lake worth LAGOON

LAKE WORTH LAGOON
MANAGEMENT PLAN

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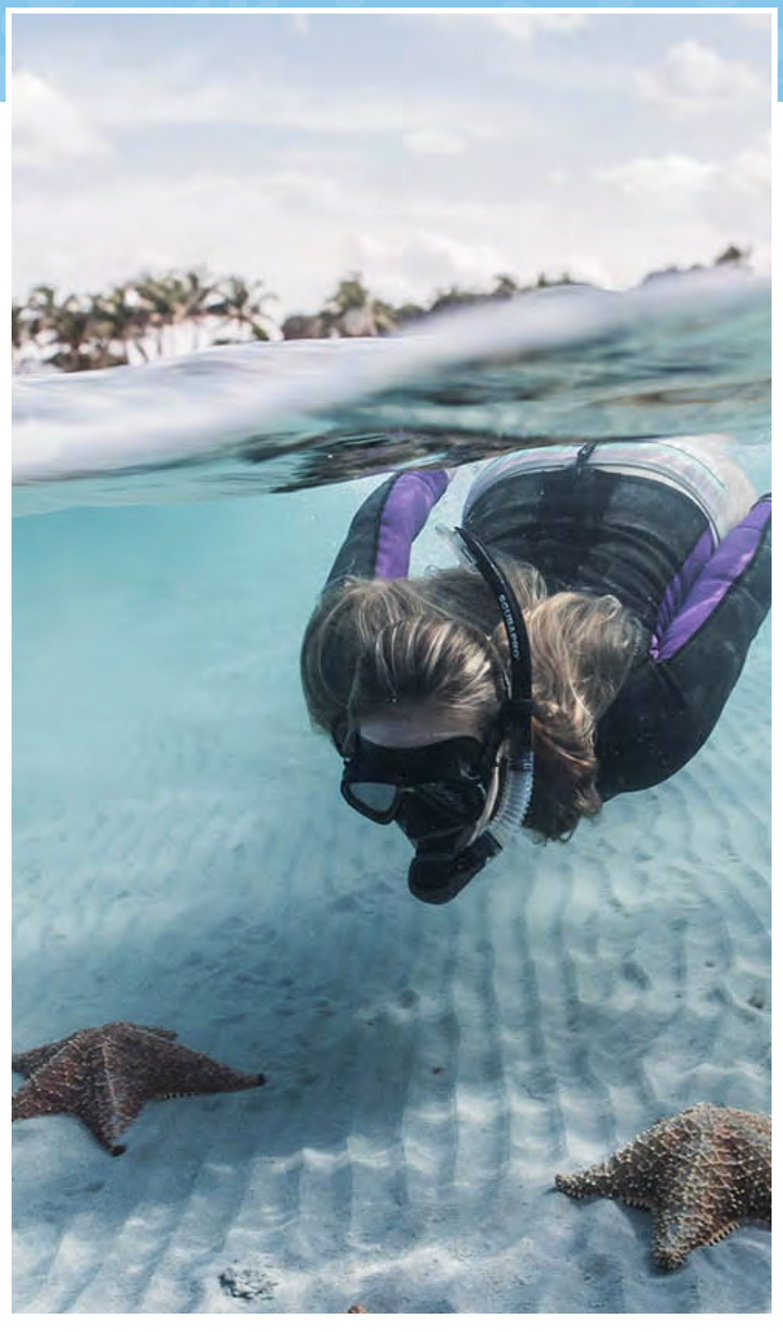
Green sea turtle swimming in Lake Worth Lagoon (Photo credit: PBC-ERM)

Cover photo: Sunset view from Singer Island (Photo credit: Kim Seng)

INTRODUCTION



Snorkeler looking at starfish (Photo Credit: Discover The Palm Beaches)

The Lake Worth Lagoon is an estuary of multiple identities. It's the backyard of the glittering oceanfront mansions and luxury resorts of Palm Beach; an aquatic playground for anglers, divers and tourists from all over the world; a bustling nautical highway for boaters cruising the Intracoastal Waterway; and home to the Port of Palm Beach, the fourth-busiest container port in Florida and a regional economic powerhouse.

Even within its narrow, 20-mile length, the Lagoon displays distinctly different personalities. The waters of the northern Lagoon are the clearest, aided by cleansing tidal flows from the Lake Worth Inlet, the largest of the two manmade inlets that connect the Lagoon to the Atlantic Ocean. Water quality declines through the Lagoon's central and southern segments, which are characterized by limited flushing compounded by ongoing contributions of nutrient-laden discharges from major drainage canals carrying both agricultural and urban runoff from the expansive watershed.

Against this backdrop, management of the Lagoon requires a thoughtful and strategic approach that recognizes the unique history and challenges facing this urban estuary, its importance to Palm Beach County's economy and to its citizens' quality of life.

The mission of the Lake Worth Lagoon Management Plan is to sustain and build upon the progress already made in protecting and restoring it. The Plan presents achievable goals and actions for improving water quality, enhancing habitat, protecting fish and wildlife, preparing for a changing climate, and fostering public awareness and responsible enjoyment of the Lagoon over the next decade.

ACKNOWLEDGMENTS

Funding for the 2021 Lake Worth Lagoon Management Plan was provided by the Palm Beach County Board of County Commissioners.

Mayra Ashton of Palm Beach County's Environmental Resources Management Department served as **Project Coordinator** for the 2021 Plan Update.

Writing and design of the Plan was provided by the team of O'Hara Communications and Bazany Design.

Partners in the Lake Worth Lagoon Initiative contributed advice, valuable perspectives, and feedback during Plan development.

American Oystercatchers at Tarpon Cove (Photo credit: PBC-ERM)

LAKE WORTH LAGOON INITIATIVE STEERING COMMITTEE (2020)

Commissioner Gregg K. Weiss
District 2
Palm Beach County

Vice Mayor Mark Mullinix
Village of North Palm Beach
Palm Beach County League of Cities

Commissioner Charles Isiminger, Palm Beach County Representative
Florida Inland Navigation District

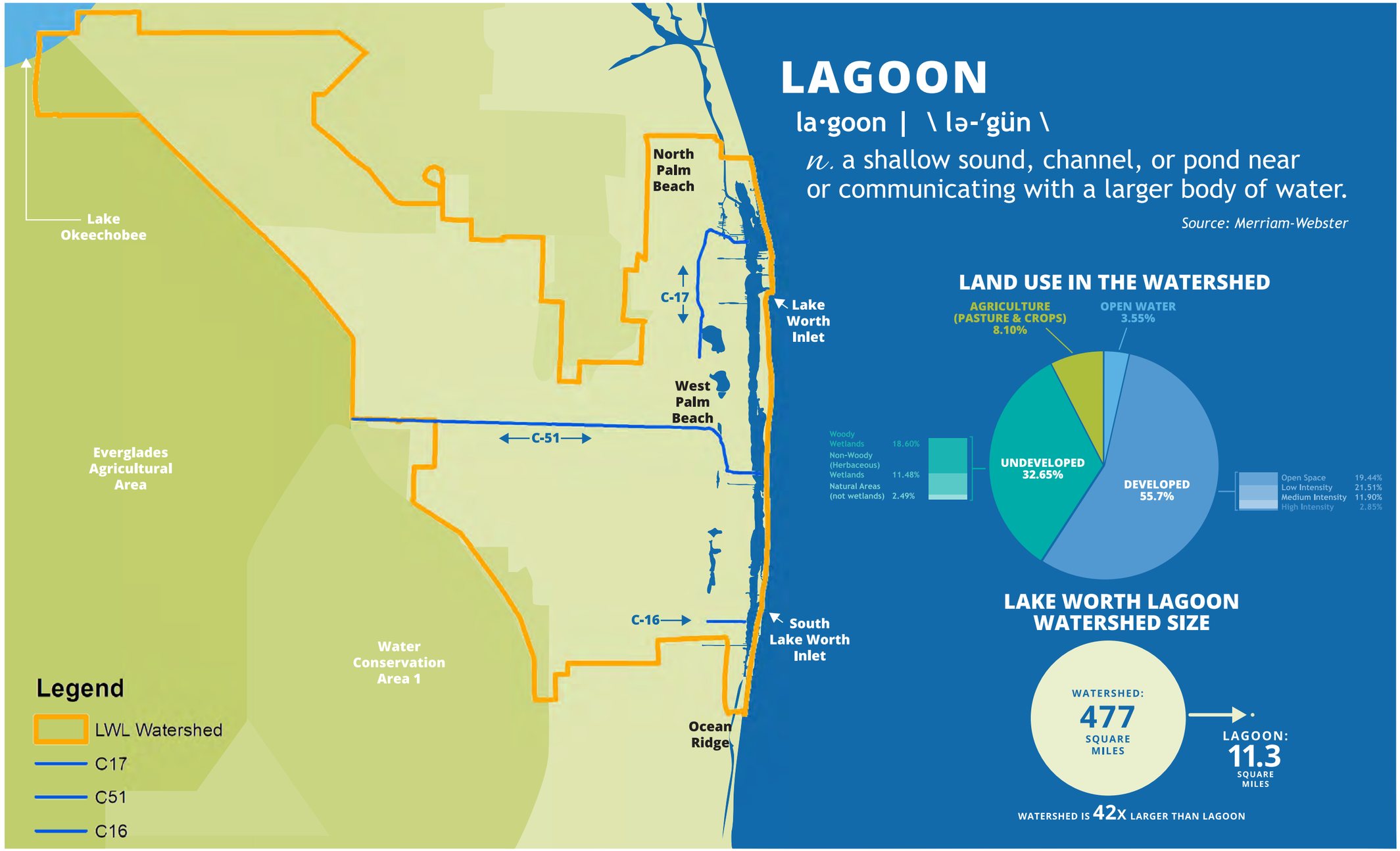
Jay Steinle
Governing Board Member
South Florida Water Management District

Jason Andreotta
District Director
Florida Department of Environmental Protection

CONTACT

Palm Beach County Department of Environmental Resources Management
2300 North Jog Road
West Palm Beach, FL 33411
Email: ERM-LWLI@pbcgov.org

LAKE WORTH LAGOON WATERSHED MAP



LAGOON

**la·goon | \ lə-ˈgün **

n. a shallow sound, channel, or pond near or communicating with a larger body of water.

Source: Merriam-Webster

LAND USE IN THE WATERSHED

LAKE WORTH LAGOON WATERSHED SIZE

WATERSHED IS **42X** LARGER THAN LAGOON

Click to toggle between Lake Worth Lagoon watershed map and LWL hydrology map.

MILESTONES IN LAGOON MANAGEMENT

1877
Pioneer Augustus Lang creates the first inlet to the sea in Lake Worth

1912
Construction of Intracoastal Waterway in Palm Beach County is completed

1915
Lake Worth Inlet is excavated; dredge material used to create Peanut Island

1917
South Lake Worth Inlet (Boynton Inlet) is created, completing Lake Worth's transition from a freshwater lake to the Lake Worth Lagoon estuary

1925
West Palm Beach Canal is dredged; freshwater from Lake Okeechobee sent to Lake Worth

1972
With population surging to 400,000 Palm Beach County adopts its first Land Use Plan

1990
LWL Natural Resources Inventory and Resource Enhancement Study completed

1992
Florida Estuarine Natural Resources Inventory and Resource Enhancement Study completed

1998
First Lake Worth Lagoon Management Plan approved

2008
LWL Management Plan Updated; Lake Worth Lagoon Initiative established to coordinate management

2013
LWL Management Plan updated, First Lake Worth Lagoon Science Symposium held

2021
LWL Management Plan updated

Palm Beach Shores in Northern Lagoon, 1945

Photos courtesy of Historical Society of Palm Beach County

Peanut Island and Lake Worth Inlet ca. 1947

Dredging the Lake Worth Inlet ca. 1918

Cocoanut Grove House front dock ca. 1880-1893

Lake Worth Inlet, Peanut Island and Port of Palm Beach ca. 1918

ABOUT THIS PLAN

Mangrove trees at a restoration site (Photo credit: PBC-ERM)

This is the third update of the Lake Worth Lagoon Management Plan since the original Plan adoption in 1998. Previous revisions were published in 2008 and 2013.

Palm Beach County's Environmental Resources Management (ERM) staff coordinated development of the Plan and subsequent updates.

WHAT'S NEW IN THIS UPDATE

- This is the first Lagoon Plan that incorporates a watershed-focused management approach.
- This Plan is designed exclusively on a digital platform.
- New and existing action plans were updated and reorganized with three new categories added: Fish and Wildlife Monitoring and Protection, Climate Change and Sea Level Rise, and Public Uses of the Lagoon.
- The Public Outreach Section has been renamed Public Outreach and Engagement.
- Several actions from the 2013 Plan were consolidated, renamed or moved to different Action Plans to more accurately reflect updated implementation strategies.
- Thirteen new actions have been added: WQ-2, WQ-3, WQ-4, WQ-5, WQ-6, SW-1, HE-1, FW-5, CC-1, CC-2, PO-1, PO-2, and PU-1.
- New or revised Goals and Priorities were adopted to address each major Action Plan focus: Water and Sediment Quality; Habitat Enhancement and Protection; Fish and Wildlife Monitoring and Protection, Public Uses of the Lagoon, Public Outreach and Engagement; and Climate Change and Sea Level Rise.
- Cost estimates are provided as a range following this key:

$	$0-$25,000
$$	$25,000-$100,000
$$$	$100,000-$500,000
$$$$	$500,000-$1,000,000
$$$$$	More than $1,000,000

CITIZEN AND PARTNER INPUT

Community input into the development of the 2021 Plan was solicited as follows:

- Members of the Lake Worth Lagoon Initiative (LWLI) Habitat and Water and Sediment Quality Working Groups participated in a facilitated brainstorming session to review progress and identify Plan priorities and goals in 2020.
- LWLI Working Groups for Habitat and Water and Sediment Quality also provided input during targeted working group meetings and provided feedback by participating in two electronic surveys to identify new action plans and rank specific management priorities for the next 10 years.
- ERM staff, partners and citizens participated in an online survey to identify and rank important issues for Plan inclusion.
- In recognition of the watershed-based approach for this Plan update, representatives from the 30 municipalities in the watershed were contacted to share information about ongoing and future plans, including implementation of septic-to-sewer conversion projects, stormwater retrofits and specific policies and ordinances that directly impact water quality in the Lagoon's extensive watershed.
- External reviewers from state and local agencies, educational institutions and non-profit groups with expertise in issues specific to each action were enlisted to provide comments and guidance.
- Actions were developed with assistance and oversight from ERM personnel and numerous partners.
- Members of the LWLI Steering Committee provided feedback, guidance and comments during the development of the update.

The spotted eagle ray is an iconic symbol of the Lake Worth Lagoon. (Photo Credit: PBC-ERM)

EXECUTIVE SUMMARY

For the first time, the 2021 Lake Worth Lagoon Management Plan strategically embraces watershed management as a central theme, acknowledging that the health of the Lagoon is inextricably connected to the activities and inputs occurring across a voluminous watershed that is 42 times the size of the Lagoon itself.

This approach elevates the importance of expanded monitoring to better understand and respond to the myriad factors that influence Lagoon health. The County and LWLI partners have initiated long-term biological monitoring for oysters, seagrass, fisheries, birds and turtles, all linked to assessing the health and productivity of the Lagoon. Additional monitoring includes water quality parameters (nutrients and salinity) as well as success of intertidal vegetation (mangroves/cordgrass) at restoration projects and throughout the Lagoon. Where possible, future monitoring should be consistent with existing regional or statewide monitoring protocols so that meaningful comparisons can be made, and data on the Lagoon can contribute to statewide knowledge of estuarine systems.

Despite unexpected challenges from the Covid-19 pandemic, Palm Beach County's Environmental Resources Management (ERM) staff adjusted monitoring, management and outreach activities to sustain progress. Contracted monitoring programs experienced minor interruptions. The long-term economic reverberations from the Covid-19 crisis may result in diminished funding in the near term for many government services, including environmental initiatives. However, funding already is secured for the Tarpon Cove Phase II, Bonefish Cove, and Monceaux Park Living Shoreline restoration projects, supported by state, federal and local matching funds.

Overall, significant progress has been made in improving scientific understanding and management of the Lagoon. Following are key accomplishments in Lagoon research, restoration and public outreach since 2013:

WATER AND SEDIMENT QUALITY

- Two high-frequency salinity sondes were deployed and maintained in partnership with the South Florida Water Management District (SFWMD) in November 2019 to augment monitoring and document salinity in the Central Lagoon. The stations are located to the north and south of the C-51 canal. The County maintains its own salinity probes at John's Island Natural Area across from the C-51 canal, and at Munyon Cove.
- A nutrient autosampler installed in 2019 at the S-155 structure enables analysis for total nitrogen and phosphorus discharged from the C-51 canal into the Lagoon and calculations of nutrient loading into the Lagoon. Water quality analysis is completed by the SFWMD in addition to maintaining and servicing the equipment.
- An assessment of the sediment trap excavated on C-51 to prevent sediments from entering the Lagoon indicates the trap's efficiency decreases as flow increases, particularly for flows higher than 850 cfs at S-155. The range of sediment

A hermit crab peers out from the safety of his shell sanctuary (Photo credit: PBC-ERM)

exported out of the trap was between 3 to 42% of total trap capacity or 0.38 to 10.36 tons/day.

Dredging of the accumulated sediment in the trap on an established schedule to maintain its efficiency as a sink and not as a sediment source, is paramount to ensure it can act to trap sediments, otherwise it will continue to contribute to the sediment load being exported downstream into the Lagoon.

Future evaluations also will examine potential modifications and maintenance to improve efficiency, reduce sediment loads and determine whether additional sediment traps would be beneficial in minimizing sediment transport.

- The Florida Legislature in 2017 awarded $1 million, matched by $1 million in local funds, to convert 246 homes in Lost Tree Village from septic systems to central sewer. In 2018, the Legislature awarded $750,000 to Riviera Beach, matched by $750,000 in local funds, for the Singer Island South stormwater retrofit project. Both of these projects were funding requests advanced by the Lake Worth Lagoon Initiative.
- Initial mapping of areas with high density septic systems throughout the County was conducted in 2019.
- 21 projects that incorporate elements of Green Infrastructure/Low Impact techniques were completed or underway throughout the County as of 2020.
- Development of a hydrodynamic model for the Lagoon was elevated in priority, with identification of steps and components needed for the model to adequately address the effects of freshwater delivered to the Lagoon via the C-17, C-51 and C-16 water conveyance canals. This effort moved closer to reality with the pending update of the Lake Okeechobee Standard Operating Manual (LOSOM) by the U.S. Army Corps of Engineers. The County requested in late 2020 that salinity standards, or Performance Measures, be established for discharges from Lake Okeechobee to the Lagoon – likely leading to deployment of a model that could serve as a pilot for Lagoon-wide adaptation.
- More than 159 acres of muck and deep dredge holes throughout the Lagoon were capped using 1.9 million cubic yards of material to create essential habitats for fish, invertebrates and waterbirds at six restoration sites: Snook Islands, South Cove, Ibis Isle, Grassy Flats, Bryant Islands, and Tarpon Cove Phase I.

HABITAT ENHANCEMENT AND PROTECTION

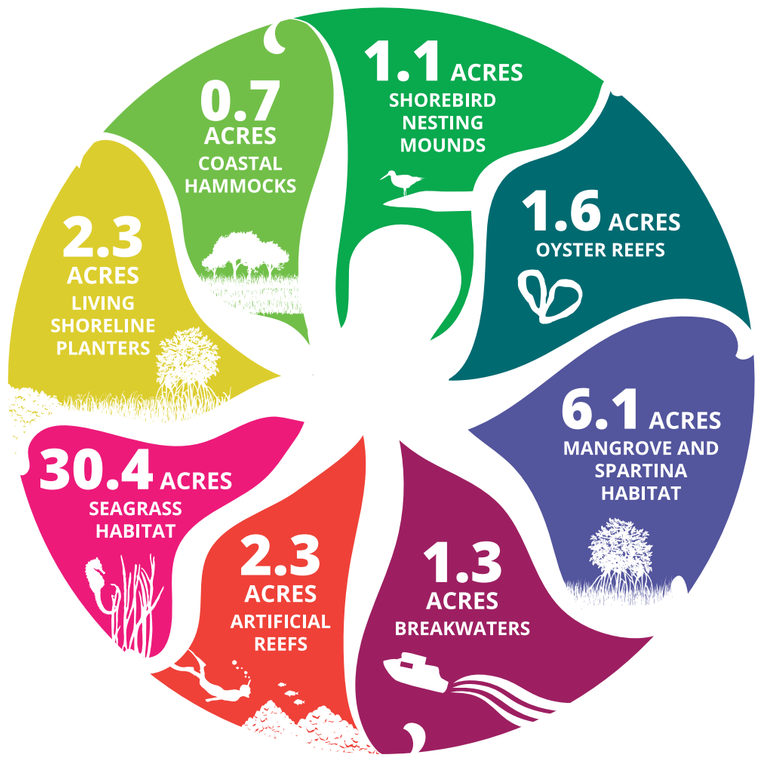
- More than 43 acres of habitat was restored or enhanced from 2013-2020, encompassing 18 individual projects, at a total cost of $11.9 million.
- Seagrass declined by 30 acres overall from 2013-2018. Despite an increase of 94 acres of seagrass mapped in the Northern Lagoon during this period, a significant portion of the seagrass beds that were mapped as moderate to high density seagrass habitat in 2013 were mapped as low density to patchy seagrass habitat in 2018, reflecting an overall decrease in seagrass coverage.
- More than 400,000 cubic yards of beneficial re-use Lagoon sediments from private and public sector dredging projects is being used to fill dredge holes and create intertidal island habitat at the Tarpon Cove Restoration Project, which started in 2018.
- More than 8,500 tons of limestone rock, concrete or other materials were used to enlarge existing reefs or create new reefs at Peanut Island Reef Complex, the Phil Foster Park Snorkel Trail, the Southern Boulevard Bridge Reef, and the Sugar Sands Reef.
- Monitoring of natural oyster reefs was expanded in 2015 to include three reefs constructed as part of habitat restoration projects. Overall oyster recruitment in the Lagoon is among the highest recorded in southeast Florida.
- A shoreline characterization study conducted in 2020 documented the percentage of armored versus natural shoreline in the lagoon, an important prelude to identifying future restoration priorities.

FISH AND WILDLIFE MONITORING AND PROTECTION

- A longstanding alliance of law enforcement agencies provided a total of 11,250 hours of on-water enforcement of seasonal manatee protection zones in the Lagoon from 2013-2020.
- Ongoing research has established the Northern Lagoon as a regionally important nursery for juvenile green sea turtles.

LIVING SHORELINE AND HABITAT RESTORATION PROJECTS

FROM 2014-2019



+6 ADDITIONAL RESTORATION PROJECTS planned or underway in the next 3 years

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Aerial photo of Lagoon near Blue Heron Bridge (Photo credit: Scott Eddy)

- Fisheries monitoring initiated in 2014 in the Central Lagoon documented a variety of commercially important fish utilizing waters adjacent to restored habitats. Fisheries sampling was expanded in 2016 to the Northern Lagoon, to track utilization of important seagrass areas. Monitoring will be expanded to the Tarpon Cove Restoration Project in 2021.
- Regular monitoring of shorebirds at Lagoon restoration sites began in 2015. The surveys are showing that Least Terns, Black Skimmers and American Oystercatchers – all imperiled species - use restored areas for both nesting and foraging. Since 2013, American Oystercatchers have successfully nested and fledged chicks at the Grassy Flats Natural Area, Bryant Park Islands, Snook Islands Natural Area and Tarpon Cove Restoration Project. Black Skimmers successfully nested at Tarpon Cove.

CLIMATE CHANGE

- A Coastal Resilience Partnership formed in 2019 by Palm Beach County's Office of Resilience and seven municipalities will complete an assessment in early 2021 of risks to critical community assets, including natural resources and water infrastructure, from climate change and rising seas.
- Living Shorelines that incorporate native plants and natural materials to buffer storms, shield coastal infrastructure and provide habitat have been installed at five locations since 2013: Bryant Park, Currie Park, Osprey Park, Jewell Cove and Lyman Kayak Park.

PUBLIC OUTREACH AND INVOLVEMENT

- LagoonFest, an annual community celebration of the Lagoon's diversity and recreational value, attracted 5,000 attendees and 80 exhibitors in 2019. The event has grown in popularity and reach since the first event held in 2014 with 27 exhibitors.
- More than 120 anglers caught more than 1,000 fish of 60 species in the Third Annual Lake Worth Lagoon Fishing Challenge held in 2019 to help document the Lagoon's value for sportfishing.
- ANGARI Foundation recruited more than 1,260 citizen-scientists to decorate, deploy and recover small wooden cards set adrift in the Lagoon from 2017-2019 to improve understanding of how surface currents disperse marine pollution.
- A Covid-19 inspired experiment in Spring 2020 to provide virtual field trips to students was expanded from 45 students to over 70 students in Fall 2020.
- More than 10,500 pounds of trash was removed from nine restoration sites from 2014-2020 by LagoonKeepers, through a contract with Palm Beach County.
- The Lake Worth Lagoon Initiative website was revamped in 2019 and received 8,500 visits from April 2019-Nov. 2020.

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GOALS AND PRIORITIES

A Great Egret at Ibis Isle (Photo credit: PBC-ERM)

WATER AND SEDIMENT QUALITY

GOALS:

Continue and expand the water quality monitoring program in the Lagoon. Update water quality assessment every 3-5 years.

Standardize monitoring programs for consistency with statewide or regional monitoring protocols for water quality, fisheries and seagrass.

Develop and utilize a predictive watershed and/or hydrodynamic model for the Lagoon to determine nutrient loading rates, sedimentation rates, resulting salinities and other variables under different water management scenarios.

Manage the timing, quantity and quality of freshwater inflows from Lake Okeechobee and the Lagoon watershed to support the optimal salinity ranges of two cornerstone species: Oysters and Seagrass.

Reduce bacterial contamination and Harmful Algal Blooms to maintain recreational uses and ecological health.

Reduce pollution from microplastics and emerging contaminants of concern.

Reduce nutrient loadings from land-based sources to meet water quality targets and support living resources.

Modify or maintain the C-51 sediment trap to reduce the volume and timing of sediment discharges to the Lagoon.

RELATED ACTIONS:

Actions to improve water quality:

- WQ-1 Expand Water Quality Monitoring
- WQ-2 Develop a Watershed-Based Modeling Program
- WQ-3 Implement Best Management Practices for Drainage Canals
- WQ-4 Monitor and Assess Ways to Reduce Bacterial Contamination and Harmful Algal Blooms
- WQ-5 Identify and Assess the Impacts of Emerging Contaminants
- WQ-6 Manage Freshwater Inflows to Optimize Environmental Benefits

Actions to reduce pollution from wastewater:

- WW-1 Assess and Reduce Occurrence of Sewer Overflows
- WW-2 Identify Priority Areas for Conversion of Septic Systems to Central Sewer

Actions to reduce pollution from stormwater:

- SW-1 Reduce Stormwater Runoff from Urban Landscapes
- SW-2 Expand Use of Green Infrastructure and Low Impact Development Practices

Actions to reduce sediment loadings to the Lagoon:

- SE-1 Assess and Manage Sediment Loading

Volunteers get ready to plant salt marsh grass at the Tarpon Cove restoration site (Photo credit: PBC-ERM)

HABITAT ENHANCEMENT AND PROTECTION

GOALS:

Inventory, monitor and protect natural hardbottom areas in the Lake Worth Lagoon.

Continue to create new artificial reefs and enhance existing artificial reefs

Adapt or modify current oyster enhancement and monitoring efforts to guide future restoration efforts.

Develop quantifiable criteria to determine long-term success of intertidal habitat restoration.

Continue seagrass monitoring and expand water quality monitoring to evaluate and address factors influencing seagrass abundance and composition.

Continue to utilize lagoon-compatible dredge material in habitat restoration projects.

Purchase available submerged lands near Singer Island and other areas as appropriate to protect seagrass and other intertidal habitats.

RELATED ACTIONS:

Actions to expand and restore a diversity of Lagoon habitats:

- HE-1 Create, Protect and Monitor Hardbottom Habitats
- HE-2 Restore, Create and Protect Intertidal Habitats
- HE-3 Maintain and Expand Seagrass Habitats
- HE-4 Acquire Ecologically Significant Submerged and Intertidal Lands

FISH AND WILDLIFE MONITORING

GOALS:

Continue fisheries monitoring at established and new restoration sites and expand monitoring to include sites throughout the Lagoon.

Continue and expand collaborative law enforcement partnership to enforce boating speed zones to protect manatees.

Continue and expand sea turtle monitoring to explore relationships between water quality, seagrass abundance and turtle health.

Continue to provide and actively manage island habitats for nesting and foraging shorebirds.

Install an acoustic telemetry network in the Lagoon to document habitat utilization by targeted species.

RELATED ACTIONS:

Actions to protect and enhance Lagoon fish and wildlife:

- FW-1 Continue Implementing Palm Beach County's Manatee Protection Plan
- FW-2 Continue Sea Turtle Monitoring
- FW-3 Continue Fisheries Monitoring
- FW-4 Manage and Monitor Shorebird Habitat
- FW-5 Implement Remote Tracking Technologies for Fish and Wildlife Monitoring

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A youngster examines Lagoon invertebrates during a "Growing Up Wild" outdoor program (Photo credit: PBC-ERM)

CLIMATE CHANGE AND SEA LEVEL RISE

GOALS:

Identify and implement management strategies to improve the resilience of coastal habitats and infrastructure most vulnerable to climate change.

Expand use of Living Shorelines to mitigate flood and storm impacts and provide habitat.

Enhance community understanding of the far-ranging impacts of climate change.

RELATED ACTIONS:

Actions to adapt to and mitigate the effects of climate change and sea level rise:

- CC-1 Conduct a Vulnerability Analysis of Resources at Risk from Climate Change
- CC-2 Improve Resiliency of Critical Habitats to Climate Change and Sea Level Rise

PUBLIC OUTREACH AND ENGAGEMENT

GOALS:

Increase multicultural outreach and education about the Lagoon.

Continue and expand hands-on and virtual opportunities to learn about and contribute to Lagoon improvement for residents of all ages, incomes and abilities.

Expand science-based education for youth, especially in underserved communities.

Incorporate enhanced use of digital communication tools in outreach programs.

RELATED ACTIONS:

Actions to increase public education and involvement:

- PO-1 Foster Public Awareness and Engagement
- PO-2 Promote Youth Education and Engagement

PUBLIC USES OF THE LAGOON

GOALS:

Continue to provide recreational opportunities for residents and tourists of all ages and abilities.

Pursue partnerships with Lagoon-dependent businesses and a certification program for ecotour providers to foster community commitment to ethical enjoyment of the Lagoon.

Reduce environmental impacts of boating through designation of additional Clean Boating facilities, and appropriate siting of mooring fields.

RELATED ACTIONS:

Actions to provide for responsible public use of the Lagoon:

- PU-1 Ensure Adequate and Appropriate Public Access to the Lagoon

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An intern in the Green Futures program assists with monitoring a restoration site (Photo credit: PBC-ERM)

FINANCING AND IMPLEMENTATION

GOALS:	RELATED ACTIONS:
Secure annual funding from the Legislature for Lake Worth Lagoon Initiative priority projects. Increase local funding sources to support monitoring and management of Lagoon resources. Sustain existing partnerships and forge new alliances with governmental and nongovernmental organizations to advance Management Plan goals. Pursue public-private partnerships to facilitate restoration, research and education. Aggressively seek state and federal grants for lagoon improvement. Strategically expand use of online meetings and forums such as the Lake Worth Lagoon Initiative's Working Groups and Lake Worth Lagoon Symposium to increase stakeholder engagement in Lagoon management.	**See** Financing and Implementation chapter

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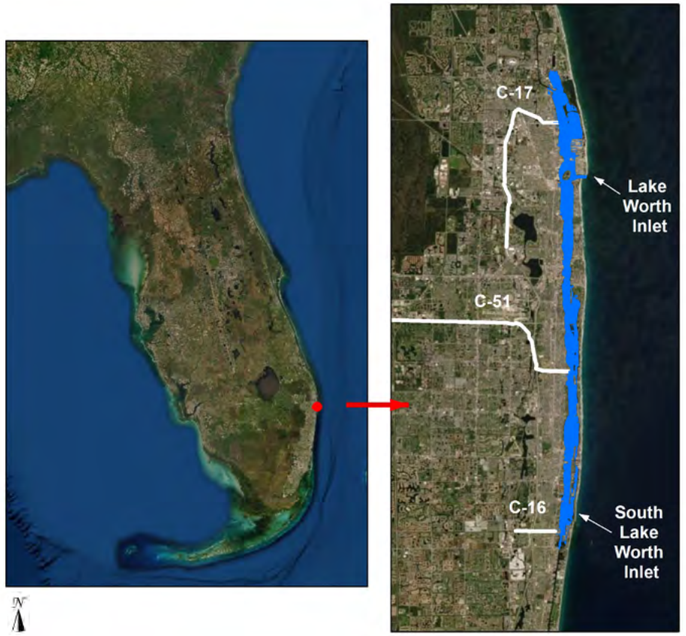


STATE OF THE LAGOON

Highly urbanized and altered by more than a century of human activities to facilitate navigation, flood control and development, the Lake Worth Lagoon is an underappreciated asset. Asked to suggest adjectives that best describe it, participants in a 2020 Lagoon Perceptions and Priorities survey offered words like "forgotten," "misunderstood," and "taken for granted." In a nod to its inherent value, they also noted the Lagoon is "stunning," "accessible" and "a treasure."

