | | | | | |
| Total Fish | R | Y | Y | G | Y |
| Non-Native Fish | R | R | R | R | Y |
| Bluefin Killifish | G | G | R | Y | Y |
| Flagfish | R | R | Y* | Y* | Y* |
| Eastern Mosquitofish | Y | R | G | G | Y |
| Everglades Crayfish | R | R | R | R | R |
| **Water Conservation Area 3A** | | | | | |
| Total Fish | G | G | Y | Y | Y |
| Non-Native Fish | Y | Y | Y | R | R |
| Bluefin Killifish | G | G | Y | G | G |
| Flagfish | Y | Y | R | Y | G |
| Eastern Mosquitofish | G | G | Y | Y | Y |
| **Water Conservation Area 3B** | | | | | |
| | | | | | |
| Total Fish | G | Y | R | R | R |
| Non-Native Fish | Y | Y | Y | Y | R |
| Bluefin Killifish | G | Y | Y | R | Y |
| Flagfish | G | G | R | R | Y* |
| Eastern Mosquitofish | G | G | Y | Y | Y |

The indicators in WCA 3A and 3B have traditionally been near expectations; being within the range or above expectations based on rainfall, but in 2020-2022 both regions of WCA 3 saw departures of the indicators from the rainfall-based targets of moderate (WCA 3A; mixed stoplight) to notable (WCA 3B; all red and yellow scores) levels. Total fish received a yellow stoplight in WCA 3A (Table 1) mostly for the low densities of fish accompanying the frequent drying in northwest WCA 3A (Figure 1). The non-native proportion also rose to >2% (red stoplight) in the WCA 3A for the first time ever in WYs 2021 and 2022. The indicator responses in the two long-term sites in WCA 3B were even more marked, with total fish falling to low levels relative to target densities (red stoplights) for the past three years and non-native fish rising above 2% (red stoplight) in for the first time ever in 2022 (dominated by Asian Swamp Eels and Jaguar Cichlids). WCA 3B sites have consistently dried more frequently than would be expected based on rainfall, but in this period they only appeared to dry in our southern site in WCA 3B. Nevertheless, total fish density fell below targets in both sites (Figure 1). We expect additional water deliveries with CEPP to improve the hydrologic conditions for fish production and density (Trexler and Goss 2009, RECOVER 2020), but WCA 3B was also colonized by Asian Swamp Eels around 2017-2019 (results observed from complementary electrofishing studies) and it appears species like Flagfish (a species that responds quickly after drying and re-flooding, Trexler and Goss 2009) has almost completely disappeared from the sites in WCA 3B despite little meaningful alteration in hydrologic conditions.

**Figure 1. Stoplight indicator colors for total fish abundance in 2022.** Plus and minus symbols indicate whether fish were more or less abundant than expected based on rainfall-based targets.




The high fraction of non-native species in WCA 3 was also found across the entire Everglades in the more widespread, but less intensive, CERP-MAP (Monitoring and Assessment Plan) monitoring in WY 2022; the sampling includes shorter hydroperiod wetlands peripheral to the sloughs as well as wetlands in the northern conservation areas WCA 1 and WCA 2. In WY 2022 we captured the highest fraction of non-native species in the system that we have ever seen in 16 years (2.5%; Figure 2). The composition of non-native species varied across the ecosystem, but Jewelfish (WCA 1) and juvenile Mayan Cichlids were prominent along with a growing number of juvenile Asian Swamp Eels (note: throw traps are not a good method to detect adults of larger predators like Mayan Cichlids and Swamp Eels). Notably, WCA 2A does not have high frequencies of non-native fish (Figure 2). Our dynamic target monitoring data and other analyses in the southern Everglades (Pintar et al. 2023) provide strong empirical evidence that these non-native fishes are re-shaping the function of Everglades aquatic animal communities. How this will ultimately affect the ability of these aquatic communities to provide critical food for iconic predators, including wading birds and alligators, remains to be learned. Filling remnant canals to depths that eliminate winter thermal refuges and refuges in years of drought is currently the most promising restoration action to diminish the abundance of the non-native fishes already in the Everglades. It is currently unclear what environmental variation might limit the Asian Swamp Eel, but they may be able to survive drought conditions unlike other non-natives and that could be devastating to crayfish living in seasonal wetlands that benefit from low-predator windows for good population growth (Pintar et al. 2023; Dorn and Cook 2015). Completing restoration of historical hydroperiods might provide greater resilience of native aquatic communities and diminish impacts of some non-native species, whose expansion and success may be facilitated by the drier and low flow conditions currently prevailing because of past water allocation and delivery choices, but this is unclear as hydrologic conditions have been variable, and even relatively wet, for some of the past 5 water-years.

In addition to hydroperiod restoration and invasions the expected effects of restored water flow (discharge) on the fish and macroinvertebrate indicators is unknown. Research in the DECOMP Physical Model suggests that a flowing Everglades may have different nutrient dynamics than in the current compartmentalized condition (Hansen et al. 2022) with implications for food-web structure and function. Because most of the conservation areas and parts of ENP have lacked expansive sheet-flow we currently have no basis to assess the impact of lost (or restored) sheet-flow on fish and macroinvertebrate communities, but new results should be produced within the next few years.

Though fish and macroinvertebrate density continue to be below or well below restoration targets based on rainfall in SRS and WCA 3B, total fish densities were generally near rainfall-based targets in TS, consistent with the higher water levels in that slough. Nevertheless, the effects of the Swamp Eel predation could diminish the trophic value of the high fish densities being produced if the fish are primarily small-bodied species (e.g., small killifishes) that do not support wading bird foraging. Research on this question is currently in process.

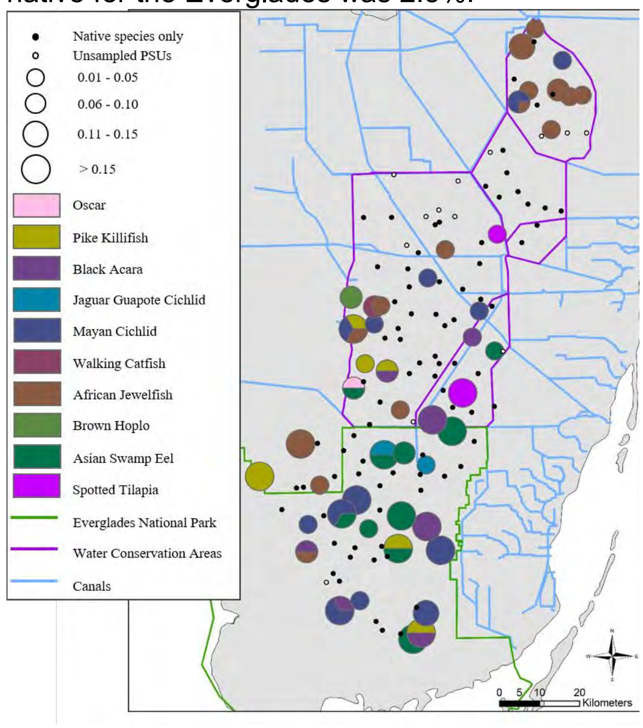
Continued funding of the monitoring datasets in the southern and central Everglades (ENP and WCA 3A, Mod Waters Program) will be necessary to produce dynamic assessments in future years. If the monitoring programs and sites that have been sampled for >25 years change then the assessment tools will need to be re-constructed to match the new monitoring designs. In addition to funding the monitoring that supports this systemwide performance measure evaluations, the Mod Waters project samples large fishes including non-native species which may have an ecological influence on vulnerable prey species (Pintar et al. 2023). Because the RECOVER (CERP-MAP) sampling does not currently incorporate quantification of larger fishes the effects of non-native predatory fish invasions on small fish or macroinvertebrate density will be difficult, or impossible, to identify.

## DATA AND CALCULATIONS

### Updates on Calculation of Indicator

The primary indicator of density is still a ‘dynamic target’ approach that models the expected value for each performance measures based on target hydrological conditions (Trexler and Goss 2009) based on total fish, four species responses and a non-native fish metric. Because fish and macroinvertebrates respond dynamically to natural depth variation and management the dynamic target assessment incorporates the rainfall variation each year in the development of targets. As in previous years, we also assessed non-native species by comparing their regional relative abundance (fraction of catch) to an arbitrary value of 2%. When the entire regional collection of non-native fishes exceeds 2% of all fishes collected, a red stoplight is assigned; yellow stoplights are assigned when non-native species are present in the collections but comprise less than 2% of the total; and green stoplights when no non-native fish species were collected. There have been no major changes from past biennial reports in the way this indicator was calculated, but we used RECOVER Monitoring and Assessment Plan (MAP) data as a secondary measure of the % non-native fish sub-metric at a larger landscape scale; we corroborated the non-native composition from the long-term 25-year study of the Mod Waters sites by considering the capture from a spatially more extensive CERP-MAP dataset including the other conservation areas (WCA 1, WCA 2) and shorter hydroperiod regions of the ENP and WCA 3 and reported this in Figure 2.

**Figure 2. Non-native fish proportions and composition** from the CERP-MAP throw trap data in WY 2022. The overall percentage non-native for the Everglades was 2.5%.




## Recent use of the MWD datasets

We have two papers in preparation or recently published examining the effects of invasive fishes (Jewelfish, Asian Swamp Eels, Mayan Cichlids) on these same fish and crayfish species over the 26 year time series (Pintar et al. 2023, Pintar at al. in prep). Time series data allow us to make determinations of periods of time when invader impacts, because they are functionally different predators than native fishes, may have influenced smaller prey species (small fish, decapods). We are also using the Mod Waters dataset to initiate development of a new evaluation tool for the second crayfish species (*P. fallax*), a species more common in longer hydroperiod sloughs. All of these Both papers should make important contributions to our understanding of how changes in predator structure and hydrology can impact the restoration outcomes.

## New insights relevant to future restoration decisions

The use of crayfish prey by White Ibis in the southern Everglades (Cocoves et al. 2021) during the record nesting season of 2018 makes it necessary to re-think the trophic support and importance of crayfish to the dynamics of the southern Everglades, particularly in Western ENP and southern BCNP. This Task Force assessment cannot evaluate responses in those regions and our understanding of population dynamics and of the crayfish (*Procambarus alleni*) and responses to hydrologic variation in that region are poorly resolved. The MAP data should be the key to monitoring such regions, but the lack of early dry season sampling and challenge to monitoring extreme years in short hydroperiod wetlands makes our ability to understand these dynamics more challenging. This coming year (WY 2023) we will initiate an effort to conduct seasonal sampling in Western ENP and southern BCNP to understand these dynamics and we hope to continue this for several years to better understand and model/predict crayfish densities in this region.

## LINKAGE TO RECOVER REPORTING ON INTERIM GOALS

### What Interim Goals evaluation model is used?

The RECOVER Interim Goal for aquatic fauna was built by updating a prey-based freshwater fish density model (Donalson et al. 2010, RECOVER 2015, 2020, Beerens et al. 2017). The model estimates densities of small freshwater fish (< 8 cm) using hydrologic drivers. High densities of small freshwater fish characterized the pre-drainage central Everglades system. The model includes a spatial component and is capable of discriminating density differences across sub-regions (e.g., WCAs, ENP), it is an evaluation tool (i.e., makes a prediction).

### What monitoring data are needed to assess if the expected responses are being achieved?

To assess responses system-wide using the dynamic approach used here would require sampling similar to that conducted for Mod Waters with temporally intensive (five seasons per year) sampling with and high numbers of samples per site each season (15-21 traps/measures per season). Current CERP MAP sampling is conducted once per year (one season), is stratified over a broader Greater Everglades landscape, with a smaller numbers of throw trap samples (3 traps/measures) in larger “sites” (Primary Sampling units); CERP MAP sampling includes WCA 1 and 2 and wetlands peripheral to SRS. During the early years of CERP MAP the project included seasonal sampling (early dry season) at a subset of “sentinel sites”, but after budget reductions to RECOVER in 2011 the CERP MAP sampling has only included once per year wet season sampling. This sampling regime is not sufficient to develop a system-wide dynamic assessment tool.

### Will the current modeling and monitoring be sufficient to report on this indicator as an Interim Goal in 2024?

The current monitoring and associated assessment modeling is not sufficient to assess the fish IGs with in 2024 for two reasons. First the Mod Waters data is restricted to the sloughs of the southern and central Everglades (ENP and WCA 3). Second, the assessment tools (models) have not been developed with covariates/parameters or target hydrology for the CERP MAP sites. This second point is explained further in the next section.

### If not, what is needed?

The current Task Force assessment of fish and macroinvertebrate densities uses the 26-year Mod Waters dataset and does not currently use the system-wide CERP MAP/RECOVER sampling (except for the systemwide evaluation of proportion non-native fishes) because the dynamic assessment modeling approach (Trexler and Goss 2009) with the Mod Waters datasets has not been finally paired with/developed using the CERP MAP sampling design. Mod Waters monitoring includes temporally intensive (five seasons per year) sampling with and high numbers of samples per site each season (15-21 traps/measures per season) over 20 sloughs sites in the southern Everglades. CERP MAP sampling is conducted once per year (one season), is stratified over a broader Central Everglades landscape, with a smaller numbers of throw trap samples (3 traps/measures) in larger “sites” (Primary Sampling units); CERP MAP sampling includes WCA 1 and 2 and wetlands peripheral to SRS. During the early years of CERP MAP the project included seasonal sampling (early dry season) at a subset of “sentinel sites”, but after budget reductions to RECOVER in 2011 the CERP MAP sampling has only included once per year wet season sampling.

In addition to resources for conducting assessments of RECOVER interim goals using CERP MAP data, resources and time will be required for model formulation, evaluation of model/data sensitivity for fish and macroinvertebrates, hydro-based restoration targets adjusted for rainfall. In addition to reformulating our ecological-hydrological predictive models for CERP MAP data, building assessment tools will require cooperation by hydrologists or modelers who can help us develop hydrologic targets that can be adjusted for annual rainfall in each region each year.

## LITERATURE CITED, REPORTS, AND PUBLICATIONS FOR MORE INFORMATION

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## SUMMARY/KEY FINDINGS

| STATUS | PREVIOUSLY REPORTED (WATER YEAR 2020 | (WATER YEAR 2021) | CURRENT (WATER YEAR 2022) | Movement toward restoration target over the last 10 years |
|---|---|---|---|---|
| SYSTEM-WIDE | Y | Y | C | ⇨ |

- Periphyton abundance, nutrient content, and diatom algae species composition provide an important indication of the oligotrophic status of the Everglades. These three metrics are combined to provide an indication of how hydrologic management influences the inflow and downstream transport of novel and legacy phosphorus.
- The multi-metric is a combination of periphyton biomass, phosphorus concentration, and the proportion of calcareous diatom species comprising the periphyton community.
- We expect a reduction in biomass, an increase in phosphorus concentration, and a reduction in calcareous diatoms at locations experiencing above-ambient phosphorus loads. A modified index is used for the Loxahatchee National Wildlife Refuge where an increase in biomass and calcareous diatoms indicates a departure from ambient conditions.
- If inflowing water total phosphorus concentrations are lower than ambient marsh concentrations, we expect that the Central Everglades Planning Project will improve the quantity, quality, and calcareous composition of periphyton communities.
- Over the last 10 years there has not been consistent directional change at the system-wide scale because in some places there are positive changes where freshwater flows are being restored and negative changes where those restored flows are mobilizing legacy nutrients. These local changes are mostly isolated to the northern and eastern boundaries of ENP.