INTRODUCTION

Just 20 miles long, the Lagoon punches above its weight in ecological and economic value. A 2019 Economic Valuation study estimated the value of recreational uses and business activities related to the Lagoon at $813.9 million per year. The total value of tangible and intangible benefits associated with the Lagoon is estimated at $5.37 billion.[1]

The Lagoon is an aquatic playground for fishing, diving, paddle sports and birdwatching enthusiasts, with a world-renowned SCUBA destination, the Phil Foster Park Snorkel Trail, just steps from shore. It is a nursery and foraging area for threatened and endangered fish and wildlife as diverse as sea turtles, goliath groupers, American oystercatchers and manatees. And it is home to the bustling Port of Palm Beach, ranked among the state's top five ports in cargo value. The successful co-existence of these distinctly differing personalities in a compact estuary of just 11.3 square miles is a testament to the Lagoon's resilience.

Originally a freshwater lake, early pioneers followed by colonists transformed Lake Worth into an estuary. Saltwater from the Atlantic Ocean enters through the Lake Worth and South Lake Worth Inlets. Freshwater is funneled to the Lagoon from three major drainage canals (C-17, C-51, and C-16), which together collect runoff from more than 305,000 acres of land. The C-51 canal alone delivers nearly 60% of the Lagoon's freshwater flows.[2] In addition, the Atlantic Intracoastal Waterway carves a nautical highway through the entire length of the Lagoon as it traverses the East Coast.

These features have in effect created three sub-Lagoons. The highest ecological diversity and most intense recreational usage occurs in the Northern Lagoon, where the Lake Worth Inlet brings salty and cleansing tides that support large seagrass beds. The Southern Lagoon also benefits from proximity to the ocean, albeit through a smaller, more constricted inlet. Markedly diminished water quality, biodiversity and recreational activities characterize the Central Lagoon, located farthest away from tidal flushing and on the receiving end of most canal freshwater discharges.

The sprawling watershed – 42 times the size of the Lagoon itself, with a 2020 population estimated at more than 1 million – has an enormous impact on the Lagoon's health, and complicates efforts to manage it holistically. The presence of 30 local municipalities, a large unincorporated area, and multiple federal, state and local water management districts, all contributing runoff to the Lagoon, compound the enormous challenges confronting Lagoon managers.

For decades, water management of the Lagoon watershed has largely focused on its role in flood control rather than its intrinsic ecological value. Dramatic fluctuations in the timing and volume of freshwater discharges result in water that is too salty for some living resources, and not salty enough for

LAKE WORTH LAGOON
BY THE NUMBERS

CLICK IMAGE TO ZOOM IN. CLICK AGAIN TO ZOOM OUT.

others. The huge influx of freshwater also delivers significant volumes of suspended sediments including silt and organic materials, or muck, especially to the Central segment. These sediments accumulate in oxygen-deficient layers on the bottom, constantly resuspend in the water column, and provide a poor substrate for seagrass that is the foundation of a healthy estuary. Impacts have been magnified in recent years, with widespread water quality impairments, and thinning or loss of seagrass.

The creation of the Lake Worth Lagoon Initiative in 2008 has provided a forum for agencies and communities with responsibility for the Lagoon to proactively and cooperatively work on policies and projects to improve it.

The 2021 Update of the Lake Worth Lagoon Management Plan supports those efforts, while striving to attain a sustainable balance between the human and ecological needs of the Lagoon.

Ongoing monitoring is conducted in the Lagoon for water quality, seagrasses, sea turtles, oysters, and fisheries. This chapter summarizes the status and trends of these key indicators of Lagoon health. It also highlights the need for development of models and other decision-support tools that are a critical step in the process of achieving data-driven, evidence-based management of the Lagoon and its natural resources. Modeling is an integral tool for forecasting both long- and short-term estuarine conditions to support operation of water control infrastructure throughout the Lagoon's watershed, and direct ecosystem restoration and water management initiatives to maximize ecological benefits.

Water quality monitoring conducted in the Lagoon since 2007 provides a vital framework for understanding factors influencing the Lagoon's health.

WATER QUALITY

STATUS:

A longstanding cooperative agreement between Palm Beach County (PBC) and the South Florida Water Management District (SFWMD) facilitates ongoing monitoring of nutrients and additional water quality parameters *(see Figure 1.2)*.

Salinity is a priority concern for the Lagoon because of the volume and timing of freshwater runoff it receives from the watershed. SFWMD deployed two high-frequency water quality sondes in November 2019 to document salinity fluctuations in the Central Lagoon. The sondes provide near real-time measurements of several physical water quality parameters, with salinity a primary driver, in addition to nutrients and sediments, for monitoring the effects of freshwater releases from the watershed. They are located approximately 2 miles to the north and south of the C-51 canal, which contributes more than half of the freshwater inflow to the Lagoon.

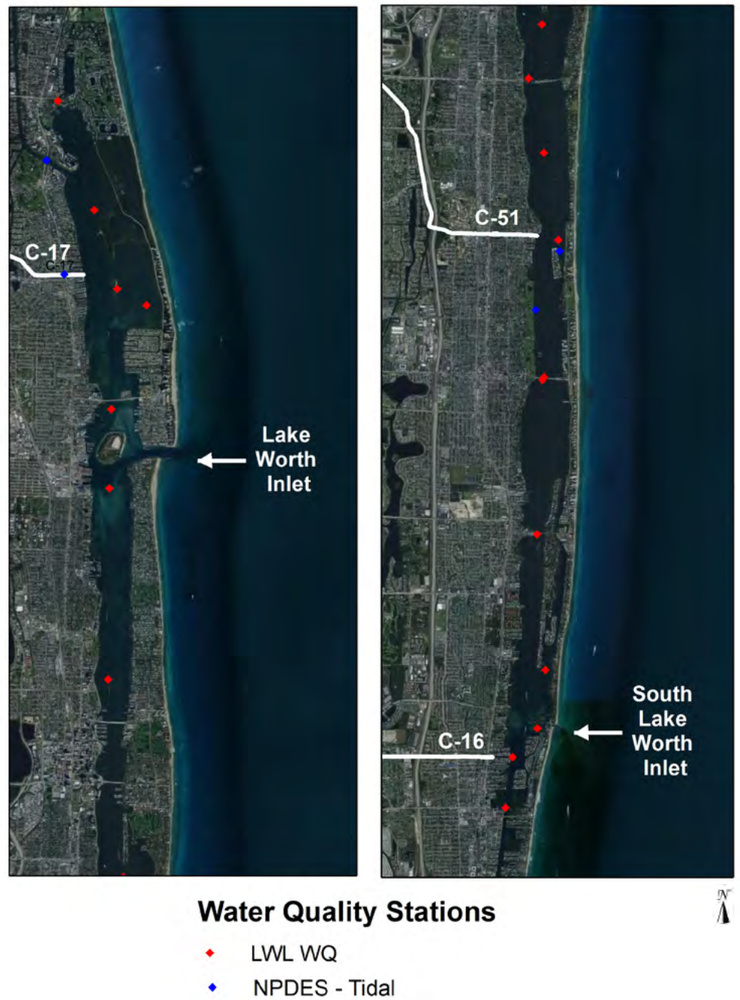
The County maintains its own high frequency salinity sonde at John's Island Natural Area across from the C-51 canal, and another sonde at Munyon Cove. These two sondes collect salinity and temperature data hourly.

A sediment trap excavated on the C-51 to serve as a "sump" to capture and prevent sediments from entering the Lagoon, was assessed in 2020 by SFWMD.

Results indicate the trap's efficiency decreases as flow increases, particularly for flows higher than 850 cfs at S-155. The range of sediment exported out of the trap was between 3% to 42% of total trap capacity or 0.38 to 10.36 tons/day.

Dredging of the accumulated sediment in the trap on an established schedule to maintain its efficiency as a sink and not as a sediment source, is paramount to ensure it can trap sediments, otherwise it will continue to contribute to the

FIGURE 1.2 LAKE WORTH LAGOON WATER QUALITY MONITORING STATIONS



SOURCE: PBC-ERM

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Resource managers and citizens who took a 2020 online survey about Lagoon perceptions and management priorities were asked to list adjectives that best describe the Lagoon. This Word Cloud shows the words they submitted, in the form of a spotted eagle ray—the mascot of the Lake Worth Lagoon Initiative.

sediment load being exported downstream into the Lagoon.

SFWMD also installed a nutrient autosampler in 2019 at the S-155 structure on the C-51 canal. This station allows for a weekly composited sample that is analyzed for total nitrogen and phosphorus discharged from the C-51 canal into the Lagoon.

Surveillance monitoring for blue-green algae (BGA) and red tide is coordinated with the Florida Department of Environmental Protection (FDEP) and the Florida Fish and Wildlife Conservation Commission, respectively. Weekly bacterial monitoring by the Florida Department of Health (FDOH) occurs at Phil Foster Park, as well as several oceanside beaches.

The Northern and Central segments of the Lagoon have been designated by FDEP as impaired for nutrients, chlorophyll, copper or other parameters. Development of Total Maximum Daily Loads (TMDLs) is required to establish numerical limits on quantities of these pollutants the Lagoon could receive and still meet water quality standards for fishable, swimmable waters under the state's Class III waters designation.

TRENDS:

An analysis of 13 years of water quality data (January 2007-June 2020) reveals some important trends, particularly with regard to relationships between freshwater inflows, salinities, microscopic algae (expressed as chlorophyll a), and nutrient loading:[2]

- While water quality in the North and South segments benefit from proximity to the inlets, discharge from the C-51 accounted for nearly 59% of the total inflow to the Lagoon and greatly influenced the Central segment. The C-16 contributed more than 30% of flows over that period, while the C-17 delivered more than 11%.
- Five variables – Chlorophyll (CHL), Total Nitrogen (TN), Total Phosphorus (TP), Total Suspended Solids (TSS), and Turbidity – have increased in the Central Lagoon since 2007. TN and TP increased in the Northern Lagoon. *(see Figure 1.3)*
- Three variables – CHL, TN, and TP – were positively correlated to inflow and to each other in all three segments.
- The variability, lack of seasonality, and lack of correlation between TSS and turbidity with other variables suggest that the input, transport, and resuspension of sediments should be examined in greater detail.

While important reductions in pollutant loading estimates have occurred, significant concentrations of nutrients continue to enter the Lagoon from the watershed. TP concentrations at the C-51 discharge were higher than the state-established Numeric Nutrient Criteria (NNC) of 0.049 mg L^{-1} for the Central Lagoon from 2009-2019. TN concentrations at this station were also higher than the NNC of 0.66 mg L^{-1} for this pollutant in the Central Lagoon.[3]

Water quality monitoring is most useful in tandem with monitoring of biological resources. Changes in water quality directly impact the health of the five biological indicators that are also part of the Lagoon's foundational monitoring: Seagrass, Sea Turtles, Fisheries, Oysters and Shorebirds.

The potentially outsized role of freshwater discharge in Lagoon hydrodynamics warrants further investigation to determine appropriate strategies to manage volumes, timing and constituents of the freshwater discharges, most importantly nutrients and sediments.

NEEDS:

Development of a robust hydrodynamic model that integrates additional environmental parameters to foster watershed-level analysis and enables predictive forecasts of outcomes under various water management scenarios.

Completion of a comprehensive evaluation of the effectiveness of the sediment trap installed at the C-51 canal in 2007, including analysis of potential modifications to the existing trap and efficacy of additional traps.

An assessment of salinity gradients along the entire length of the Lagoon with varying flows from the watershed to determine impacts to resulting water quality and effects on valued ecosystem components (such as seagrass and oysters).

A detailed study of the content and magnitude of sediment loads to and sediment transport within the Lagoon and effects on water quality and valued ecosystem components. The assessment should focus on both the source and fate of materials derived from the Lagoon's watershed via C-51, C-17 and C-16 and include tracking of copper and other heavy metals.

Overall, expanded and targeted research and monitoring protocols are needed to proactively address a host of management needs in the Lagoon, including:

- Identification of land-based sources of pollution and relative contributions to FDEP-designated impairments.

FIGURE 1.3 TREND ANALYSIS FOR MAJOR WATER QUALITY VARIABLES BY LAGOON SEGMENT 2007-2020

	S	CHL	TN	TP	TSS	TURB	Q
North			+	+			
Central		+	+	+	+	+	
South							

SOURCE: Coastal Ecosystems, LLC

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- More robust sampling for turbidity and total suspended solids in the Central Lagoon to fully understand water quality impacts associated with freshwater discharges.
- Identification of hot spots, sources and pathways for Harmful Algal Blooms, bacterial contamination and emerging contaminants such as microplastics.
- Source tracking to identify nutrient pollution associated with leaching from septic systems or municipal wastewater overflows.

SEAGRASSES

STATUS:

Seagrass is an essential building block of a healthy estuary, a vital habitat for a host of marine life large and small. The diversity found within seagrass beds also supports important recreational and ecotourism activities like fishing and snorkeling. Sustaining seagrass is critical to the Lagoon environment and economy.

All seven seagrass species found in Florida occur in the Lake Worth Lagoon, including the imperiled Johnson's Seagrass *(Halophila johnsonii) (see Action HE-3)*. This seagrass is the only marine plant designated as a federally threatened species. Two of the 10 state-designated critical habitat areas for Johnson's seagrass are within the Lagoon.[4]

In 2018, a total of 1,552 acres of seagrass was observed in the Lagoon, with 1,301 acres (83.8%) in the Northern Lagoon, 249 acres in the Southern Lagoon (16%) and 1 acre (.06%) in the Central Lagoon. This is a decrease of 30 acres from the previous Lagoon-wide mapping effort in 2013.) Seagrass cover increased by 94 acres in the north segment between 2013 and 2018.[5]

Habitat restoration contributed an additional 30 acres of potential seagrass habitat in 2018 through construction of four projects: Grassy Flats and Bryant Park Islands, Jewell Cove Living Shoreline, Snook Island Modifications, and Tarpon Cove Islands Phase I.

Overall, seagrasses declined from 1,582 acres in 2013 to 1,552 acres in 2018.

Any positive gains in seagrass have been overshadowed by significant and troubling shifts in composition and density of seagrasses, including dramatic thinning from dense coverage to patchy coverage or loss of seagrass in some areas.

Lagoon seagrasses are monitored using two primary methods: "Groundtruth" Mapping and Fixed Transect Surveys *(see Figure 1.4)* Additional patch monitoring is conducted by Palm Beach County and Palm Beach Atlantic University. Together, these programs provide critical information about spatial and temporal changes in seagrass cover.

Seagrass Mapping

Lagoon-wide mapping to document watershed-scale trends in seagrass occurs every five years; the last large-scale mapping effort was completed in 2018. The 2013 and 2018 seagrass maps are based on diver verification of previously mapped habitats with additional ground-truthing (900 points) outside previously mapped habitats.

The 2018 mapping and ground truthing effort sought to capture significant changes in bed composition/density, outer bed boundaries, and spatial extent of seagrasses within the three lagoon segments (Northern, Central and Southern) in comparison to the 2013 map.

The next Lagoon-wide mapping effort is planned for 2023.

Fixed Transect Sampling

As shown in Figure 1.4, ten permanent transects are monitored annually to assess fine-scale changes in seagrass presence, composition, and abundance (generally categorized as dense, moderate, and patchy). With more robust, targeted water quality and seagrass monitoring, this data could be integrated with environmental parameters such as salinity, temperature, turbidity, rainfall, and freshwater inflows to document changes

FIGURE 1.4 LWL SEAGRASS MONITORING SITES

SOURCE: PBC-ERM

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to seagrass density and species composition over time.

Transect monitoring is especially useful in areas like the Lake Worth Lagoon, with poor visibility throughout the water column, or where low-profile, diminutive species such as paddle grass and Johnson's seagrass are dominant and could be overlooked by aerial mapping efforts.

Other Monitoring Efforts

Palm Beach County monitors four seagrass beds adjacent to major drainage canals, utilizing permanently established polygons of 1.5 to 2.5 acres on a bi-annual basis. Two of the polygons are in the Northern Lagoon near the C-17 canal, and two are on either side of the C-51 canal in the Central Lagoon. This monitoring documents the presence/absence of seagrasses, and the relative proportion of component species within randomly selected quadrats. Canopy height and species also are documented.

Palm Beach Atlantic University monitors seagrass biannually in Lake Worth Cove at John D. MacArthur Beach State Park. This 10-year dataset documented a high of 40% seagrass coverage in the Cove in 2010-2011 and a decline to 10% coverage in 2019.

TRENDS:

Overall, seagrasses declined from 1,582 acres in 2013 to 1,552 acres in 2018. The number of sites with less than 5% cover of seagrass increased, while the number of sites with more than 5% seagrass cover declined lagoon-wide.[6]

The Northern Lagoon, with its generally higher salinities and clear waters strongly influenced by tidal flushing, remains a stronghold for seagrasses in the Lagoon. Seagrass coverage here expanded into new areas by 94 acres from 2013 to 2018. Near record high coverage was observed in all northern transects for 2019, but those gains disappeared during the 2020 monitoring. Moreover, thinning of seagrasses has been dramatic, with a decline from 588 acres in moderate and high-density seagrasses in 2013 to 256 acres in 2018. The amount of low-density, patchy seagrasses increased from 528 to 881 acres in the same period.

As of May 2020, seagrass was not present in sampled transects within the Central Lagoon; the predominantly patchy seagrasses of the Southern Lagoon had declined by 54.5%; and the high-value, high-density seagrasses of the Northern Lagoon had contracted by more than 56%.

No single cause has been identified as the culprit in the seagrass shifts. Multiple factors may be at play. Freshwater inflows can lower salinities below optimal ranges for many seagrass species and contribute nutrients, suspended sediments, and contaminants. Wind- and boat-induced wave action causes turbidity, magnified by hardened shorelines, that also may play an important role. Several of these factors can significantly decrease water clarity in the Lagoon and impact the availability of light essential for seagrasses to thrive.

NEEDS:

Develop hydrologic and/or hydrodynamic models for the Lagoon to simulate historical salinities, integrate current inflow and flushing rates, estimate nutrient loading and sedimentation rates, and predict outcomes under various water management scenarios (*see Actions WQ-1 and WQ-2*).

Develop seagrass restoration targets for each Lagoon segment based on an understanding of various factors currently affecting SAV recruitment and growth, specifcally:

Paddle grass in the Lagoon (Photo credit: PBC-ERM)

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- Determine species-specific responses to light, temperature, salinity and sediment characteristics such as grain size and organic content.
- Better understand the drivers of change for these parameters in the LWL.
- Develop management strategies to mitigate fluctuations in these parameters.

Implement appropriate management strategies, including water quality improvements and habitat restoration, to recover, sustain and expand seagrasses in the Lagoon.

Permanently protect seagrass beds adjacent to John D. MacArthur Beach State Park through acquisition or donation from willing sellers within park boundaries.

SEA TURTLES

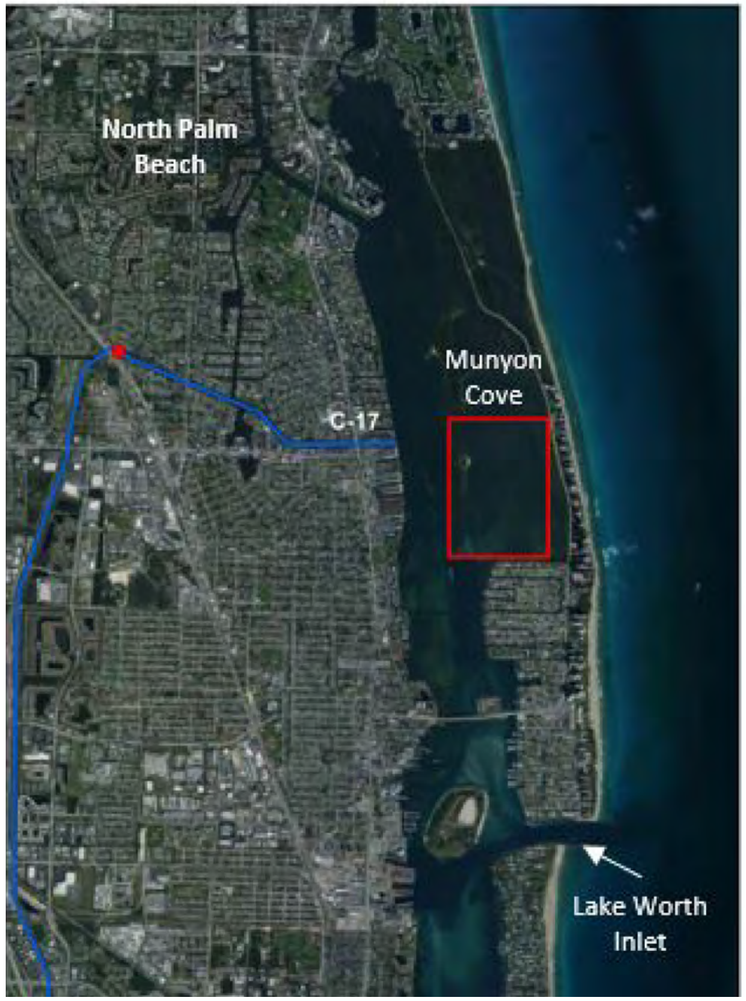
STATUS:

The Northern Lagoon is a regionally important nursery area for juvenile Green Sea Turtles, with an average density of 37.4 turtles/km2. This is a markedly greater abundance than the Indian River Lagoon, Florida Keys, or nearshore reefs in Palm Beach County.[7] Sampling has been conducted quarterly since 2005, using a combination of visual observations and net captures *(see Figure 1.5*).

The primary objectives of this long-term effort are to:

- Obtain data on species abundance, size, and sex ratios.
- Determine the Catch per Unit Effort (CPUE) at specific sites.
- Document the prevalence of Fibropapilloma virus (FP).
- Collect esophageal and anterior stomach contents to evaluate preferred foods (seagrass vs. algae)
- Obtain blood samples for genetic, sex ratio and disease analysis.
- Determine preferred habitats by collecting GPS

FIGURE 1.5 TURTLE SAMPLING LOCATION MAP



SOURCE: PBC-ERM

waypoints to mark sighting, capture and recapture locations, or through use of acoustic tags to document site fidelity within an acoustic array network proposed in the Lagoon.

From March 2005 to February 2018, researchers observed 920 sea turtles through visual transects and captured 178 green turtles and 2 loggerhead turtles (including 22 recaptures). The vast majority of sightings were in the Northern Lagoon, east of Little Munyon Island. Sightings and captures are more prevalent during spring and summer months than winter and fall.

The Northern Lagoon is a regionally important nursery area for juvenile Green Sea Turtles.

In 2019, sampling crews began collecting blood samples from individual turtles for analysis by partners at Harbor Branch Oceanographic Institute, to evaluate relationships between turtle health and disease status, food sources and biotoxins associated with Harmful Algal Blooms.

TRENDS:

In 2018-2019, green turtle abundance at the Little Munyon Island site was 1.54 turtles per kilometer. This closely mirrors the average abundance of 1.47 turtles per kilometer from surveys conducted there since 2013, and an average abundance of 1.23 turtles per kilometer there from 2005-2011. These surveys indicate the population in the area has remained relatively stable over the years.[8]

The dietary preferences of turtles near Little Munyon Island have significantly changed. Prior to 2014, the turtles mostly consumed seagrasses, including turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*), with little to no algae.

From 2014-2018, their diets shifted largely to shoal grass (*Halodule wrightii*), with *Thalassia* almost absent from the samples.[9] Additionally, analysis showed a significant increase in consumption of algal species *(see Figure 1.6)*. These dietary shifts correspond with dramatic declines in seagrass abundance

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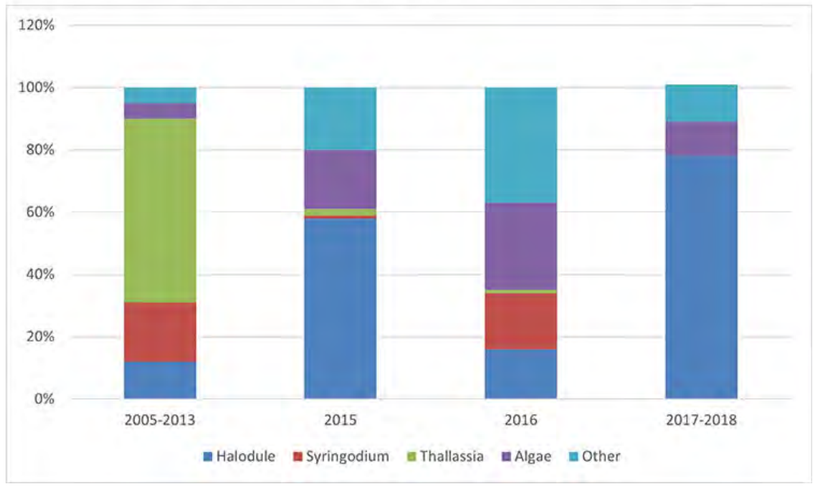
FIGURE 1.6 DIETARY COMPOSITION OF LWL SEA TURTLES 2005-2018



SOURCE: Inwater Research Group

and species composition over roughly the same period.

Nearly half (48.3%) of the 179 turtles captured (or recaptured) exhibited the presence of benign tumors associated with fibropapillomatosis (FP), a viral infection occurring mainly in green turtles. This rate has remained relatively stable throughout the study period, except for spikes to nearly 80% in 2006, 2012 and 2013. Overall, fewer Lagoon turtles exhibit FP tumors than turtles in the Indian River Lagoon. However, all of the estuarine locations sampled in Southeast Florida show a significantly larger percentage of turtles with FP tumors than offshore waters.

NEEDS:

Implement acoustic or GPS tracking of turtles to document habitat utilization and spatial distribution of sea turtles in the Lagoon.

Determine if sea turtle dietary changes correlate to shifts in seagrass abundance and resulting impacts, if any, on the overall health and fitness of Lagoon turtles.

Monitor and assess potential links between water quality, seagrass declines and presence or severity of FP in Lagoon turtles.

OYSTERS

Oyster recruitment in the Lagoon is among the highest recorded in Southeast Florida.

STATUS:

Three natural oyster reefs in the Lagoon have been monitored since 2005. Surveys were expanded in 2015 to include three reefs constructed as part of habitat restoration projects in the Central Lagoon. Palm Beach County has funding in place to monitor all six reefs through 2023 *(see Figure 1.7)*.

Oysters are valuable indicators of ecosystem health. Oyster monitoring in the Lagoon seeks to document the responses of oyster populations to changes in water quality arising from water management activities and natural events. It includes spring and fall surveys of oyster density and shell height (a measure of growth rates), and monthly collection of live oysters to assess reproductive development, and presence of dermo disease, a parasitic infection that causes mass oyster mortality. Additionally, spat monitoring arrays are deployed and retrieved monthly to assess oyster recruitment throughout the year.

Most of the monitored stations contained healthy live oysters. Live Oyster Density from 2014-2019 ranged from 200 to 500 oysters per square meter. Juvenile oyster spat were settling monthly at most monitored stations from 2014 to 2019 except in January 2017. Peak annual recruitment rates ranged from 2 to 20 spat per shell from 2014-2020.

Salinity is a driving force behind oyster population density and health. Oysters tolerate a wide range of salinities but generally prefer a range of approximately 12-20 parts per

FIGURE 1.7 MAP OF OYSTER REEF LOCATIONS

SOURCE: PBC-ERM

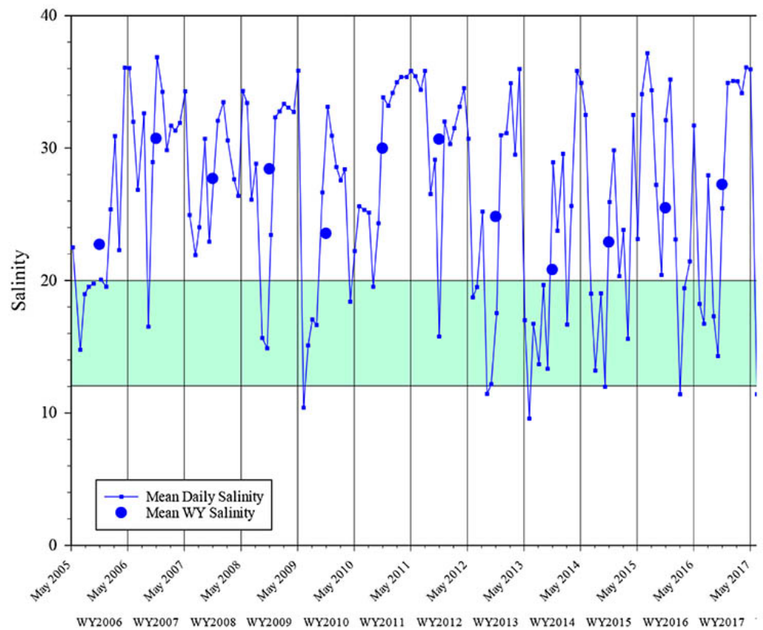
thousand (ppt). Prolonged periods of high salinity can lead to increased dermo infection rates and predation. Even with high oyster recruitment numbers the newly settled recruits often do not survive due to elevated predation and disease rates

common during the dry season as a consequence of elevated salinity in the Central Lagoon.

TRENDS:

The Lagoon's oyster population is currently stable.[10] Abundance, health, and population ecology are generally within normal ranges for South Florida oyster populations. The County constructed an additional 1.6 acres of oyster reefs between 2014-2019. Constructed reefs are functioning as well as natural reefs in the Lagoon to support additional oyster populations and provide habitat for species in the Lagoon.

FIGURE 1.8 SALINITIES AT LAKE WORTH LAGOON OYSTER MONITORING STATIONS 2006-2019



The shaded area shows the 12-20 ppt preferred optimal salinity range for oysters in the Central Lagoon.

SOURCE: Florida Fish and Wildlife Conservation Commission

Salinities in the Lagoon are highly variable according to proximity to inlets contributing salty ocean waters or drainage canals contributing large volumes of freshwater. Researchers believe the freshwater releases generally were more beneficial than harmful to oysters, keeping salinities closer to the optimal range during the summer months (July-Sept.). Likewise, reduced freshwater flows during the dry season (Oct.-June) caused salinity spikes, a likely factor in the high incidence of dermo infections.

Salinities for the LWL from 2006 to April 2019 exceeded the optimal range 70% of the sampled months and were in the optimal range only 26% of the time sampled *(see Figure 1.8)*.

Dermo was present in Lagoon oysters at all sites in all months at rates ranging from 20% to 100%, although few oysters exhibited infection rates considered fatal.

Fisheries monitoring is reinforcing the importance of restored habitats in the Central Lagoon and natural seagrass habitats in the Northern Lagoon to commercially and recreationally valuable species throughout their life cycles.

NEEDS:

Improve management of freshwater flows and rates, and the quality of water being discharged, to maintain lower salinities within the optimal range for oysters throughout the year.

Continue to provide substrates suitable for oyster recruitment and refuge from predation as part of habitat restoration efforts, such as Living Shorelines and oyster reefs.

FISHERIES

STATUS:

Central Lagoon

Fisheries monitoring is conducted monthly in the Central and Northern Lagoon, using different methods in each segment *(see Figure 1.9)*. In the Central Lagoon, monitoring focuses on fisheries utilization of waters adjacent to restored habitats. Sampling in the Northern Lagoon adheres to statewide standardized protocols for stratified-random sampling to estimate fish abundance and population trends in estuarine areas.

From 2014-2020, sampling in the Central Lagoon provided a basis for comparing differences in fisheries use of a mature restoration site (Snook Islands Natural Area), a new restoration site (Grassy Flats) and an unimproved control site. Sampling crews have consistently found juveniles of commercially important species, including shrimp (*Farfantepenaeus* spp.), Spot (*Leiostomus xanthurus*), and Striped Mullet (*Mugil cephalus*) – evidence that the restored habitats are serving as a nursery area. The presence of both juvenile and adult Common Snook (*Centropomus undecimalis*) and Sheepshead (*Archosargus probatocephalus*) suggests that the sites host resident species throughout their life cycles.

Northern Lagoon

Sampling here has chronicled a more diverse fish community than in the Central Lagoon, likely due to extensive seagrass beds valuable to fisheries. This segment also is influenced by ocean waters and tidal flushing via the Lake Worth Inlet. Many juvenile reef species (e.g., snappers and grunts) are collected in the sampling trawls, along with barracuda, permit and green sea turtles.

The stratified-random sampling design used here is consistent

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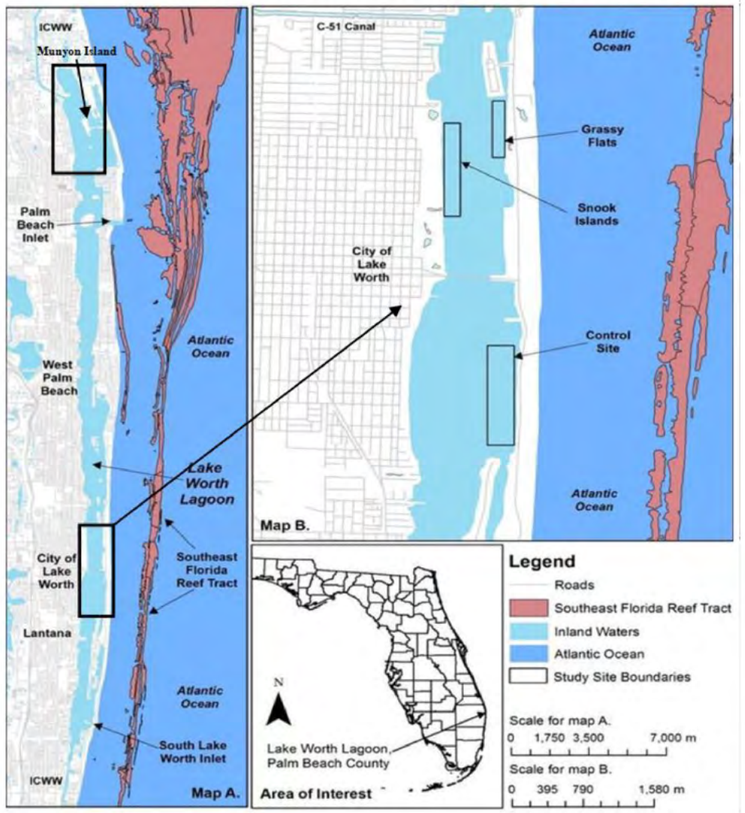
FIGURE 1.9 MAP OF FISH SAMPLING LOCATIONS



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SOURCE: Florida Fish and Wildlife Conservation Commission

with fisheries monitoring conducted in seven other estuarine areas of Florida. This approach distributes the sampling effort among habitat types and directs more sampling to habitats with higher variability in catches to reduce variability in the data.