On a system-wide scale the periphyton indicator remains below the restoration target (yellow stoplight) in central and northern WCA-3A and WCA-2A because these areas have not recovered from a history of higher than ambient phosphorus loading and have not received the benefits of restoration projects that have not yet been implemented. Some areas of WCA-1 are in a caution state likely due to runoff of canal-derived carbonates into the typically ombrotrophic, acidic ecosystem. Downstream/coastal regions of the ENP are below the restoration target because they are receiving accelerated coastal supplies of phosphorus as sea water intrudes in the absence of full-scale restoration implementation.

*A full system-wide status assessment for periphyton and the stoplight color for WY 2022 cannot be provided yet because of delays in the microscopic identification of diatoms due to a slow-down of activities related to COVID-19 restrictions, but should be available by early Spring 2023.

**The periphyton indicator is below the restoration target (yellow stoplight).**

**Table 1. Stoplight Table for Periphyton Indicator for WY 2018 – WY 2022 (Data for WY 2022 are not yet available, C)**

| | WY 2018 | WY 2019 | WY 2020 | WY 2021 | WY 2022 |
|---|---|---|---|---|---|
| **SYSTEM-WIDE** | | | | | |
| Quality (TP) | Y | **G** | **G** | Y | Y |
| Biomass | Y | Y | Y | Y | Y |
| Composition | Y | Y | Y | Y | C |
| **Multi-Metric** | Y | Y | Y | Y | C |
| **WCA 1 (A.R.M. Loxahatchee NWR)** | | | | | |
| Quality (TP) | G | Y | Y | Y | Y |
| Biomass | G | G | G | G | G |
| Composition | Y | Y | Y | Y | C |
| **Multi-Metric** | Y | Y | Y | Y | C |
| **WCA 2** | | | | | |
| Quality (TP) | Y | G | G | Y | Y |
| Biomass | Y | G | Y | Y | Y |
| Composition | Y | G | Y | R | C |
| **Multi-Metric** | Y | G | Y | Y | C |
| **WCA 3** | | | | | |
| Quality (TP) | Y | G | G | Y | Y |
| Biomass | R | Y | Y | Y | Y |
| Composition | Y | G | Y | Y | C |
| **Multi-Metric** | Y | G | Y | Y | C |
| **SRS** | | | | | |
| Quality (TP) | G | G | G | Y | Y |
| Biomass | Y | Y | G | Y | Y |
| Composition | G | Y | G | Y | C |
| **Multi-Metric** | Y | Y | G | Y | C |
| **TS** | | | | | |
| Quality (TP) | G | G | G | G | G |
| Biomass | G | G | G | G | Y |
| Composition | Y | Y | Y | Y | C |
| **Multi-Metric** | G | Y | Y | G | C |

**Figure 1. Stoplight colors for the multi-metric periphyton indicator for WY 2021.**

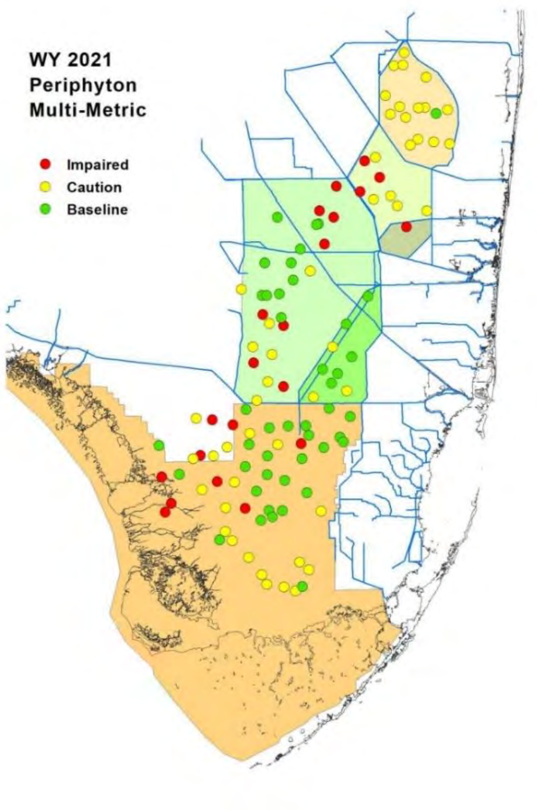


**Figure 2. Time series of change in the periphyton multi-metric.**

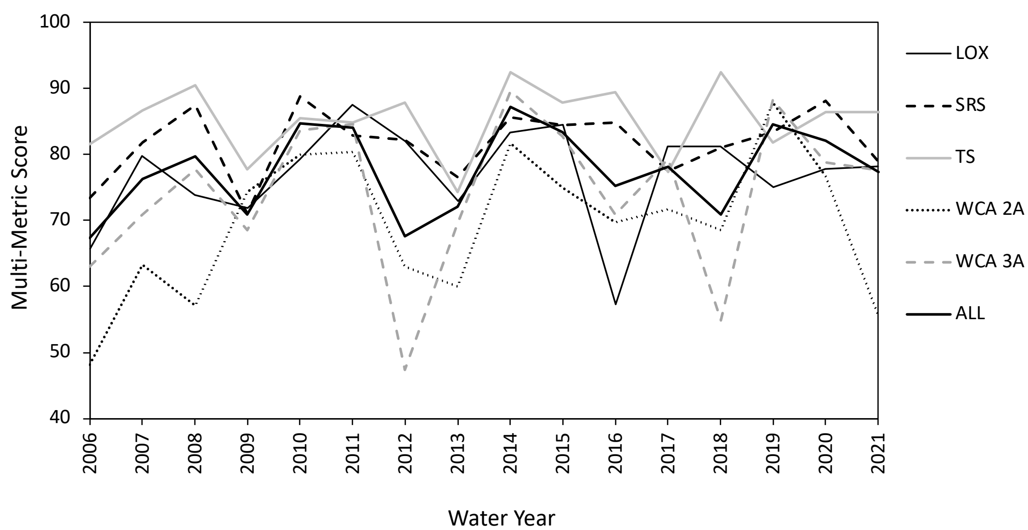

**Table 2. Stoplight values for the periphyton indicator multi-metric.**

| Metric | Measurement | Stoplight | WCA1 | WCA2A | WCA3A | SRS | TS |
|---|---|---|---|---|---|---|---|
| Quality | Total Phosphorus (ug/L) | Baseline | <500 | <200 | <300 | <200 | <150 |
| | | Caution | 501-600 | 201-300 | 301-400 | 201-300 | 151-200 |
| | | Impacted | >601 | >301 | >401 | >301 | >201 |
| Quantity | Ash-Free Dry Mass (ug/g) | Baseline | <10 | >20 | >10 | >20 | >50 |
| | | Caution | 11-20 | 1-19 | 1-9 | 1-19 | 1-49 |
| | | Impacted | >21 | <1 | <1 | <1 | <1 |
| Composition | Endemic Diatom s (%) | Baseline | <10 | >95 | >95 | >95 | >95 |
| | | Caution | 11-70 | 75-94 | 75-94 | 75-94 | 75-94 |
| | | Impacted | >71 | <74 | <74 | <74 | <74 |

## DATA AND CALCULATIONS

### How these data being used

These data and findings were also reported in the RECOVER 2019 System Status Report and are being used to support models for synthesis efforts. This information also can be used in the context of interim goals. We have also conducted comparative studies in other karstic wetlands in the Caribbean region and have provided this tool for use there (La Hée and Gaiser, 2012; Gaiser et al. 2015).

### New insights relevant to future restoration decisions

Insights stemming from long-term analyses (Gaiser et al. 2015; Marazzi et al. 2018) 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 Total Phosphorus (TP) concentrations, suggesting high sensitivity to loads that change with water flow. This explains why wet years on record show greater impairment than dry years.

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# WADING BIRDS (WOOD STORK & WHITE IBIS INDICATOR)

## SUMMARY/KEY FINDINGS

| STATUS | PREVIOUSLY REPORTED (WATER YEAR 2020 | (WATER YEAR 2021) | CURRENT (WATER YEAR 2022) | Movement toward restoration target over the last 10 years |
|---|---|---|---|---|
| SYSTEM-WIDE | R | R | C | ↑ |

- Historical accounts and data indicate that large breeding colonies of wading birds were a defining characteristic of the pre-drainage Everglades. Wading bird nesting is strongly driven by hydrology, as water depths and distribution are important for the production of aquatic prey animals and accessibility of those prey for foraging wading birds. This makes wading birds an important integrative indicator of the general state of Everglades restoration
- Changes in hydrology and water availability across the Everglades region is expected to improve wading bird nesting conditions by increasing prey production and foraging quality and quantity. Expected changes in hydrology should result in earlier nesting by Wood Storks, a shorter interval between White Ibis “supercolony” nesting events (i.e. notably large breeding events), a higher ratio of tactile to visual foragers, and a higher proportion of wading bird nesting concentrated in coastal areas of ENP.
- Everglades Restoration projects that restore freshwater flows to the productive southwest estuarine region are seen as key to restoring wading bird nesting.
- It is difficult to associate wading bird nesting responses on a system-wide basis with any particular project, though those that contribute the most to restoration of hydrological flows typical of the pre-drainage period are those that would be highest priority.
- Data for WY 2022 are still being collected, processed, and collated and are not available for the 2022 report. Nesting wading birds responded in a typical fashion to hydrologically driven food production and availability that is consistent with the overall trophic restoration hypothesis that improved water conditions will improve prey abundance and availability for wading birds), under the currently unrestored conditions

**The wading bird indicator remains well below the restoration target (red stoplight).**
Early nesting, coastal nesting, and proportions of tactile feeding waders probably will respond only within a limited range until the Everglades Restoration projects that affect wading bird food production and availability at large spatial scales are implemented. However, over the past 10 years, we have seen general improvement in several wading bird metrics, all of which are consistent with predicted responses to future restored hydrology. In general, good years for wading birds are related to high water level events occurring before the breeding season (for example, high rainfall in summer or fall months from tropical storms). This supports expectations that restoration actions that result in higher water levels in the Everglades will be beneficial for wading bird nesting.

Historical records from pre-drainage Everglades indicate that wading birds in the Everglades used to form large coastal colonies, were dominated by tactile foraging species relative to visual foragers, supported both early nest initiation by Wood Storks and regular exceptionally large breeding colonies of White Ibises.

Large breeding colonies in the coastal regions of the Everglades disappeared as freshwater flows to this region were reduced (Ogden et al. 1997). Coastal nesting has improved substantially since the mid-1990s to early 2000's when only 2-10% of birds nesting in the Everglades ecosystem were found in the coastal colonies of Everglades National Park (Figure 1). In the last decade, the running 3-year average for this metric has been consistently above 10%. The past four years (WY 2018, 2019, 2020, 2021) have all exhibited values >20%, indicating an additional recent improvement in this metric. Despite improvement, this metric is not yet meeting the target of 50%, though the upward trend is encouraging. This steady growth suggests that estuarine conditions have become more attractive for nesting birds in the Everglades.

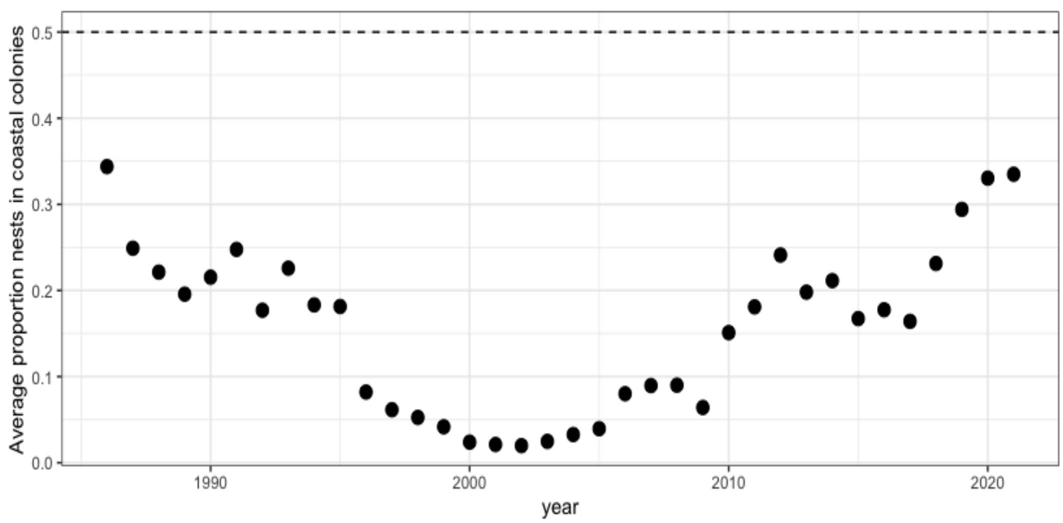


**Figure 1. Proportion of nests in coastal colonies. Dashed line indicates target value. Data points reflect 3-year running averages.**

Changes in the Everglades due to drainage have shifted breeding populations dominated by tactile foragers - such as storks and ibises – to being dominated by visual foragers -such as Great Egrets (Frederick et al 2008). Reflecting data from 1930s breeding colonies, restoration targets are set at 30 breeding tactile foragers per breeding visual forager. This metric has shown gradual improvement since the mid-1990s (Figure 2), increasing from a 3-year average of 0.68 in 1996 to 5.62 in WY 2021. However, despite this improvement, this metric is still far below the target value. So, while conditions may have improved slightly for tactile foragers relative to visual foragers, the ecosystem is far from pre-drainage levels and restoration targets.

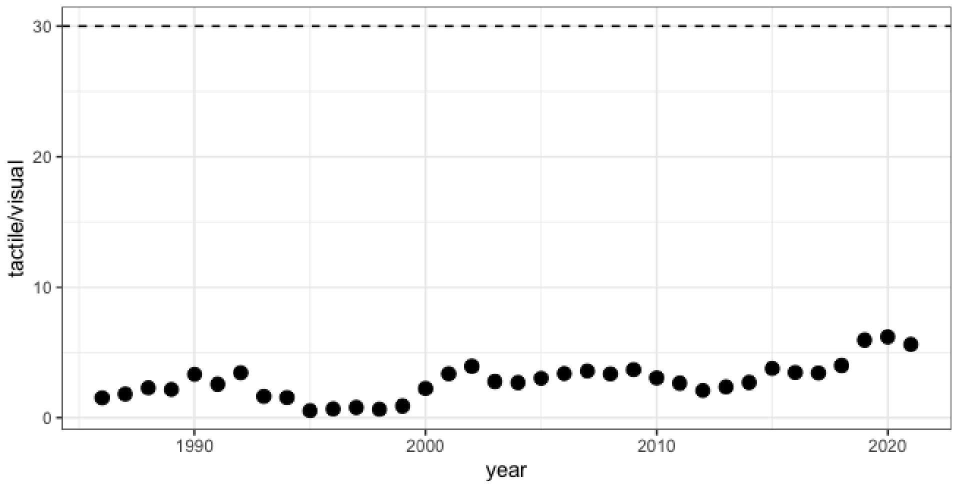


**Figure 2. Ratio of tactile to visual foraging species nesting in Everglades colonies from 1986-2021.** Dashed line = target value of 30

Timing of Wood Stork nest initiation is an important indicator of restoration because Wood Storks forage on larger fish in the Everglades and take longer to raise their offspring to independence. Before the 1960s (1930s-1960s), Wood Storks initiated nests very early in the breeding season (November-December), leaving time to rear young before the onset of the wet season (Ogden 1994). Later nesting typical of the post-1960s period has been associated with poor nest success, largely because adults cannot find enough food to feed young after the onset of the rainy season (Ogden 2006). Nest initiation scores have improved slightly since the late 1980s (Figure 3) shifting from about mid-February in the late 1980s (1986-1989 average score= 1.5) to mid-January in the late 2010s (2018-2021 average score =2.6). Despite slight improvement, this metric is still substantially below its target value with considerable year-to-year variation. In the past few years alone we have seen some of the best years for wood stork nest initiation (WY 2019 = 3.8) and worst (WY 2016=0.5). This indicates that while it is still possible for early nesting to occur in a restored Everglades, we have not yet hit those conditions with any consistency.

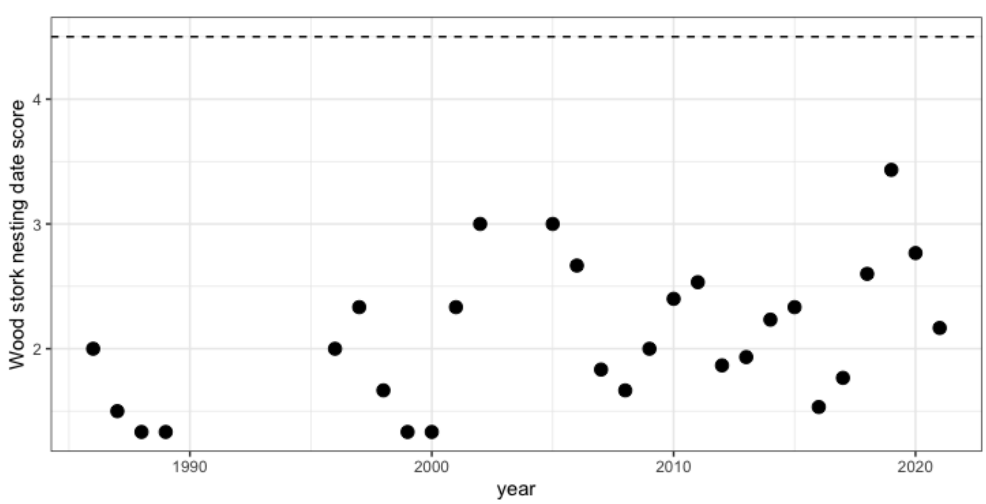


**Figure 3. Timing of Wood Stork nest initiation.** November = 5, December = 4, January = 3, February = 2, March = 1. Dashed line = target value of 4.5

The formation of exceptionally large White Ibis breeding colonies is the one indicator that has consistently met target values in recent years. During the pre-drainage period, the interval between large nesting events of this species (defined as > 16,977 nests from historical data) occurred every 1.6 years (Frederick and Ogden 2001, 2003). Starting around WY 2000, the interval between large events has consistently met this target.

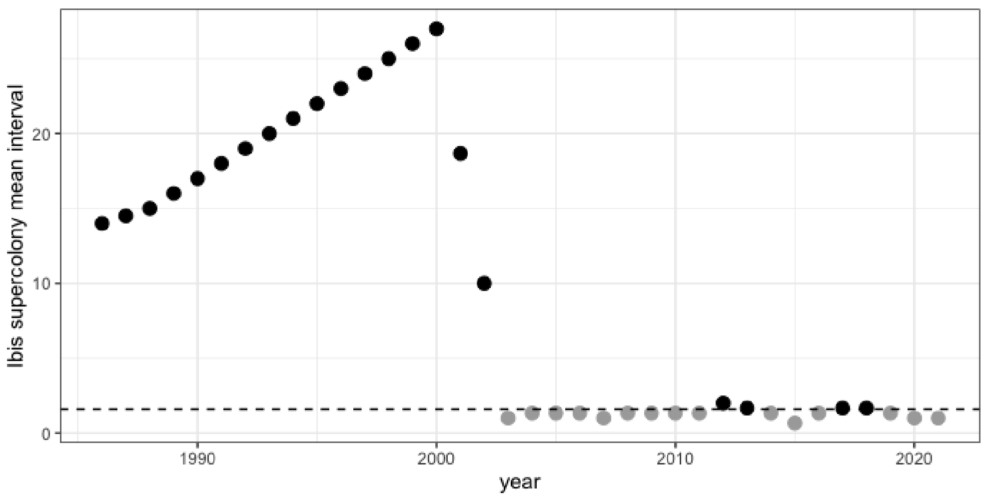


**Figure 4. Number of years between White Ibis large breeding events**. Dashed line = target value.

While the Stoplights for these metrics (Table 1) indicate that we are still far from management targets, Figures 1-4 show how much progress has been made over the past 40 years. Improvement has been seen in every metric, even those that are still very far from their goals (for example, Figure 2). If the trophic restoration hypothesis is essentially correct, then this response is to be expected, since strong positive responses by birds are predicted only with the onset of restored hydrological conditions. Further, the variation in response that we do see in the current pre-restoration conditions is so far completely supportive of the predictions underlying the trophic restoration hypothesis. Bird responses to recent natural events where exceptional rainfall events generated markedly better hydrological conditions (WY 2018 and to some extent WY 2021) are strong indicators that improving the hydrology of the Everglades will improve ecological conditions for wading birds.

**Table 1. Stoplight Table for Wading Bird Indicators for WY 2018- WY 2021**

| Indicator | WY 2018 (previous report) | WY 2019 (previous report) | WY 2020 (previous report) | WY 2021 | WY 2022 (in progress) |
|---|---|---|---|---|---|
| Wading Bird Indicator Summary | Y | R | R | R | C |
| Ratio of tactile:visual foragers | R | R | R | R | C |
| Index of Wood Stork nest initiation | Y | R | R | R | C |
| Proportion nests in coastal areas | Y | Y | Y | Y | C |
| Mean interval between exceptional ibis nesting years | G | G | G | G | C |

C = data collection and processing currently in progress

## DATA AND CALCULATIONS

### Updates on calculation of indicator

Due to disruptions due to COVID-19, colony counts in 2020 and 2021 in the WCAs and ENP could not be monitored via manned fixed-wing aircraft – the standard approach which has been in use since the mid-1980s. Data from WY 2020 and WY 2021 come primarily from helicopter surveys conducted by SFWMD and UAV surveys flown the University of Florida Wading Bird Project. UAVs in particular fly at lower altitude with higher image quality than images taken by personnel in small aircraft. Images taken by UAVs were hand counted in a method similar to that used on images taken from manned airplanes. We are working on assessing how colony counts differ between UAV-obtained images and fixed-wing airplane-obtained images. Given our experience with both methods and with the specifics of locating and counting colonies, we expect little difference between the approaches, but it is possible that UAV images capture more birds and thus result in higher counts than in previous years. Until this is formally assessed, WY 2020 and WY 2021 results should be viewed with some caution.

We also note some minor differences in how data are reported in this report compared to previous ones. Water year designation has been inconsistently applied in the past partly because wading birds typically begin nesting in one standardly applied water year, and finish in another. For this report, WY is defined consistently to be the calendar year in which the water years ends (i.e. WY 2020 = May 2019 to April 2020) and includes data after that water year ends (i.e. data from May-Jul 2020 which technically occurs in WY 2021). This is consistent with data reported in the 2020 Biennial report. The only other change to indicator calculations is to consistently report 3-year averages for all components of the indicator. Previous reports have reported 5-year, 4-year and unaveraged data. Precise values thus may differ from previous reports, but patterns relative to the target values are qualitatively the same.

### How are these data being used?

These indicators are calculated from bird colony data that is collected by the UF Wading bird Group, SFWMD, and ENP. Data are reported annually in the publicly available South Florida Wading Bird Nesting Report published by the SFWMD. This outlet is used by the media and is an important tool for communicating with both the public and with decision makers. Data are shared regularly to Ecosystem Based Management (EBM) and used as part of their weekly management recommendations. Foraging and nesting information also goes into predictions about future nesting years, usually in December or January of each year (U.S. Geological Survey [USGS] and SFWMD).

### New insights relevant to future restoration decisions

Mercury is a contaminant of concern in the Everglades with known effects on wading bird behavior and nesting. Despite widespread declines in the exposure of wading birds to mercury in the late 1990s, there are still sites in the Everglades where mercury exposure in wading birds can be substantial. Recent studies show that the impact of mercury on wading bird nesting in the Everglades is not constant but has substantially higher negative effects when food availability is low (Zabala et al. 2020). The negative effect of Hg can be quite powerful. In some years, the modeled net effect of Hg exposure can be to reduce nesting pairs by up to 50%.

We continue to monitor for potential impacts of invasive Burmese pythons on wading bird nesting. Wading birds place their nests on tree islands that most native predators have trouble accessing. The ecology and hunting behavior of Burmese pythons is very different from the native Everglades predators and studies have shown that pythons may be 5x more effective at destroying wading birds nests than native predators (Orzechowski et al 2019). This creates the potential for predation to become an important driver of wading bird nesting when it has historically had little influence. This could disrupt predicted responses of wading birds to restoration actions, since increased predation might confound otherwise positive effects of hydrological restoration.

The 2018 extreme nesting event revealed that traditional monitoring approaches relying on observers in aircraft struggle with the extremely large colonies that will be increasingly expected with Everglades restoration. New approaches that meld drone-based imagery with artificial intelligence show promise in detecting and counting birds in a consistent and repeatable manner amenable to monitoring exceptionally large bird aggregations (Weinstein et al in press). Continued investment in these approaches may be necessary to improve monitoring accuracy as high-nesting effort years become more common.

Ecological forecasting is shifting from static models to iterative near-term forecasting approaches where models are regularly evaluated and updated as new data becomes available (Dietze et al. 2018, White et al. 2019). Iterative near-term forecasts ensure that the most up-to-date data and models are used when predicting how ecological systems will change in the future or in response to management decisions. The wading bird indicators are an ideal system for implementing near-term iterative forecasting due to the extensive and frequent monitoring of their populations, availability of daily forecasts for their key environmental drivers, and the ability to annually evaluate forecast performance. The application of iterative forecasting in this system would allow for regular improvements to forecasting models, produce a better understanding of their accuracy, and ensure that forecasts reflect the changing state of the Everglades.

## LINKAGE TO RECOVER REPORTING ON INTERIM GOALS

### What Interim Goals evaluation model(s) is used?

The Interim Goals report used the WADEM model (Beerens et al. 2015a, b) to predict landscape changes in wading bird foraging conditions and foraging abundances using the 2019 Interim Goals scenarios. WADEM is a species distribution model that links the distribution and abundance of foraging individuals (collected by Systematic Reconnaissance Flights [SRF] conducted 2000-2009) to hydrologic conditions in order to estimate spatially explicit foraging habitat distribution and quality. For the Interim Report, the model was used to predict 1) Average daily foraging index for wood storks, 2) Average daily individual foraging abundance for great egrets and white ibis, 3) Spatial foraging conditions for wood storks and white ibis.

### What monitoring data are needed to assess if the expected responses are being achieved?

Unfortunately, because Wader Distribution Evaluation Modeling (WADEM) focuses on foraging and not nesting, the model does not directly predict any of the Wading Bird indicators. Data on foraging flocks is also not currently being systematically collected in the Everglades to assess the WADEM model predicted outcomes. There is an extension of the WADEM model linking foraging conditions to nesting effort, but those predictions are not included in the Interim Goals report and the model has not been evaluated in a forecasting context. EverWaders, an updated version of WADEM using joint species distribution modeling (D'Acunto et al 2021), also focuses on foraging and predicts an index of foraging occupancy across the Everglades. Because the SRF was discontinued in 2009, both models assume that the relationship between foraging activity and hydrological conditions have remained unchanged over the past decade and that the full range of conditions seen in the Everglades occurred during that time span.

### Will the current monitoring and modeling be sufficient to report on this indicator as an Interim Goal in 2024?

No.

### If not, what is needed?

Currently, there is no evaluated forecasting model that directly predicts outcomes for the wading bird Indicators used to monitor restoration progress. To assess expected future changes in the indicators, either new models are required that focus on directly forecasting the wading bird indicators, or new data needs to be collected to robustly assess existing models with extensions that provide predictions about the nesting indicators used for restoration. Advancements in the field of ecological forecasting would also suggest that establishing more regular evaluation and assessment of any forecasting model will strengthen our confidence in the models and provide timely feedback on changes in model performance which may indicate important changes in the behavior of the ecosystem.

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Wein

## SUMMARY/KEY FINDINGS

| STATUS | PREVIOUSLY REPORTED (WATER YEAR 2020 | (WATER YEAR 2021) | CURRENT (WATER YEAR 2022) | Movement toward restoration target over the last 10 years |
|---|---|---|---|---|
| SYSTEM-WIDE | Y | Y | Y | ⇨ |

- Phytoplankton blooms, commonly called algal blooms, are an indicator of water quality. In the context of Everglades Restoration, the bloom indicator is cautionary, helping to ensure that restoration actions cause no indirect harm to coastal ecosystems via water quality degradation.
- We expect that implementation of Everglades restoration projects, in conjunction with State-led water quality improvement projects being implemented to meet water quality standards may improve water quality conditions because restored plant communities and soils are expected to increase nutrient uptake and retention in Everglades wetlands and estuarine seagrass beds. Additionally, conditions that result in seagrass die-offs that can trigger algae blooms will occur much less frequently after restoration.
- Unlike other indicators where we expect to see continual improvement, our expectation with the algal bloom indicator is that the frequency of red, yellow and green scores will not change due to Everglades Restoration. Thus, this indicator is needed to ensure that Everglades Restoration “does no harm” to coastal water quality.
- There was degradation in algal bloom indicator scores in the Southern Coastal System (SCS) region (Ten Thousand Islands to Biscayne Bay) in 2021 with the region receiving a red rating overall. This may be in part because WY 2021 was abnormally wet with higher levels of precipitation potentially increasing the watershed nutrients derived from plants (especially mangroves) and soils that were transported to coastal waters.
- Algae blooms have continued to occur in central Florida Bay each year during this reporting period in areas where the seagrass die-off occurred in 2015.
- The southwest Florida shelf and the 3 subregions in Biscayne Bay continue to show signs of decline. All 4 sub-regions have had persistently poor indicator scores since 2005. Additional nutrients derived from anthropogenic sources in developed areas likely were transported to downstream estuaries (e.g. to northern and central Biscayne Bay). Biscayne Bay has also recently experienced hypoxia and associated fish mortality events. This suggests the need to act soon to improve water quality in Biscayne Bay. Miami-Dade County has assembled a Biscayne Bay Task Force to develop methodologies to improve water quality in Biscayne Bay.