The gear and sampling techniques tend to target juvenile and sub-adult fishes, making the data collected valuable in determining trends for specific fish stocks, identifying essential habitat, and managing recreational or commercial harvests. The sampling also provides an important window into the ecological contributions of the seagrasses of the Northern Lagoon.

Sampling for Toxins

Mercury samples were collected from economically important species such as juvenile Snook and Sheepshead; laboratory analysis did not find concentrations above acceptable limits.

TRENDS:

In the absence of significant disruptions like red tides or oil spills, discerning trends in fish populations is often a long-term prospect. Sampling has only been conducted in the Central Lagoon since 2014, in association with habitat restoration projects, and in the Northern Lagoon since 2016.

Sampling in the Northern Lagoon reveals more recreational and offshore/reef-associated species than in the Central Lagoon, where filter feeders and detritivores are more prevalent.

The monitoring is laying the groundwork for predicting and protecting future fisheries in the Lagoon, while validating the investments made by Palm Beach County in restoring and enhancing intertidal habitats in the Central Lagoon and reinforcing the value of the extensive seagrass beds of the Northern Lagoon.

NEEDS:

Expand fisheries sampling to the Southern Lagoon.

Utilize random-stratified sampling throughout the Lagoon to ensure uniformity and comparability with sampling in other estuaries.

Implement an acoustic tracking network within the Lagoon to collect more comprehensive and timely information about fish movements and distribution in the Lagoon.

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1 Economic Valuation of Lake Worth Lagoon, Palm Beach County, FL. PFM Group Consulting LLC. 2019.
2 Assessment of Freshwater Inflow and Water Quality in Lake Worth Lagoon from 2007-2020. Report for the Palm Beach County Department of Environmental Resources Management. Prepared by Coastal Ecosystems LLC. 2021.
3 Water Quality Trends in the West Palm Beach C-51 Canal Impacting Lake Worth Lagoon. Daroub et al. Everglades Research and Education Center, Institute of Food and Agricultural Sciences, University of Florida. 2020.
4 Final Rule Designating Critical Habitat for Johnson's Seagrass. Document FR 65 17786. National Oceanic and Atmospheric Administration, 2000.
5 2018 Lake Worth Lagoon Seagrass Status and Annual Transect Monitoring Report. Prepared for Palm Beach County by Coastal Eco-Group Inc., 2018.
6 Same as above
7 Assessment of Marine Turtles in the Lake Worth Lagoon 2017-2018. Inwater Research Group, 2018.
8 Same as above
9 Same as above
10 Oyster Monitoring in the Lake Worth Lagoon. Final Report, April 2019-June 2020. Florida Fish and Wildlife Conservation Commission. 2020.

FWC crews using seine nets to sample fish at the Grassy Flats restoration site (Photo credit: Florida Fish and Wildlife Conservation Commission)

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WATER AND SEDIMENT QUALITY

WATER QUALITY

WQ-1 Expand Water Quality Monitoring **Renamed from 2013 Plan*

WQ-2 Develop a Watershed-Based Modeling Program **NEW*

WQ-3 Implement Best Management Practices for Drainage Canals **NEW*

WQ-4 Monitor and Assess Ways to Reduce Bacterial Contamination and Harmful Algal Blooms **NEW*

WQ-5 Identify and Assess the Impacts of Emerging Contaminants **NEW*

WQ-6 Manage Freshwater Inflows to Optimize Environmental Benefits **NEW*

WASTEWATER

WW-1 Assess and Reduce Occurrence of Sewer Overflows **Renamed from 2013 Plan*

WW-2 Identify Priority Areas for Conversion of Septic Systems to Central Sewer **Renamed from 2013 Plan*

STORMWATER

SW-1 Reduce Stormwater Runoff from Urban Landscapes **NEW*

SW-2 Expand Use of Green Infrastructure and Low Impact Development Practices **Renamed from 2013 Plan*

SEDIMENT MANAGEMENT

SE-1 Assess and Manage Sediment Loading **Renamed from 2013 Plan*

HABITAT ENHANCEMENT AND PROTECTION

HE-1 Create, Protect and Monitor Hardbottom Habitats **NEW*

HE-2 Restore, Create and Protect Intertidal Habitats **Renamed from 2013 Plan*

HE-3 Maintain and Expand Seagrass Habitats **Renamed from 2013 Plan*

HE-4 Acquire Ecologically Significant Submerged and Intertidal Lands **Renamed from 2013 Plan*

FISH AND WILDLIFE MONITORING AND PROTECTION

FW-1 Continue Implementing Palm Beach County's Manatee Protection Plan **Renamed from 2013 Plan*

FW-2 Continue Sea Turtle Monitoring **Renamed from 2013 Plan*

FW-3 Continue Fisheries Monitoring **Renamed from 2013 Plan*

FW-4 Manage and Monitor Shorebird Habitat **Renamed from 2013 Plan*

FW-5 Implement Remote Tracking Technologies for Fish and Wildlife Monitoring **NEW*

CLIMATE CHANGE AND SEA LEVEL RISE

CC-1 Conduct a Vulnerability Analysis of Resources at Risk from Climate Change **NEW*

CC-2 Improve Resiliency of Critical Habitats to Climate Change and SLR **NEW*

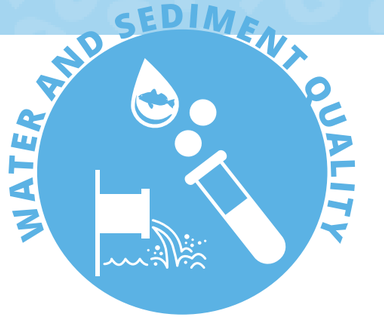
PUBLIC OUTREACH AND ENGAGEMENT

PO-1 Foster Public Awareness and Engagement **NEW*

PO-2 Promote Youth Education and Engagement **NEW*

PUBLIC USES OF THE LAGOON

PU-1 Ensure Adequate and Appropriate Public Access to the Lagoon **NEW*



WATER AND SEDIMENT QUALITY ACCOMPLISHMENTS AT A GLANCE

Two sampling units were installed in 2019 in the Central Lagoon near the C-51 Canal to **transmit near-continuous data about salinity and other water quality parameters.**

SEE ACTION WQ-1

A nutrient autosampler installed in 2019 at the S-155 structure will **facilitate calculations of nutrient loading** from the C-51 canal into the Lagoon.

SEE ACTION WQ-1

Health advisories due to bacterial contamination were posted at Phil Foster Park 16 times from 2016-2020—9.9% of the time that samples were taken.

SEE ACTION WQ-4

A 2020 study by a Palm Beach Atlantic University student on the abundance and variation of microplastics in surface waters of the Lagoon found **an average of 8.6 microplastic pieces per liter.**

SEE ACTION WQ-5

Initial mapping of areas with **high density septic systems** throughout the County was conducted in 2019.

SEE ACTION WW-2

21 projects incorporating **Green Infrastructure design elements** were completed or underway in Palm Beach County as of 2020.

SEE ACTION SW-2

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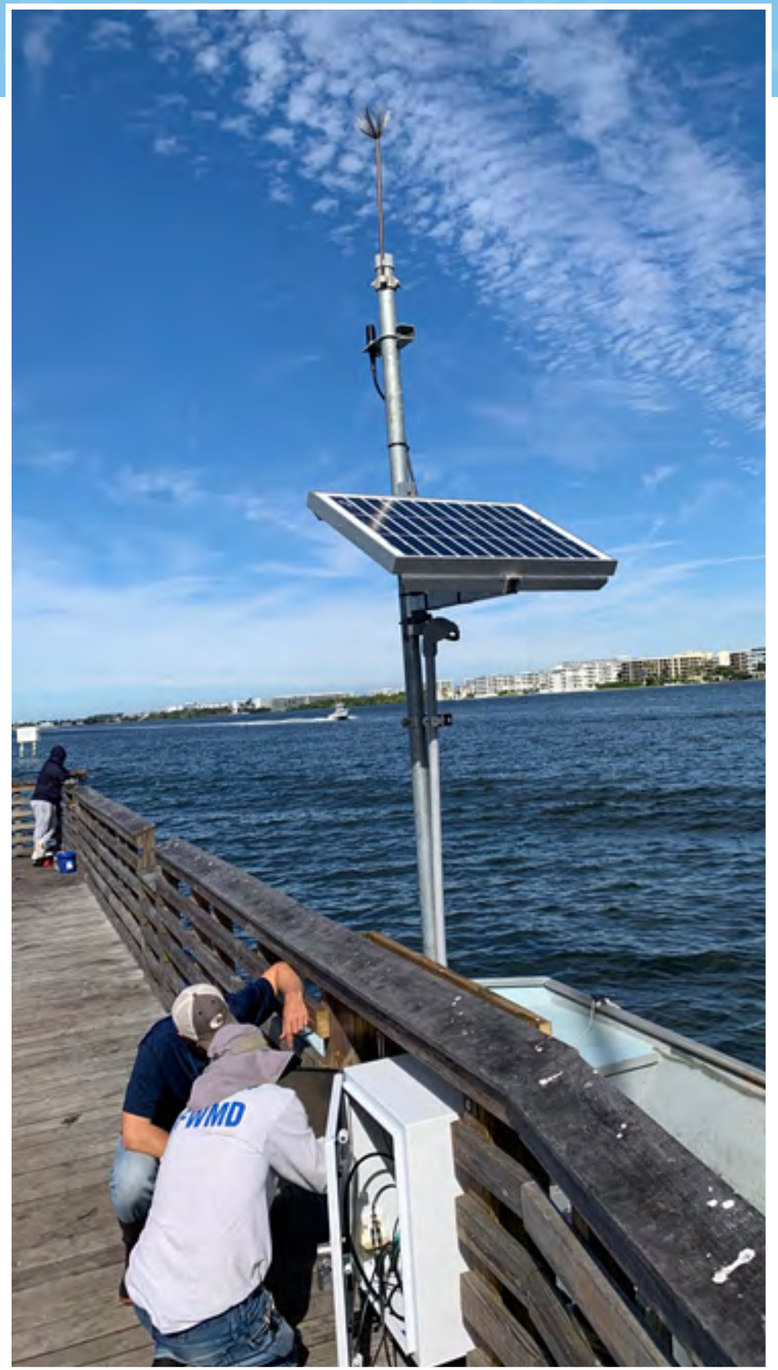


Scientists check one of the solar-powered, real-time water quality monitoring stations in the Lagoon (Photo credit: PBC-ERM)

WQ-1 EXPAND WATER QUALITY MONITORING

ACTION: Expand monitoring programs to address land-based sources of pollution that influence water quality as well as public and environmental health.

IMPORTANCE:

Water quality monitoring conducted in the Lagoon since 2007 provides an important foundation for understanding trends and factors influencing the Lagoon's health. Regular, comprehensive and standardized monitoring is essential for formulating appropriate management response to maintain or improve water quality.

RELATED ACTIONS:

WQ-2, WQ-4, WQ-5, WQ-6, SE-1, WW-1, WW-2

BACKGROUND:

A cooperative agreement between Palm Beach County (PBC) and the South Florida Water Management District (SFWMD) facilitates water quality monitoring in the Lagoon. Samples are collected monthly at 14 sites by county Environmental Resources Management (ERM) staff and analyzed for a suite of physical and chemical properties at a SFWMD laboratory *(see Figure 1.1)*.

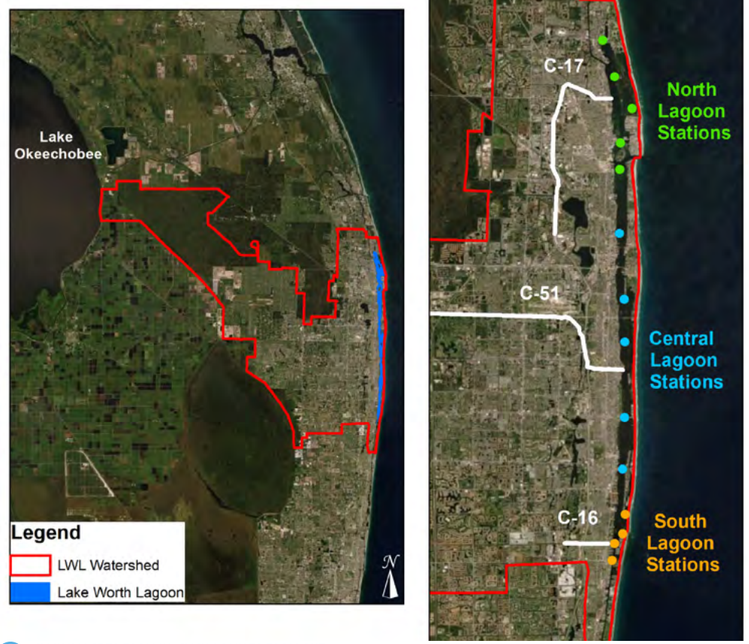
Data are stored in DBHYDRO, a searchable SFWMD environmental database of hydrologic, meteorologic, hydrogeologic and water quality data, accessible to local governments, regional agencies and stakeholders. The SFWMD data from 2017 forward has been entered in the Florida Department of Environmental Protection's Watershed Information Network (WIN), the modernized successor to the STORET (Storage and Retrieval) system.

In addition to the monthly grab samples, new tools added in recent years provide current, timely data on nutrients and salinity, in an effort to better characterize and evaluate the effects of significant and seasonally variable freshwater discharges from the watershed via major drainage canals.

In partnership with the County, SFWMD deployed two salinity sonde stations in November 2019 to document salinity fluctuations in the Central Lagoon. The sondes provide near real-time measurements of salinity, temperature, dissolved oxygen, pH and turbidity. They are located to the north and south of the C-51 canal, which contributes more than half of the freshwater inflow to the Central Lagoon.

The County maintains its own high-frequency salinity sondes at John's Island Natural Area across from the

FIGURE 1.1 WATER QUALITY MONITORING STATIONS



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C-51 canal, and at Munyon Cove. These sondes collect salinity data hourly.

SFWMD also installed a nutrient autosampler in 2019 at the S-155 structure on the C-51 canal. This upstream station allows for a weekly composited sample that is analyzed for total nitrogen and phosphorus discharged from the C-51 canal into the Lagoon.

A sediment trap installed in 2007 on the C-51, intended to serve as a "sump" to capture and prevent sediments from entering the Lagoon, is still being assessed (*see Action SE-1*).

Surveillance monitoring for blue-green algae (BGA) and red tide is coordinated with the Florida Department of Environmental Protection (FDEP) and the Florida Fish and Wildlife Conservation Commission, respectively.

Several areas within the Lagoon have been designated by FDEP as impaired for nutrients, chlorophyll, copper or other parameters *(see Table 1.1)*. Development of Total Maximum Daily Loads (TMDLs) is required to establish numerical limits on how much of these pollutants the Lagoon could receive and still meet state water quality standards.

Additionally, two freshwater lakes within the Lagoon's watershed – Pine Lake and Lake Osborne – currently have TMDLs under development. Both are designated as impaired for nutrients, based either on Chlorophyll and/or Phosphorus, and will require improvements in stormwater management for their respective basins, with benefits for the Lagoon. An analysis of Lagoon water quality data from 2007-2020 reveals some important trends, particularly with regard to relationships between freshwater inflows, salinities, microscopic algae (expressed as chlorophyll α), and nutrient loading.[1] For this analysis the Lagoon was divided into 3 segments (north, central and south) to assess spatial and temporal patterns of inflow and water quality.

TABLE 1.1 IMPAIRED WATERS IN THE LAKE WORTH LAGOON

	Parameters Assessed Using the Impaired Surface Waters Rule (IWR)	Criterion Concentration or Threshold Not Met	Summary Assessment Status	Verified Period Assessment Data 5	Comments
Lake Worth Lagoon (Northern Segment)	Nutrients (Chlorophyll-a)	≤ 3.7 µg/L	Impaired	13/35	This waterbody is impaired for this parameter based on the number of exceedances for the sample size. This parameter is being added to the 303(d) List.
Lake Worth Lagoon (Northern Segment)	Copper	ENRR1: AGM ≤ 2.9 µg/L	Impaired	ENRR1: AGM 2008 (2.1 µg/L) 2009 (1.6 µg/L) 2010 (2.0 µg/L) 2011 (1.7 µg/L) 2012 (2.8 µg/L) 2013 (3.1 µg/L) 2014 (3.2 µg/L) 2015 (1.9 µg/L)	This waterbody is impaired for this parameter because the annual geometric means exceeded the criterion more than once in a three year period. This parameter is being added to the 303(d) List.
Lake Worth Lagoon (Central Segment)	Nutrients (Chlorophyll-a)	≤ 3.7 µg/L	Impaired	6/22	This waterbody is impaired for this parameter based on the number of exceedances for the sample size. This parameter is being added to the 303(d) List.
Lake Worth Lagoon (Central Segment)	Copper	ENRR2: PCT ≤ 10.2 µg/L	Impaired	ENRR2 (PCT) 68/412	This waterbody is impaired for this parameter based on the number of exceedances for the sample size. This parameter is being added to the 303(d) List.
Lake Worth Lagoon (Central Segment)	Nutrients (Chlorophyll-a)	ENRR2: AGM ≤ 0.049 mg/L	Impaired	ENRR2: AGM 2008 (0.023 mg/L) 2009 (0.035 mg/L) 2010 (0.033 mg/L) 2011 (0.026 mg/L) 2012 (0.028 mg/L) 2013 (0.032 mg/L) 2014 (0.056 mg/L) 2015 (0.052 mg/L)	This waterbody is impaired for this parameter because the annual geometric means exceeded the criterion more than once in a three year period. This parameter is being added to the 303(d) List.

SOURCE: Florida Department of Environmental Protection

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- Water quality in the north and south segments benefit from proximity to the inlets, while discharge from C-51 on average accounted for 59% of the total inflow to LWL and greatly influenced water quality in the central segment.
- CHL, TN, TP, TSS and turbidity increased in the Central Lagoon over the 13-year period analyzed *(see Table 1.2)*.
- Three variables, CHL, TN and TP, were positively correlated to inflow and to each other in all three Lagoon segments (north, central and south).
- Flushing time for the entire volume of the Lagoon ranged from 3 to 14 days, depending upon inflow conditions and salinity of the coastal ocean.
- Turbidity increased with C-51 discharge while TSS was often inversely related to inflow.

These results revealed the considerable uncertainty associated with TSS and turbidity processes and patterns throughout the LWL. While it is likely that the C-51 is a source of silt and organic materials, monthly data may not have the resolution to detect significant changes. The input, transport and resuspension of sediments in the Lagoon should be examined in greater detail particularly since wind-driven tidal mixing and resuspension affects sediment transport on the time scales of hours to days.

A previous analysis of water quality data from 2007 to 2015 also found that chlorophyll α, TN and TP were all greater in the wet season and positively correlated to discharge in the Lagoon.[2]

Nutrient loading for the Lake Worth Lagoon has not been calculated, despite its importance to water quality status and trends. Installation of the nutrient analyzer at the S-155 structure on the C-51 (C51S155) in late 2019 would assist in these calculations.

A report detailing water quality trends in the C-51 canal and corresponding impacts to the Lagoon reported that

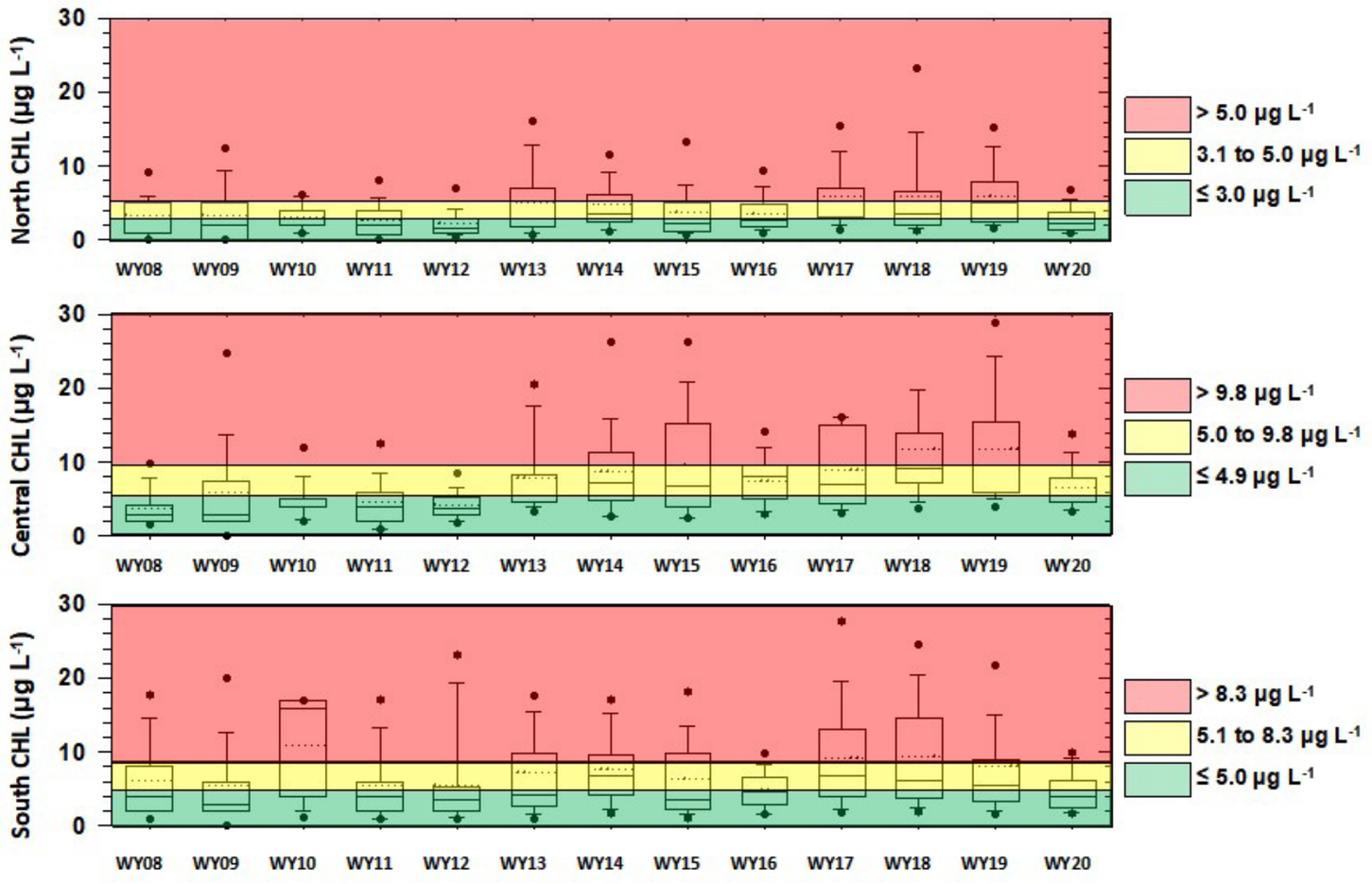

Figure 12 Stoplight representation of variations in chlorophyll a (CHL; µg L-1) determined in the (A) North, (B) Central, and (C) South Segments of Lake Worth Lagoon from Water Year 2008 to 2020. Points outside of error bars were greater than the 95th percentile. The classes were less than the median value (green), between the median and the 75th percentile (yellow), and greater than the 75th percentile (red).

SOURCE: Coastal Ecosystems LLC

TP concentrations (52 to 87 ug per L) observed at station C51S155, where the canal discharges into the Lagoon, are higher than the allowable annual geometric mean of 49 ug per L under FDEP's estuarine Numeric Nutrient Criteria (NNC) for the central segment of the Lagoon. Similarly, TN concentrations (0.86 to 1.41 mg per L) at the same station were higher than the annual geometric mean NNC of 0.66 mg per L for the central segment of the Lagoon.[3] Regular flushing of the Lagoon likely insulates it from severe water quality issues. However, steady increases in CHL, correlated with freshwater inflows, indicate the potential for algae to accumulate. This prospect is greatest in the Central Lagoon because it is farther away from ocean inlets that facilitate rapid flushing.

Water quality monitoring is most useful in tandem with monitoring of biological resources. Changes in water quality directly impact the health of the four indicator species that are also part of the Lagoon's foundational monitoring: Seagrass, Sea Turtles, Fisheries, and Oysters.

The potentially outsized role of freshwater discharges in Lagoon hydrodynamics warrants further investigation to determine appropriate strategies to manage volumes, timing and constituents of the freshwater discharges.

Expanded monitoring in the Lagoon will support new regulatory requirements expected in coming years as a result of the passage in 2020 of Senate Bill 712, the Clean Waterways Act. This significant and far-reaching legislation carries a wide range of water quality protection provisions aimed at minimizing the impact of nutrient pollution from urban stormwater and wastewater systems, septic systems and agricultural runoff. The Florida Department of Environmental Protection (FDEP) is the lead state agency charged with implementing the Act.

In a related initiative, FDEP is developing allowable load reductions from both structural and non-structural stormwater projects, based on loading data submitted by stakeholders and nutrient removal efficiencies established by FDEP. Reductions from wastewater projects and agricultural BMPS in the watersheds also will be determined. Monitoring by Palm Beach County and other Lagoon stakeholders will be important for demonstrating that the reductions are being achieved.

WATER QUALITY PARAMETERS MONITORED IN THE LAKE WORTH LAGOON:

Dissolved Oxygen (DO)	**Ammonia nitrogen (NH4)**	**Total Suspended Solids (TSS)**
pH	**Nitrite-nitrate nitrogen (NOx)**	**Turbidity**
Salinity	**Total Phosphorus (TP)**	**Chlorophyll (CHL)**
Total Nitrogen (TN)	**Orthophosphorus (OPO4)**	

APPROACH:

STEP 1 Continue water quality monitoring and trend analysis every 3-5 years.

STEP 2 Increase frequency of current monitoring or add parameters necessary to pinpoint impairments or specific issues of concern related to water quality.

STEP 3 Develop a monitoring plan to proactively address a host of management needs in the Lagoon, including:

- Identification of land-based sources and relative contributions to FDEP-designated impairments for nutrients, TSS and copper.
- More robust sampling for turbidity/TSS in the Central Lagoon to fully understand water quality impacts associated with freshwater discharges, including nutrient and sediment loads from drainage canals and municipal structures (*see Action SE-1*).
- Identification of hot spots, sources and pathways for Harmful Algal Blooms, bacterial contamination and emerging contaminants such as Microplastics (*see Action WQ-4)*.
- Source tracking to identify nutrient pollution associated with leaching from septic systems (*see Action WW-1)*.
- Light attenuation requirements for seagrass to flourish at different depths in the Lagoon *(see Action HE-3)*.
- Source tracking to identify hot spots for sewer overflows and prioritize infrastructure repairs and upgrades (*see Action WW-1*)

TIMEFRAME:

STEP 1 Ongoing

STEP 2 can begin in 2022 if funds can be secured

STEP 3 Plan Development can be initiated in 2022

COST ESTIMATE:

Step 1 $$

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Step 2 $$$

Step 3 $$-$$$

EVALUATING PROGRESS:

Increase in monitoring programs and schedules

REGULATORY NEEDS:

None

FUNDING:

County budget allocations or special appropriations; state or federal grant assistance could serve as seed money for monitoring pilot projects to establish protocols

POTENTIAL PARTNERS:*

PBC-ERM, SFWMD, FDEP

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

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1 Assessment of Freshwater Discharge and Water Quality in Lake Worth Lagoon from 2007-2020. Coastal Ecosystems LLC. 2021.

2 Assessment of Freshwater Inflow and Water Quality for an Urbanized, Subtropical Estuary (Lake Worth Lagoon, Florida, USA). Buzzelli, C. et al. Marine Technology Society Journal. 2018.

3 Water Quality Trends in the West Palm Beach C51 Canal Impacting Lake Worth Lagoon, Final Report. Daroub, S.H. et al. 2020.

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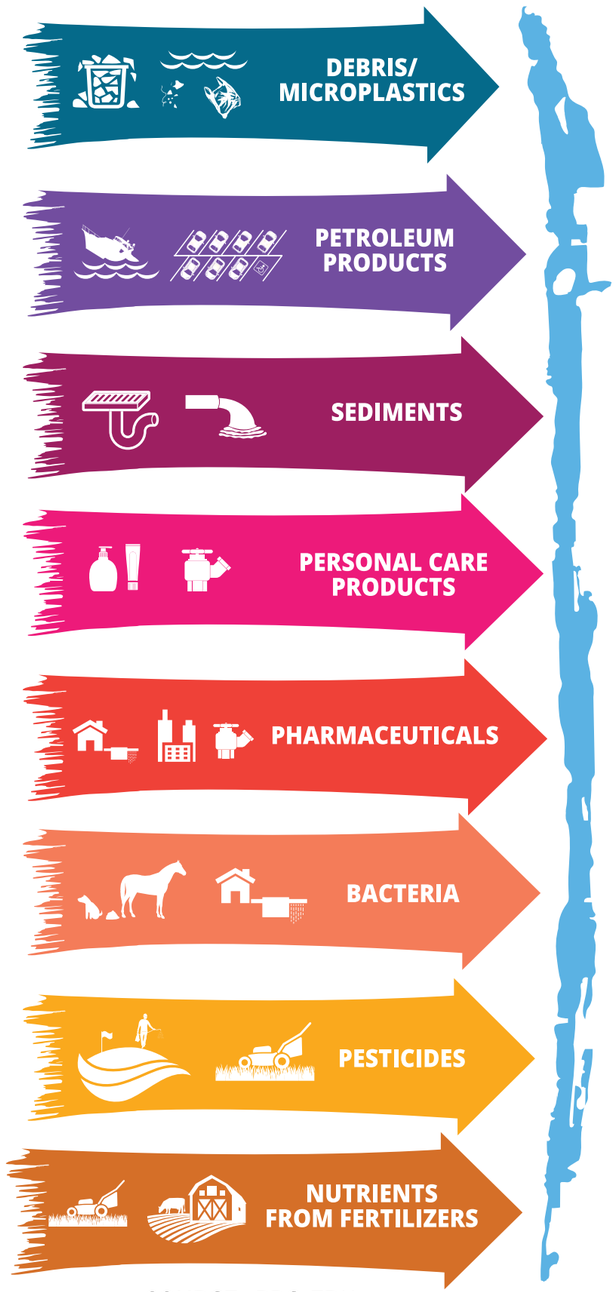
LAND-BASED SOURCES OF POLLUTION TO THE LAKE WORTH LAGOON



SOURCE: PBC-ERM

WQ-2 DEVELOP A WATERSHED-BASED MODELING PROGRAM

ACTION: Develop a watershed modeling strategy and deploy an appropriate suite of modeling tools to inform management actions that consider the needs of all the Lake Worth Lagoon Estuary's living resources.

IMPORTANCE:

Modeling that takes into account the full range of parameters that contribute to ecosystem health will enable watershed-scale management strategies that benefit and support the Lagoon's varied living resources.

RELATED ACTIONS:

WQ-1, WQ-6, SE-1, HE-3

BACKGROUND:

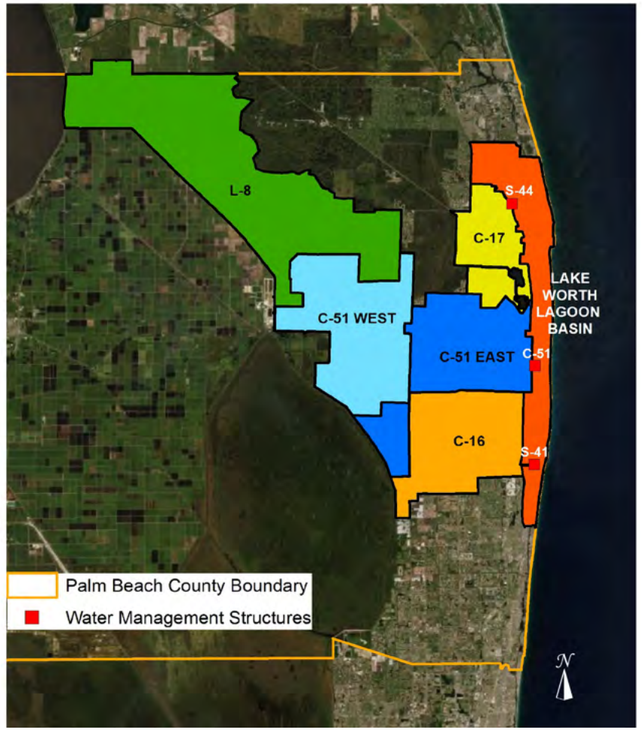
Palm Beach County is committed to a watershed management approach that considers the varied and sometimes contradictory needs of the living resources of the Lake Worth Lagoon. Oysters in the Central Lagoon, for example, benefit from a reliable infusion of freshwater, while turtle grass in the Northern Lagoon requires consistently salty water to flourish.

Development of a comprehensive suite of modeling tools is a critical step in building the robust scientific foundation needed to determine optimal conditions for diverse species, and to implement watershed-scale management strategies to support them *(see Figure 1.1)*.

This Action Plan proposes a watershed-based modeling program for the Lagoon that employs at least two different modeling approaches:

- A pollutant loading model that simulates freshwater, sediments, nutrients and other inputs to the Lagoon from the watershed. This tool can assist in better understanding water management operations and system dynamics, identifying problems and evaluating potential solutions.
- In addition to estimating current pollutant loads, this model would predict changes resulting from implementation of Best Management Practices (BMPs) or other nutrient reduction measures. A robust non-point source monitoring network that measures pollutant concentrations and water flows from multiple areas in the watershed would facilitate accurate nutrient loading calculations.

FIGURE 1.1 LAKE WORTH LAGOON WATERSHED CONSISTS OF 6 MAJOR DRAINAGE BASINS



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- A hydrodynamic model of the Lake Worth Lagoon itself can assess the physical and meteorological factors that influence the Lagoon's ecological resources and help evaluate concepts to improve conditions.

Various historical modeling efforts have addressed some of these elements in a piecemeal fashion.

Modeling of estimated pollutant loads is required for all entities (including cities and counties) holding NPDES permits for point-source discharges, defined under the Clean Water Act as "any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, discrete fissure, or container."

Additionally, the Federal Emergency Management Agency (FEMA) utilizes modeling to update local flood maps and set flood insurance rates.

Hydrodynamic modeling of the Lagoon was first conducted by the South Florida Water Management District (SFWMD) in 1996. The model was also calibrated and applied for flow scenario evaluations in the Lagoon in 2002.

At the County's request in 2019, SFWMD provided recommendations for improvements to the original hydrodynamic model to support detailed salinity assessments under a variety of scenarios. Specifically, the following data needs were identified to establish accurate boundary conditions for the model:

- *Tidal information at the offshore boundary*

  Confirmation is needed to ensure that the East Coast tidal database utilized in the 2002 model has been updated. An alternative would be to use tidal data collected at the Lake Worth Pier, when available, supplemented by the East Coast database as needed.

- *Freshwater inflow*

  Gaged flows at structures S155, S44, and S41 should be used. In addition, contribution of the LWL watershed also should be included. Previously, the District's Regional Hydrological Model was used to provide the flow information.

- *Meteorological forcing*

  Wind, rainfall, and evaporation data should be collected at nearby weather stations and applied at the water surface.

- *Salinity data*

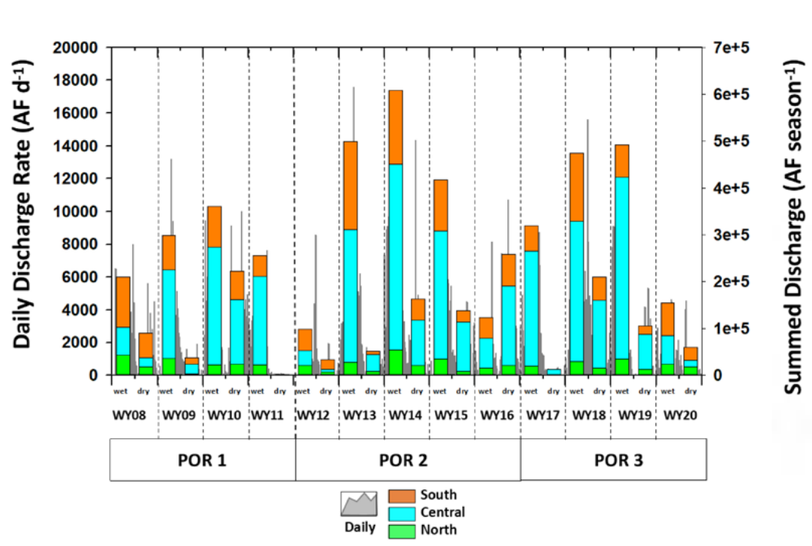
  Salinity data collected in the lagoon should be compared with the model results as a further validation of the model.

Once the model is successfully updated it can be used to assess a range of physical and meteorological factors that influence the Lagoon's ecological resources, including the following priority concerns:

- The ecological impacts of widely fluctuating freshwater discharges *(see Figure 1.2)*.
- Precise flushing rates for the entire Lagoon and for different segments of the Lagoon, along with the relationship between freshwater discharges and flushing rates.
- Sea level rise based on NOAA's high, medium and low projections, with associated salinity responses.
- Sedimentation rates at specific locations, utilizing and comparing historic versus current bathymetry data.

In late 2020, the County submitted a document titled "Lake Worth Lagoon Estuary Freshwater Flows at S-155A" to the U.S. Army Corps of Engineers. This document formally requested that the Corps establish a Performance Measure for freshwater flows to the Lagoon from Lake Okeechobee as part of upcoming revisions to the Lake Okeechobee System Operating Manual (LOSOM). The Performance Measure will require use of a predictive model. While limited to evaluations of discharges from Lake Okeechobee – which constitute a small fraction of the total freshwater funneled to the Lagoon – the model will nevertheless serve as a useful surrogate (pilot) for a larger, more robust model that can address watershed-scale needs. It incorporates the use of optimal salinity ranges for two key indicator species in the Lagoon – seagrasses and oysters. The model would be used to manage freshwater discharges to avoid salinity extremes and maintain salinities at the desired optimal ranges of these organisms – 15 parts per thousand (ppt) for the Central Lagoon to accommodate salinity needs for oysters, and 20 ppt for the Northern Lagoon to accommodate salinity needs for seagrass.[1]

FIGURE 1.2 DAILY INFLOW TO LAGOON



Time of series of daily discharge rate (C17 + C51 + C16; acre-feet d-1; grey; left axis) from 5/1/07 to 4/30/20, and stacked bars for seasonal average discharge (right axis). Total discharge in the wet (May-Oct) and dry (Nov-Apr) seasons was the sum of C17 (green), C51 (cyan), and C16 (orange). The 13 WY record was divided into three periods of record (POR) to evaluate patterns and trends.
SOURCE: Coastal Ecosystems LLC

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APPROACH:

STEP 1 Develop a Scope of Work to determine data needs and develop two predictive watershed models:

- A model for estimating current pollutant loading from the watershed and potential reductions from implementation of BMPs and other water quality improvements.
- A hydrodynamic estuary model assessing physical and meteorological influences on Lagoon ecology, incorporating the existing data sets and boundary information recommended by SFWMD.

Explore partnerships to finance model development, including grant funding and in-kind support from SFWMD for the models and regional research consortiums or area universities to gather and analyze datasets.

STEP 2 Utilize the models to determine the optimal water quality conditions and salinities to support the full range of the Lagoon's ecological resources, by simulating various water management scenarios.

STEP 3 Develop additional modeling tools as needed to address specific management needs.

TIMEFRAME:

STEPS 1 and 2 can be initiated in 2022 if funding is secured.

STEP 3 to occur as additional models are needed to understand and address specific aspects of watershed management.

COST ESTIMATE:

Step 1 $

Step 2 $-$$

Step 3 $-$$$

EVALUATING PROGRESS:

Design and implementation of hydrodynamic model

REGULATORY NEEDS:

None

FUNDING:

County budget appropriation, state or federal grants, direct or in-kind support from regional research consortiums or area universities

POTENTIAL PARTNERS:*

PBC, SFWMD, FDEP, NOAA, FAU or other research institutions

Interns in the Green Futures program assist county staff with monitoring water quality (Photo credit: PBC-ERM)

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

[1] Northern Estuaries Performance Measure Salinity Envelopes. CERP System Wide Performance Measure Documentation Sheet. 2007 and 2020.

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WQ-3 IMPLEMENT BEST MANAGEMENT PRACTICES FOR DRAINAGE CANALS

ACTION: Encourage implementation of Best Management Practices (BMPs) to reduce sediment and nutrient loading from drainage canals to the Lake Worth Lagoon.

Canal maintenance includes sediment removal to improve flows and functioning of water conveyance canals (Photo credit: Lake Worth Drainage District)

IMPORTANCE:

Widespread use of BMPs within and adjacent to drainage canals is a cost-effective strategy for preventing conveyance of excessive nutrients and pollutants from the vast network of drainage canals within the Lagoon's watershed, contributing to water quality impairments.

RELATED ACTIONS:

WQ-2, SE-1

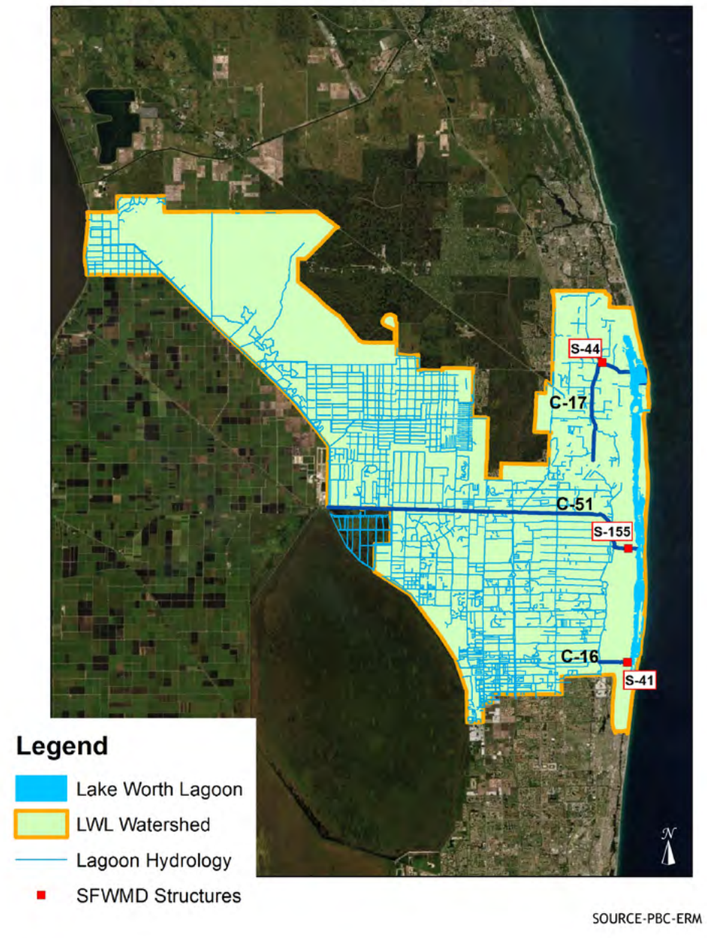
BACKGROUND:

More than 850 miles of drainage canals bisect the Lake Worth Lagoon watershed *(see Figure 1.1)*. They are part of a complex, far-reaching water management system in South Florida that conveys large volumes of runoff across long distances, spanning watersheds, coursing through inlets and eventually reaching the coastal waters of the Atlantic. The canals are designed to move high flows at relatively high velocities.[1] While these canals are important for flood control, they also transport sediments and nutrients to the Lagoon from its disproportionately large watershed *(see Action SE-1)*.

The surface water that enters canals often consists of runoff from urban and agricultural lands. It may contain chemical fertilizers, pesticides, and other pollutants, as well as large amounts of suspended solids.

Regular and ongoing maintenance is required to ensure this network of canals and water control structures functions properly. Floodgates have to be opened, closed, and maintained in working order. Pumps have to be operated and repaired. Canals must be cleaned to keep aquatic plants from clogging them, and periodically dredged to remove sediments. Canal banks must be stabilized to prevent erosion. This work may even occur simultaneously during

FIGURE 1.1
MAP OF DRAINAGE CANALS IN LWL WATERSHED



SOURCE-PBC-ERM

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emergencies or peak flows.

BMPs are structural or non-structural activities intended to treat, prevent or reduce water pollution. Structural BMPs include constructed features or installed devices; non-structural BMPs include maintenance procedures, prohibitions of activities, and modified practices or processes. Use of BMPs upstream in drainage canals is a cost-effective way to reduce pollutants that impair water quality downstream in the Lagoon.

Non-structural canal maintenance BMPs rely on modified maintenance and operational protocols intended to reduce water pollution impacts to canals and downstream water bodies. Examples include:

- Reducing or eliminating mowing of banks to slow runoff and reduce erosion. Replacing grass with native plant communities also may provide habitat for pollinators.
- Eliminating or reducing use of herbicides to control weeds or invasive plants, a BMP facilitated by use of native bank vegetation.
- Mechanical harvesting of invasive or nuisance aquatic plants that obstruct flows.
- Skimming devices that remove trash, weeds, and debris to facilitate water flow.
- Removing dead, dying, leaning, unhealthy, or invasive/ exotic trees to ensure proper water conveyance.

Applying herbicides to aquatic weeds (Photo credit: Lake Worth Drainage District)

- Removing shoals created when sediment accumulates within the canal and reduces the ability to convey design water flows.

Non-structural BMPs can be used in conjunction with structural BMPs such as grading of berms and levees, and installation of culverts to prevent bank erosion. They may be the only viable maintenance option in densely developed urban areas.

In addition to the South Florida Water Management District, there are eight independent drainage districts in the Lagoon's watershed *(see Figure 1.2.)* Thirty municipalities also have drainage responsibilities in the watershed. This action plan recommends convening a working group of representatives from local governments and water control districts to develop standardized guidelines for maintaining drainage canals within their jurisdictions. Coordinated and consistent use of BMPs over time will provide a framework for measuring results and comparing cost-savings versus more traditional canal maintenance methods. BMP implementation also provides a model for consistent education of residents who live adjacent to canals so they understand how their landscape practices (mowing, plant choices, fertilizer and pesticide applications) affect their local canal and ultimately the Lagoon *(see Action SW-1)*.

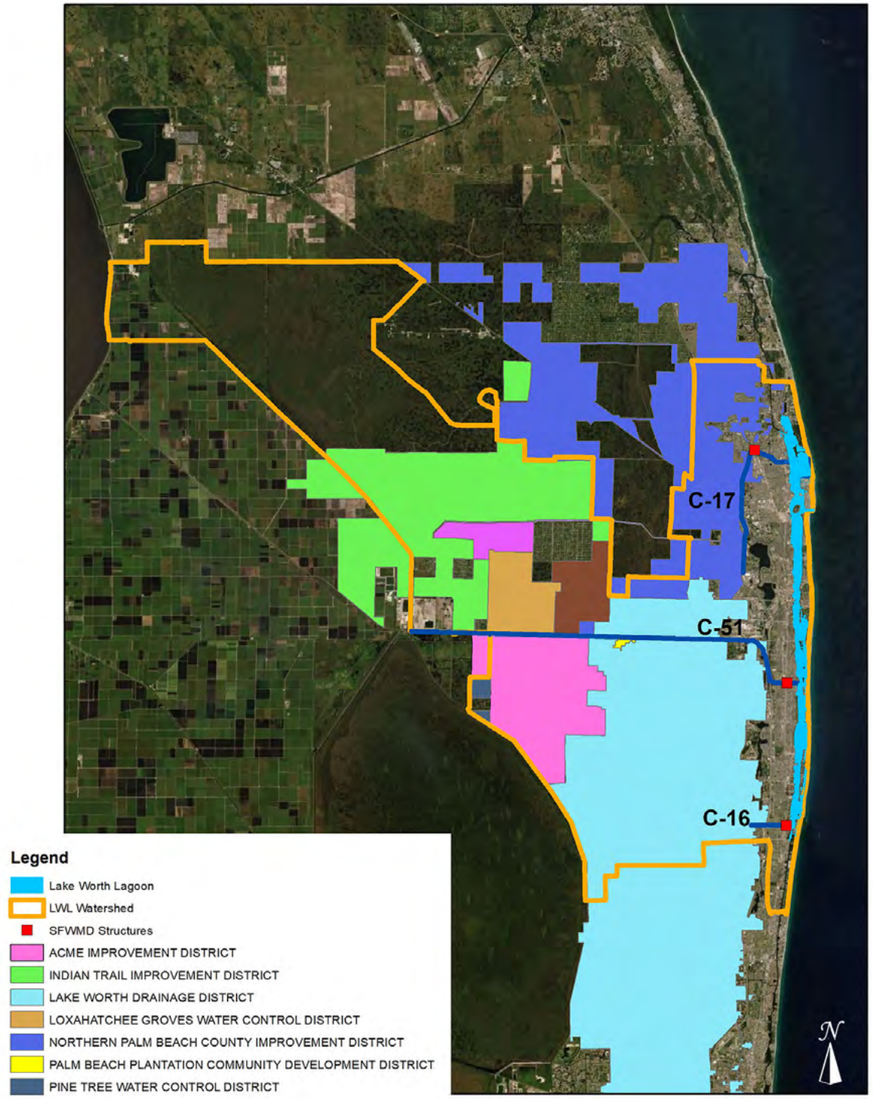
APPROACH:

STEP 1 Form a working group of stakeholders from municipalities and drainage districts with canal management responsibilities to develop standardized guidelines for non-structural BMPs.

STEP 2 Encourage adoption of BMPs by partner agencies and organizations.

STEP 3 Evaluate reductions in nutrients and/or sediments over time. Evaluate cost savings from adopted BMPs.

FIGURE 1.2 WATER CONTROL AND DRAINAGE DISTRICTS IN WATERSHED



SOURCE-PBC-ERM

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TIMEFRAME:

STEP 1 can be initiated in FY 2021 or FY 2022

STEP 2 can occur pending agreement on BMP guidelines

STEP 3 can be initiated in 2022 or whenever BMPs are adopted

COST ESTIMATE:

STEPS 1 and 2 = $

STEP 3 = $$ as part of overall water quality monitoring program

EVALUATING PROGRESS:

Number of municipalities and water management entities adopting BMPs

Number of BMPs adopted

Reductions in nutrients and sediments

REGULATORY NEEDS:

None

Mowing a canal bank (Photo credit: Lake Worth Drainage District)

Typical drainage canal in residential area

FUNDING:

Annual budgets for local governments and water management/ drainage districts

POTENTIAL PARTNERS:*

PBC, SFWMD, Lake Worth Drainage District, Indian Trails DD, Acme DD, Loxahatchee Groves Water Control District, Seminole WCD, Pine Tree WCD, Northern PBC Improvement District, 30 municipalities within Lagoon watershed

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

[1] Canals in South Florida: A Technical Support Document. Carter, K., Redfield, G., et al. 2016.

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No swimming sign and flag at Phil Foster Park (Photo credit: PBC-ERM)

WQ-4 MONITOR AND ASSESS WAYS TO REDUCE BACTERIAL CONTAMINATION AND HARMFUL ALGAL BLOOMS

ACTION: Continue sampling for harmful algae blooms and bacteria in the Lake Worth Lagoon. Consider bacterial sampling of additional recreation sites in the Lagoon. Identify sources of bacteria and ways to reduce loads. Improve public understanding of HABs and waterborne pathogens.

IMPORTANCE:

Bacteria associated with fecal matter and blooms of harmful algae are serious threats to humans and environmental health, and can also devastate the region's economy through loss of water recreation such as fishing and swimming.

RELATED ACTIONS:

WQ-1, WW-1, WW-2, PU-1

BACKGROUND:

Contamination of waterways with human or animal waste can contribute bacteria, viruses and parasites that cause a variety of illnesses when ingested or absorbed through the skin via a cut or sore. Health effects range from rashes, infections and diarrhea to life-threatening conditions such as hepatitis, salmonella and giardia.

Harmful algal blooms (HABs) such as the Red Tide organism *(Karenia brevis*) and Cyanobacteria, or blue-green algae (primarily *Microcystis aeruginosa*), can cause oxygen levels in water to plummet and lead to widespread fish kills. These blooms also may cause severe respiratory distress in people (red tides) or fever, vomiting, headache, sore throat, and diarrhea in people (blue-green algae). Toxins in HABs can be fatal to manatees, sea turtles, seabirds and other marine life.

Bacterial Contamination

Thirteen recreational areas in Palm Beach County are regularly sampled by the county Health Department as part of the Florida Healthy Beaches

Algae bloom in C-51 canal, 2016 (Photo credit: WPTV)

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Program. Phil Foster Park is the only sampling site within the Lagoon; the others are at oceanside parks and municipal beaches.

As with all marine waters in Florida, enterococci bacteria (*Enterococcus* species) are now used to indicate fecal contamination instead of *E. coli*, which is a short-lived and less reliable indicator than enterococci in saltwater. If they are present in high concentrations in recreational waters and are ingested while swimming or enter the skin through a cut or sore, enterococci may cause human disease, infections or rashes.

Health advisories due to high bacterial counts were posted at Phil Foster Park 16 times from 2016-2020, or 9.9% of the time that samples were taken.

Additional bacteria sampling is conducted at 16 sites in the Lagoon by the Lake Worth Waterkeeper organization, using commercial test kits. This information is shared with the public through the Waterkeeper social media network, to assist recreational users in making informed decisions about diving, swimming, paddling or other activities. No advisories are issued based on these sampling results, and the sampling protocols have not been vetted by the Health Department.

The potential sources of fecal bacteria are numerous: Municipal sewer overflows and spills (*see Action WW-1*);

FLORIDA HEALTHY BEACHES PROGRAM CATEGORIES

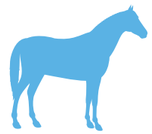
GOOD =	MODERATE =	POOR =
0-35 Enterococci per 100 milliliters of marine water	36-70 Enterococci per 100 milliliters of marine water	71 or greater Enterococci per 100 milliliters of marine water

TABLE 1.1 SOURCES OF BACTERIAL CONTAMINATION


Malfunctioning septic systems

Sewer overflows


Operations


Equestrian Facilities


Urban pet waste


Wildlife

leaking septic tanks (*see Action WW-2*); pet waste (especially dog poop, which contains almost as much bacteria as human waste); equestrian facilities, livestock operations; even manure from backyard chickens *(see Table 1.1)*. Expanded water quality monitoring that incorporates bacterial source tracking would be useful in identifying chronic hot spots and targeting management strategies (*see Action WQ-1*). Broad-based Best Management Practices and education programs that promote proper disposal of pet waste or horse manure also could result in significant and measurable reductions in bacteria *(see Action PU-1)*.

Harmful Algal Blooms (HABs)

In general, the Lagoon is not considered a high risk for red tide and blue-green algae blooms, with only one occurrence of each in more than a decade. However, resource managers are keenly aware that these trends can change, in particular as we gain a better understanding of the effects of nutrients as a primary driver in algae proliferation and degradation of water quality. The influence of nutrients on the formation, magnitude and persistence of blue-green algae blooms in Florida's waters, is likely to be exacerbated in the future by changes in land-use and hydrology, along with rising temperatures and rainfall variations associated with climate change.[1]

The County's participation in the Blue-Green Algae Task Force, created in 2019 by Florida Governor Ron DeSantis, offers a forum for elevating awareness of the Lagoon's vulnerability to algae blooms as part of a statewide effort to reduce harmful algal blooms in state waterways.

The Florida Department of Environmental Protection (FDEP) is charged with coordinating the response to blue-green algae (BGA) blooms throughout Florida. FDEP dispatches a sampling team to investigate reported blooms and collect water samples to ascertain if toxins are present. Potential blooms can be reported by the public through a DEP online portal that also presents recent sampling results, maps and other data in a graphical dashboard format.

Blue-green algae (BGA) blooms in the Lagoon are seeded by blooms originating in Lake Okeechobee. Thus, management of lake levels and freshwater discharges are of paramount interest to Lagoon resource managers.

The last BGA bloom to reach the LWL was in 2016, in waters north and south of the C-51 Canal. Sampling at Summa Beach along the western side of the Central Lagoon identified the bloom as the toxic cyanobacteria *Microcystis aeruginosa*. In 2018, releases of surface water from Lake Okeechobee to the Palm Beach Canal (C-51) via the L-8 Canal fueled blue-green algae blooms that came within eight miles of the Lagoon. During algae blooms, Environmental Resources Management (ERM) staff conducts reconnaissance in the C-51 Canal and southeast inflow locations of Lake Okeechobee to assess the threat of BGA reaching the Lagoon. Extensive and economically devastating BGA blooms in the St. Lucie, Caloosahatchee and other northern estuaries draining Lake

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Okeechobee prompted development of a draft risk assessment metric as part of pending updates to the U.S. Army Corps of Engineers' Lake Okeechobee System Operation Manual.[2] The South Florida Water Management District also increased sampling in watersheds vulnerable to toxic algae outbreaks. The Lagoon was not included in the ramped-up monitoring, but has indirectly benefitted from a concerted effort to avoid releases of nutrient-enriched water from Lake Okeechobee during the summer when algae blooms peak.

When necessary, ERM in conjunction with SFWMD and DEP conducts reconnaissance for blue-green algae in particular during the wet season when flows from the watershed into the Lagoon increase or when a suspected BGA bloom is reported by the public. Although the risk of BGA blooms in the Lagoon is currently low, ongoing vigilance is required. Additionally, there is clear evidence that cyanobacteria blooms are increasing with climate change, and scientists suspect these blooms could trigger or exacerbate blooms of other species including red tide.[3]

Red tide monitoring is coordinated at the state level with sampling results reported weekly by the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWRI). Red tides are rare on Florida's East Coast, although one reached Palm Beach County in fall 2018, causing fish kills and multiple beach closures. Concentrations high enough to cause respiratory irritation were detected inside the Lake Worth Lagoon at Phil Foster Park. ERM staff worked with FWRI to monitor levels for several weeks until the bloom subsided. FWRI continues to routinely monitor for red tide along established sites throughout Palm Beach County.

Prior to the 2018 event, red tide was last reported in the County in 2007. Red tides have been documented along the Florida east coast at least 8 times since the 1950's.

APPROACH:

STEP 1 Continue sampling for HABs, including blue-green algae and red tides, in addition to bacterial contaminants that could pose a health risk to marine life and the public. Evaluate the need to add additional sampling sites.

STEP 2 Better understand the current factors contributing to harmful algal blooms in the lagoon, and potential problem species in the future due to changing climate.

STEP 3 Identify sources of bacterial contamination at Phil Foster Park and other recreation areas where additional sampling indicates ongoing problems. Provide education about Best Management Practices (BMPs) to reduce bacterial loads in wastewater and stormwater.

STEP 4 Increase public education and awareness of HABs and waterborne pathogens, and ways to reduce exposure. Coordinate with the Health Department and FDEP to ensure that health advisories are posted in a timely manner utilizing multiple communication channels in order to reduce the potential health risks to the public.

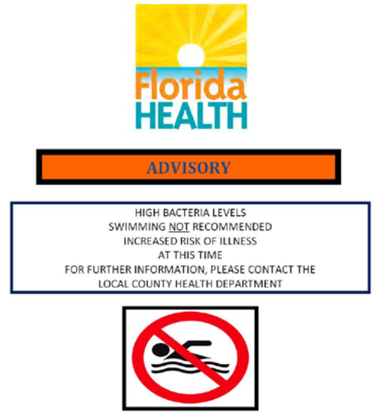
TIMEFRAME:

STEP 1 Ongoing. Evaluation of additional sites can occur in 2021 or 2022.

STEP 2 TBD, as opportunities to collaborate in research or expand monitoring arise.

STEP 3 TBD, when funds for source tracking study are available. Outreach about BMPs to reduce bacteria from broad-based sources such as pet waste or equestrian facilities can begin in 2021, with a literature review of existing programs and materials that can be adapted for County use.

STEP 4 A review of educational messages, materials and communication channels can occur in 2022 via collaboration with the Health Department, Lake Worth Waterkeeper, recreational equipment and ecotour providers, with an eye toward expanding outreach and leveraging internal and external communication platforms.



(Photo credit: Florida Healthy Beaches Program)

COST ESTIMATE:

STEP 1 $$$ for sampling of sites within Lagoon by Health Department and FWRI

STEP 2 Costs highly variable depending on scope of research and lead entities

STEP 3 $-$$ for educational outreach; $$-$$$ for source tracking study

STEP 4 $ Staff time only to coordinate communication review and planning

EVALUATING PROGRESS:

Number of recreation or high public use sites routinely sampled for bacterial contamination

Number of sites with high bacteria counts

Number of red tide or HAB events in or near the Lagoon

Number of citizens reached by health advisories

Number of targeted audiences (dog owners, septic tank owners, horse owners) reached by educational messages and materials about BMPs to responsibly manage waste

REGULATORY NEEDS:

None

FUNDING:

Recurring county/city budget allocations, recurring state agency budgets, grants for research or targeted education programs

POTENTIAL PARTNERS:*

PBC-ERM, PBC Health Department, FDEP, State Blue-Green Algal Task Force, FWRI, SFWMD, Lake Worth Waterkeeper, UF/IFAS Florida Sea Grant, academic institutions and research organizations

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

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1 Governor's Blue-Green Algae Task Force Consensus Document. October 2019. https://floridadep.gov/sites/default/files/Final%20Consensus%20%231_0.pdf

2 LOSOM Algae Bloom Risk Assessment Metric, CERP System-Wide or Project Performance Measure. October 2020. https://protectingfloridatogether.gov/sites/default/files/documents/LOSOM_Algal_Bloom_Risk_Metric_Documentation_Sheet.pdf

3 State of the Science for Harmful Algal Blooms in Florida: Karenia brevis and Microcystis spp. Summary from Florida Harmful Algal Bloom State of the Science Symposium. August 2019.

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WQ-5 IDENTIFY AND ASSESS THE IMPACTS OF EMERGING CONTAMINANTS

ACTION: Identify sources and distribution pathways for contaminants found in pharmaceuticals, personal care products and microplastics throughout the watershed and Lake Worth Lagoon. Assess and monitor impacts on living resources. Promote education to reduce pollution from microplastics and emerging contaminants.

IMPORTANCE:

Currently, the short term and cumulative impacts of emerging contaminants to the Lagoon's environment, fish, shellfish, turtles, manatees and water quality are unknown. Gathering baseline information about these contaminants is an important first step in assessing whether and to what extent they pose a threat to fish, wildlife and human uses of the Lagoon.

RELATED ACTIONS:

WQ-1, WW-1, WW-2, PO-1

BACKGROUND:

Global research is confirming the widespread presence in waterways of a variety of chemical compounds that are byproducts of our everyday lives. These include tiny fragments of plastic, human and animal medications, and personal care products such as cosmetics and lotions. Together they encompass literally thousands of substances.

These "emerging contaminants" find their way to surface and groundwater through multiple routes. They may be flushed down drains and transported in wastewater effluent or septic leachate *(See Actions WW-1 and WW-2)*. They may be tossed in trash cans and wind up in landfills, where they can spread to groundwater. They may be carried in rainfall runoff from biosolids used on farms or manure from ranches and livestock operations. Research has shown that some of these compounds are not completely removed by wastewater treatment processes, and may persist for decades in the water column or sediments.[1] Scientific understanding of how these chemicals influence living organisms, what concentrations or combinations trigger effects, and how they interact with complex aquatic food webs is far from complete.

Little is known about the existence, distribution or accumulation of these contaminants in the waters, sediments or fish and wildlife of the Lake Worth Lagoon. A basic assessment of the presence of these contaminants in the Lagoon is a practical first step to inform future actions.

Microplastics

Microplastics are pieces of plastic less than 5 millimeters, or about one-quarter inch, in size. These tiny plastic pellets, also called "nurdles," may be manufactured as small pellets, or may result from the breakdown of larger plastic marine debris. Aquatic life and birds can mistake microplastics for food, causing physical blockage or damage to the digestive tract, and leaching of chemical components into tissues. Filter feeders also may unintentionally ingest them: Microplastics have been found embedded in the tissues of worms, crustaceans, and sea cucumbers.[2] Microplastics were found in nearly 80% of upside-down jellyfish (*Cassiopea xamachana)* examined in three Florida estuaries, including Jupiter in Palm Beach County.[3] Plankton tows conducted in 2019-2020 by researchers studying Giant Manta Rays (*Manta*

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SOURCE: Palm Beach Atlantic University

birostris) in Indonesia (a species also found in Southeast Florida waters) unexpectedly harvested microplastics in virtually every tow.[4] The Loggerhead Marinelife Center (LMC) in Juno Beach reports that nearly 100% of post-hatchling sea turtles brought to the facility for care have plastics in their stomachs.[5]

A study completed in 2020 on the abundance and variation of microplastics in surface waters of the Lagoon found an average of 8.6 microplastic pieces per liter.[6] A total of 414 pieces of microplastics were counted from 48 samples collected at three sampling locations in the north, central and south Lagoon *(see Figure 1.1)*. Fibers were the most abundant type of microplastics found, followed by fragments and films *(See Table 1.1)*. No microbeads were present. There was no statistical difference in the amount of microplastics found in the sampling locations. To date, this work is the most extensive sampling for microplastics conducted in the Lagoon.

TABLE 1.1 MEANS, STANDARD ERROR, AND SUMS FOR THE THREE TYPES OF MICROPLASTICS (N=48)

MICROPLASTIC TYPE	MEAN +/- SE	SUM
Fibers	5.40 ± 0.50	259
Fragments	2.42 ± 0.35	116
Films	0.81 ± 0.17	39
TOTAL		414

SOURCE: Palm Beach Atlantic University

Prior to this effort, the only known microplastics sampling in the Lagoon was conducted in 2016 at Phil Foster Park, as part of the Florida Microplastics Awareness Project (FMAP) coordinated by UF/IFAS Florida Sea Grant. That limited effort (only a handful of samples) collected primarily fibers rather than plastic pieces. More data from more sites, gathered and analyzed consistently over a longer timeframe utilizing improved protocols, is needed to better understand the scope of microplastics pollution in the Lagoon.

Ocean currents and circulation patterns scatter microplastics like confetti, making them difficult to track. But this also presents an opportunity to capitalize on a citizen-science effort that is exploring how localized currents affect the way particles, including marine debris and pollutants, travel in and around the Lagoon. Launched in 2017 by the ANGARI Foundation, the project enlists citizens to decorate, deploy, recover and report small wooden degradable drift cards. For the most recent data for the LWL Drift Card Study, visit angari.org/lagoondrift. Four deployments occurred in the Lagoon from 2017-2019. Deployments for 2020 were cancelled due to Covid-19, with tentative plans to resume in 2021 (*see Figure 1.2*).

Some 59% of the recovered drift cards were found within the Lagoon, with the majority recovered along the western shore. The remainder were found outside the Lagoon, a somewhat surprising result given the Lagoon's limited connectivity with the ocean *(See Table 1.2)*.