**The Southern Coastal Systems Phytoplankton Blooms Indicator remains below the restoration target (yellow stoplight).**

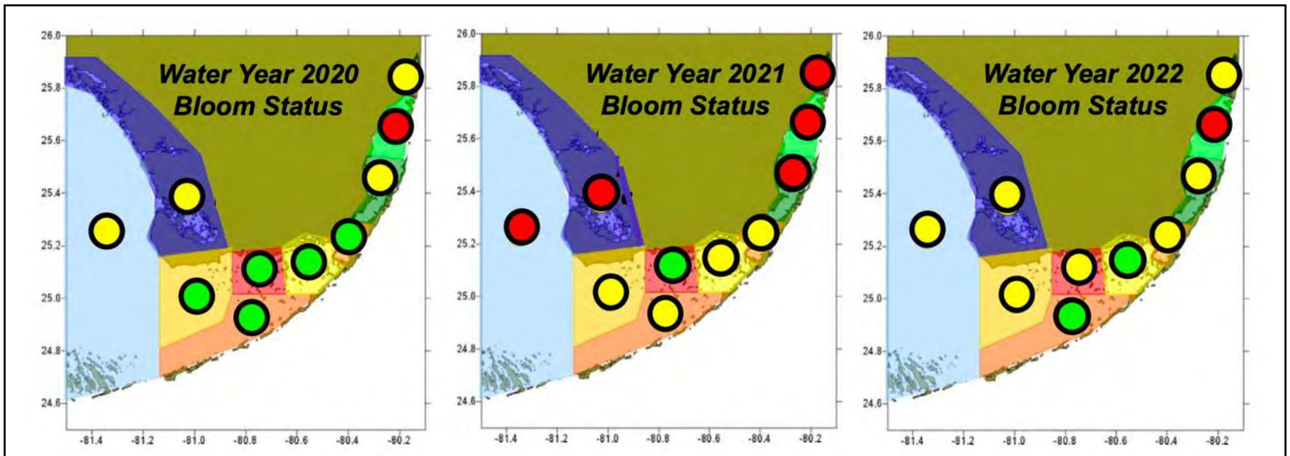



**Figure 1. Map showing the spatial distribution of the water quality indicator scores improving throughout the SCS from WY 2021 through WY 2022.**

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

| Water Year | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| System Wide | G | R | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | R | Y | Y | Y | Y |
| SWFS | R | R | R | Y | R | Y | R | R | **B** | **B** | Y | Y | Y | R | Y | Y | R | Y |
| MTZ | G | Y | Y | G | Y | Y | Y | Y | Y | Y | G | G | G | Y | Y | G | Y | Y |
| WFB | G | G | G | G | G | G | G | G | G | G | G | G | Y | Y | Y | G | R | Y |
| SFB | G | Y | Y | R | G | Y | G | G | G | G | Y | Y | G | Y | Y | G | Y | G |
| NCFB | G | Y | Y | G | G | G | G | G | G | G | G | Y | Y | R | Y | G | G | Y |
| NEFB | G | R | Y | Y | G | G | Y | Y | R | Y | G | G | G | R | G | G | Y | G |
| BMB | G | R | R | R | G | G | Y | Y | Y | Y | Y | Y | G | G | Y | G | Y | Y |
| SBB | Y | R | R | Y | Y | Y | R | Y | Y | R | Y | Y | Y | Y | Y | Y | R | Y |
| CBB | Y | R | Y | Y | Y | Y | Y | Y | Y | R | R | R | Y | R | R | R | R | R |
| NBB | Y | Y | Y | Y | Y | Y | Y | Y | Y | R | R | R | R | R | Y | Y | R | Y |

Overall, from WY 2020 to WY 2021, every sub-region except for NCFB declined. Those regions that were meeting restoration targets in WY 2020, were below restoration targets in WY 2021 and those that were below restoration targets in WY 2020 were now well below restoration targets in WY 2021. In WY 2022, there was some improvement with regions in the red moving to yellow, and two regions (SFB and NEFB) now reaching restoration targets as they had previously in WY 2020. The only region which fell below restoration targets In WY2022 was NCFB, which had been meeting restoration targets for the two years prior. It is possible that gaps in sampling effort in

WY2021 due to COVID-19 restrictions may have contributed to these drastic changes, but no formal analysis has been done to confirm this.

## Data and Calculations

### Updates on calculation of indicator

Calculation methodology for the SCS algal bloom indicator remains unchanged from the description in Boyer et al. (2009), but indicator results have been affected by decreases in the number of field sample sites, changes in sample site locations, decreased sampling frequency, and changes in analytical methods. One program, Biscayne Bay Water Watch, which was a community-based volunteer water quality monitoring program, was discontinued altogether in 2017 and removed from the analysis. This program was only sampling 13 stations spread out between NBB, CBB and SBB, and some of these stations are still being sampled by other programs. The stoplight threshold chlorophyll *a* concentrations were recalculated for this report after removing field sample sites that are no longer being monitored. For this report, only NOAA data from WY 1998-2004 were used to recalculate the reference period thresholds that define stoplight categories, and only NOAA data were used to assess SWFS bloom conditions from WY 2005-2022. Most of the station and sampling frequency changes occurred between 2010 and 2012, so confidence in consistency is higher for the results within the past 8 years, and results prior to 2010, than confidence in the consistency of results between these two periods. No obvious change in the chlorophyll a concentration patterns occurred around 2011. There were also gaps in sampling in WY2020-2021 due to COVID-19. Many programs only missed sampling in March and April 2020. NOAA was not able to sample from March through July. The effects of other sampling and analytical changes have not been thoroughly analyzed.

### How are these data being used?

The occurrence of algal blooms in south Florida coastal waters has drawn strong public attention in recent years. Blooms along the southwest coast (including red tides), in Florida Bay, and in Biscayne Bay have been a public concern. The data presented here provide an easily understood indicator of bloom status throughout these southern coastal waters. The underlying data have been used to track the status and trends of these systems and gain insight of bloom causes and effects. Most importantly, the data are providing insight of how potential restoration actions can directly (e.g., via nutrient loading from the watershed) or indirectly (e.g., via affecting the health or mortality of seagrass beds) affect the frequency, spatial extent, intensity, duration and ecological effects of blooms. To date, the data suggest that Everglades Restoration foundation projects and CERP project implementation in the southern Everglades have had minimal negative impacts on the SCS. The results have pointed toward the importance of major storm events as drivers that strongly influence algal bloom dynamics concurrently with anthropogenic drivers. In addition to this report, data is also being used for water quality modeling efforts in Biscayne Bay (NBB, CBB and SBB). Data is also being included in an FDEP-funded project compiling data from all comparable water quality monitoring programs in South Florida to analyze long term changes and trends in water quality along the Florida Reef tract.

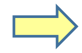
### New insights relevant to future restoration decisions

Long-term water quality monitoring data and the results of this report not only show the susceptibility of coastal waters to conditions producing algal blooms, but also the resilience of these systems. Biscayne Bay appears to have changed its ecological state over the past 15 years, with increased phytoplankton biomass. This change has been most apparent in the central and northern bay over the past 7 years. This finding, combined with observations of increased macroalgae and seagrass die-off in these Biscayne Bay sub-regions, likely indicate increased and likely continuing nutrient enrichment. These increases in nutrients and chlorophyll *a* are most pronounced near the coast and in areas with restricted circulation, suggesting they are coming from increased watershed nutrient loading. The exact source is unclear but may be related to local urban land use or local sea-level rise effects on local nutrients, especially via ground-water changes. Restoration projects affecting water inputs to Biscayne Bay (especially BBSEER) should be aware of these uncertainties. Research to identify causes of changing Biscayne Bay water quality and potential management actions for improving the Bay is needed.

Recent Florida Bay phytoplankton blooms appear to have been related to the health of seagrass beds and hurricane disturbance. In the decades following the late 1980s and early 1990s seagrass die-off event, seagrass recovered and algal blooms decreased, yielding good algal bloom indicator scores from WY 2005 to WY 2015 (Table 1). However, following another seagrass die-off event in WY 2016 and then a major hurricane, intense blooms occurred. Extremely high salinity conditions in the summer of 2015 contributed to initiating the die-off and Everglades restoration is expected to decrease the risk of high salinity stress in the future. Sustaining the health of seagrass beds appears be a key to sustaining good water quality in Florida Bay, and seagrass community health has been identified as a key CERP target. It is notable that the Florida Bay ecosystem has shown strong resilience, rebounding after seagrass die-off events and after hurricane-induced algal bloom events. Good algal bloom indicator scores in WY 2020 provided a positive indicator of the bay's overall resilience, however, many of the regions that were meeting their restoration targets in WY2020 fell below or well below restoration targets in WY2021 and WY2022.

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

## SUMMARY/KEY FINDINGS

| STATUS | PREVIOUSLY REPORTED (WATER YEAR 2020 | (WATER YEAR 2021) | CURRENT (WATER YEAR 2022) | Movement toward restoration target over the last 10 years |
|---|---|---|---|---|
| SYSTEM-WIDE | Y | Y | Y |  |

- Submersed aquatic vegetation (SAV) is fundamentally important to the ecology of Florida Bay, providing critical habitat, sequestering nutrients, stabilizing sediments and sustaining high biological productivity. The status of SAV health is an important indicator of the overall health of the bay and the progress of ecological restoration.
- Although the 10-year general trend for SAV was on an improving trajectory for several years, in recent years Florida Bay SAV has suffered through several negative impacts- a drought and hypersalinity event in 2014-15, a die-off event in 2015-16, a hurricane and two tropical storms in 2017-18 and a (resultant) large and persistent algal bloom in the central bay in 2021-2. These uncontrollable events have contributed to declining status indicators for several areas of the bay.
- Data that contributes to calculation of the SAV indicator for 2021-2022 are limited during the current reporting period due to COVID-19, research area closures and other logistical factors that prevented sampling. Data from the few sites that are available were used to make a modified, qualitative assessment of SAV status.
- Abundance and Diversity indexes show that SAV status is variable across Florida Bay. The overall cover and density of Turtlegrass (*Thalassia testudinum*), remains below levels observed prior to the die-off, and during 2021-22 showing improvement in the western bay and losses in the central bay. Two of the basins in the eastern bay maintained good status while a single site at Duck Key showed a decline in quality to fair. A single basin in the southern bay showed improvement from poor to fair. No sites in the transition zone were able to be assessed.
- Based on the limited data and prior trends in indicator status the overall bay status continues to be Fair, as does the overall trend in recovery.
- Natural weather patterns as well as enhanced restoration flows to Florida Bay during 2021-22 raised water levels in Taylor Slough and increased freshwater flows to Florida Bay which should be favorable for near-term seagrass recovery. Everglades stages were consistently higher than recent historical averages resulting in a bay salinity regime that was fresher than average. Salinities in all sectors of the bay were predominantly within the historical interquartile (25%-75%) salinity range, and well below the 25th percentile for long periods, with no evidence of hypersalinity.
- In a return to normal levels of sampling it is expected that SAV status will show some improvement based on favorable hydrologic conditions.

*Provisional assessment based on limited data.

**The Florida Bay SAV indicator remains below the restoration target (yellow stoplight).**

# JUVENILE PINK SHRIMP INDICATOR

## SUMMARY/KEY FINDINGS

| STATUS | PREVIOUSLY REPORTED (WATER YEAR 2020 | (WATER YEAR 2021) | CURRENT (WATER YEAR 2022) | Movement toward restoration target over the last 10 years |
|---|---|---|---|---|
| **System-wide Modified (no renewed sampling)** | B | B | B | |

For several years the pink shrimp indicator has been consistently represented by data acquired in southwestern Biscayne Bay by the CERP RECOVER Integrated Biscayne Bay Ecological Assessment and Monitoring (IBBEAM) project. Previously, data from the CERP RECOVER Fish and Invertebrate Assessment Network (FIAN) monitoring and assessment project was used to represent the pink shrimp indicator in Florida Bay, but FIAN was not funded after 2011 when funding to RECOVER was reduced broadly; therefore, that data were no longer available to represent the pink shrimp indicator in Florida Bay. In this report, ancillary data from another CERP RECOVER project, the Florida Bay Sport Fish Monitoring and Assessment project, has been used to produce an alternative Florida Bay pink shrimp indicator.

- The pink shrimp, *Farfantepenaeus duorarum*, is a commercial species that uses Florida Bay as a nursery ground. Growth and survival rates in Florida Bay are influenced by environmental conditions there, including salinity, and may affect the economic outcomes of offshore fishing operations. Abundance has traditionally been higher in the western part of the bay than in the interior, where consistent hypersalinity often prevails for months and even years.
- Pink shrimp density in the interior regions of Florida Bay is expected to increase when hypersaline conditions are reduced in frequency, duration, and severity. Pink shrimp density may increase in Biscayne Bay when freshwater inflow is more distributed along the shoreline rather than entering the bay only from canal mouths.
- Conditions for pink shrimp will improve when CEPP and BBSEER are implemented successfully.
- Full implementation of "Mod Waters" and the original C111 Project was expected by some to relieve hypersaline conditions by bringing more water to interior Florida Bay, however, improvements have not been consistent. Similarly, the Deering Estate Project of the CERP-Biscayne Bay Coastal Wetlands (BBCW) Project was expected to reduce salinity substantially in the nearshore bay immediately downstream from the Deering Estate flow-way, but, so far, there has not been much gain in mesohaline (5-18 psu) conditions.
- During WY 2021 and WY 2022 Florida Bay moved slightly closer to the density estimates of the most recent preceding years, but Biscayne Bay moved further away in both seasons.
- Compared to the last 10 years, the pink shrimp indicator in Biscayne Bay declined substantially in the evaluation years, both dry season and wet season. The pink shrimp indicator was higher (and into the good range) in Florida Bay in WY 2021 but back into the Ordinary range in WY 2022. The indicator reached the good (i.e., green) zone only in 2015, 2016, and 2018 in Biscayne Bay and in Florida Bay in WY 2010, 2013, and 2021. In both systems, the reason for the shortfall was a lack of sufficient fresh-water inflow in most years.

## Time Series of Stop Lights

Time series data are provided graphicly for IBBEAM sites in Biscayne Bay (Figure 1) and FAIN sites in Florida Bay (Figure 2).