This information could help to guide initial baseline sampling for microplastics that aligns with the County's goal of expanded, watershed-scale monitoring in the Lagoon (*see Action WQ-1*). The ANGARI Foundation is interested in partnering with the County, collecting samples at stationary locations and through plankton tows within the Lagoon. A partner with the capability for laboratory analysis is needed; researchers from Florida Atlantic University's Harbor Branch Oceanographic Institute and Harriet L. Wilkes Honors College already are conducting a range of research into the fate and transport of microplastics and may be logical partners, along with other regional universities.

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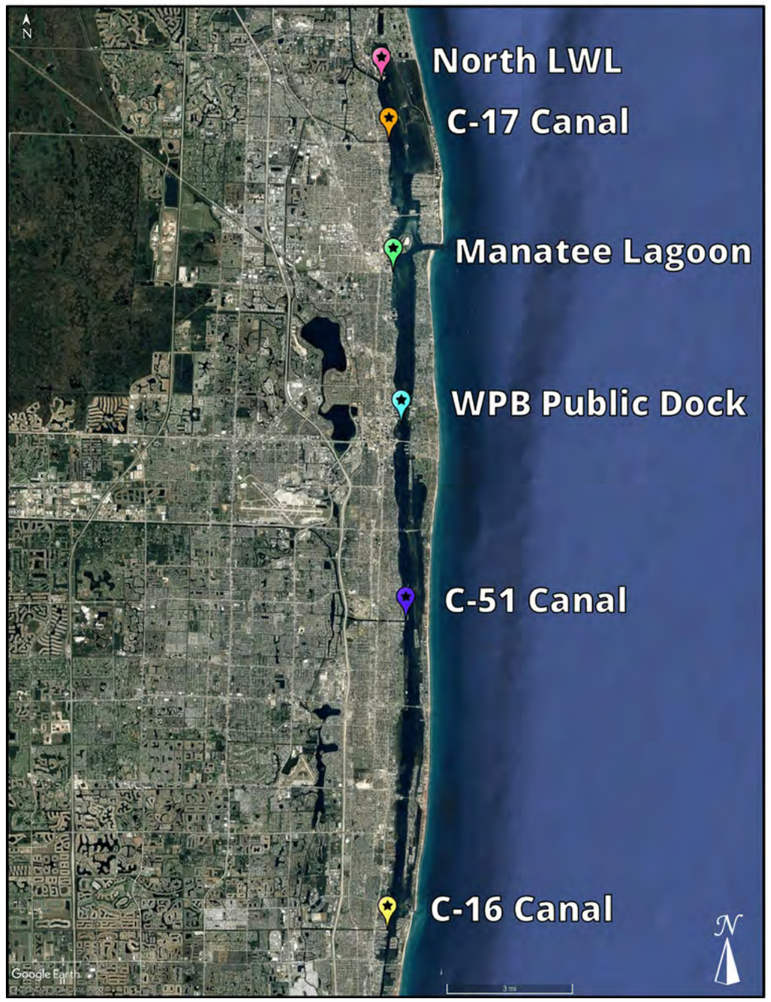
The lack of a dedicated Sea Grant agent for Palm Beach County has posed challenges to participation in the Florida Microplastic Awareness Project, a citizen-science project that trains volunteers to collect, filter and document microplastics. However, the Loggerhead MarineLife Center serves as a local hub for education about microplastics, and plastic pollution in general. The Center is a logical partner for outreach to encourage reuse, reduction and recycling of plastics and to involve citizen-scientists in microplastics sampling.

FIGURE 1.2 DRIFT CARD RELEASE SITES



SOURCE: ANGARI Foundation

Pharmaceuticals and Personal Care Products

Pharmaceuticals and Personal Care Products (PPCPs) include thousands of substances used for personal health or cosmetic purposes, as well as prescription and over-the counter drugs intended for human and veterinary use. These substances have been shown to pose a risk to fish or other wildlife in aquatic environments, by affecting their ability to reproduce, altering their behavior, or through direct toxicity.[7]

For example, the synthetic estrogen used in human contraceptives (ethinyl estradiol) and constituents of six commonly prescribed anti-depressants were observed at detectable and, in some cases, quantifiable levels in plasma of Caloosahatchee River sharks.[8]

Research published in 2015 found that fathead minnows exposed to a suite of highly prescribed narcotics, sleep aids, muscle relaxants and anti-depressants found in treated wastewater experienced variable effects ranging from reduced growth, to abnormally large livers (females), to production of proteins indicative of feminization (males).[9]

Wastewater treatment plants, which are built to remove solids and contaminants from water before release into the environment, aren't designed to remove chemicals found in pharmaceuticals and similar products, although there is evidence that treatment can dilute them. However, proof is mounting that even at exceptionally low concentrations, these contaminants can be harmful to fish.

Once in a water body, actual exposure is difficult to determine because of the varied source pathways (wastewater, stormwater, landfill leachate) as well as highly variable environmental conditions. Another challenge lies in assessing the potential effects on fish and wildlife of exposure to multiple PPCPs, potentially over long periods.

Current toxicity testing required of chemical products does not evaluate endocrine-disrupting effects. Research also is needed to assess the efficacy of various wastewater treatment technologies at removing these contaminants prior to discharge or reuse.

To date, no studies have been conducted to assess potential source pathways or concentrations of PPCPs in Lagoon sediments, waters, or living organisms.

Educational efforts are underway to draw attention to the environmental threats posed by PPCPs. A National Prescription Drug Take Back Day provides a mechanism for safe disposal of prescription drugs. The most recent Take Back Day, held on October 24, 2020, brought in a record 492.7 tons of medications nationwide and 19 tons in Florida. Many major pharmacy retailers, including CVS and Walgreens in Palm Beach County, also routinely accept unused prescription medications for disposal.

APPROACH:

STEP 1 Support sampling and analysis to assess the scope and distribution of microplastics in the watershed and LWL. Monitoring data is essential to better characterize occurrence levels and to inform next steps.

STEP 2 Track research on PPCPs in wastewater and surface water, and emerging research on associated toxicity in fish and wildlife. Support localized research that addresses the presence of microplastics or PPCPs in treated effluent, septic and landfill leachate, agricultural runoff, and in downstream receiving waters in the Lagoon watershed.

STEP 3 Promote and support education about emerging

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contaminants to the public, and ways to reduce plastic pollution and PPCPs. Support prescription drug take-back programs.

TIMEFRAME:

STEP 1 can be expanded in 2021 if a partnership can be established for lab analysis of samples.

STEP 2 is ongoing, with in-kind support for localized research as opportunities arise.

STEP 3 can begin in 2021, with inclusion of info about microplastics and PPCPs in social media posts and with distribution of existing materials at community events and through K-12 education partners.

COST ESTIMATE:

STEP 1 $-$$ depending on scope of sampling program

STEP 2 $ (no direct costs associated with monitoring published research; staff time for letters of support for local research, or access to water quality monitoring program data)

STEP 3 $ (utilizing existing materials developed by partner organizations such as The Loggerhead Marinelife Center or UF/IFAS Extension Sea Grant)

EVALUATING PROGRESS:

Number of samples collected and analyzed for microplastics

Number of citizens engaged in Drift Card project, or microplastics sampling and analysis

Number of citizens reached with educational messages and materials

REGULATORY NEEDS:

None

FUNDING:

Possible grant funding through NOAA Marine Debris grants or private foundations

POTENTIAL PARTNERS:*

PBC-ERM, local municipalities, ANGARI Foundation, Loggerhead Marine Life Center, PBAU, FAU or other universities and colleges, UF/IFAS Extension Sea Grant

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

1 The occurrence of pharmaceuticals, personal care products, endocrine disruptors and illicit drugs in surface water in South Wales, UK. Kasprzyk-Hordern, B. et al. Water Research 2008.

2 Critical Review: Grand Challenges in Assessing the Adverse Effects of Contaminants of Emerging Concern on Aquatic Food Webs. Nilsen. E., et al. Environmental Toxicology and Chemistry. 2018.

3 Evidence of microplastics from benthic jellyfish (*Cassiopea xamachana) in Florida estuaries. Iliff S.M., et al. Marine Pollution Bulletin 159. 2020.*

4 Pate, Jessica. Personal Communication. 2020.

5 https://marinelife.org/2020/10/11/the-plastic-apocalypse/

6 Effects Tides and Location Have on the Abundance and Variation of Microplastics in the Surface Waters of the Lake Worth Lagoon. O'Brien, K. Senior Research Paper, Palm Beach Atlantic University. 2020.

7 Options for a strategic approach to pharmaceuticals in the environment. Final Report to the European Commission. Deloitte Sustainability. 2018.

8 Uptake of human pharmaceuticals in bull sharks (Carcharhinus leucas) inhabiting a wastewater-impacted river. Gelsleichter J, Szabo NJ. Sci Total Environ. 2013

9 https://www.usgs.gov/news/understanding-how-pharmaceuticals-environment-affect-fish

TABLE 1.2 DRIFT CARD DEPLOYMENT AND RECOVERY SITES

RELEASE DATE (TIME)	RELEASE SITES	# CARDS RELEASED	# CARDS RECOVERED (RECOVERY RATE IN %)		
November 2, 2019 (15:00)	Burt Reynolds Park C-17 Canal Manatee Lagoon WPB Public Dock C-51 Canal C-16 Canal	240	**58 (24%)**		
			IN LWL	OUTSIDE	CANAL/ ICW
			26 (45%)	27 (47%	5 (9%)
April 11th, 2019 (15:00)	North end LWL C-17 Canal Manatee Lagoon WPB Public Dock C-51 Canal C-16 Canal	240	**78 (33%)**		
			IN LWL	OUTSIDE	CANAL/ ICW
			30 (38%)	41 (53%)	7 (9%)
September 9th, 2018 (11:00)	North end LWL C-17 Canal Manatee Lagoon WPB Public Dock C-51 Canal C-16 Canal	240	**35 (15%)**		
			IN LWL	OUTSIDE	CANAL/ ICW
			27 (77%)	7 (20%)	1 (3%)
April 8th, 2018 (15:30)	North end LWL North end LWL C-17 Canal Manatee Lagoon WPB Public Dock C-51 Canal C-16 Canal	240	**34 (14%)**		
			IN LWL	OUTSIDE	CANAL/ ICW
			23 (68%)	10 (29%)	1 (3%)
November 5th, 2017 (12:00)	C-17 Canal Manatee Lagoon WPB Public Dock C-51 Canal	160	**48 (30%)**		
			IN LWL	OUTSIDE	CANAL/ ICW
			43 (90%)	5 (10%)	0 (0%)
TOTAL		1,120	**253 (23%)**		
			IN LWL	**OUTSIDE**	CANAL/ICW
			149 (59%)	**90 (36%)**	**14 (6%)**

** Percentages may not total 100 due to rounding*

SOURCE: ANGARI Foundation

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WQ-6 MANAGE FRESHWATER INFLOWS TO OPTIMIZE ENVIRONMENTAL BENEFITS

ACTION: Evaluate and implement strategies to balance freshwater flows to achieve optimal salinities for oysters and seagrasses, and decrease nutrients and sediments entering the Lagoon.

IMPORTANCE:

The delivery and timing of freshwater to the Lagoon is critical to maintaining the health of the Lagoon's living resources and to boosting their resiliency to climate change and sea level rise.

RELATED ACTIONS:

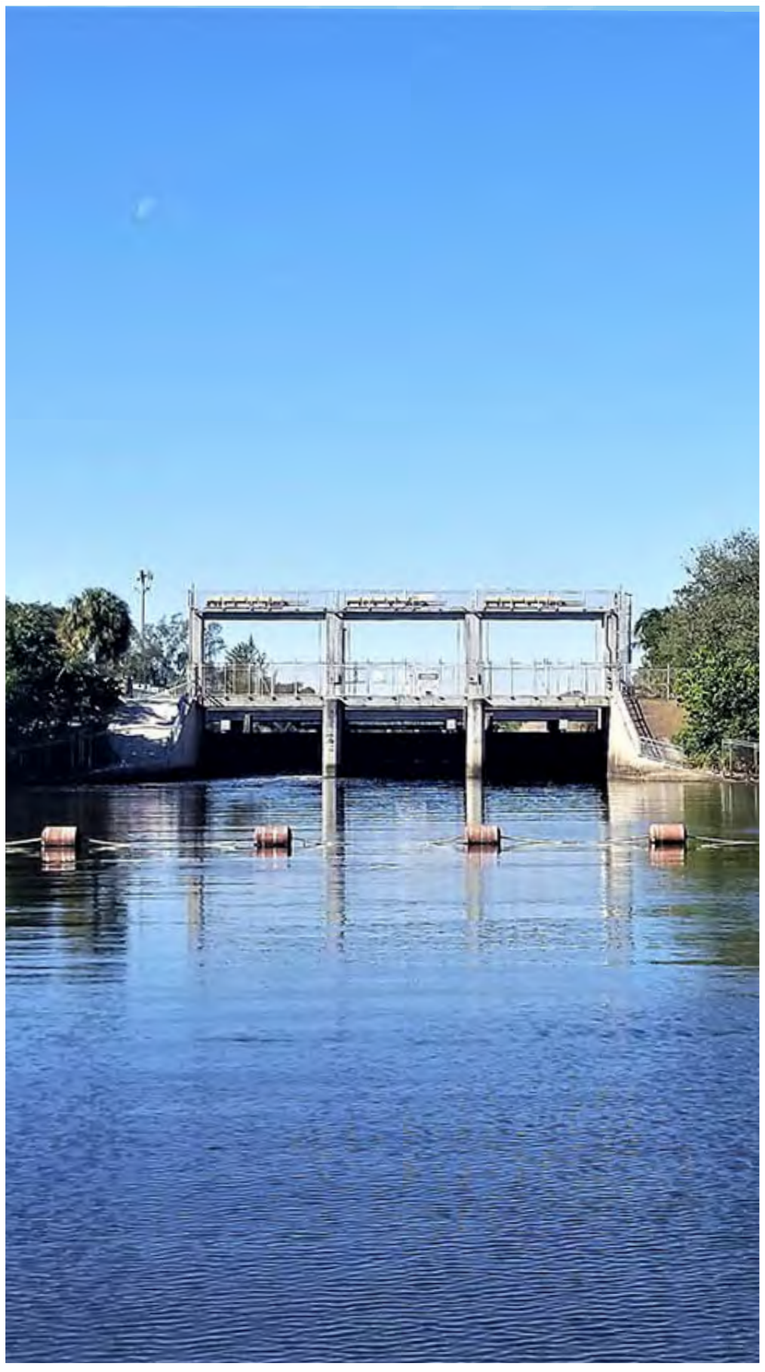
WQ-1, WQ-2

BACKGROUND:

Almost all of the freshwater entering the Lake Worth Lagoon is transported via three major drainage canals – the C-51, C-16 and C-17 *(see Figure 1.1)*. They receive water from more than 850 miles of smaller canals that, combined, drain a watershed 42 times the size of the Lagoon itself. Responsibility for management of this vast network is shared by the South Florida Water Management District (SFWMD), eight additional water improvement agencies and water control districts, Palm Beach County and 30 municipalities within the watershed.

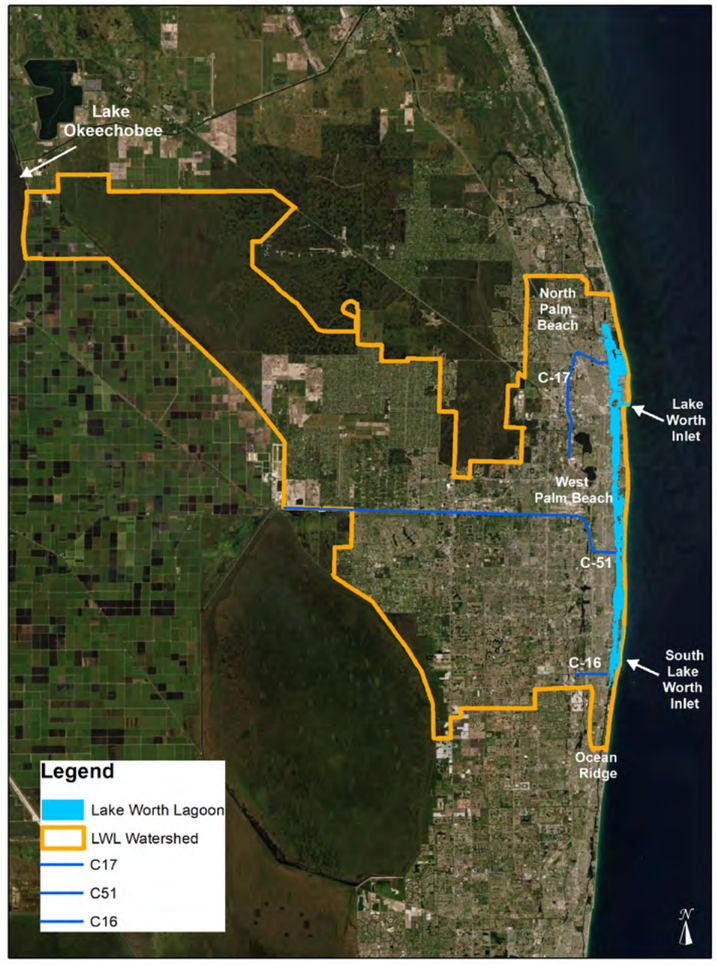
The C-51, C-16 and C-17 canals and associated water control structures are managed by the South Florida Water Management District for the primary purpose of flood control. They are not as a matter of principle or practice operated to deliver freshwater in volumes or on schedules that meet the ecological needs of the Lagoon's key indicators of ecosystem health: the American oyster (*Crassostrea virginica*) and three species of seagrass: paddle grass (*Halophila decipiens*), shoal grass (*Halodule wrightii*) and Johnson's seagrass (*Halophila johnsonii*), a federally threatened species.

The optimal salinity range for oysters in the Lake Worth Lagoon is 12-20 parts per thousand (ppt).[2,3] The optimal



Water control structure on the C-51 Canal (Photo credit: PBC-ERM)

FIGURE 1.1 WATERSHED MAP



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SOURCE: PBC-ERM

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salinity range for seagrasses is 22-35 ppt.[5] Current operational protocols for the canal network mean that Lagoon oysters are exposed to higher salinities than they prefer during the dry winter months, while seagrasses, especially within the Central Lagoon, are often subjected to lower salinities than optimal for sustained growth and/or survival.

Nine years of data collected from a salinity sonde at John's Island, located directly east of the C-51 canal, show that salinity fell below 10 ppt on 180 of 620 days recorded, or 30% of the time *(see Table 1.1)*. Adverse effects to paddle, shoal and Johnson's seagrass can occur when salinity falls below 15 ppt for prolonged periods[1] (*see Action HE-3*). Additionally, oyster reproduction is impaired at salinity levels below 8 ppt[5] (*see Action HE-1*).

Conversely, oysters experience higher prevalence of predation and disease at salinities greater than 32 ppt.[5] Average salinities for the Lagoon from 2005 to April 2019 exceeded the optimal range for oysters 70% of the sampled months and were in the optimal range only 26% of the time sampled.[2]

Freshwater flows to the Lagoon are frequently characterized by extreme highs and lows which subsequently impact salinity. The most recent oyster monitoring report from the Florida Fish and Wildlife Conservation Commission shows that salinity varied significantly month to month (from a low of 8 ppt to a high of 36 ppt), corresponding with variable flows from the C-51 Canal *(see Figure 1.2)*. The lowest flow rates were measured in March 2020 when the monthly mean was 0 cubic feet per second. Highest flows were in March 2019, at 743 cfs.[3] Additionally, analysis of high frequency salinity data recorded in the Central Lagoon at John's Island revealed several distinct events, both in duration and severity (low salinity), that could severely stress seagrass species.[6] These extended periods of no flows and extremely high flows are the main culprit in salinity fluctuations that are damaging to oysters and seagrass.

This action seeks to modulate freshwater inflows to maximize environmental benefits, especially in the Central Lagoon. This segment is a priority because it receives a disproportionate amount of freshwater via the C-51 Canal, it has the largest population of oysters, and the longest water residence time (up to 13 days).[4] The desired salinity envelope within the Central Lagoon is 12-20 ppt.

Progress in addressing freshwater inflows has been hampered by the exclusion of the Lagoon from the Northern Estuaries management area of the Comprehensive Everglades Restoration Plan since 2007. However, a pending update of the Lake Okeechobee Standard Operating Manual (LOSOM) has provided an opportunity for Palm Beach County to request that salinity standards, or Performance Indicators, be established for discharges from Lake Okeechobee to the Lagoon.

Although discharges from the Lake are historically a small fraction of the total freshwater coming from the Lagoon watershed, development of Performance Indicators would facilitate use of a predictive model to evaluate ways to maintain optimal salinities for oysters and seagrasses. The model could serve as a pilot for subsequent adaptation and expansion to address the timing and quantity of freshwater runoff from the entire Lagoon drainage basin *(see Action WQ-2)*. In addition to seagrasses and oysters, Lagoon fisheries also would benefit from more dependable and consistent freshwater flows, as several species require predictable salinities, especially in juvenile and sub-adult life stages *(see Action FW-3)*.

Deployment of the model would also help system operators and Lagoon managers evaluate options for achieving optimal salinities, among them:

- Modifications to existing Stormwater Treatment Areas (STAs) to increase capacity and reduce nutrient and sediment loads to the Lake Worth Lagoon.
- Identification of new STAs and alternate water storage options, potentially within urban stormwater systems.
- Modifications to water control structures to release water from the top rather than the bottom of floodgates and weirs, to slow water movement. This option would require ongoing removal of sediments that build up behind the structures.

APPROACH:

STEP 1 Evaluate and implement modifications to operational protocols for drainage canals and water control structures to reduce damaging freshwater pulses and velocities, as well as nutrient and sediment loading *(See Action WQ-3)*.

STEP 2 Evaluate and implement improvements to canal operations to reduce dramatic fluctuations in freshwater flows that contribute to salinity extremes.

TABLE 1.1 ACTUAL VS. OPTIMAL SALINITY FOR CENTRAL LAGOON (JOHN'S ISLAND SONDE)

	Minimum Salinity Target (ppt)	Optimal Salinity	Central LWL Salinity (ppt)	References for Optimal Salinity
Oyster Tolerance (Adult)	15	10-28	22.7	Loosanoff, 1965 in Rudolph 1998
Oyster Growth (Adult)	15	8-22	22.75	Mote Marine Laboratory, 1990 in Rudolph, 1998
Oyster Growth (Spat)	15	15-22	22.7	Sellers and Stanley, 1984
Oyster Spawning	15	>7.5	22.7	Sellers and Stanley, 1984
Seagrass Growth *(Halodule wrightii)*	20	23-37	22.7	McMahan, 1968 in Rudolph 1998
Seagrass Flowering *(Halodule wrightii)*	20	26-36	22.7	McMahan, 1968 in Rudolph 1998

Optimum target range: WITHIN ABOVE BELOW

Salinity ranges contained in the Northern Estuaries Performance Measure Salinity Envelopes.[2]

SOURCE: PBC-ERM

Develop a long-term water management plan to maintain optimal salinity ranges for oysters and seagrasses.

STEP 3 Support modifications to existing STAs to improve storage capacity, nutrient reduction and sediment containment.

STEP 4 Identify potential new Stormwater Treatment and Water Conservation Areas in the western C-51 basin to capture, treat and gradually release freshwater downstream. Identify potential STAs in the eastern C-51 basin, including small-scale sites of 1 acre or more within neighborhoods and golf courses.

TIMEFRAME:

STEP 1 can begin in 2021 with initial consideration of operational modifications, and development of a framework for hydrodynamic modeling. Development of the model itself is dependent upon funding through grants or other mechanisms.

STEPS 2, 3 and 4 can begin in FY 2021, with evaluation of effectiveness of techniques in FY 2022-2023 and beyond.

COST ESTIMATE:

$$-$$$$$

EVALUATING PROGRESS:

Water quality monitoring combined with data from salinity sondes will document salinities in relation to flows from C-51, rainfall, and other parameters.

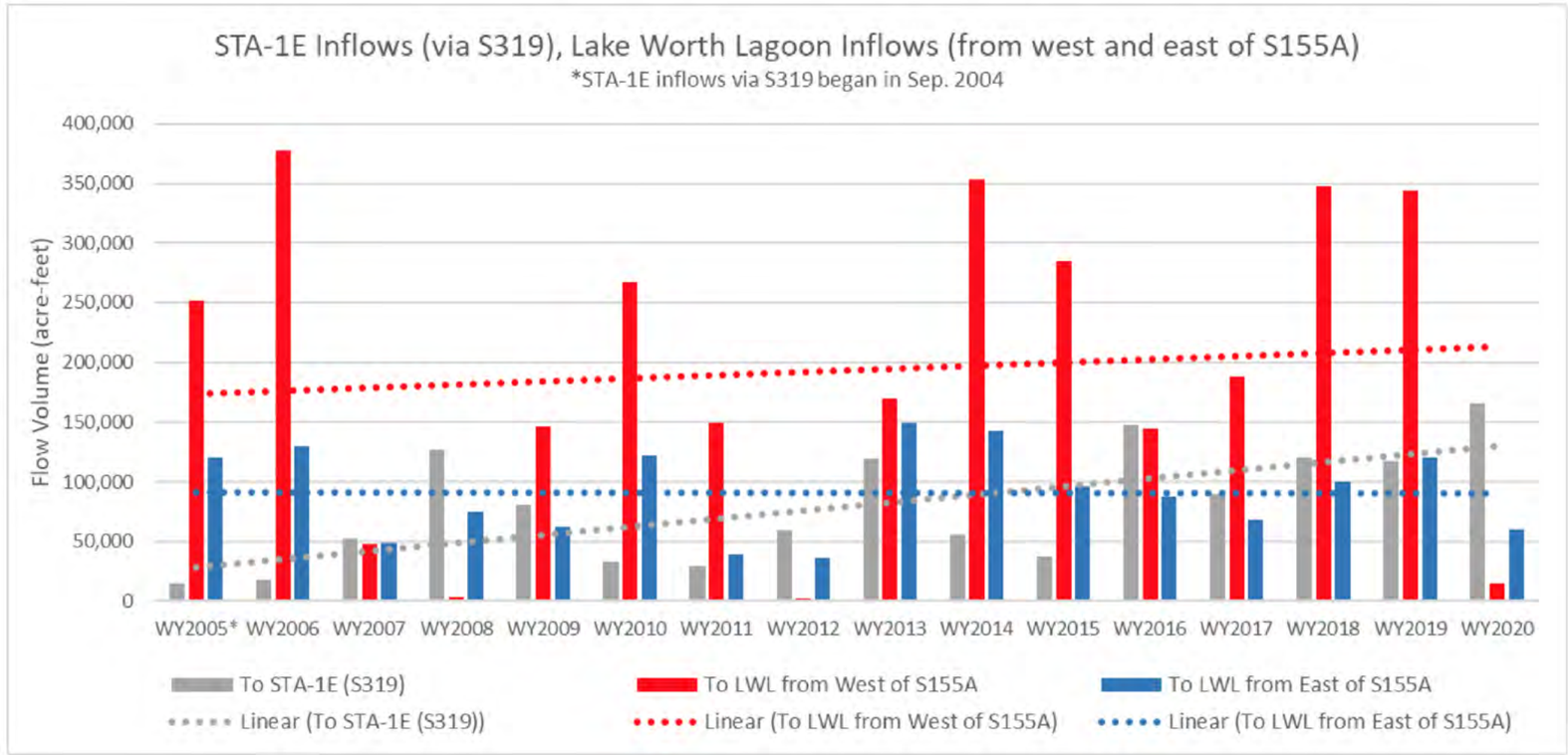
REGULATORY NEEDS:

None

FUNDING:

To be determined, depending on management steps to be implemented and land acquisition needs identified.

FIGURE 1.2 FRESHWATER FLOWS TO LAKE WORTH LAGOON FROM EAST AND WEST OF S155A 2005-2020



SOURCE: PBC

POTENTIAL PARTNERS:*

ERM, SFWMD, USACOE, Local Municipalities

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

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1 Northern Estuaries Performance Measure Salinity Envelopes. CERP System-Wide Performance Measure Documentation Sheet. 2007 and 2020.

2 LWL Oyster Monitoring Program Summary. Parker, M. Florida Fish and Wildlife Conservation Commission. 2020.

3 Oyster monitoring in Lake Worth Lagoon Final Report April 2019 – June 2020. Geiger, S and Maloney, N. Florida Fish and Wildlife Conservation Commission. 2020.

4 Assessment of Freshwater Inflow and Water Quality for an Urbanized, Subtropical Estuary (Lake Worth Lagoon, Florida, USA). Buzzelli, C., et al. Marine Technology Society Journal. 2018.

5 LOSOM Performance Measure Documentation Sheet. 2020.

6 2020 Lake Worth Lagoon Fixed Transect Seagrass Monitoring. CSA Ocean Sciences Inc. 2021.

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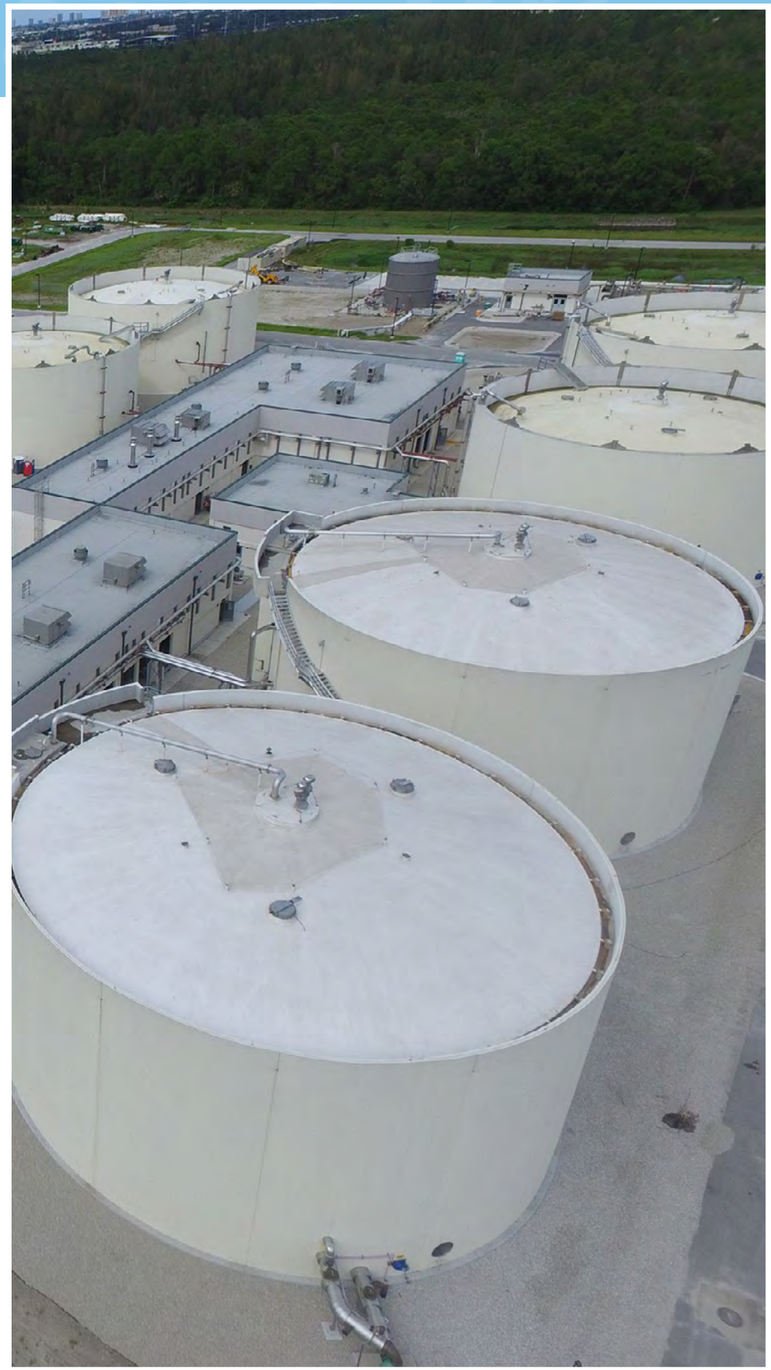
WW-1 ASSESS AND REDUCE OCCURRENCE OF SEWER OVERFLOWS

ACTION: Create a decision-support tool to assess, prioritize and inform management decisions about wastewater system problem areas with a high likelihood of sanitary sewer overflows and/or spills that could impact the Lake Worth Lagoon. Encourage the installation and maintenance of emergency generators to ensure uninterrupted wastewater collection and treatment functions during power outages. Encourage the implementation of proactive management and maintenance programs to reduce system failures and implement short- and long-term solutions. Educate citizens about proper use of wastewater systems, and what items should not be disposed down drains and toilets.



East Central Water Reclamation Facility (Photo credit: PBC)

IMPORTANCE:

Overflows and spills of treated and untreated wastewater pose a threat to public health, environmental resources, and the economic viability of tourist-driven local economies.

RELATED ACTIONS:

WQ-1, WQ-5, WW-2, PO-1

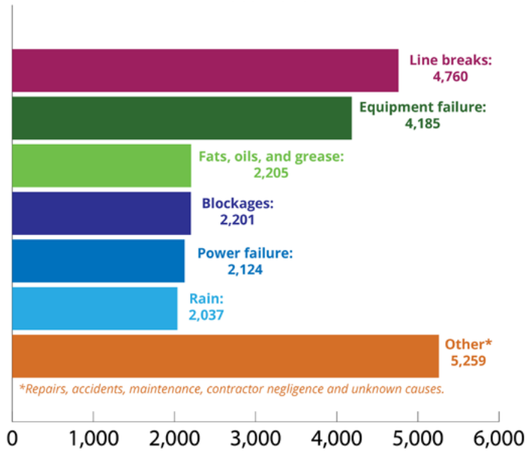
BACKGROUND:

Sanitary sewers can overflow for a number of reasons, including improper design and capacity, aging infrastructure, line blockages and breaks, infiltration and inflow of stormwater, malfunctioning equipment and a lack of backup power sources to keep lift stations operating in emergencies. Wastewater discharged into the Lake Worth Lagoon is a threat to both environmental and human health. Raw sewage contains harmful bacteria as well as microplastics, pharmaceuticals, personal care products and other household chemicals. *(see Action WQ-5)*

Addressing these challenges through proper operation and proactive maintenance, capital improvement investments in repairs and replacements, and public education about proper use of the wastewater system will help reduce the incidence of sanitary sewer overflows.

From 2009-2018, nearly 23,000 sewage spills have been reported statewide to the Florida Department of Environmental Protection (FDEP). These spills released about 1.6 billion gallons of wastewater, including more than 370 million gallons of untreated sewage, according to an analysis of state data.[1] From 2014-2019, FDEP records show that 69 sewer overflows were reported in Palm Beach County, including a January 2014 release of 2.3 million gallons of treated wastewater into the Intracoastal Waterway near Delray Beach *(see Figure 1.1)*.

FIGURE 1.1 CAUSES OF SEWER SPILLS IN FLORIDA 2009-2018



SOURCE: Florida Department of Environmental Protection

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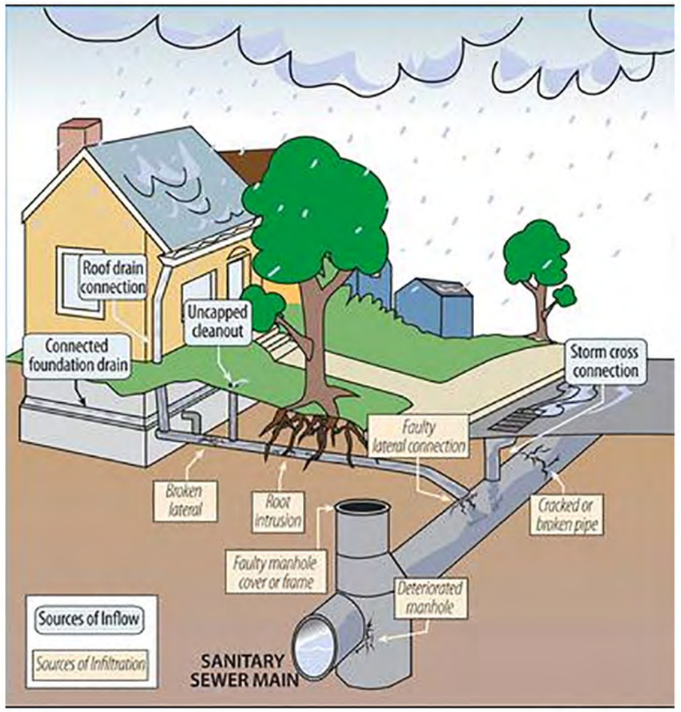
Sanitary sewer overflows (SSOs) in urban areas like the Lagoon watershed are primarily caused by stormwater infiltration/inflow from heavy rains, and line blockages and breaks *(see Figure 1.2)*. Heavy rains funnel stormwater into cracked sewer pipes, overwhelming lift station capacity, causing manholes to overflow, and sending wastewater into nearby water bodies. Spills happen most often during storm events: In October 2020, rains from Hurricane Eta combined with stormwater inflows to overwhelm some lift stations and cause force main breaks in West Palm Beach, Lake Worth Beach and Palm Beach County, according to reports submitted by those governments to FDEP. Approximately 1,500 gallons of raw sewage spilled along Washington Road and South Flagler Drive in West Palm Beach, flowing into a storm drain discharging to the Lagoon before the spill was contained.

Multiple communities own and operate wastewater utility components within the Lagoon watershed *(see Figure 1.3)*. Infrastructure improvements are underway or planned in several communities. For example, the City of West Palm Beach's capital improvement plan includes 18 lift station projects involving, rehabilitation or replacement of wet wells, pumps, electrical systems and/or operational controls. The City also plans repair or replacement of existing sewer pipelines in high-priority areas.

Throughout the Lagoon watershed, installation of emergency generators at central lift stations is an interim step that could immediately reduce the potential for overflows *(see Figure 1.4)*.

Preventive maintenance is a cost-effective strategy that could benefit all communities in the Lagoon watershed. The U.S. Environmental Protection Agency's Capacity, Management, Operation, and Maintenance (CMOM) manual provides guidance for self-audits of wastewater systems to reduce overflows. CMOM programs shift maintenance actions from reactive to proactive, create operational efficiencies, reduce risk, and save money by lowering emergency repair and response costs.

FIGURE 1.2 SOURCES OF INFLOW AND INFILTRATION INTO SANITARY SEWERS



Source: EPA

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They also improve internal and external communications.

The 2020 Clean Waterways Act creates a wastewater grants program within FDEP that provides 50% matching funds to local governments for constructing, upgrading, or expanding facilities to provide advanced wastewater treatment. The law also gives preference in state revolving loan funds to wastewater projects that prevent leaks, overflows, infiltration, and inflow. It also substantially increases penalties for failing to prevent spills.

An important first step in developing a comprehensive plan to reduce spills in the Lagoon watershed is to develop a GIS database and prioritization process to help identify and communicate wastewater collection components with the highest potential to impact Lagoon water quality. This tool would consider age, condition, proximity to the Lagoon or drainage canals, water table elevation, vulnerability to sea level rise and other relevant factors. The County's Department of Environmental Resources Management (ERM) has expertise in identifying sensitive habitats and other environmental considerations, while the County's Wastewater Department can provide information about chronic problem areas, based on documented spills, emergency repairs and cleanouts in response to line breaks, overflowing manholes and blockages.

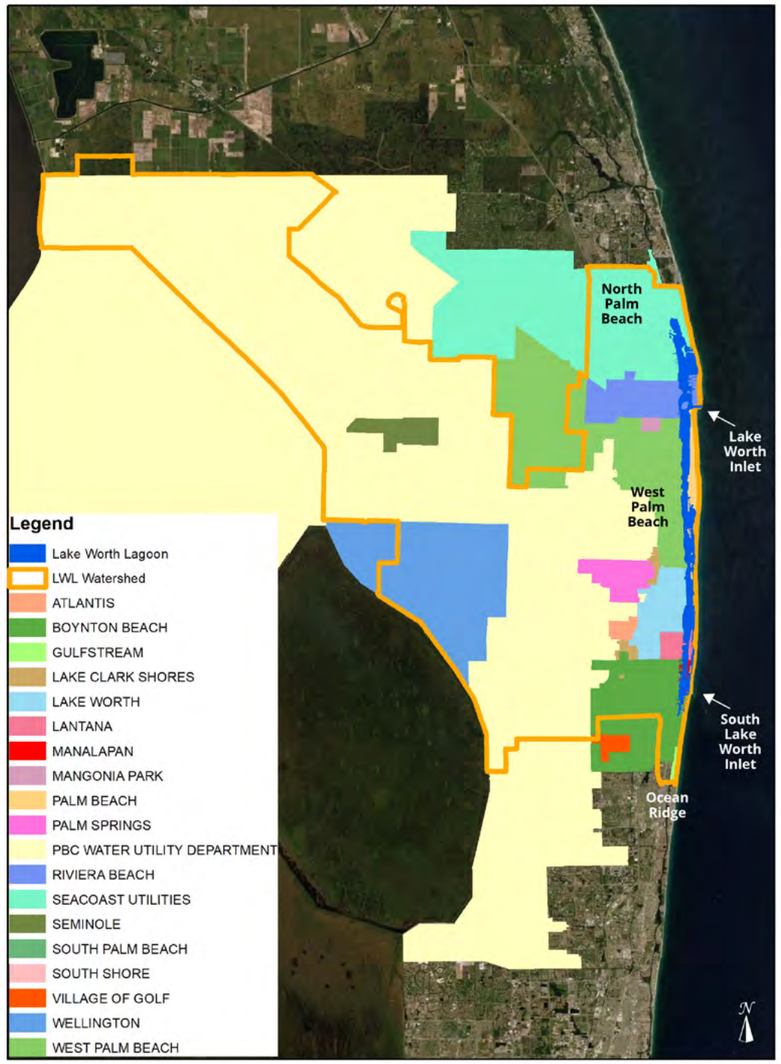
Together, this information could be used to create a decision tool or matrix that sets priorities for short- and long-term infrastructure improvements that reduce the potential for overflows or spills impacting the Lagoon.

Public education is a critical component of efforts to reduce overflows. Restaurants, transportation/equipment cleaning establishments, service stations, repair shops, and other commercial activities are required to use grease traps, interceptors, or oil/water separators to keep greases and oils out of the sewer system.

However, residents routinely flush inappropriate items down drains and toilets – including disposable wipes, kitchen grease, oils, and feminine products – clogging pipes and overflows of raw sewage into the environment. Consolidation of these

Typical "fatberg" in municipal sewer line

FIGURE 1.3 WATERSHED UTILITY SERVICE AREAS IN THE LAGOON WATERSHED



Source: PBC

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materials in sewer pipes is so common worldwide that they've been given the name "Fatbergs."

Cracked lateral sewer lines that connect homes and businesses to the public sewer system also cause backups and overflows by allowing stormwater and groundwater to enter and swamp the system *(see Figure 1.3)*. Property owners are largely unaware that they are responsible for maintenance and replacement of these private laterals. Costs for lateral line replacement range from $3,000-$10,000, depending on the length of the line and excavation difficulty. A rebate program like those offered by the cities of Gulfport and St. Petersburg in the Tampa Bay area could encourage homeowners in priority "hot spots" to invest in upgrades.

Educating and incentivizing citizens to understand what can and cannot be flushed down toilets, sinks and drains, and the importance of maintaining their privately owned laterals, will reduce sewage spills and overflows. Addressing proper use and maintenance of the sanitary sewer system will reduce the release of nutrients and pathogens into the environment.

APPROACH:

STEP 1 Encourage installation of emergency generators to ensure continued operation of lift stations in the event of power failures.

STEP 2 Create a decision-support tool for prioritizing wastewater system improvements, including a map of "hot spots" of chronic overflows and problem areas, and identification of environmental risk factors.

STEP 3 Encourage wastewater utilities within the Lagoon watershed to develop and implement a CMOM program to proactively address maintenance needs. A working group of representatives of wastewater departments could develop a uniform checklist for adoption throughout the watershed. This working group could also develop protocols for improved coordination and communications especially during high rainfall/storm events.

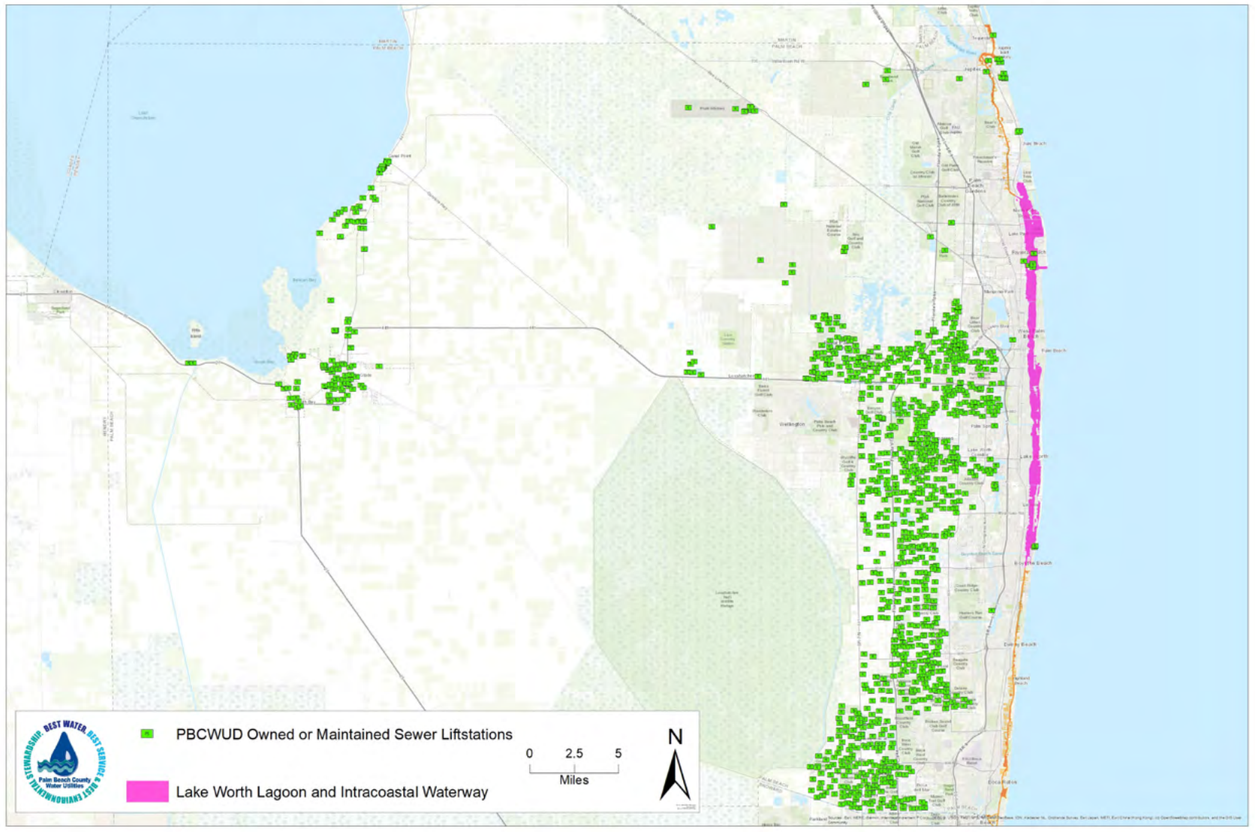
STEP 4 Educate citizens about what can and cannot be flushed down toilets, sinks and drains, and the importance of maintaining their privately owned lateral lines. Create incentives for repair or replacement of laterals.

TIMEFRAME:

STEP 1 is dependent upon funding, possibly through a DEP grant

STEPS 2, 3 and 4 can be initiated in FY 2021-2022

FIGURE 1.4 PALM BEACH COUNTY WATER UTILITY DEPARTMENT OWNED OR MAINTAINED LIFT STATIONS



Source: PBC

COST ESTIMATE:

STEP 1 $$$

STEP 2 $$

STEP 3 $

STEP 4 $-$$$ (higher cost for lateral line rebate program)

EVALUATING PROGRESS:

Number of sanitary sewer overflows reported to DEP database

Number of wastewater utilities participating in CMOM self-audit program

Reduction in maintenance and emergency response costs for local utilities

Number of participants in rebate or other incentive programs

Reduction in sewer line clogs and backups caused by disposal of improper items

REGULATORY NEEDS:

None

FUNDING:

PBC, local municipalities, EPA (wastewater grants), DEP (wastewater and revolving loan fund grants), other federal and state funding mechanism as opportunities arise. Specific wastewater improvement projects, or Lagoonwide initiatives, could be submitted as part of the Lake Worth Lagoon Initiative's annual request to the Florida Legislature.

POTENTIAL PARTNERS:*

PBC-ERM and Wastewater Departments, Local municipalities, FDEP, Florida Department of Health, EPA Region 4

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

1 Aging infrastructure and storms contribute to massive spills. Salman, J. et al. Gatehouse Media. 2019.

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Septic system being installed (Photo credit: Stock photo/Dreamstime)

WW-2 IDENTIFY PRIORITY AREAS FOR CONVERSION OF SEPTIC SYSTEMS TO CENTRAL SEWER

ACTION: Create a detailed inventory of Onsite Sewage Treatment and Disposal Systems, OSTDS), commonly referred to as septic systems in the Lagoon watershed. Identify and prioritize septic systems for upgrade or conversion based on estimated nutrient loading, potential failure and/or underperformance, soil conditions, groundwater table conditions, proximity to surface water bodies, etc. Pursue funding and homeowner assistance programs for conversion of priority areas to central sewer and/or advanced or nutrient-reducing septic systems. Support statewide requirements for inspection and maintenance.

IMPORTANCE:

While newer and properly maintained septic systems can provide more effective nutrient removal, all septic systems discharge nitrogen and phosphorus to the environment via their drainfields. In addition, underperforming and/or failing septic systems can contribute disproportionately to nutrient pollution in surface and ground water and pose increased risks to human and environmental health.

RELATED ACTIONS:

WW-2, WQ-4, WQ-5, CC-1

BACKGROUND:

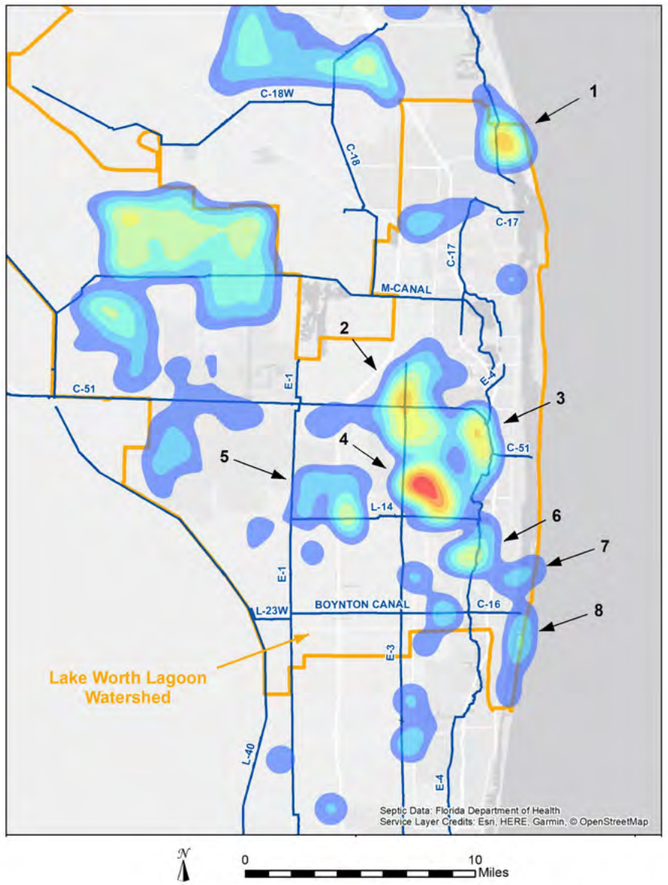
Data from the Florida Department of Health (FDOH) show nearly 22,000 septic systems in the Lake Worth Lagoon watershed in 2018, with approximately 16,500 of those in unincorporated areas and 5,500 within municipalities. Palm Beach County has completed basic mapping of these systems and noted general densities *(see Figure 1.1)*.

Failing or underperforming septic systems can contribute nitrogen to surface and ground water, especially in areas with high densities of older septic systems more prone to malfunctioning. Septic systems also may contribute phosphates, “emerging contaminants” such as pharmaceuticals, personal care products and microplastics (*see Action WQ-5*) and bacterial pollution (*see Action WQ-4*).

A properly constructed and functioning septic system can remove between 30% and 40% of the gross nitrogen load, according to the Florida Department of Health. Removal occurs primarily in the drainfield, where bacteria readily convert ammonia nitrogen to nitrate through nitrification *(see Figure 1.2)*. Many factors influence the efficiency of this process, including how well the system has been maintained, how old it is and, most importantly, whether natural denitrification is likely to occur downstream before the effluent reaches a waterway *(see Figure 1.3)*. Soil type, in particular, may have an outsized influence in how fast and far nutrients from septic systems travel, with sandy soils common to coastal areas providing less denitrification.[1] Understanding all these factors is important for accurately estimating nutrient loads to the Lagoon from septic systems, and for prioritizing upgrades to central sewer or advanced or nutrient-reducing septic systems.

Additionally, knowledge of septic

FIGURE 1.1 MAP OF SEPTIC SYSTEM DENSITIES



AREA 1: Little Lake Worth Lagoon, 1,255 systems

AREA 2: West of Palm Beach Intl. Airport, 2,357 systems

AREA 3: Lake Clarke, 1,051 systems

AREA 4: West Lake Worth, 2,104 systems

AREA 5: Turnpike and Lake Worth Rd., 1,135 systems

AREA 6: Lake Osborne, 881 systems

AREA 7: Manalapan, 158 systems

AREA 8: South of the SLWI, 545 systems

SOURCE: PBC-ERM

CLICK IMAGE TO ZOOM IN. CLICK AGAIN TO ZOOM OUT.

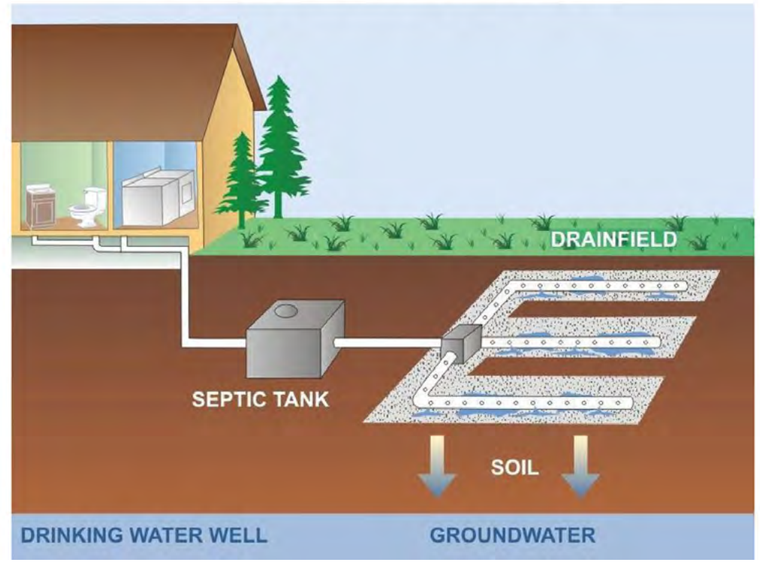
system elevations can provide valuable insights into older units already experiencing impacts from sea level rise, and those most vulnerable to future impacts (*see Action CC-1*).

One source-tracking study with potential applicability to the Lagoon was conducted in the St. Lucie Estuary by researchers with Harbor Branch Oceanographic Institute at Palm Beach Atlantic University. This study documented a strong correlation between the presence of multiple constituents associated with wastewater and septic systems (dissolved nutrients, the artificial sweetener sucralose, and stable nitrogen isotope ratios in macroalgal tissue) in ground and surface waters adjacent to residential areas with septic systems.[2] These markers are primary drivers of harmful blooms of blue-green algae.

Converting properties with septic systems to central sewer is costly, with residential hookup fees ranging from $2,000 to $5,000 or more. The total cost of conversion projects to local governments can range from $30,000 - $60,000 per home. Financial assistance through interest-free loans and cost-sharing grants can assist residents who may have limited ability to pay. Additionally, local governments must bear the costs of additional operating capacity for their wastewater treatment plants, although user fees can offset those.

Palm Beach County and municipalities in the Lagoon watershed recognize the environmental and public health threats posed by aged, improperly sited or poorly maintained septic systems. Most recently, the Lost Tree Village Septic-to-Sewer project was awarded $1 million in 2018 by the Florida Legislature, with $1 million in local matching funds. This project, which extended central sewer to 246 homes directly on or adjacent to the Lagoon, was submitted by the Lake Worth Lagoon Initiative (LWLI). The LWLI also requested $333,600 for a sewer expansion in the Town of Hypoluxo in 2020 – a project that would have removed the only remaining septic systems in the Town, located within 1000 feet of the Lagoon. The Legislature allocated $200,000 that was subsequently eliminated from the final state budget.

FIGURE 1.2 DIAGRAM OF A TRADITIONAL SEPTIC SYSTEM



SOURCE: Snohomish County, WA

The 2020 state Clean Waterways Act incorporates several important changes relating to management of septic systems, including:

- Transferring oversight of septic systems from FDOH to the Florida Department of Environmental Protection (FDEP.
- Mandating that FDOH approve more nutrient-reducing septic systems for use in ecologically sensitive watersheds where sewers are not feasible. These “Performance-Based Treatment Systems” incorporate the denitrification of effluent into the system design itself, and can reduce nitrogen inputs by 90% or more.[3]
- Creating an On-Site Treatment and Disposal System Technical Advisory Committee within FDEP

- Requiring Basin Management Action Plans (BMAPs) for impaired waters to include remediation plans where septic systems are responsible for at least 20% of point or non-point source pollution (or if FDEP deems necessary). The Plan must identify cost-effective, financially feasible projects necessary to achieve nutrient load reductions and include:
  - An inventory of septic systems and identification of systems to be eliminated, replaced, upgraded, or left in place
  - Cost estimates for alternatives
  - Timeline for projects
- Requiring FDEP to submit reports on wastewater projects in BMAPs
- Establishing a Wastewater Grant program

Requiring routine inspection and maintenance of septic systems is a cost-effective tool for reducing pollution and extending their service life until central sewer can be extended to more neighborhoods. A law requiring septic system inspections and pumpouts every five years was passed in 2010 but repealed in 2012. In 2019, another bill to require septic system inspection and monitoring was introduced but again failed to gain traction.

APPROACH:

STEP 1 Create an inventory and geographic database of septic systems with the most potential to contribute problematic nutrients to the Lake Worth Lagoon based on proximity to Lagoon, age of system, density, soil conditions, depth to groundwater table, potential for denitrification, vulnerability to sea level rise and other relevant factors.

STEP 2 Estimate nutrient loading associated with leaching from septic systems by conducting a source tracking study or generating estimates based on information gathered from the STEP 1 inventory.

STEP 3 Create priority list for conversion of septic systems to central sewer and/or advanced or nutrient-reducing septic systems and identify and pursue cost-sharing opportunities, grants and/or capital improvement funds to implement septic system conversion projects.

STEP 4 Support state legislation to require regular maintenance and inspection of septic systems. Support efforts to allow stricter setbacks and standards for new septic systems in areas with impaired waters.

TIMEFRAME:

STEP 1 can be initiated in 2021 or 2022

STEPS 2 and 3 can occur in 2023

STEP 4 is dependent on obtaining sponsors for legislation.

COST ESTIMATE:

STEP 1 $$

STEP 2 $-$$$

STEP 3 $$$$-$$$$$ (based on cost of septic-to-sewer construction)

STEP 4 $

FIGURE 1.3 FACTORS AFFECTING SEPTIC TANKS AND WATER QUALITY

EVALUATING PROGRESS:

Creation of a septic tank inventory and geographic database of septic system areas within the Lagoon watershed. This datebase should include physical parameters that increase risk of septic system failure or underperformance such as soil conditions, depth to groundwater, proximity to surface water bodies, etc.

Nutrient Loading Estimates

Ranked list of priority projects for septic-to-sewer conversions/upgrades

Implementation of septic system management and reporting provisions in the Clean Waterways Act

Approval of state legislation require maintenance and inspection of septic systems

REGULATORY NEEDS:

City and county permits issued through the National Pollutant Discharge Elimination System (NPDES) offer a mechanism for addressing chronic failures of septic systems. Local Land Development Codes may also address problem areas with repeated failures of septic tanks, or mandate stricter setbacks for new systems.

FUNDING:

State Legislative funding requests, county and city capital investment funds, FDEP Wastewater Grants or 319 Program grants,

POTENTIAL PARTNERS:*

PBC-ERM, Wastewater and Planning Departments' local municipalities, LWLI, FDEP, FDOH. Harbor Branch Oceanographic Institution or other research institutions

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

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[1] Developing Data-Driven Septic Policy for the Indian River Lagoon. Listopad, C., et al. Applied Ecology. 2018.

[2] Septic systems contribute to nutrient pollution and harmful algal blooms in the St. Lucie Estuary, Southeast Florida, USA. Lapointe, B. et al. HARMFUL ALGAE. 2017.

[3] Florida Onsite Sewage Nitrogen Reduction Strategies Study: Evaluation of Full Scale Prototype Passive Nitrogen Reduction Systems (PNRS) and Recommendations for Future Implementation. Hazen and Sawyer. 2015.

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Old Palm Golf Club

SW-1 REDUCE STORMWATER RUNOFF FROM URBAN LANDSCAPES

ACTION: Quantify nutrient loadings to Lagoon from residential fertilizers and expected reductions from decreased use. Support education about local fertilizer ordinances. Expand Best Management Practices (BMPs) certification programs for general landscape maintenance personnel. Expand outreach to homeowner and condo associations. Increase golf course compliance with best practices recommended by DEP.

IMPORTANCE:

Stormwater runoff from residential and commercial landscapes and golf courses transports excess nutrients and chemical contaminants to the Lagoon, contributing to water quality problems.

RELATED ACTIONS:

SW-2, PO-1, PU-1

BACKGROUND:

Lush manicured lawns and fairways are synonymous with Florida for many people, yet the nutrients and chemicals required to achieve this look can harm the waterways that are the centerpiece of the state's tourism and growth.

The price of our "green obsession" is high: It costs local governments an average of $3,500 to remove a pound of nitrogen once it enters a waterway, based on information from statewide stormwater projects.[1] Preventing the pollution in the first place is much more practical. A 2018 management plan for the Boynton Inlet watershed identified the reduction of fertilizer use as potentially the most impactful and cost-effective strategy for decreasing nitrogen loads in the coastal waters that support southeast Florida's coral reefs.[2]

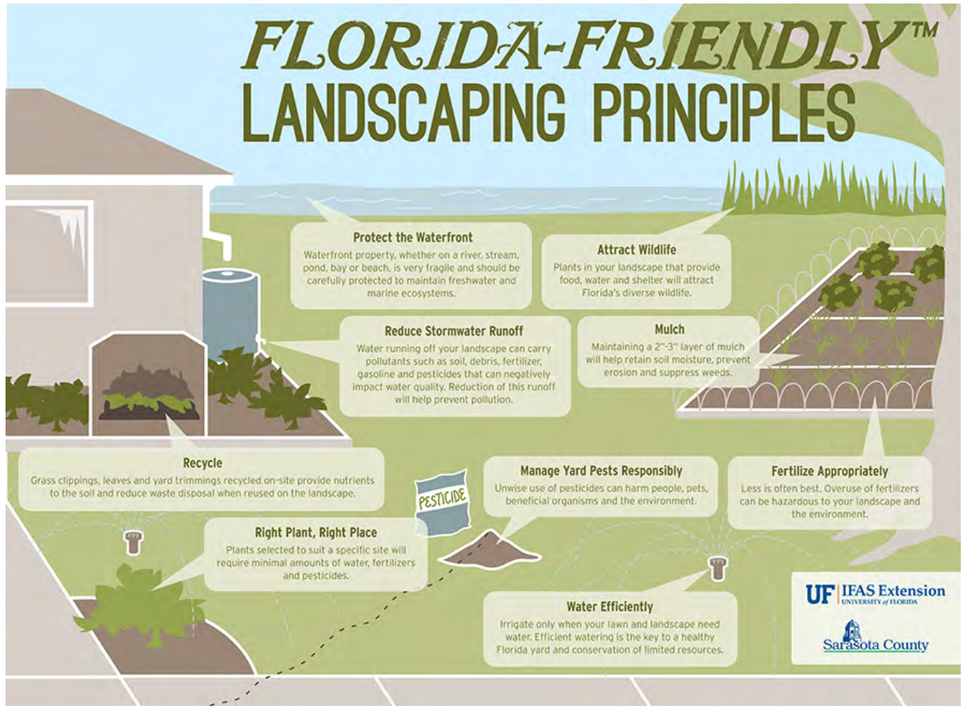
Fertilizer ordinances can be an important tool for motivating changes in landscape practices by homeowners, property managers and lawn care professionals. All local governments are required to adopt, at a minimum, a state-approved Florida-Friendly Fertilizer Ordinance, that prohibits lawn fertilizer application when flood or storm watches are issued, or heavy rains are expected. The ordinance also bans fertilizer application with 10 feet of a water body or wetland, and prohibits blowing or sweeping of fertilizer and grass clippings into water bodies, storm drains or streets.

As of 2020, Palm Beach County and 20 municipalities had enacted the state-approved ordinance, a few with minor deviations from the state template. (It

Riding lawn mower (Photo credit: iStock)

is worth noting that some 90 Florida communities have enacted stricter laws banning most fertilizer use altogether during summer months, when frequent rains increase the potential for runoff.)

Education about fertilizer restrictions would benefit from uniform messaging countywide, by the County, municipalities and UF/IFAS Extension, to avoid conflicting information about when and where fertilizer use is allowed. Effectiveness also could be enhanced by requiring stores where fertilizer is sold to post signs about the laws. Local governments also should be role models for their own ordinances,



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ensuring that fertilizer use on county-owned properties aligns with ordinance restrictions and that groundskeepers and maintenance personnel follow Best Management Practices.

Uniform messaging also would foster compliance among full-service lawn care companies who provide fertilizer, weed and pest management services in multiple governmental jurisdictions.

The well-established Florida-Friendly Landscaping™ program administered by UF/IFAS Extension promotes holistic management of residential and commercial landscapes to reduce water, fertilizer and pesticide use. A key focus is minimizing and replacing high-maintenance turfgrass with native or Florida-compatible plants that are drought-tolerant and resistant to pests and disease. Local workshops in FFL principles are routinely offered by Extension specialists in Palm Beach County.

An FFL toolkit is available for community associations with landscape covenants; the kit includes a model contract to facilitate use of Florida-friendly practices by landscape maintenance companies. Increased outreach to HOAs and condo associations is always needed, as these organizations often manage large areas with a substantial environmental footprint, and typically experience high turnover among association board members.

Extension agents also provide certification in Best Management Practices for lawn and landscape professionals, another key audience for education about landscaping to reduce pollution. This training covers appropriate fertilizer use, mowing and pruning, disposal of grass clippings and other fundamentals.

A typical 18-hole golf course requires three to four tons of fertilizers, herbicides, and pesticides every year to support its intensive usage and aesthetic requirements.[3] Golf courses also irrigate intensively, increasing the potential for fertilizer and chemical residues to enter waterways. There are 47 golf courses within the Lake Worth Lagoon watershed, with seven of those in the immediate vicinity of the Lagoon. Golf courses encompass more than 8,000 acres, or 3%, of the Lagoon's watershed.