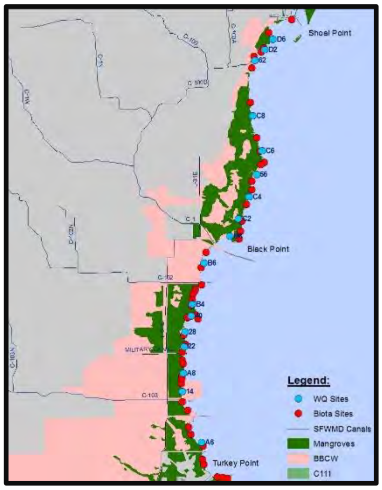



**Figure 1. IBBEAM biological (red) and water property (blue) sampling sites in western nearshore south-central Biscayne Bay.**

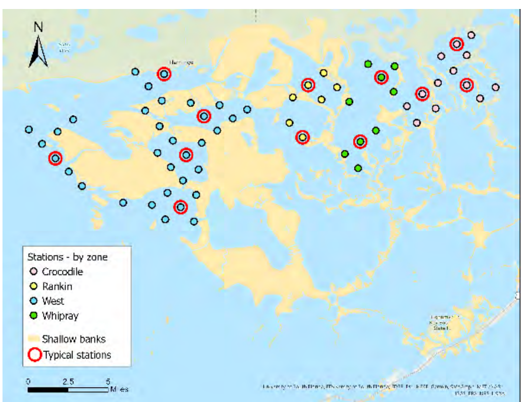



**Figure 2. "Collection sites" for identifying recording full set of animals captured in the haul, including forage fish and macroinvertebrates.** Pink shrimp from this subset of juvenile sport fish sampling sites was used to estimate the time series of annual wet season pink shrimp density in Florida Bay. Sites encircled in red were the most consistently used collection sites from 2012 through 2021, following optimization of the main set of samples for sampling the abundance of juvenile spotted seatrout.

**Biscayne Bay Data**
IBBEAM monitors the abundance and distribution of pink shrimp (*Farfantepenaeus duorarum*) and other small forage species in the very nearshore area (<~100 meters from shore) of southwestern Biscayne Bay along the stretch of shoreline from Shoal Point to Turkey Point (Browder et al. 2021). This area is affected by the BBCW, which is redistributing a portion of canal discharge, before it reaches canal mouths, to neighboring wetlands, where pumps and gravity move it into the bay along the shoreline. The area also is affected by upstream CERP projects that influence the amount of water from the regional system that reaches Biscayne Bay. Sampling is at 47 stations distributed along the coastline. Sampling consists of three throws of a 1 $m^2$ throw-trap, with samples removed by four sweeps of the area within the trap with a small seine at each throw. Contents (including small fish, penaeid shrimp, caridean shrimp, crabs, and echinoderms) are sorted, identified, and counted; and fish, penaeid shrimp, and crabs are measured and weighed individually. Collections are made twice each year, wet season and dry season, providing a pink shrimp (*F. duorarum*) density estimate for each year and season.

**Florida Bay Data**
The primary purpose of the Florida Bay Sportfish Project is to follow the year-to-year abundance of juvenile (<100 ml) spotted seatrout, *Cynoscion nebulosus*, in four bay regions, West, Rankin, Whipray, and Crocodile (see Kelble et al. 2021). Sampling is conducted monthly from May through November, the period when juvenile spotted seatrout are most consistently present in the bay. Sampling is with an otter trawl with an effective mouth width of 6 ft 10 2. Inches (2.1 m). One haul to sweep an area of approximately 5,382 $ft^2$ (500 $m^2$) is made on each station visit. Beginning in 2009, the complete faunal sample from each of 12 sampling units (hauls) was retained in each sampling month for identification and counting of all fish and macroinvertebrates (including especially *Farfantepenaeus duorarum* shrimp).in the haul. These are the data providing this year’s annual time series estimate of Florida Bay juvenile pink shrimp wet season relative abundance from WY 2010 through 2022.

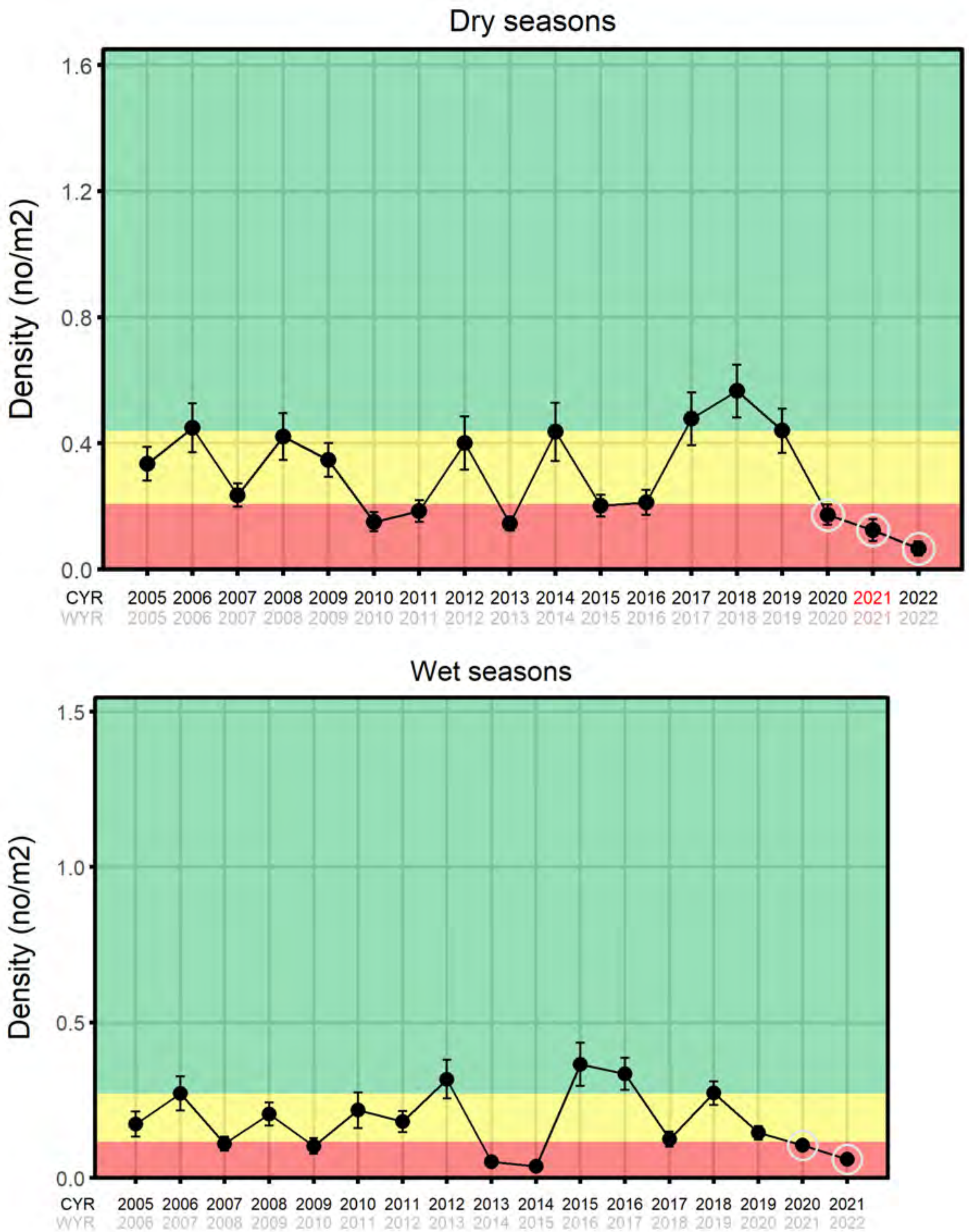



**Figure 3 Dry (upper) and wet (lower) season juvenile pink shrimp density in southwestern nearshore Biscayne Bay, from the CERP RECOVER IBBEAM 2022.** WY (and CY) 2020, as well as 2021 and 2022, was circled for evaluation since timing of the WY 2021 dry season sampling was delayed until early wet season by COVID-19 restrictions.

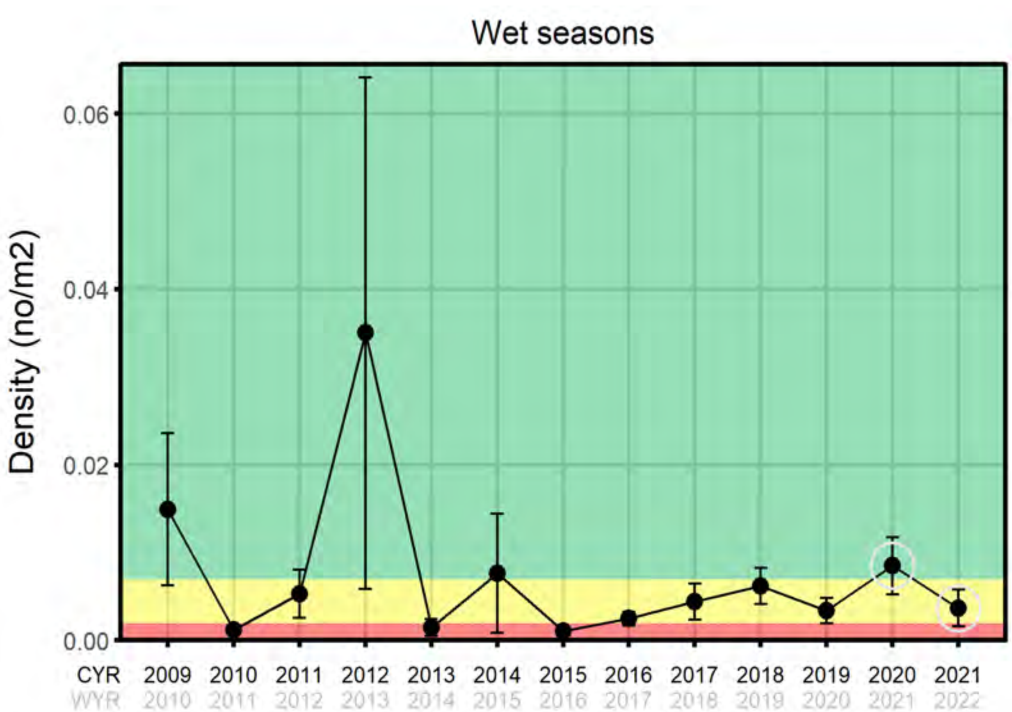



**Figure 4. Wet season relative density of juvenile pink shrimp across northern Florida Bay from the CERP RECOVER Florida Bay Sport Fish Monitoring and Assessment project.**

In Figures 3 and 4, Calendar Years (CY) are plotted on the top abscissa scale and corresponding Water Years (WY) are shown below. Enclosed black circles are mean density (or relative density) values for each year, and vertical bars are standard errors. Intersections between the green, yellow, and red background areas are the 25th (red-yellow) and 75th quartile (yellow-green) boundaries, respectively, calculated from annual values for the 11 years preceding the two years being evaluated. Evaluated years, WY 2021 and WY 2022, are scored as **good**, **ordinary**, or **poor** depending on whether they fall within the green, yellow, or red background areas. (Those that fall directly on the red-yellow boundary are considered **poor**, and those that fall directly on the yellow-green boundary are considered **good**.) In the cases above, a **good** year for pink shrimp relative density occurred only in Florida Bay in WY 2021. WY 2022 relative abundance in Florida Bay was **ordinary**. All evaluated density values in Biscayne Bay (Dry Season WY 2020, 2021 and 2022 and Wet Season WY 2021 and 2022 scored **poor**.

## DATA AND CALCULATIONS

### Updates on Calculation of the Indicators

The data in Figures 2 and 3 are from the CERP RECOVER IBBEAM MAP. The data in Figure 4 are from the "Collection" Data of the CERP RECOVER Florida Bay Juvenile Sport Fish Monitoring Project. For both Biscayne Bay and Florida Bay, the plotted data are of those specimens identified as *Farfantepenaeus duorarum*, *F. d. brasiliensis* or *F. notialis* (which genetic results suggest is still a subspecies of *F. duorarum*, rather than a separate species; Timm *et al.* 2019). Those penaeids too small to be identified to species were considered most likely to be *F. duorarum* and were also included. Evaluated years are scored as **good**, **ordinary**, or **poor** depending on whether they fall within the green, yellow, or red background areas. Those that fall directly on the red-yellow boundary are considered **poor**, and those that fall directly on the yellow-green boundary are considered **good**. An otter trawl such as that used in Florida Bay has been criticized as a poor sampler of penaeid shrimp, likely excluding the smaller sizes that, if present, might be caught in the throw-trap. Although the trawl net cod end mesh is about 1/8th of an inch (3 mm) in size compared to the 1/16th inch (1.59 mm) mesh size of the seine that sweeps the throw trap, the size frequency distributions of the farfantepenaeid catches are comparable, as examples from each area and gear (Figures 5 and 6) illustrate, indicating that smaller size classes are not excluded to any greater extent by the trawl. Although the throw- trap is a more efficient sampler of shrimp than the otter trawl, the area covered by the otter trawl is larger and the annual relative densities resulting from trawl sampling are within the same range over most of the years (except for the earliest years, when results may have been somewhat affected by visiting a less consistent set of collection sites than in the later years).

## How are these data being used?

The IBBEAM data are being used to inform water and resource managers on the progress of CERP in bringing sufficient water for restoration of estuarine conditions and communities into nearshore Biscayne Bay. While the focus is the BBCW project, BBSEER and other CERP components could influence the amount of freshwater flow to Biscayne Bay for a given volume and spatial and temporal distribution of rainfall. Projects to generate more water would include, but not be limited to, BBSEER, Wastewater Reuse, Aquifer Storage and Reuse, and surface local and regional storage projects under discussion. The Florida Bay annual wet season time series on relative pink shrimp density is being used to determine whether implementation of CERP projects is improving habitat for shrimp and other members of the community of small species that provide a food supply for sport fish and other larger species in Florida Bay. CERP's CEPP, which combines many Yellow Book projects, is likely to affect the amount of freshwater flow to Florida Bay for a given volume, timing, and spatial distribution of rainfall. COP, the culmination of Mod Waters and C-111, may also increase the flow of freshwater to Florida Bay.

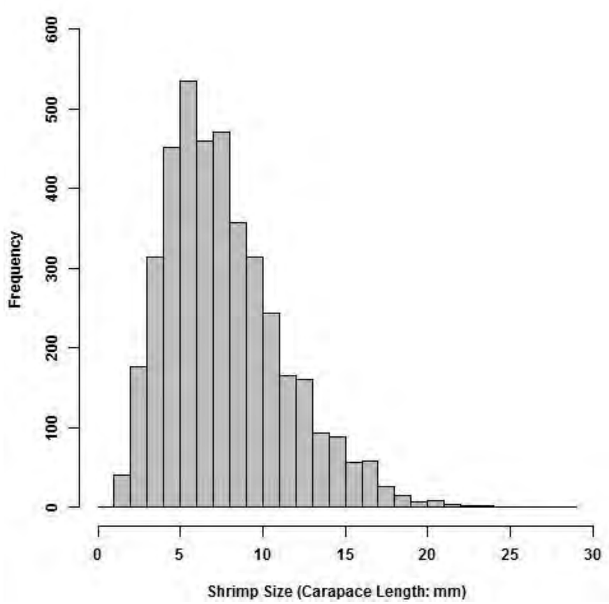



**Figure 5. Biscayne Bay *Farfantepenaeus duorarum* size frequency distributions (2016 and 2017 IBBEAM data, Ian Zink).**

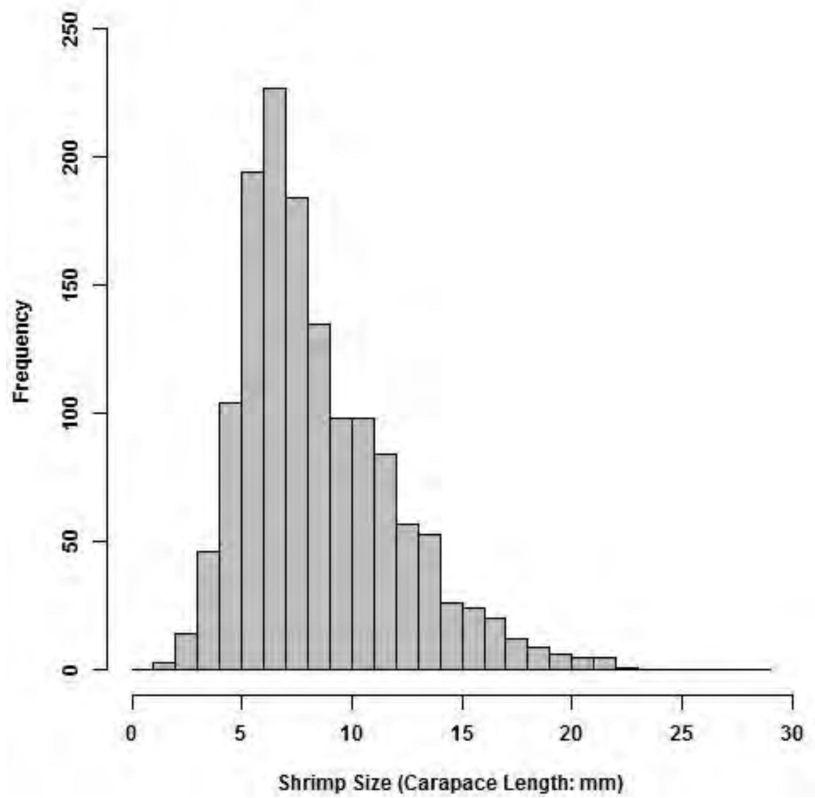



**Figure 6, Florida Bay *Farfantepenaeus duorarum* and *F.* spp. size frequency distributions (2016 and 2017 from West Region, Florida Bay Sport Fish "Collection" sampling, Zink).**

**New Insights Relevant to Future Restoration Decisions**

CY 2012, when pink shrimp relative density was highest, was a low-salinity year in all regions of Florida Bay where pink shrimp were sampled (Figure 7). CY 2020 was also a low salinity year at the sites of larger sampling effort for spotted seatrout and other sport fish (Kelble *et al*. 2021), although not at the sites where pink shrimp were sampled (i.e., the "Collection" sites).

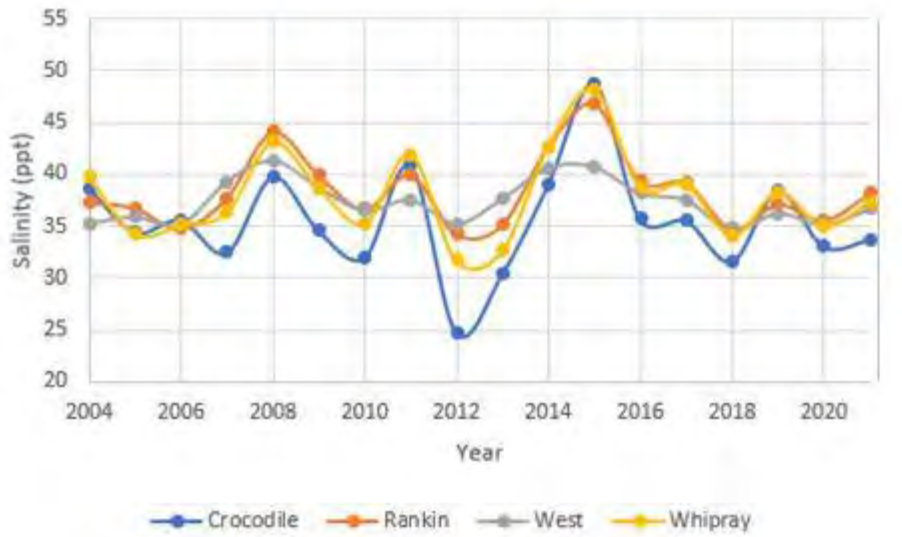



**Figure 7. Time series of salinity measurements, by region, at time and date of collections contributing to the Florida Bay pink shrimp (*Farfantepenaeus duorarum*) relative density dataset presented in this report.**

## LINKAGE TO RECOVER REPORTING ON INTERIM GOALS

### What Interim Goals evaluation model was used?

The same growth and survival-based "potential production" pink shrimp model applied in the 2005 Interim Goals and Interim Targets study and the CEPP planning study was re-coded in the R programming language and used in the 2020 Interim Goals Report. The new model code allowed for faster prediction of yearly shrimp production in two Florida Bay basins, Johnson Key Basin and Whipray Basin. The growth and survival equations that drive pink shrimp production in the model yielded realistic relative production predictions under input of various scenarios of daily average salinity. The metric used was relative annual pink shrimp production from the July cohort.

### What monitoring data are needed to assess if the expected responses are being achieved?

The Florida Bay data used in the present indicator report might be useful for assessment relative to model results.

### Will the current modeling and monitoring be sufficient to report on this indicator as an Interim Goal in 2024?

No

### If not, what is needed?

Further assessment of the current Florida Bay data to ensure that it is appropriate. In addition, the new R version of the pink shrimp production model, which was especially efficient in providing simulations of multiple scenarios, was not well documented and will have to receive considerable attention from a new person with R capability before it can be used again because its developer left our employee for a permanent job.

## LITERATURE CITED, REPORTS, AND PUBLICATIONS FOR MORE INFORMATION

Browder, J.A., J.E. Serafy, Lirman, D. 2021. Integrated Biscayne Bay Ecological Assessment and Monitoring (IBBEAM). Report to the U.S. Army Corps of Engineers and the RECOVER Monitoring and Assessment Plan Team of the Comprehensive Everglades Restoration Project. UM Rosenstiel School of Marine and Atmospheric Science, National Park Service, and NOAA National Marine Fisheries Service Southeast Fisheries Science Center. NOAA-NMFS-SEFSC-PRBD-2021-06.

Kelble, C.R., J. Browder, A. Fine, I. Smith, K. Montenero, E. Milton, J. Contillo. 2021. Juvenile sportfish monitoring in Florida Bay, Everglades National Park. Monitoring and Assessment Plan Results from 2004 through 2020. 2021. Annual Report to the U.S. Army Corps of Engineers, Jacksonville District, and the RECOVER group of the Comprehensive Everglades Restoration Project from Miami NOAA Laboratories: Atlantic Oceanographic and Meteorological Laboratory and Southeast Fisheries Science Center. NOAA-NMFS-SEFSC-PRBD-2021-05..

Timm, L., J. A. Browder, S. Simon, T. L. Jackson, I. C. Zink, and H. D. Bracken. 2019. A tree money grows on: the first inclusive molecular phylogeny of the economically important pink shrimp (Decapoda, *Farfantepenaeus*) reveals cryptic diversity. Invertebrate Systematics 33:488-500.

## SUMMARY/KEY FINDINGS

| STATUS | PREVIOUSLY REPORTED (WATER YEAR 2020 | (WATER YEAR 2021) | CURRENT (WATER YEAR 2022) | Movement toward restoration target over the last 10 years |
|---|---|---|---|---|
| Spoonbill Nesting | R | R | R | ↓ |
| Spoonbill prey fishes | R | Y | Y | ↑ |
| SYSTEM-WIDE | R | Y | R | → |

- Roseate Spoonbills nesting in Florida Bay forage in the coastal mangrove zone north of the Florida Bay where they feed mostly on small (<13cm) prey fish species. This area was negatively affected by upstream water management practices that altered hydroperiods, reduced freshwater flow and made the area much more saline resulting in reduced productivity of spoonbill prey that ultimately led to major declines in nesting activity.
- Restoration activities designed to restore the proper quantity, timing and distribution through the Everglades should stabilize hydroperiods, reduce salinity, increase prey productivity and result in greater nesting success and increased nesting activity.
- The BBSEER and the proposed Southern Everglades Project are proposed largescale projects whose stated goals are to restore more natural flow quantities, timing and distribution to this area and should result in increased biological productivity, thereby benefiting this indicator.
- Projects that have affected this area are the C-111 Spreader Canal Western Phase (C-111 SCWP), the COP and the completion of the Mod Waters. These projects appear to have had an incremental positive impact by increasing freshwater flow and lowering salinity in normal to high rainfall years but fail to ameliorate high salinity during drought years. Any potential affect that these projects would have on water depths and hydroperiods are being masked by permanently high water from sea level rise (SLR).
- During this report period spoonbill nesting metrics fell to the lowest point in the last decade in 2022, however, the metric still remain just below the cutoff between RED and YELLOW and a single highly productive nesting cycle could result in a transition to YELLOW. The positive response of the prey fish metric (transitioned from RED to YELLOW in 2021) suggest that a highly productive nesting year may occur over the next 2-year cycle.
- Spoonbill nesting metrics have hovered just below the transition from red to yellow for the last decade but have been slowly declining for the most part, thereby accounting for the reported declining (RED) trend. Currently spoonbills require low water to concentrate their prey and SLR has made such events rarer. The increase in the prey fish metric (upward YELLOW trend), however, may make prey more available without requiring these low water events. Evidence suggests that perhaps the proposed large scale projects mentioned above will increase prey to such a point that spoonbills will successfully nest without requiring such low water conditions but currently the overall indicator continues to hover just at the transition from red to yellow as it has for the last decade (stable YELLOW trend).

Overall, the stoplight color for the wading bird (Roseate Spoonbill) indicator changed from red to yellow for WY 2021 and back to red in WY 2022 (Table 1). This is the seventh consecutive year that the indicator switched between red and yellow and ranged from scores of 24 to 35 over that period. This suggests that although conditions may have improved over historic baseline, those improvements seem to have plateaued, however, the individual sub-metrics used to calculate the overall score are heading in different directions. These sub-metrics indicate that restoration is improving wetland conditions while any positive responses bay wide may be masked by external factors. As explained in both the 2018 and 2020 reports, the decline in nesting parameters may be more related to SLR effects than to the failure of restoration activities. The metrics were calculated based on those published by Lorenz et al. (2009) with some calculations revised as per the WY 2018 and WY 2020 Stoplight Report.

**The Roseate Spoonbill metric is well below the restoration target (red stoplight)**

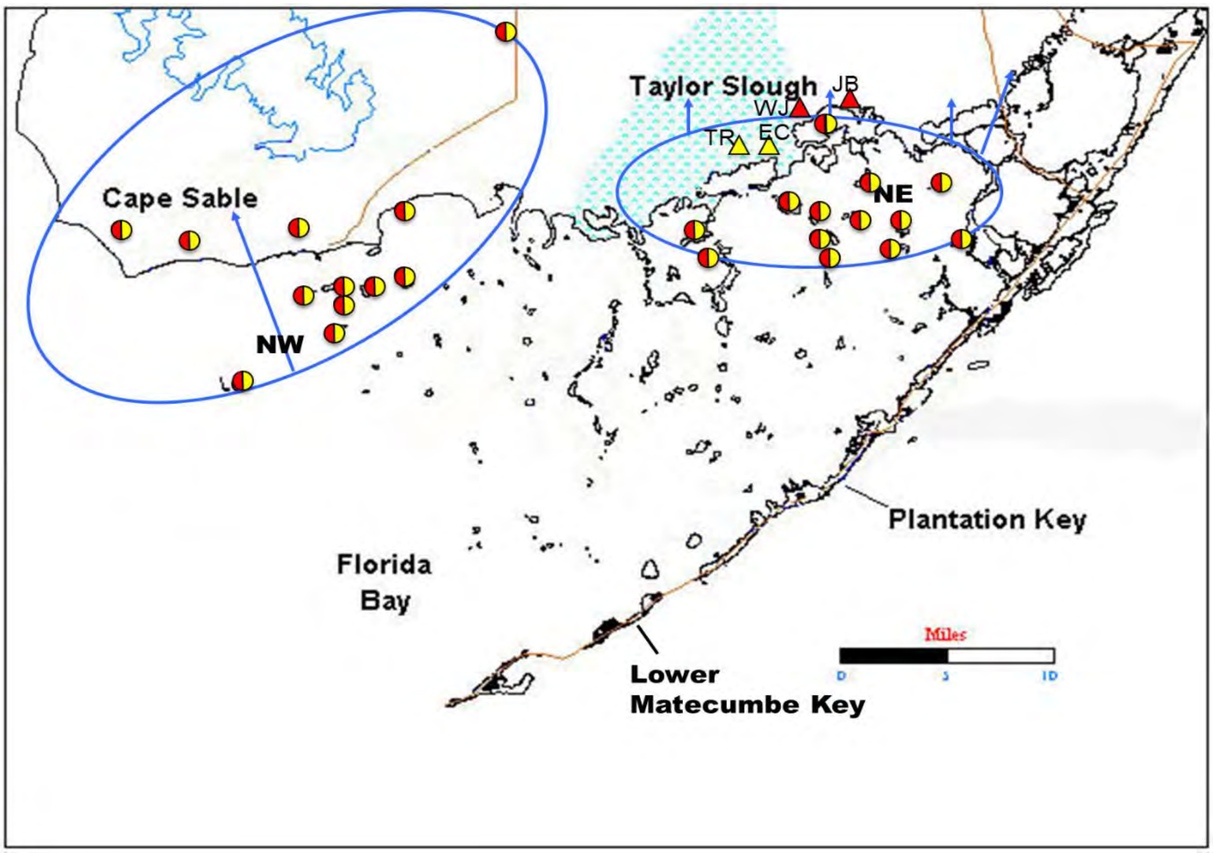



**Figure 1. Map of northern Florida Bay showing approximate spoonbill nesting locations (circles) in both the northeastern and northwestern regions of Florida Bay as well as prey base sampling locations (triangles) on their foraging grounds**. The triangle color represents the prey score of the mangrove prey base fish metric at each sampling location in 2022. The two-letter name of each fish collection site is provided next to each triangle. Right half of each circle represents the 2022 score for the nest number sub-metric and the left half of each circle represents the 2022 score for the nest production and success sub-metric within each region.