A Best Management Practices manual developed and periodically updated by the Florida Department of Environmental Protection (FDEP) presents guidelines for environmentally responsible management of golf courses. Among the topics covered are turfgrass cultural practices, fertilization, irrigation, and chemical handling/application.

There is no certification process for golf courses, and compliance with the manual is strictly voluntary. The non-profit Audubon International organization (not affiliated with the Audubon Society) does offer technical assistance and certifications for golf courses that demonstrate principles of environmental stewardship. This certification encompasses six key components: environmental planning, wildlife and habitat management, chemical use reduction and safety, water conservation, water quality management and outreach and education.

APPROACH:

STEP 1 Quantify estimates of nutrient loading from residential landscapes and golf courses.

STEP 2 Foster compliance with fertilizer ordinances and landscape BMPs on public properties owned by Palm Beach County and municipalities, including government centers, parks and athletic fields.

STEP 3 Review existing educational messaging about fertilizer and promote consistent messaging countywide to foster compliance with local ordinances. Provide suggested language for signage in retail outlets selling fertilizer.

Example of a Florida-friendly landscape (Photo credit: UF-IFAS)

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PRIVATE COURSES IN THE LAGOON WATERSHED THAT HAVE EARNED AUDUBON INTERNATIONAL CERTIFICATION:

- Ballen Isles Country Club
- Frenchman's Reserve
- Old Palm Club (Gold Certification)
- The Everglades Club
- High Ridge Country Club
- Quail Ridge Country Club

PUBLIC COURSES IN THE LAGOON WATERSHED THAT HAVE EARNED AUDUBON INTERNATIONAL CERTIFICATION:

- John Prince Golf Learning Center
- Park Ridge Golf Course
- The Links at Boynton Beach
- Okeeheelee Golf Course

STEP 4 Quantify reductions in water, fertilizer, and pesticide use, and associated cost savings, for one or more golf courses in the Lagoon watershed that follow the DEP Manual of BMPs or are certified through Audubon International. Share results with other courses.

STEP 5 Identify a potential program and partners to offer voluntary, no-commitment site visits to golf courses and community associations to identify improvements to maintenance programs to reduce impact to the Lagoon. Offer voluntary, no-commitment inspections to golf courses and community associations to identify improvements to maintenance programs to reduce impact to the Lagoon.

STEP 6 Continue to promote Florida-Friendly Landscaping™ through programs and community events sponsored by ERM and partners in the Lake Worth Lagoon Initiative Outreach Working Group.

TIMEFRAME:

STEP 1 is contingent upon development of a Lagoon watershed model and analysis of nutrient loading by source. (*See Action WQ-2*).

STEPS 2 and 3 can begin in FY 2021.

STEP 4 can be initiated upon identification of one or more golf course partners, as soon as FY 2021-2022, and extending for at least two years to accurately assess reductions in cost and pollutants.

STEP 5 will commence upon completion of STEP 4, contingent on identification of a partner agency or organization to coordinate site visits.

STEP 6 is ongoing.

COST ESTIMATE:

STEP 1 $$$ for modeling and assessment of nutrient sources to Lagoon

STEP 2-5 $ for educational components

EVALUATING PROGRESS:

Updated messaging about local fertilizer ordinances to ensure uniformity and consistency countywide.

Percentage of public properties managed according to fertilizer ordinance and landscape BMPs.

Number of lawn and landscape professionals certified in Green Industries BMPs.

Number of golf courses in the Lagoon watershed following DEP Manual or certified through Audubon International.

Number of residents reached through Florida-Friendly Landscaping™ educational efforts.

REGULATORY NEEDS:

Amendments to fertilizer ordinances likely would be needed for any local governments that wish to require retail signage about fertilizer restrictions; Land Use Plan updates could incorporate language recommending that new golf courses adhere to the FDEP Manual of BMPs.

FUNDING:

Educational activities funded through recurring budget allocations. Possible funding or in-kind contributions from Audubon International or the Golf Course Superintendents Association of America for gold course assessments and partnerships.

POTENTIAL PARTNERS:*

ERM, Local Municipalities, UF IFAS/PBC Cooperative Extension Service, LWLI Outreach Working Group, Palm Beach County Soil and Water Conservation District, PBC Parks and Recreation, Golf Course Superintendents, Audubon International, Palm Beach County Chapter of Florida Native Plant Society, Loxahatchee Group of the Sierra Club

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

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1 Florida Department of Environmental Protection 319h stormwater project database. https://fdep.maps.arcgis.com/apps/MapSeries/index.html?appid=1696c8bc33e7464b8249998f23f6795a.

2 Boynton Inlet Contributing Area Watershed Management Plan. Prepared by Horlsey Whitten for Palm Beach County. 2018.

3 Golf and the environment: A deadly serious debate. O'Connor, T. Score, 1990.

Example of bioswale to treat and retain stormwater (Photo credit: City of Hallandale Beach, FL)

SW-2 EXPAND USE OF GREEN INFRASTRUCTURE AND LOW IMPACT DEVELOPMENT PRACTICES

ACTION: Expand use of Green Infrastructure (GI) and Low Impact Development (LID) practices to treat rainfall runoff in place. Conduct a cost-benefit analysis of a local GI and LID versus conventional stormwater project. Support development and delivery of tools and incentives to expand GI/LID implementation, including professional training; compatibility reviews of land development codes and comprehensive plans; and demonstration sites. Consider creation of stormwater utilities to finance stormwater improvements.

IMPORTANCE:

Green Infrastructure and Low Impact Development offers potentially significant cost savings over traditional stormwater management systems in urban areas, while also providing quality-of-life benefits to the community. GI can reduce nutrients and sediments by storing and treating stormwater that would otherwise flow directly into the Lagoon.

RELATED ACTIONS:

CC-1, CC-2

BACKGROUND:

Green Infrastructure and Low Impact Development is an innovative, low-impact approach to managing stormwater that works by slowing down stormwater to treat it at its source, instead of discharging it to the nearest water body. The results are more natural, and often more aesthetically pleasing, than traditional stormwater practices that utilize pipes, drains and retention ponds. Studies show that Green Infrastructure can be easier to maintain, may reduce or eliminate the need for regulatory permits, and often results in lower capital costs than conventional stormwater management approaches.

Beyond stormwater management and flood control, Green Infrastructure adds value by creating recreational and passive greenspace and wildlife habitats within urban areas. Together, these benefits improve overall community resilience to climate change *(see Figure 1.1)*.

Examples of Green Infrastructure include:

- Bioswales: Vegetated, mulched, or xeriscaped shallow, gently sloping drainage channels that capture runoff and allow it to evaporate or percolate into the ground.
- Pervious Surfaces such as pavers, bricks, gravel, shell and porous concrete that allow gradual absorption of rainwater in parking areas, driveways and walkways.
- Tree Boxes or Islands: A pre-manufactured concrete box in which trees are planted to serve as compact bioretention areas, especially suited for urban streetscapes where space is limited.
- Rainwater harvesting systems, such as aboveground and underground cisterns, to capture rainfall and store it for later use.
- Green Roofs, featuring small plants and shrubs embedded in planting trays or grown directly on building rooftops, can intercept rainfall before it hits the ground.

Multiple techniques can be incorporated in a single project or interconnected projects to create a “treatment train” that maximizes environmental, recreational and aesthetic benefits

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Figure 1.1 Green infrastructure for climate resiliency

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(see Figure 1.2.). One example of a sequenced project with direct benefits for the Lagoon is a proposed retrofit of Lake Shore Drive. As part of its Stormwater Master Plan, the Town of Lake Park plans to use GI techniques such as bioswales and biodetention treatment to treat runoff along this waterfront drive before it enters the Lagoon. This project was considered for funding from the Florida Legislature in 2019 but was not included in the final state budget.

Since 1982, Florida's stormwater rules have required new and redevelopment projects to treat the first inch of rainfall runoff, which contains the majority of nutrients, suspended solids and heavy metals. In general, this has been accomplished through construction of wet and dry detention areas, where sufficient land is available, that capture stormwater and allow pollutants to gradually settle out. In densely developed areas with impervious surfaces and a scarcity of open land, highly engineered networks of curb-and-gutter, catch basins, and storm drains are the norm.

However, a report commissioned by FDEP in 2007 determined that the existing criteria were, in many cases, not achieving the pollutant load reductions necessary to protect water quality.[1] A subsequent series of task force recommendations drafted in March 2010 were never adopted.

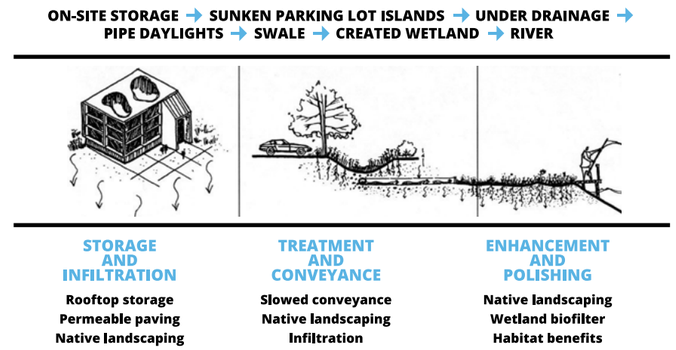
Passage of the 2020 Clean Waterways Act by the Florida Legislature marks a potential sea change for stormwater management. The law requires the Florida Department of Environmental Protection (FDEP) and the state's five Water Management Districts (WMDs) — each with their own specific stormwater design and performance standards — to initiate rulemaking on new statewide stormwater criteria by January 1, 2021.

This process presents an opportunity to create unified standards for low-impact development to accelerate the use of Green Infrastructure techniques. Updated state criteria also could encourage revision of local development codes and stormwater manuals to provide guidance in Green Infrastructure techniques that are especially appropriate to urban redevelopment and stormwater retrofits.

The 2019 completion of a comprehensive manual prepared for FDEP's Coral Reef Conservation Program provides a regionally tailored foundation for site selection, planning, design, operation, maintenance, and evaluation of Green Infrastructure projects in the unique Southeast Florida physical and regulatory environment.[2] A companion reference matrix allows users to compare and assess different Green Infrastructure siting and design options.

Multiple studies show that implementation of Green Infrastructure practices provide significant cost-savings over conventional stormwater methods and provide multiple community benefits in addition to water quality protection, including improvements to human and environmental health, recreational opportunities, property value, natural habitat and quality of life. These case studies provide a useful starting framework and suggest methods that could be applied to a cost-benefit analysis of "green" versus "gray" infrastructure in the Lake Worth Lagoon watershed.

FIGURE 1.2 STORMWATER TREATMENT TRAIN



SOURCE: Applied Ecological Services

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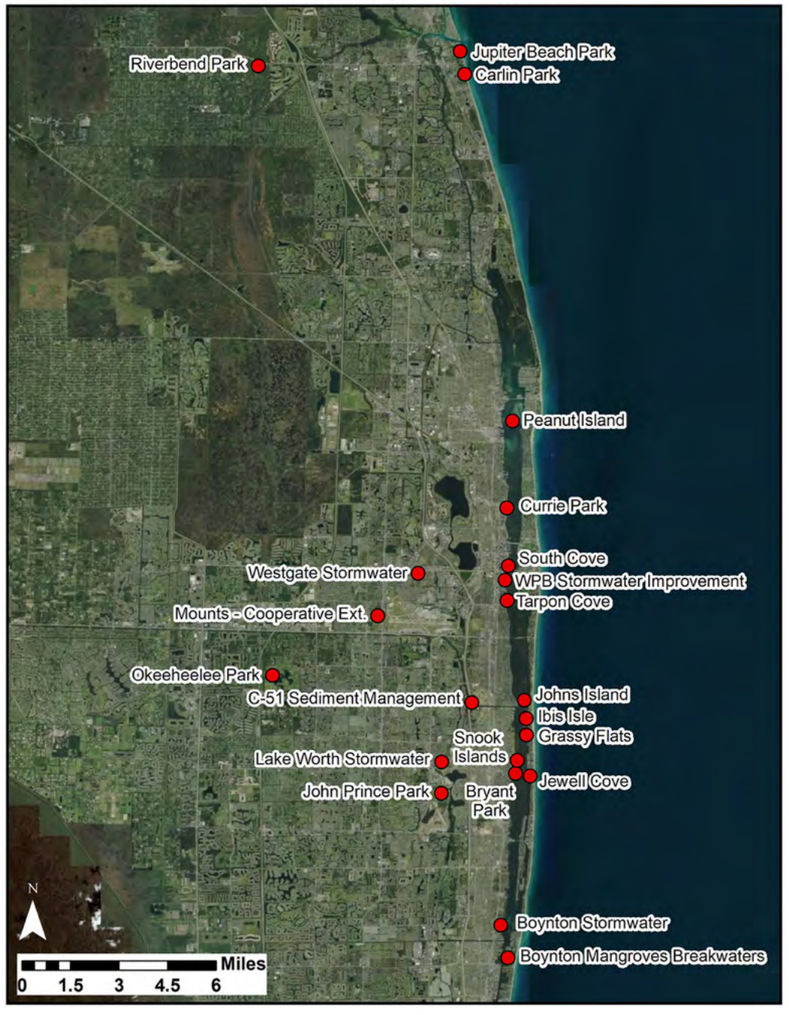
Palm Beach County (PBC) is already implementing Green Infrastructure, with 21 projects that incorporate low-impact stormwater management techniques completed or underway as of 2020 *(see Figure 1.3)*. Figure 1.3 only shows projects funded in part by PBC and is not an exhaustive list of all Green infrastructure projects in the County completed by other entities. The County's Office of Resilience conducted a successful workshop on Green Infrastructure for County staff, municipal partners, and community stakeholders in 2019. Similar workshops for the private development community would help to encourage more widespread use of these techniques.

Mapping of County-maintained stormwater culverts and roads is underway, a task that can help to identify suitable locations for Green Infrastructure retrofits. As part of a shoreline characterization study to be completed in 2022, PBC's Environmental Resources Management Department has mapped 204 outfall pipes along

the Lagoon *(see Figure 1.4)*. The shoreline study also will help pinpoint potential Green Infrastructure and Living Shoreline enhancements (*see Action CC-2*) that can improve stormwater treatment of runoff prior to entering the Lagoon.

FIGURE 1.3 GREEN INFRASTRUCTURE PROJECTS PALM BEACH COUNTY ONLY



SOURCE: PBC-ERM

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Adoption of stormwater utility fees by the County or municipalities would provide a stable and recurring source of funds for comprehensive stormwater improvements in the Lagoon watershed, including GI activities on public lands. As of 2019, approximately 170 stormwater utilities had been established by local governments throughout Florida, including in the cities of Pompano Beach and Jupiter, and the Village of Wellington *(see Figure 1.5)*. The average monthly fee collected by all utilities was $7.80 per unit (average unit size of 2,857 square feet), with revenues ranging from $21,000 a year for a small community like Fruitland Park to $5.7 million a year for the Village of Wellington and $31 million a year for Miami-Dade County.[3]

APPROACH:

STEP 1 Encourage expanded use of GI/LID techniques to treat rainfall runoff in place. Promote and implement "treatment trains" that leverage multiple GI techniques in a development to maximize water effectiveness.

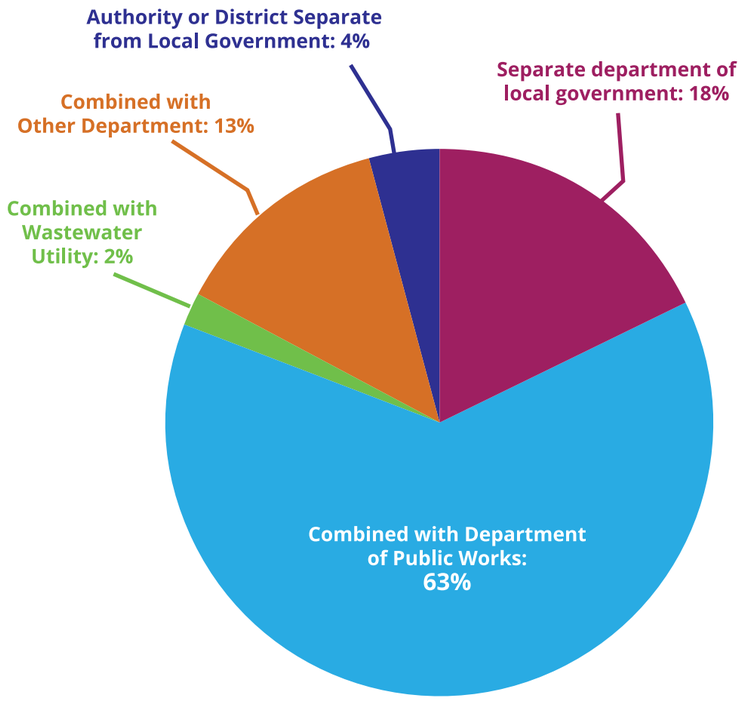
STEP 2 Conduct a cost-benefit analysis on the benefits associated with a local Green Infrastructure project relative to traditional "gray" stormwater treatment.

STEP 3 Conduct a Green infrastructure workshop for stormwater professionals, landscape architects, and water resource planners hosted by the PBC Office of Resilience and appropriate partners.

STEP 4 Provide public education about the benefits of GI, such a signage at a demonstration project or a webinar showcasing examples in Palm Beach County.

STEP 5 Incorporate support for GI in comprehensive plans and land use codes. Review and update ordinances and policies to remove barriers to GI implementation, such as a requirement for curb-and-gutter or large building setbacks in residential areas.

FIGURE 1.5 HOW FLORIDA STORMWATER UTILITIES ARE ORGANIZED



SOURCE: FLORIDA STORMWATER ASSOCIATION

STEP 6 Consider incentives such as increasing density allowances or streamlining permitting when GI is used within a development.

STEP 7 Consider creation of County and municipal stormwater utilities as a mechanism to finance ongoing water quality improvements.

TIMEFRAME:

STEP 1 is ongoing

STEPS 2-7 can occur in 2021-2024 timeframe

COST ESTIMATE:

STEPS 1-7 combined $$

EVALUATING PROGRESS:

Increase in number of Green Infrastructure projects.

Number of Public Outreach elements, such as a training workshop or signs at demonstration projects.

Changes in land use plans, zoning regulations or land development codes to facilitate GI projects.

Adoption of stormwater utility fees by County and Municipalities.

REGULATORY NEEDS:

Adoption of policies, regulations or ordinances to facilitate GI implementation. Adopt of stormwater utility fees.

FUNDING

Legislative allocation, FDEP Nonpoint Source Management Program grants, Stormwater Utility Fees or other user-based revenues

POTENTIAL PARTNERS:*

PBC-ERM and Office of Resilience, Local Municipalities, FDEP, SFWMD

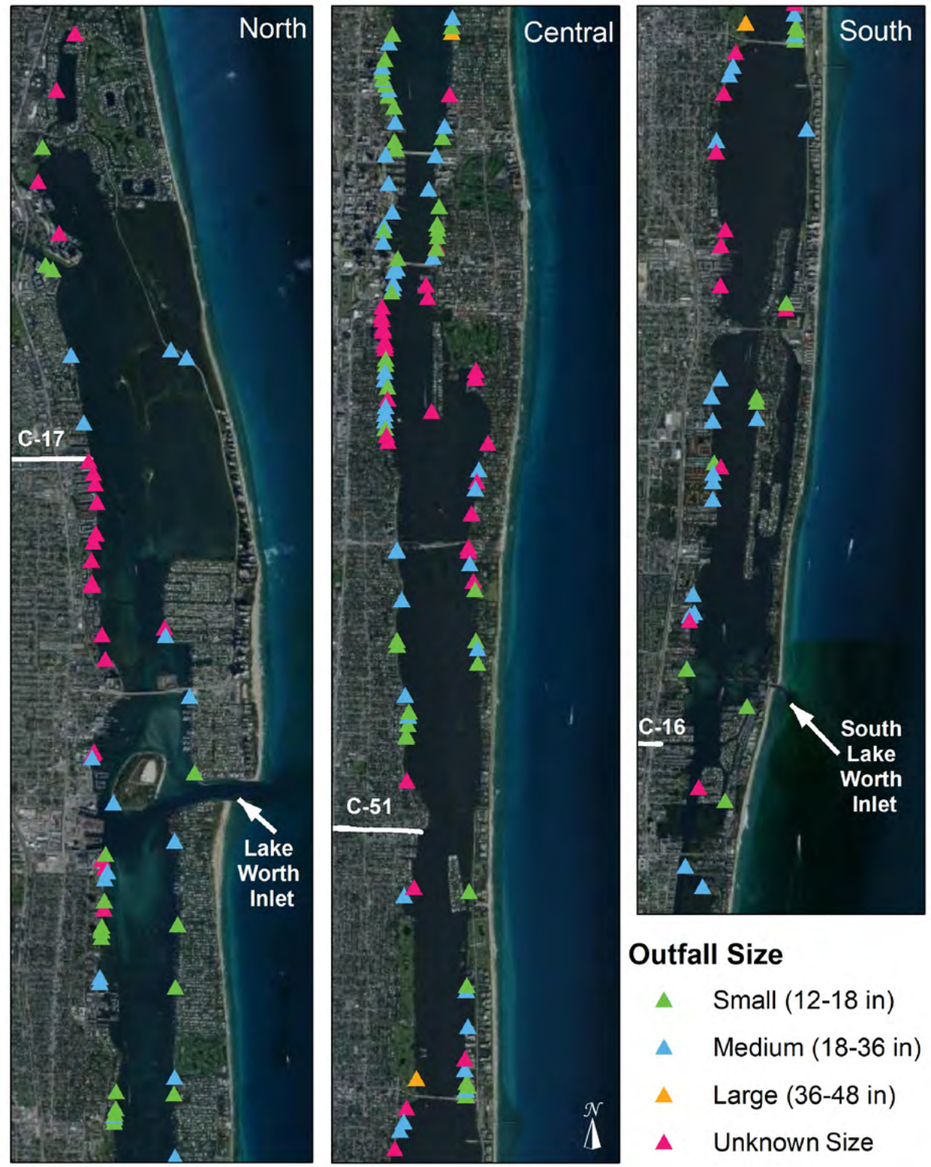
**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

[1] Evaluation of Current Stormwater Design Criteria within the State of Florida. Final Report prepared for DEP by Environmental Research & Design, Inc. Harper, H. and Baker, D. 2007.

[2] Low-Impact Development & Green Infrastructure: Pollution Reduction Guidance for Water Quality in Southeast Florida. Prepared for FDEP Coral Reef Conservation Program. Bean, E., et al. 2019.

[3] FSA 2018 Stormwater Utility Report. Florida Stormwater Association. 2018.

FIGURE 1.4 STORMWATER OUTFALLS OF LAKE WORTH LAGOON



SOURCE: PBC-ERM

Water conveyed down the C-51 Canal also carries sediments to the Lagoon (Photo credit: PBC-ERM)

SE-1 ASSESS AND MANAGE SEDIMENT LOADING

ACTION: Complete study of C-51 sediment trap efficiency and identify strategies to reduce sediment loads throughout the watershed. Assess and characterize sediment contributions to the Lake Worth Lagoon from all major stormwater conveyances. Implement projects to reduce sediment loading to the Lagoon and cap or remove muck sediments in the Lagoon to improve benthic health and foster seagrass colonization.

IMPORTANCE:

Water and habitat quality in the Central Lagoon is significantly impacted by the ongoing accumulation of organic muck transported in freshwater inflow from drainage canals.

RELATED ACTIONS:

WQ-1, WQ-2, WQ-3, WQ-6, HE-2, HE-3

BACKGROUND:

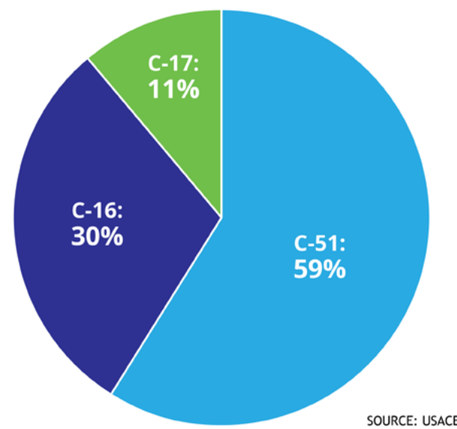
The sprawling network of drainage canals that crisscross the Lake Worth Lagoon watershed deliver problematic sediments in addition to freshwater to the estuary. These sediments build up as layers of oxygen-deficient muck in the Lagoon, and constant resuspension by wind and waves creates murky water that is less supportive of seagrass, fish and shellfish. The sediments contribute to excess nutrient loads, reduce light penetration to benthic habitats and may also contain heavy metals and other toxins.

Three drainage canals – the C-17, C-51 and C-16 – collect and convey most of the runoff from the Lagoon's expansive watershed, as well as sediments that accompany those flows. The C-51 Canal is the largest and oldest of those, with initial construction completed in 1929. It is now managed, along with the C-16, C-17, and multiple other flood control conveyances, by the South Florida Water Management District (SFWMD).

From 2008-2020, the C-51 delivered 59% of the freshwater flows into the Lagoon via the S-155 spillway[1] (*See Figure 1.1*). The S-155 opens at the bottom, allowing sediments to flow more easily into adjacent coastal waters. The amount of sediment entering the Lagoon is not quantified: the only detailed study to date determined that Lagoon sediments within 1.2 miles of the canal terminus are derived largely from the canal.[2] Canal sediments in turn are derived primarily from agricultural lands in the western portion of the canal.

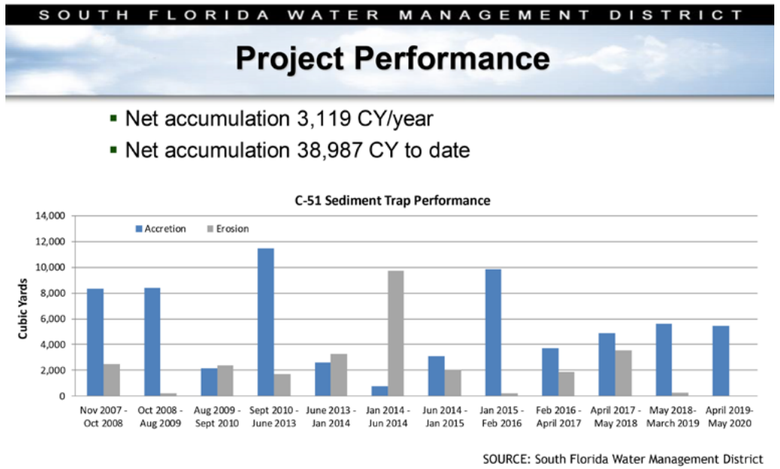
The structure empties into the Central Lagoon, an area characterized by the poorest circulation and longest water residence time because of its distance from ocean inlets. Sediments deposited in the Central Lagoon tend to stay in the Central Lagoon, accumulating over time. Water quality in the Central Lagoon is generally the poorest overall, and sites closest to the C-51 Canal's discharge location (e.g. S-155 spillway)

FIGURE 1.1 FRESHWATER INFLOWS INTO THE LAKE WORTH LAGOON, 2008-2020



SOURCE: USACE

TABLE 1.1
C-51 SEDIMENT TRAP PERFORMANCE



SOURCE: South Florida Water Management District

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have the highest percentage of fine-grained suspended sediments and the thickest muck substrate.[3]

Muck accumulation associated with the C-51 Canal has long been recognized as a problem for the Lagoon. The Surface Water Improvement and Management (SWIM) Plan (Palm Beach County 1997) identified the C-51 Basin as the most critical area for reversing water quality and ecological degradation in the Lagoon. The 1999 Comprehensive Everglades Restoration Plan (CERP) included project features to remove and trap sediment within the C-51 Canal and within the Lake Worth Lagoon downstream of S-155.

In 2007, a 12-acre sediment trap was constructed in the C-51 Canal to act as a "sump" to sequester sediments that would otherwise be discharged to the Lagoon *(See Figure 1.2)*. Per a 2006 Interlocal Agreement, SFWMD is responsible for the operation, management and maintenance of the trap, and has been conducting annual surveys to determine accretion and erosion rates. From November 2007 through March 2019, a net accretion of 33,635 cubic yards of sediment was measured *(See Table 1.1)*.

SFWMD commissioned a study in 2019 to determine the efficiency of the trap. That evaluation, completed in 2021, shows the trap is about 33% full. The report indicates that it has not filled more rapidly because at flows greater than 850 cubic feet per second (cfs) it actually exports sediments.[4] In general, the study shows, trap efficiency decreases as flow increases. The range of sediment exported out of the trap was between 3% to 42% of total trap capacity, or 0.38 to 10.36 tons/day. Flows below 600 cfs generally led to sediment retention in the C-51 trap.

Additional study would more precisely pinpoint maximum flow rates at which the trap functions as intended.

Dredging of the accumulated sediment in the trap on an established schedule is paramount to ensuring it acts as a sink and not a source of sediments to the Lagoon.

Sediments in the trap are coming from both canal bank erosion and stormwater runoff from the vast watershed directed into the canal. A 2008 sediment study estimated that runoff from land contributes an average of 65% of the organic matter in Lagoon sediments, while 35% was produced through primary production in the Lagoon itself.[5]

Central Lagoon muck sample (Photo credit: PBC-ERM)

Also included in the 2021 SFWMD report was an analysis of the sediments for the presence of contaminants and their specific concentrations. Early results show high levels of arsenic *(see Table 1.2)*. Additional analysis would clarify the potential effects of nutrients and metals on estuary and human health.

TABLE 1.2 NUTRIENTS (TP AND TN) AND METALS IN THE THREE SEDIMENT TRAP SAMPLES

NUTRIENT	CONTENT PER VOLUME (MG/KG) IN SAMPLE		
	I	II	III
TP	491	378	704
TN	1910	1810	2730
METALS			
Arsenic	6.35	7.20	5.52
Barium	51.40	57.50	47.40
Cadmium	0.27	0.34	0.28
Chromium	20.60	23.70	19.40
Lead	14.70	17.10	14.20
Mercury	0.16	0.16	0.10
Selenium	1.10	2.50	1.20
Silver	0.03	0.03	0.03

SOURCE: Palm Beach Environmental Laboratories Inc., 2017

Once in the Lagoon, muck may be continually dispersed with tides, wind and waves, filling deep dredge holes first and eventually covering shallow-water benthic communities that are the foundation of a healthy estuary. The County has invested significant time and financial resources in capping muck layers with lagoon-compatible sediments to facilitate habitat restoration, often in conjunction with fill material derived from dredging of the Intracoastal Waterway by the Florida Inland Navigation District *(see Action HE-2)*.

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Figure 1.2 Location of C-51 Sediment Trap

Understanding the sources, distribution, constituents and fate of sediments discharged to the Lagoon from the C-51 Canal – and, more generally, from the entire system of drainage canals and structures that affect the Lagoon – is essential to improving habitat and ecological diversity. Solutions will require a wide-angle management approach that seeks to address land uses and runoff from the 30 municipalities, large unincorporated area, and over 1 million residents that comprise the Lagoon watershed.

APPROACH:

STEP 1 Continue annual surveys of the C-51 Canal sediment trap and consider expanding the survey area along the C-51 closer to the S-155 structure. Incorporate recommendations of the SFWMD sediment trap efficiency study into future sediment management activities.

STEP 2 Assess sediment loads to the Lagoon along the main drainage canals (C-17, C-51, C-16) and structures (S-44, S-155, S-41). Implement a Lagoon-wide sediment characterization and sourcing study.

STEP 3 Conduct a feasibility study to identify strategies for reducing sediment loads within the C-51 Canal. Evaluate both structural and non-structural actions, including modifications to canal and/or trap maintenance, re-engineering of the S-155 structure to facilitate reduced sediment loads to the lagoon, construction of additional sediment traps, and new Stormwater Treatment Areas. Regulatory, policy and educational initiatives aimed at reducing sediment contributions from land-based activities also should be considered. (*see Action WQ-3*).

STEP 4 Implement projects to reduce sediment loading to the Lagoon (structural and non-structural) and manage sediment within the Lagoon by capping or removing muck layers to improve habitat value (*see Action HE-2*).

TIMEFRAME:

STEP 1 A Phase II Sediment Trap Study is necessary to fine tune the operation of the S-155 structure during high flow events and to determine how to improve C-51 trap efficiency. Annual surveys of the sediment trap should continue until optimal flows and maintenance regimes can be determined to ensure the trap's effectiveness as a sediment sink.

STEP 2 is contingent upon identification of funding partners.

STEP 3 Feasibility study can begin in 2021.

STEP 4 is ongoing to ensure consistency with state water quality improvement

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activities and proposed statewide stormwater rules, and as opportunities arise to obtain and use dredged material to cap muck sediments or to support removal of muck from the system.

COST ESTIMATE:

STEP 1 $ per year for annual monitoring of accretion/erosion and trap capacity.

STEP 2 $$-$$$ depending on scope and phasing of assessments and sediment source tracing.

STEP 3 $$ for feasibility study.

STEP 4 $$$$-$$$$$ significant costs savings are realized from beneficial uses of dredged material.

EVALUATING PROGRESS:

Number of stormwater treatment projects.

Implementation of actions to reduce sediment loading to Lagoon.

Volume of sediment removed from canals that drain to the Lagoon (via dredging or other technologies).

Volume of nutrients (e.g. phosphorus, nitrogen) removed from canals that drain to the Lagoon (via dredging or other technologies).

Capping or removal of muck from dredge holes in Lagoon.

Education/Outreach, Policy and Regulatory Actions implemented.

REGULATORY NEEDS:

Stronger requirements for stormwater system components to capture sediments and regular maintenance of current systems through MS4 or NPDS permits.