## Introduction

Spoonbills were largely extirpated in Florida prior to 1900 due to excessive hunting for the millinery trade. In 1935, spoonbills returned to Florida Bay and nested on Bottle Key in southern Florida Bay and have since expanded across the bay and rapidly increased nest numbers in the northeastern region of the Bay beginning in about 1960 (Figures 1 and 2; Lorenz et al 2002). Birds nesting in this region concentrate their foraging in the dwarf mangrove forests that line the mainland coast from Taylor Slough to Card Sound. Nest numbers in this region began to decline in the mid-1980's (Figure 2) following the completion of a set of canals and water control structures known as the South Dade Conveyance System (SDCS) in 1984. The SDCS has been shown to have negatively altered Florida Bay both physically and ecologically (McIver et al. 1994, Lorenz et al 2002, Lorenz 2014a). Spoonbills also began to focus nesting effort in the northwestern region of Florida Bay in the 1970's (Figure 2), with a steady increase in numbers that coincided with the declining numbers in the northeastern region in the 1980's and 1990's (Figure 2; Lorenz et al. 2002). However, numbers in the northwestern region also began to decline in the mid-2000's (Figure 2). Birds nesting in the northwestern region focus their foraging on the wetlands of Cape Sable (Figure 1).

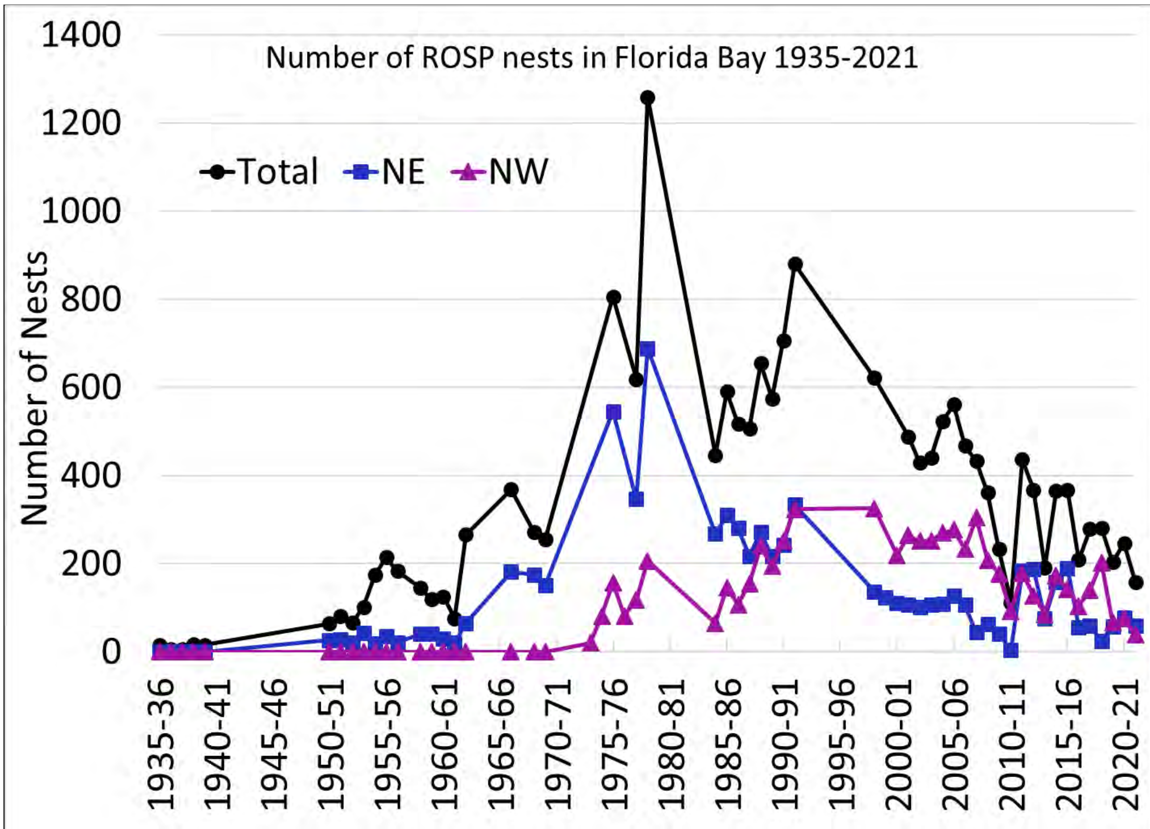



**Figure 2. Number of roseate spoonbill nests in Florida Bay and for the Northeastern and Northwestern regions of Florida Bay from WY 1936 to WY 2020.**

## Stoplight Format

The indicator sub-metrics for spoonbills nesting are: total number of nests for all Florida Bay, as well as the number of nests in both the northeastern and northwestern nesting regions, and the nest production and success in both region. Spoonbill prey fish community structure at foraging sites for birds nesting in the northeastern region was an additional sub-metric in the original stoplight (Lorenz et al. 2009) but has been raised to carry equal weight as the Spoonbill nesting metric as per the 2018 and 2020 reports due behavioral changes in spoonbills due to SLR (Rafferty et al. 2021; see Updates on Calculation of indicator section below).

## Stoplight Scores

The target for total spoonbill nests is 895, the highest 5-year average number of nests prior to completion of the SDCS (Figure 2; see Updates to calculation of indicator section below). This sub-metric is the average from the previous five years expressed as a percentage of 895 (Table 1). All years from the WY 2018 nesting cycle through WY 2022 ranged from 26% (WY 2022) to 33.5% (WY 2019) and has been declining for the last 4 years. The sub-metric for the number of nests in northeastern Florida Bay is the five-year average expressed as a percentage of 526 nests (the highest 5-year average number of nests in northeastern Florida Bay recorded prior to SDCS completion; Figure 2; see Updates on Calculation of indicator section below). This sub-metric was even less encouraging than the total nests in Florida Bay dropping steadily from 20.4% in 2018 to only 10.5% in 2022, indicating that spoonbill nesting has not responded as expected to completion and operation of the C-111 SCWP CERP project in 2012. The C-111 SCWP project was designed to increase flows through Taylor Slough but certain operation that were part of the design for the C-111 SCWP have not been implemented (e.g., raising the canal stages at the S-18C structure) and the restoration benefits of the project have not been fully realized, however some beneficial responses have been documented (see prey community structure sub-metric below). The sub-metric for the number of nests in the northwest region is also expressed as a percentage but is based on the minimum, maximum and mean of the number of nests found in the northwest region at the time the sub-metrics were established. Nest numbers in northwestern Florida Bay have also steadily declined for the last 4 years but not nearly as precipitously as in the northeastern bay. One caveat, however, is that declining nesting throughout Florida Bay may be in response to increased SLR since 2011, thereby partially masking positive responses in the ecosystem to recent advances in restoration activity such as completion of the C-111SCWP, Mod Waters and the COP (See the 2018 and 2020 reports as well as Rafferty et al. 2021 for detailed accounts of the effect of SLR on spoonbill nesting and foraging patterns).

**Table 1. Stoplight scores for each sub-metric, and the overall score for the indicator for the last five years.** Spoonbill nesting score is the average of the five sub-parameters. Overall score was the average of nesting score and the prey score. Scores are in percentages of restoration with 0% representing a system unaffected by restoration efforts and 100% being fully restored. Scores assigned a green if the score of the parameter was green for ≥67, yellow for 34-66 and red for ≤33.

| Parameters | WY 2018 | WY 2019 | WY 2020 | WY 2021 | WY 2022 |
|---|---|---|---|---|---|
| Total Nests in Florida Bay | 31.5 | 33.5 | 29.9 | 27.2 | 26.1 |
| Number of Nests in NE Florida Bay | 20.4 | 18.4 | 14.6 | 10.4 | 10.5 |
| Number of Nests in NW Florida Bay | 32.9 | 42.4 | 33.5 | 30.1 | 26.7 |
| NE Production and Success | 59.6 | 55.0 | 53.1 | 47.5 | 34.3 |
| NW Production and Success | 76.8 | 76.4 | 68.6 | 53.0 | 42.4 |
| **Spoonbill Nesting Score** | **44.3** | **45.1** | **39.9** | **33.6** | **28.0** |
| **Spoonbill Prey Score** | **18.1** | **23.7** | **17.3** | **33.7** | **35.72*** |
| **Overall Spoonbill Indicator Score** | **31.2** | **34.4** | **28.6** | **33.6** | **31.9** |

**provisional score; may change after data is quality assured*

Nest production is the average number of chicks produced per nest attempt (c/n) for a given year. Th nest production sub-metric is the five year mean of these estimates and is expressed as a percentage of several thresholds (0 to 0.7c/n is a declining population; 0.7 to 1.0 is stable; >1.0c/n is an increasing population and 1.38c/n was the average production prior to completion of SDCS). As per the 2020 report, this metric is now on a zero-to-one scale using calculations as presented in the 2020 report and is expressed as a percentage. The nesting success sub-metric is simply the percentage of the last 10 years that spoonbills nested successfully (i.e., produced 1.0c/n or more on average). In the original stoplight metrics (Lorenz et al. 2009), the lower of these two scores was used as the production and success sub-metric, however, following recommendation made in the 2020 report, we now use the average of these two sub-metrics (see Updates on calculation of indicator section below for justification for this change). In the northeast, the nest production parameter was relatively stable from 2018 to 2021 and remained just above the threshold between yellow and red scales, however, it dropped precipitously into the red in 2022 after 4 consecutive years of below an average of 1c/n with two of them below 0.3c/n (Table 2). These poor years are also reflected in the nesting success parameter for northeastern Florida Bay as well as when the two parameters are averaged to provide the northeastern production and success sub-metric. The same patterns were repeated for the northwestern production and success where there were also 4 consecutive years of production below 1c/n, however, unlike in the northeast, production was near 1c/n (>0.8c/n) for 3 of the 4 years. Still the production sub-metric for the northwestern region went from green to nearly red (87% to 35%) in the three years from 2020 to 2022 and the combined production and success sub-metric from 77% (green) to 42% (yellow). As with the nest number sub-metrics, these declines may be a result of SLR rather than a lack of restoration performance (2018 and 2022 reports and below).

**Table 2. Nest production and nesting success sub-metrics by nesting sub-region of Florida Bay.** The nest production sub-metric is the five year average nest production (chicks fledged/nest; c/n) and is expressed as a percentage of the target (1.38c/n). The nesting success is the number of years out of the last 10 that spoonbills produced >1c/n expressed as a percentage. The combined sub-metric is average of the two sub-metrics. Scores assigned a green if the average score was>66, yellow for 33-66 and red for <33.

| Nesting Parameter | WY 2018 | WY 2019 | WY 2020 | WY 2021 | WY 2022 |
|---|---|---|---|---|---|
| Nest Production Northeast | 39.1 | 39.9 | 36.2 | 35.0 | 18.5 |
| Nesting Success Northeast | 80 | 70 | 70 | 60 | 50 |
| **NE Production and Success** | 59.6 | 55.0 | 53.1 | 47.5 | 34.3 |
| Nest Production Northwest | 93.7 | 102.8 | 87.3 | 55.9 | 34.8 |
| Nesting Success Northwest | 60 | 50 | 50 | 50 | 50 |
| **NW Production and Success** | 76.8 | 76.4 | 68.6 | 53.0 | 42.4 |

Prey fish communities at historic spoonbill foraging sites within the mangrove transition zone have been quantified from primary foraging locations of wading birds (including spoonbills) nesting in Florida Bay (Figure 1; Lorenz 1999, Lorenz 2014b). We quantified the prey community at four of these sites that were associated with Taylor Slough and the C-111 basin and the restoration efforts that affect these flow ways. The prey community structure metric is simply the percentage of the fish prey base that are classified as freshwater species at each site (Lorenz and Serafy 2006). This is based on the finding that prey are more abundant and have higher biomass when a significant component of all prey base fishes are freshwater species (Lorenz and Serafy 2006). Simply stated; prey productivity is greater at lower salinity and the presence of freshwater species is representative of that increased production. The calculation of this metric was changed from the published version (Lorenz et al. 2009) in the 2020 report. These changes were to use only 4 sampling sites instead of 7 and the way the mean percentages were calculated were changed. Both of these changes were implemented, at least in part, to higher water levels at the sites caused by SLR and although the 2020 report provided a detailed account of why these changes were made, we feel the reasons were significant enough to warrant a brief explanation here. Reconstruction of US-1 to the Florida Keys in 2008 resulted in two of the sites being subjected to tidal forces that have steadily increased with SLR. This resulted in much higher salinity than the 2009 publication accounted for (only data through 2008 was used in Lorenz et al. 2009) and were removed from the calculation because this biased these samples away from having freshwater fish species (the third site removed was due to financial constraints). Changes to the way the calculation was made were due to the impact that higher water levels caused by SLR that resulted in fewer days that water level was low enough to concentrate prey fishes at these sites (Lorenz 2014b, Figures 3 and 4). Fewer concentration events greatly reduced the chances that any single sample collection would happen during a concentration event, thereby increasing the probability of capturing an event only once or twice annually. If the calculation of percent of catch that were freshwater species was based on the total number of fish collected at all sites and samples the result would be heavily biased toward the individual month and site that happened to be collected during a concentration event. All of the samples not collected during such an even would be dwarfed by the sheer number collected during the concentration event thereby marginalizing these samples. Using WY 2020 as an example, the total number of fish collected in all samples was 1660 at WJ, 951 at TR and 794 at EC. We did sample during a concentration event in March 2020 at WJ but no concentration events were collected at either TR or EC thereby explaining the much higher fish total at WJ. If we simply took the total number of freshwater fish collected at these sites (108) and divided by the total number of fish collected (3405) the result is 3.1% freshwater catch, however, this result is heavily biased toward the community structure that occurred at WJ in March. For this reason, we now calculate the percent freshwater catch for each month at each site and then take the average of these collections.

The target for the spoonbill prey sub-metric is to have at least 40% of all prey fish be classified as freshwater, based on the findings of Lorenz and Serafy (2006), with a percentage of higher than 5% indicating a positive response to restoration efforts. These thresholds were set as the transition points between stoplight colors (<5% is red, ≥5% to ≤40% is yellow, >40% is green) and equations used to set these on zero to one scale expressed as a percentage to match the other metrics (2020 report).

For the first time in almost a decade, the metric was scored as yellow in 2021 and this was repeated for a second consecutive year in 2022 (Table 3; note: the WY 2022 data is preliminary based on an cursory examination of the fish samples and may change some with a more thorough analyses and quality control measures). Furthermore, the two sites found within Taylor Slough (TR and EC; Figure 1) were yellow in both years (Table 3). The C-111 SCWP, Mod Waters and the COP were designed and implemented, at least in part, to increase freshwater flows through Taylor Slough and appear to be having a positive ecological impact in that the prey base has responded. Unfortunately, as stated above, these fish may not be being concentrated frequently enough to translate into increased nesting parameters in spoonbills.

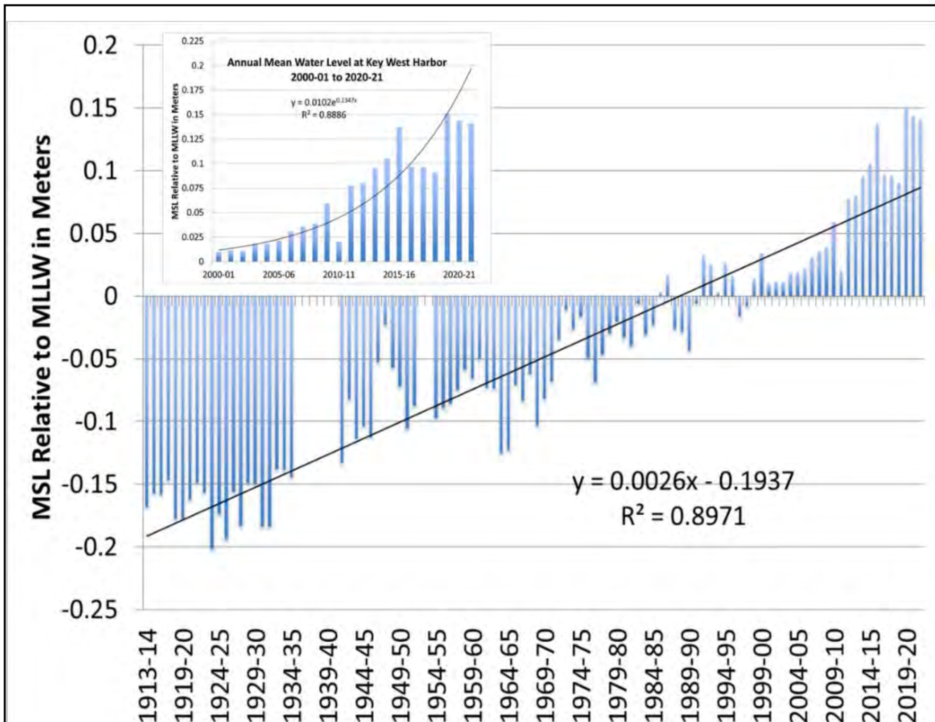



**Figure 3. Mean sea level in relation to Mean Low Low Water for Key West Harbor 1913 to present.** Inset is the same data from 2000 to present indicating an exponential increase in sea level rise as predicted by many climatologists.

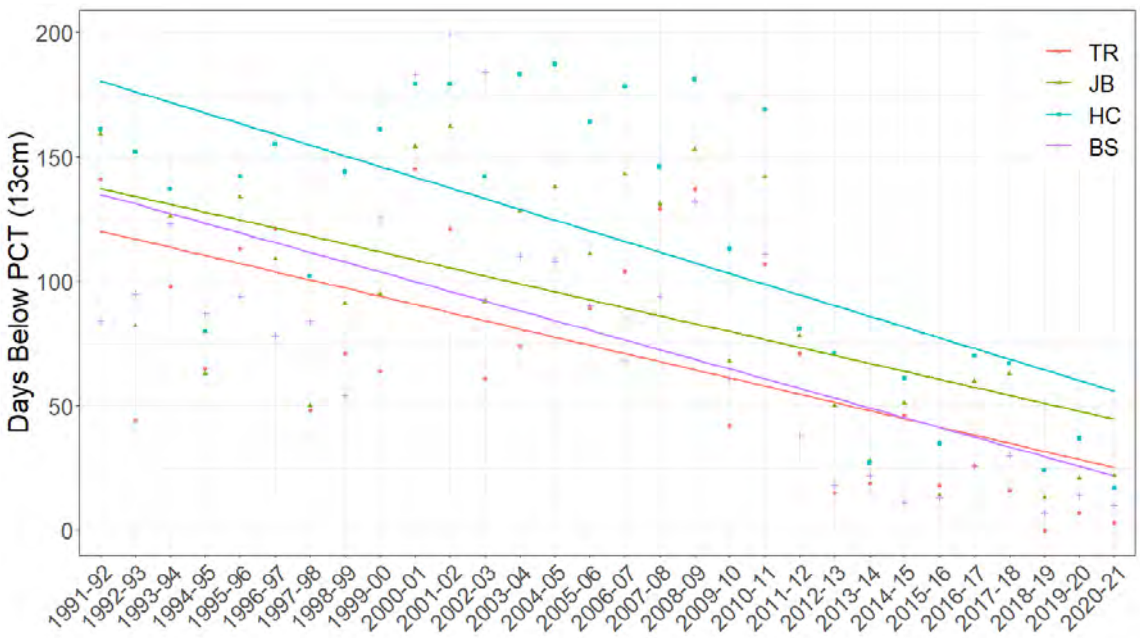



**Figure 4. Number of days each hydrologic year that water levels were below the prey concentration threshold (13cm relative depth; Lorenz 2014b).** Note: data collection did not begin at BS until 1992-93; data were unavailable at the time of this writing for WY 2022.

**Table 3. Mean of monthly percent catch of freshwater fish species estimates for each of four sampling locations, mean percent catch of all 4 sites and Spoonbill Prey Score based on percent of full successful restoration efforts.** Percent of catch was scored red <5%, Yellow 5-40% and Green >40%. Prey Score is the mean percent catch placed on a zero to 100 score using these same thresholds.

| % Catch Classified as Freshwater Species | WY 2018 | WY 2019 | WY 2020 | WY 2021 | WY 2022* |
|---|---|---|---|---|---|
| TR | 5.2 | 8.21 | 5.4 | 11.9 | 7.82 |
| EC | 1.7 | 2.6 | 3.9 | 8.1 | 19.24 |
| WJ | 1.4 | 1.7 | 0.7 | 0 | 0.64 |
| JB | 2.6 | 1.7 | 0.4 | 1.4 | 2.35 |
| **Mean** | 2.7 | 3.6 | 2.6 | 5.4 | 7.51 |
| **Spoonbill Prey Score** | **18.1** | **23.7** | **17.3** | **33.7** | **35.72** |

***2022 are provisional scores; may change after data is quality assured***

The overall spoonbill stoplight score is calculated as the average of spoonbill nesting score and the spoonbill prey score sub-metrics (see Updates on calculation of indicator section below). Because all metrics are on a 0-100 scale this can be expressed as the percentage of ecosystem functionality of a restored system. The overall spoonbill restoration metric increased from 29% to 34% in 2021 and then declined to 32% in 2022. That the overall spoonbill indicator score has been flipping between red and yellow for almost a decade perhaps indicates that the overall indicator has become stagnant in response to restoration efforts. However, an examination of the two sub-metrics that were averaged together to arrive at the overall score suggest a different conclusion. The spoonbill prey sub-metric has increased in the past two years overall and especially at the two sampling sites located in Taylor Slough. With the completion of the C-111 SCWP (2012), Mod Waters (2020) and implementation of the COP (2020), freshwater flows though Taylor Slough have increased resulting in lower overall salinity and longer periods under freshwater conditions for the last two years in the mangrove habitats north of Florida Bay (Blochel and Lorenz 2022). This is the habitat that traditionally served as the foraging habitat for spoonbills nesting in northeastern Florida Bay. The lower salinity patterns exhibited in the last two years has resulted much higher abundance of freshwater species in the last two years compared to the previous three (Table 3) and suggest a higher overall abundance of prey (Lorenz and Serafy 2006). In contrast all of the sub-metrics that are used to arrive at the Spoonbill nesting score, have declined from 5 years ago (Table 1), especially those associated with northeastern Florida Bay, suggesting that the increased prey abundance has not translated into nesting success. The disconnect is that neither sub-metrics consider the availability of the more abundant prey to wading birds. With increasing SLR (Figure 3), fewer prey concentration events are occurring in these wetlands, reducing availability of prey to spoonbills and other wading birds (Figure 4). So even though the overall indicator appears to have plateaued, the sub-metrics indicate that restoration is having a positive response, however, the broader responses expected are being masked by external stressors that are beyond the scope of restoration efforts. This, however, does not mean that spoonbill nesting metrics will never respond positively to restoration efforts even though SLR continues to increase. Ogden (1994) showed that the massive wading bird nesting events that occurred in the Everglades during the 1930's and 1940's only happened in the highest rainfall years. His conclusion was that the pre-drainage Everglades had much higher water levels during highly productive nesting years, i.e., the historic Everglades did not need such low water to concentrate prey. Rather, the historic Everglades had such high prey productivity that concentration events occurred at much higher water levels than the current Everglades. Logically, it follows that if the spoonbill prey score continues to increase to recovery targets (i.e., green score), prey may become so abundant as to be highly available to spoonbills at the higher water levels induced by SLR.

## DATA AND CALCULATIONS

### Updates on calculation of indicator

**1) Use of the maximum five-year average of number of nests prior to SDCS as target.**

In the 2020 report we explained the need to change the target to for total nests and nest number in the northeastern region to the maximum multi-year average number of nests that occurred prior to the construction of SDCS rather than the single highest year. We argued that since this metric uses a five year average so should the target. This changes the target for total nests from 1258 to 895 and the target number for the northeastern region from 688 to 526, these changes are implemented in this report.

**2) Use average of production and success metrics for each region**

The published version of this indicator (Lorenz et al. 2009) used the lower of the two production and success sub-metrics to calculate the overall indicator score. The 2009 publication justified using the lower of the two because both sub-metrics are calculated from the same raw data set. As pointed out in the 2020 report, however, we argued that each evaluates different important aspects of spoonbill population dynamics. Productivity is based on the number of chicks produced per year using the 5 year mean. This numerically tells how many spoonbill chicks were produced in a five year period and can be high regardless if only one or two years had very high productivity while the other 3 or 4 were complete failures or if all 5 years were moderately successful. The success sub-metric evaluates how consistently Florida Bay provides the ecosystem services required for spoonbills to raise young by measuring how many times spoonbills produced 1c/n on a decadal scale. The efficacy of using both as independent sub-metrics rather than the lowest can be best understood by using an example from Table 2. In WY 2019, the restoration target for the nest production in the northwest region was exceeded (>100%) but the combined score was only 50% because the success metric was the lower of the two. Taking the lower of the two completely discounts that spoonbills were highly productive from WY 2015 through WY 2019 because they averaged only 0.9c/n in both WY 2011 and WY 2012 and 0.8c/n in WY 2019 and WY 2020. Technically these are considered failed years because they did not produce 1.0c/n and lowered the success metric to 50% even though four of the five failed years were borderline successful (Table 2). Taking the actual success rate for the same 10 years, five had very high production, 4 were just below the 1c/n cutoff and only one year had actually low productivity (<0.7c/n). Taking the average for the previous 5 years of productivity resulted in a score of above 100%. So taking the lower of the two scores (success) entirely dismissed that for five years the chick production was actually very high (productivity) even if production did not exceed 1c/n in most years. If both were used, the metric would consider that Florida Bay was inconsistent in providing the necessary ecosystem services in the northwestern region on an annual basis but, when those services were provided, they were much higher than the minimum requirement. By averaging the two sub-metrics (as implemented above) both important aspects of the ecosystem are taken into account.

**3) Use average of nesting score and prey score as overall spoonbill score**

In the 2018 report, we proposed elevating the spoonbill prey score to its own indicator and reported it separately from the spoonbill nesting score. In 2020 we reported both together but gave each an independent score. Both of these efforts were unsatisfying in that the actions needlessly complicated what was designed as a simple and easily understandable reporting process. The methods also seemed to marginalize the spoonbill prey score, which for reasons stated above, has become increasingly important in understanding the effects of restoration efforts. Neither report seemed to elevate the metric to its proper level. In this report, we decided to take the average of the two metrics, thus both raising the importance of the prey metric and making the reporting process much easier to understand. Going forward, this will continue to be the way these metrics are calculated.

These three changes were necessitated by the impact of SLR on spoonbill nesting patterns in Florida Bay (Rafferty et al. 2021). Please review the 2020 for a full explanation of the impact of SLR on nesting and foraging patterns and the justification for these changes based on these changes.

## How have these data been used?

Data from this monitoring program was used to evaluate overall wading bird health in southern Florida through the annual South Florida Wading Bird report for 2021 and 2022. However, neither of these reports has been released at the time of this writing because of delays created by the existing Covid 19 pandemic. Likewise, the data was used in the 2020 SFER. Results of data collection have been presented on the weekly Ecosystem Based Management Calls and seasonal meetings. Annual reports to the USACE, the SFWMD and ENP analyzed these data as well.

## LITERATURE CITED, REPORTS, AND PUBLICATIONS FOR MORE INFORMATION

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https://storymaps.arcgis.com/stories/a44a6f148bc244ab98f7fb008b7098cf

## ACRONYMS

Alligator Production Suitability Index (APSI)
A.R.M. Loxahatchee National Wildlife Refuge (LNWR)
Big Cypress National Preserve (BCNP)
Biscayne National Park (BNP)
Biscayne Bay Coastal Wetlands (BBCW) Project
Biscayne Bay Southeastern Everglades Ecosystem Restoration (BBSEER)
C-111 Spreading Canal Western Phase (C-111 SCWP)
Caloosahatchee River Estuary (CRE)
Central Everglades Planning Project (CEPP)
Combined Operating Plan (COP)
Comprehensive Everglades Restoration Plan (CERP)
CERP Guidance Memorandum (CGM)
Conceptual Ecological Models (CEM)
Ecosystem Based Management (EBM)
Everglades Agricultural Area (EAA)
Everglades National Park (ENP)
Fish and Invertebrate Assessment Network (FIAN)
Florida Power and Light Company Turkey Point Power Plant (Turkey Point)
Habitat Suitability Indices (HSI)
Integrated Biscayne Bay Ecological Assessment and Monitoring (IBBEAM)
Interim Goals and Interim Targets (IGIT)
Lake Okeechobee Regulation Schedule (LORS)
Lake Okeechobee Watershed Restoration Project (LOWRP)
Lake Worth Lagoon (LWL)
Loxahatchee River Estuary (LRE)
Monitoring and Assessment Plan (MAP)
Modified Water Deliveries to Everglades National Park (Mod Waters)
National Park Service (NPS)
Northeast Shark River Slough East (NESSE)
Old World climbing fern (OWCF)
REstoration COordination & VERification (RECOVER)
Sea level rise (SLR)
Shark River Slough (SRS)
South Dade Conveyance System (SDCS)
South Florida Environmental Report (SFER)
South Florida Management District (SFWMD)
Southern Coastal System (SCS)
St. Lucie Estuary (SLE)
Stormwater Treatment Area (STA)
Submersed aquatic vegetation (SAV)
Systematic Reconnaissance Flights (SRF)
Taylor Slough (TS)
Total Phosphorus (TP)
US Army Corps of Engineers (USACE)
U.S. Geological Survey (USGS)
Wader Distribution Evaluation Modeling (WADEM)
Water Conservation Areas (WCA)
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