FUNDING:

State, regional, county/city budget allocations, LWLI Legislative Funding Request

POTENTIAL PARTNERS:*

SFWMD, FDEP, USACE, PBC-ERM, local municipalities, UF-IFAS, universities or research consortiums, Lake Worth Lagoon Keepers

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

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1 Engineering Appendix for Lake Worth Lagoon Ecosystem Restoration Project. U.S. Army Corps of Engineers and Palm Beach County. 2016.

2 Sediment Sourcing Study of Lake Worth Lagoon and C-51 Basin, Palm Beach County. Trefry, J., et al. 2009.

3 Assessment of Freshwater Inflow and Water Quality for an Urbanized, Subtropical Estuary (Lake Worth Lagoon, Florida, USA). Buzzelli, C., et al. Marine Technology Society Journal. 2018.

4 C-51 Canal Sediment Trap Assessment. South Florida Engineering and Consulting LLC. January 26, 2021.

5 Sediment Sourcing Study of Lake Worth Lagoon and C-51 Basin, Palm Beach County. Trefry, J., et al. 2009.

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HABITAT ENHANCEMENT AND PROTECTION ACCOMPLISHMENTS AT A GLANCE

More than 8,500 tons of limestone rock, concrete or other materials were used to **enlarge existing reefs or create new reefs** at four locations: Peanut Island, Phil Foster Park, the Southern Boulevard Bridge Reef, and Sugar Sands.

SEE ACTION HE-1

From 2014-2020, nearly **43 acres of habitat was created** in the Lake Worth Lagoon, including 30 acres of seagrass habitat, 6.1 acres of mangroves and salt marshes, and 7.2 acres of breakwaters, living shorelines and reefs.

SEE ACTION HE-2

More than **400,000 cubic yards of material from dredging projects**—enough to fill 130 Olympic-sized swimming pools—is being re-used to **create habitat** at the Tarpon Cove Restoration Project.

SEE ACTION HE-2

More than **83% of the Lagoon's total seagrass acreage is in the Northern Lagoon,** in close proximity to the Lake Worth Inlet.

SEE ACTION HE-3

Palm Beach County is working to **identify funding to purchase** 152 acres of submerged land near Singer Island from willing sellers to **permanently protect the large seagrass beds** there.

SEE ACTION HE-4

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Lowering concrete reef components at Southern Boulevard (Photo credit: PBC-ERM)

HE-1 CREATE, PROTECT AND MONITOR HARDBOTTOM HABITATS

ACTION: Develop an Oyster Enhancement and Monitoring Plan to guide future restoration efforts. Create a baseline map and inventory of natural hardbottom areas in the Lake Worth Lagoon. Continue to create and enhance artificial reefs in locations with appropriate water quality to support these habitats.

IMPORTANCE:

Hardbottom habitats contribute to the Lagoon's biodiversity by supporting unique assemblages of invertebrates, fish, and shellfish.

RELATED ACTIONS:

HE-2, HE-3, FW-3, FW-4, CC-2

BACKGROUND:

Hardbottom habitats in the Lake Worth Lagoon include oyster reefs, live and fossilized corals, Anastasia rock formations, and other natural "reef-like" materials, and artificial reefs and submerged riprap limestone that act as breakwaters to the newly established mangrove islands and living shoreline projects. Together, they provide important substrate for benthic species such as sponges, corals and oysters, and support a diverse community of invertebrates and fish.

Precise estimates of the amount and location of natural hardbottom communities in the Lagoon are lacking. Sonar mapping verified by groundtruthing could be a useful tool for assessing the type and distribution of hardbottom. Baseline mapping would help identify additional monitoring needs (e.g., for corals) and facilitate watershed-level management of these rare and valuable habitats.

Presently there are 17.52 acres of artificial reefs at 11 locations throughout the Lagoon *(see Figure 1.1)*. Since 2013, reefs constructed of various materials – including limestone rock and concrete slabs, pilings and bridge sections – have been installed at Peanut Island Reef Complex, Phil Foster Snorkel Trail, Southern Boulevard Bridge Reef, and Sugar Sands Reef (including Roach's Reef). Some 6,000 tons of donated concrete from the bridge replacement project were strategically placed to create ledges and discrete pods at the Southern Boulevard Bridge Reef alone *(see Table 1.1)*.

All artificial reef sites listed in Table 1.1 have active permits and can accommodate additional structures. When structures are deployed, the placement and quantity of each component are carefully evaluated to provide valuable habitat and foraging areas. The degree of rugosity and

Reef components placed at Phil Foster Snorkel Trail attract thousands of visitors each year (Photo credit: PBC-ERM)

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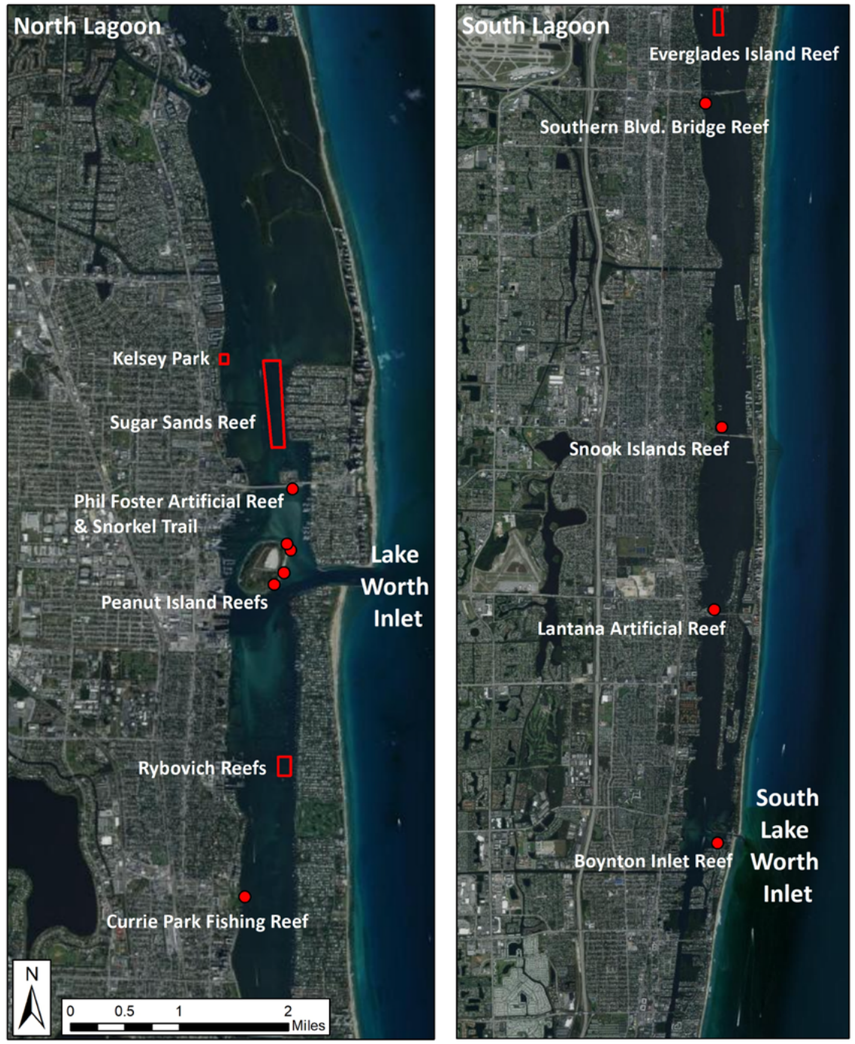
FIGURE 1.1
ARTIFICIAL REEF LOCATIONS



SOURCE: PBC-ERM

complexity of the structures are two important components incorporated into the design of artificial reefs deployed throughout the Lagoon.

More than 9.4 acres of natural and created/enhanced oyster reefs were present in the Lagoon in 2020, according to estimates from Palm Beach County's Department of Environmental Resources Management (ERM). This figure includes 1.6 acres resulting from habitat restoration projects from 2013-2020.

Additional artificial reef locations throughout the Lagoon will be determined as hardbottom mapping and habitat monitoring progress and the need for additional sites becomes evident. Table 1.1 on Page 146 lists locations under consideration for future artificial reefs. Final siting determinations will include consultations with the fishing community, FWC partners and regulatory agencies involved in permitting these structures.

Oysters are a special management focus in the Lagoon because of their response to changes in salinity and function as indicators of overall estuarine health. Oyster reefs provide a number of ecological, economic and recreational benefits, including food and habitat for fish, shellfish, and shorebirds. They also can reduce erosion, stabilize shorelines and improve water quality.

The Florida Fish and Wildlife Conservation Commission (FWC) began to monitor three natural oyster reefs in the Lagoon in 2005. The program was expanded in 2015 to include oyster reefs created at three restoration sites. Palm Beach County's Environmental Resources Management (ERM) Department has committed to fund monitoring of all six oyster reefs through 2023.

The goal of the monitoring is to document the responses of oyster populations to changes in water quality arising from water management activities and natural events.

Researchers examine oyster density, juvenile recruitment and presence of a disease known as Dermo *(Perkinsus marinus)* that degrades oyster tissues.

Between 40% and 100% of oysters at the natural reef stations in 2019 were infected with Dermo. Between 20% and 100% of oysters at the constructed reefs at restoration sites were infected.

In the sampling period that ended in June 2020, oyster abundance, health and population ecology within the Lagoon generally fell within expected ranges for south Florida oyster populations and no substantial differences were detected between oysters at the natural reef stations and the restored reef stations.[1]

The optimal salinity range for oysters is approximately 12 to 20 parts per thousand. Salinities measured in Lagoon sampling trips from 2005 through April 2019 exceeded the optimal range in 70% of sampled months. Salinity was within the optimal range only 26% of the time.[2] Those optimal salinities occurred most frequently during the summer months (July – September) when freshwater runoff and inflow rates were elevated.

Higher salinities and temperatures are associated with a high percentage of *Dermo* infections, though infection intensities in Lagoon oysters were generally below levels considered fatal.

Future management actions that improve the timing, volume and consistency of freshwater flows in the Lagoon during the dry season could substantially reduce disease and predation rates, according to FWC researchers. Increased freshwater flows in the cooler winter months could also help Lagoon oysters physiologically adapt to lower salinities in the warm summer period.

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APPROACH:

STEP 1 Continue and expand the Oyster Enhancement and Monitoring Plan that defines long-term goals, assesses the suitability of restoration sites to support oysters, and evaluates available larval supplies to sustain oyster populations. Specifically, oyster restoration efforts should consider:

- Water quality parameters (dissolved oxygen concentrations, pH, etc.) appropriate for oysters.
- Risk of exposure to high wave energy or frequent large boat wakes. For example, sites that are less than 100 meters from the Intracoastal Waterway may be less successful than those placed further from congested areas. Alternatively, place oyster reefs on the backside of restoration sites where they are not directly exposed to boat wakes and waves from the Intracoastal Waterway.
- Sedimentation rates. High rates may bury settled oysters or impede their filter-feeding efficiency. One solution may be to allow the first layer of substrate to settle before adding additional layers to ensure the reef remains elevated above the soft sediments.
- Availability of hard substrate appropriate for oyster settlement.
- Proximity to other oyster reefs for larval recruitment. If there is limited larval supply, planting of hatchery-raised oysters (spat on shell) or oyster gardening programs may be a viable alternative.
- Design and Layout of Habitat. Oyster shell is preferred for construction, but costs and availability are often prohibitive. Alternatives include fossil shell and limerock. Large rocks or boulders typically used for breakwater or shoreline stabilization projects offer minimal value as they provide little to no refuge. Materials should be selected based on project goals and locations – the generally high salinities in the Lagoon emphasize the need for interstitial space and 3-D structure to provide adequate refuge from predators and exposure.

STEP 2 Inventory/map all natural hardbottom areas to characterize communities and identify monitoring and management needs.

TABLE 1.1 ARTIFICIAL REEFS IN THE LAKE WORTH LAGOON

REEFS	ACRES	Pre - 2002 (tons)		2003 - 2007		2008 - 2012			2013 - 2018		
		Concrete	Limestone	Concrete	Limestone	Concrete	Limestone	Other	Concrete	Limestone	Other
Kelsey Park	2.00			2,300	2,000	12					
Sugar Sands Reef	7.50	5,770	4,265						10	815	
Phil Foster Snorkel Trail	0.60					12	600			300	3 statues, 17 modules
Peanut Island Reefs	1.70	20	40		1,000	2.5	4,240		170	1,270	
Rybovich Reefs	2.00	1,323	4,730		3,500						
Currie Park Fishing Reef	0.01		100								
Everglades Island Reef	0.76					1,100		87 ft. Barge			
Southern Blvd. Bridge Reef	1.70								6,000		
Snook Islands Reef	0.05					700					
Lantana Artificial Reef	0.50	250			500						
Boynton Inlet Reef	0.70		1,400								
Total	**17.52**										

SOURCE: PBC-ERM

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STEP 3 Continue to pursue opportunities to create artificial reefs to provide habitat for marine life, reduce erosion of shorelines, and provide recreational areas for anglers and snorkelers. Support research on artificial reef design and evaluate and compare results.

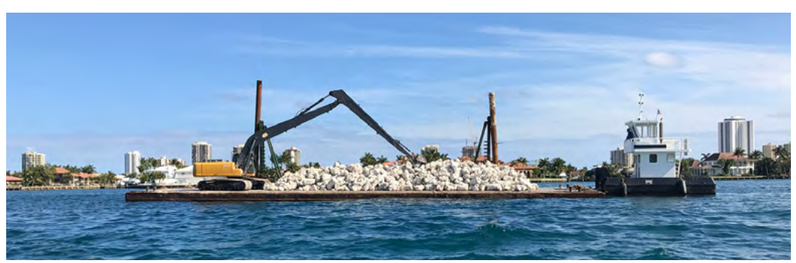
STEP 4 Encourage volunteer and stakeholder involvement by creating an oyster gardening program. The program would provide bags of oyster shells covered in oyster larvae (spat) for placement along residential docks. Homeowners, students or community groups monitor the growth of the spat for several months, and resulting live oysters are used to seed new reef sites.

TIMEFRAME:

STEP 1 can be initiated in FY 2021-2022 through internal discussion of goals, long-range restoration projects and data reviews. Additional support may be needed from FWC, FAU-HBOI, or other local researchers.

STEP 2 will likely require grant funds and in-kind support to achieve. ERM could request seed money for this effort in FY 2022-2023.

STEP 3 is ongoing. ERM plans to install new reefs as appropriate locations are determined and enhance existing reefs at Sugar Sands Reef in the northern Lagoon and Everglades Reef and Southern Boulevard Bridge Reef in the central Lagoon.



Installing artificial reef at Sugar Sands (Photo credit: PBC-ERM)

Restored oyster bars at Grassy Flats Restoration Area (Photo credit: PBC-ERM)

STEP 4 can be initiated in FY 2021-2022 through partnerships with interested non-profits, waterfront Lagoon communities, Palm Beach Zoo and area schools.

COST ESTIMATE:

STEP 1 $-$$

STEP 2 $$-$$$

STEP 3 $$-$$$

STEP 4 $

EVALUATING PROGRESS:

Completed baseline map of hardbottom communities throughout Lagoon.

Creation and implementation of Comprehensive Oyster Enhancement and Monitoring Plan.

Improved survival of oysters and reduction in prevalence of Dermo disease at both natural and artificial reef sites.

Increase in acres of reefs.

Weight or volume of cultivated oysters from oyster gardening program placed at restoration sites.

REGULATORY NEEDS:

Federal or state permits to install reefs and oyster gardening structures within the Lagoon.

FUNDING:

Recurring county allocation for ongoing FWC oyster monitoring. Special allocation or grant funding to support mapping of all hardbottom communities and new reef creation/enhancement. Grant funds from FDEP, NOAA, FWC and non-profit groups for artificial reefs.

POTENTIAL PARTNERS:*

PBC-ERM, FWC, FIND, FDOT, local universities and non-profit conservation and research organizations

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

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[1] Oyster monitoring in Lake Worth Lagoon Final Report April 2019-June 2020. Geiger S. and Maloney N., FWC Fish and Wildlife Research Institute. 2020.

[2] Lake Worth Lagoon Oyster Monitoring Program. Parker, M. FWC Fish and Wildlife Research Institute. 2020

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Volunteer planting mangrove at Tarpon Cove Restoration (Photo credit: PBC-ERM)

HE-2 CREATE AND PROTECT INTERTIDAL HABITATS

ACTION: Identify and pursue opportunities for beneficial reuse of dredged materials to create and enhance habitats. Complete shoreline characterization and restoration suitability modeling study to identify and prioritize future restoration opportunities. Develop measurable standards for determining restoration success and expand post-restoration assessments beyond permit requirements. Increase public support for and involvement in habitat protection and enhancement.

IMPORTANCE:

Coastal habitats such as mangrove, wetland or marsh grasses and seagrasses support fish and wildlife, create recreational opportunities, store carbon, filter pollutants, buffer the impacts of storm, and absorb and mitigate rising sea levels.

RELATED ACTIONS:

HE-1, HE-3, HE-4, SW-2, PU-1

BACKGROUND:

Palm Beach County's innovative habitat enhancement program is widely recognized as a model for creative estuarine renewal in an urban setting. Projects include widespread reuse of lagoon- compatible dredge material to fill deep holes, build protected islands and cap silt and mucky, oxygen-deficient sediments; installation of rock breakwaters and concrete or limestone reefs to reduce erosion and facilitate oyster colonization; and an expanding network of Living Shorelines to mitigate sea level rise by naturally stabilizing shorelines and enhancing intertidal habitats.

From 2014-2020, nearly 43 acres of habitat was created in the Lake Worth Lagoon *(see Figure 1.1 and Table 1.1)*. This includes 30 acres of shallow-water habitat suitable for seagrasses, 6.1 acres of mangroves and salt marshes, and 7.2 acres of breakwaters, living shoreline planters and reefs (oyster and artificial). By 2023, future projects will add more than 60 acres of habitat that includes potential seagrass habitat, mangroves and cordgrass, oyster reefs and bird nesting mounds *(see Figure 1.1)*.

Table 1.1 presents a list of the 18 projects completed during this timeframe. Most of the enhancements occurred in the Central Lagoon, where 30 acres of potential seagrass habitat resulted from just five projects: Grassy Flats, Bryant Park Islands and Living Shorelines, Jewell Cove Living Shoreline, and Tarpon Cove, Phase 1. The Central Lagoon is a priority for water quality improvement because of its distance from the two ocean inlets, and its dubious distinction as the destination for fully half of the freshwater (and associated sediment loads) discharged from drainage canals in the Lagoon watershed.[1]

Monitoring underway at select project sites demonstrates the value of habitat restoration and enhancement to the

Sand shooter in use at Ibis Isle restoration (Photo credit: PBC-ERM)

TABLE 1.1 LIVING SHORELINE AND HABITAT RESTORATION PROJECTS FOR LWL FROM 2014-2020

TOTAL ACRES OF HABITAT CREATED AND/OR ENHANCED

Projects	Completion Date	SAV Habitat (ac)	Intertidal Habitat (Mangrove/ Spartina) (ac)	Breakwater (ac)	Revetment (ac)	Oyster Reef (ac)	Artificial Reef (ac)	Hammock (ac)	Bird Habitat (ac)	Total Acres Restored	Structures & Features
Bryant Park Islands	2014	4.6	0.3	0.2		0.1				5.3	Islands
Grassy Flats	2015	10.5	1.9	0.3		0.09			0.2	12.9	Islands
Bryant Park Living Shorelines (Phase 1)	2015		0.04		0.1	0.04				0.2	Includes 124 feet of artistic modules for breakwater
Peanut Island Reef Complex	2016						0.2				limestone & concrete modules
Jewell Cove Living Shorelines	2016	9.1	0.7		0.2	0.07		0.7		10.7	Intertidal planters
Phil Foster Trail	2017						0.2				limestone, 3 statutes and 17 concrete modules
Sugar Sands Reef	2017						0.2				limestone & concrete modules
Currie Park Living Shoreline	2017		0.3		0.4	0.1				0.8	Intertidal planters
Osprey Park Living Shoreline	2017		0.05		0.06	0.02				0.1	Intertidal planters
Bryant Park Living Shorelines (Phase 2)	2017		0.1		0.3	0.1				0.6	Intertidal planters
Old Bridge Park Dock	2017				0.04	0.01				0.05	Dock, Seawall
Lyman Kayak Park Living Shoreline	2018		0.01		0.03	0.01				0.05	Intertidal planters
Snook Island Modifications	2018	0.2	0.6	0.2	1	0.4			0.4	2.8	Islands
Grassy Flats Modifications	2018			0.04		0.1			0.1	0.3	Islands
Bryant Park Repairs	2018			0.2		0.05			0.1	0.36	Islands
Southern Blvd Bridge Reef	2018						1.7				
Tarpon Cove (Phase 1)	2019	6	2	0.2		0.2			0.2	8.6	Islands
LWL Mangrove Pods	2020		0.1	0.1							mangroves and limestone rocks
	Totals	**30.4**	**6.1**	**1.3**	**2.3**	**1.3**	**2.3**	**0.7**	**1.1**	**42.8**	

Summary 2014-2020 timeline:
* 18 living shoreline/enhancement and restoration projects completed in the Lagoon from 2014-2020
* A total of 42 acres of habitat was created/enhanced throughout the LWL
* 5 projects in the Central Lagoon created 30 acres of potential SAV habitat during this timeline (Grassy Flats, Bryant Park, Repairs and Jewell Cove, Tarpon-Phase I)
* 1.1 acres of bird habitat added to the Lagoon
* 6 additional projects in the Lagoon have been identified and are currently in the construction, permitting and/or design process (Tarpon Cove, Monceaux LS, Bonefish Cove, Providencia Cay Restoration, Lake Worth Inlet Flood Shoal, Palm Beach Resilient Islands)

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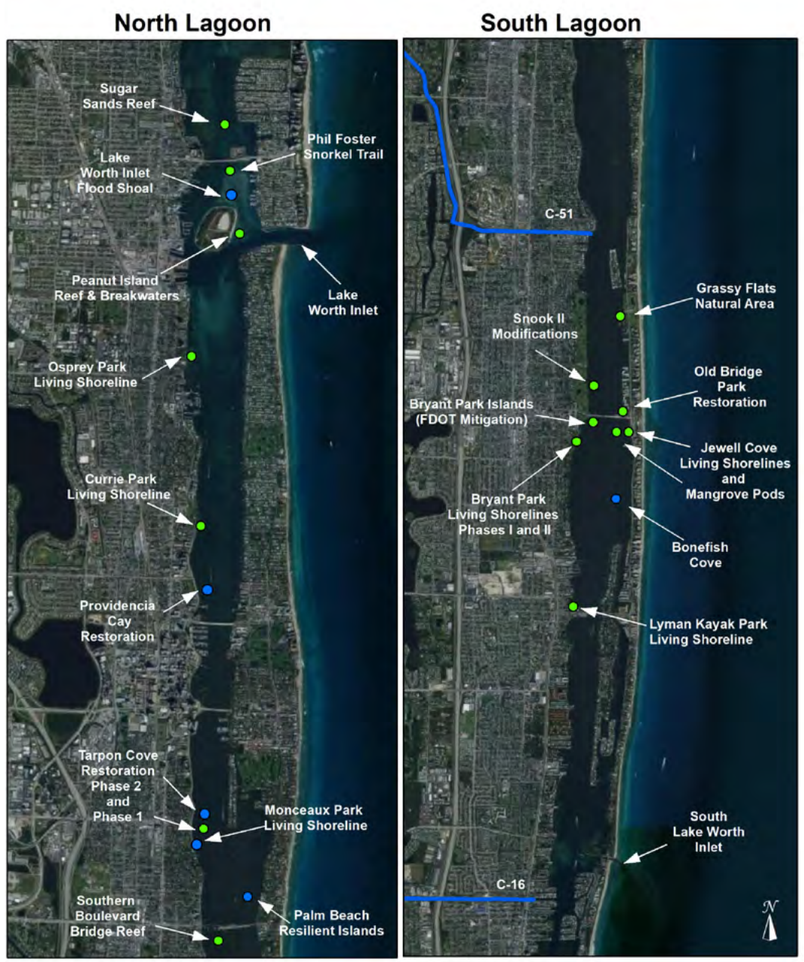
FIGURE 1.1 COMPLETED AND PROPOSED PROJECTS



SOURCE: PBC-ERM

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overall vitality of the Lagoon. The consistent presence of juvenile fish and shellfish in sampling conducted in restoration areas indicates they may provide nursery habitat as well as foraging areas for important sportfish like snook *(see Action FW-3)*. Surveys of shorebirds have documented successful nesting of imperiled American Oystercatchers at four restoration sites: Snook Islands Natural Area, Grassy Flats, Bryant Park Islands and Tarpon Cove Restoration Project *(see Action FW-4)*. Black Skimmers, a threatened species in Florida, successfully nested at Tarpon Cove Restoration in 2020, the first documented nesting in the Lagoon.

Living Shorelines such as the intertidal mangrove planters installed at Jewell Cove are helping to bolster the resilience of the 70% of the Lagoon shoreline armored with seawalls (see Action CC-2). A comprehensive shoreline characterization study incorporating wind, wave and fetch modeling will be completed in 2022, in partnership with the University of Central Florida. The modeling will aid in identifying suitable locations and techniques for future restoration projects integrating living shorelines *(see Figure 1.2)*.

Restoration efforts are led by the County's Environmental Resources Management (ERM) staff, which continually seeks to maximize benefits and reduce costs through partnerships with municipalities, the South Florida Water Management District, the Florida Fish and Wildlife Conservation Commission, Florida Department of Environmental Protection, Florida Department of Transportation, marine industries and, especially, the Florida Inland Navigation District (FIND).

FIND regularly dredges tens of thousands of cubic yards of material from the Intracoastal Waterway (ICW) to facilitate safe navigation. When the dredged material is of suitable quality, it can be used to restore or enhance Lagoon habitats, sometimes in combination with other dredging projects.

Beneficial reuse of material excavated during maintenance dredging has been used in three principal ways:

Creation of Tarpon Cove, phase 1 (Photo credit: PBC-ERM)

- To fill deep holes that were originally dredged decades ago to create land for development, but are now muck-filled, often anoxic pits with little habitat value.
- To create islands that, when complete, form the foundation of multi-purpose "habitat mosaics" including oyster reefs, intertidal areas for mangroves and subtidal areas for seagrasses, and even nesting mounds for shorebirds.
- To cover, or "cap," silty sediments that have been deposited over time by runoff from drainage canals. Entombing these sediments under a layer of clean fill prevents turbidity caused by constant resuspension and provides a more suitable substrate for submerged vegetation to grow.

Snook Islands NA, Bryant Park Islands, South Cove NA, Ibis Isles Restoration, Grassy Flats and Tarpon Cove Restoration are examples of restoration projects aided by beneficial reuse of dredged materials. At Tarpon Cove, all of the sand needed to construct habitat islands in Phase 1 came from maintenance dredging of the ICW and Town of Palm Beach navigation channels, as well as the expansion of the Rybovich Marina and

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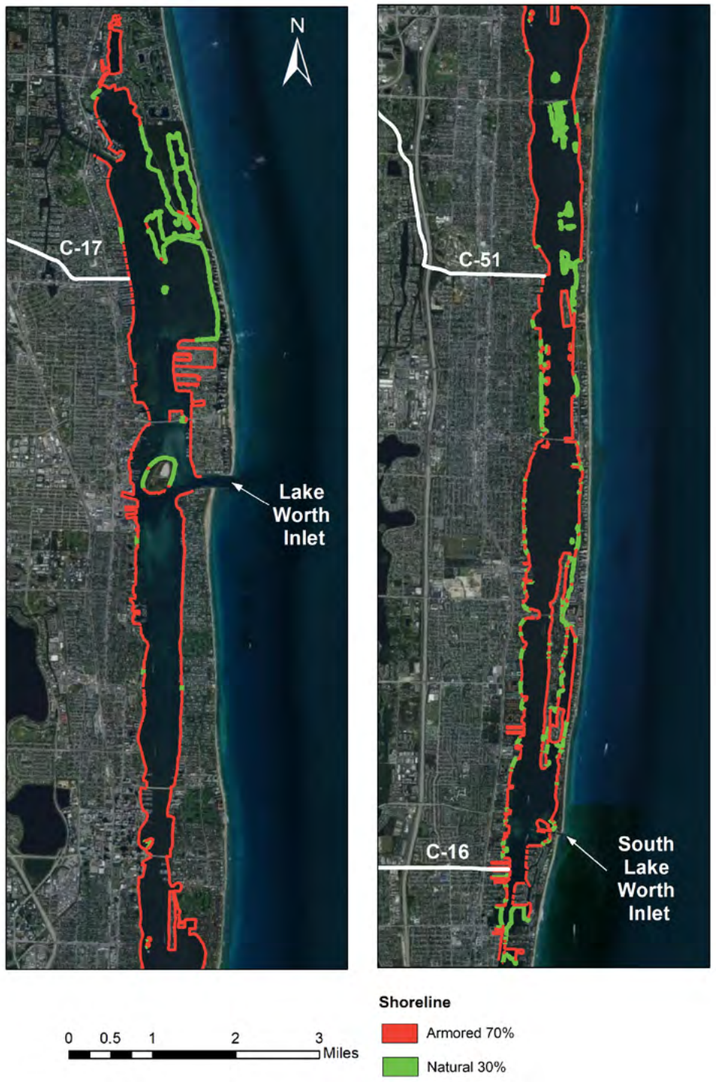
FIGURE 1.2 2020 LAKE WORTH LAGOON SHORELINE CHARACTERIZATION



SOURCE: PBC-ERM

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the Palm Beach Town Docks. The availability of this material saved $10.8 million versus purchase of an equivalent volume of fill.

The planned Bonefish Cove restoration, slated for completion in 2023, also will utilize dredged material: about 375,000 cubic yards of fill will be barged to the site from FIND's and the Port of Palm Beach's Dredged Material Management Areas (DMMA) at Peanut Island, representing a cost savings of $15.8 million.

The Lake Worth Lagoon has been intensely altered by human activities for more than a century. Restoration is an important tool for repairing and replacing areas already damaged or destroyed. Just as important is preservation of the natural habitats that remain – especially seagrasses, a fragile and sensitive indicator of estuarine health that, once lost, is difficult to recover. Acquisition and protection of privately owned submerged lands in the Northern Lagoon that harbor dense seagrass is significantly more cost-effective than restoring seagrass to areas where it has been lost. The cost of restoring suitable substrates and elevations to recruit an acre of seagrass habitat in the Lagoon averaged $550,000 over the last five years, with success in fostering seagrass growth at the restored location not guaranteed.

APPROACH:

STEP 1 Complete the shoreline characterization and suitability restoration modeling study and implement recommendations to enhance seawalls with Living Shorelines or focus future restoration efforts in specific areas of the Lagoon where habitat improvements would be most beneficial.

STEP 2 Continue to pursue opportunities for beneficial reuse of lagoon-compatible dredge material to enhance/expand existing restoration projects, create new restoration sites and cap silty sediments to increase elevations and improve substrate for seagrass recruitment and expansion.

TABLE 1.2 FUTURE RESTORATION PROJECTS

Tarpon Cove (Phase 2)	2020-2022
Monceaux Park Living Shoreline	2021
Bonefish Cove	2021
Lake Worth Inlet Flood Shoal	2021
Providencia Cay Restoration	2022
Palm Beach Resilient Islands	2022

STEP 3 Develop quantifiable criteria to determine long-term restoration success. Expand post-construction monitoring to assess utilization by fish and wildlife over a longer period, as sites mature and evolve. Integrate with water quality and living resources monitoring to direct future restoration activities based on the needs of the entire Lagoon system. Integrate adaptive management into existing restoration projects and make improvements where applicable.

STEP 4 Increase public awareness of the value and connectedness of coastal habitats, the economic contribution of ecosystem services provided by the Lagoon, and the importance of community investment in habitat restoration and protection. Enlist volunteer involvement in monitoring restoration sites or maintaining a county nursery to provide wetland plants for restoration projects.

TIMEFRAME:

STEP 1 Shoreline study to be completed in 2021-2022. Restoration suitability modeling will be completed when funding is acquired.

STEP 2 is ongoing, as opportunities arise to time restoration needs with scheduled maintenance dredging.

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STEP 3 can begin in 2021 with development of measurable criteria for determining restoration success. Long-term monitoring of restoration sites could be conducted by graduate students. Citizens could also be trained in monitoring techniques and involved in monitoring, particularly for Living Shorelines readily accessible from land.

STEP 4 is ongoing. An existing corps of volunteers who participate in habitat restoration projects can be expanded and deployed as Habitat Ambassadors to share information with community members. Volunteers can be trained to assist in monitoring of restoration sites and maintenance of any future county-run wetland plant nursery.

COST ESTIMATE:

STEP 1 $ The field work for the shoreline characterization and restoration suitability modeling study has been completed. Funding for the analysis of the collected datasets and restoration suitability modeling still require funding. Development of recommendations and priorities would require staff time.

STEP 2 $$$-$$$$$ County provides baseline or matching funds for Lagoon restoration.

STEP 3 $ Monitoring criteria can be developed by LWLI Habitat and Water and Sediment Quality Working Groups. Staff time is required to train and supervise students and citizens involved in monitoring and determining individual project's long-term restoration success.

STEP 4 $

EVALUATING PROGRESS:

Acres of specific habitat types restored.

Number of Living Shoreline projects completed.

Creation and utilization of monitoring criteria. Number of students/citizens involved in monitoring.

Number of volunteers for community restoration projects.

Number of residents reached by educational messages and programs about Lagoon habitats.

REGULATORY NEEDS:

None

FUNDING:

LWLI Legislative Funding Request, County/city budget allocations, grants, FDOT (for projects financed by mitigation)

POTENTIAL PARTNERS:*

PBC-ERM, FIND, FDOT, FDEP, FWC, West Palm Beach Fishing Club, area universities, waterfront developers and marine industries, The Nature Conservancy and other land trusts, regional or local conservation organizations, community volunteers

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

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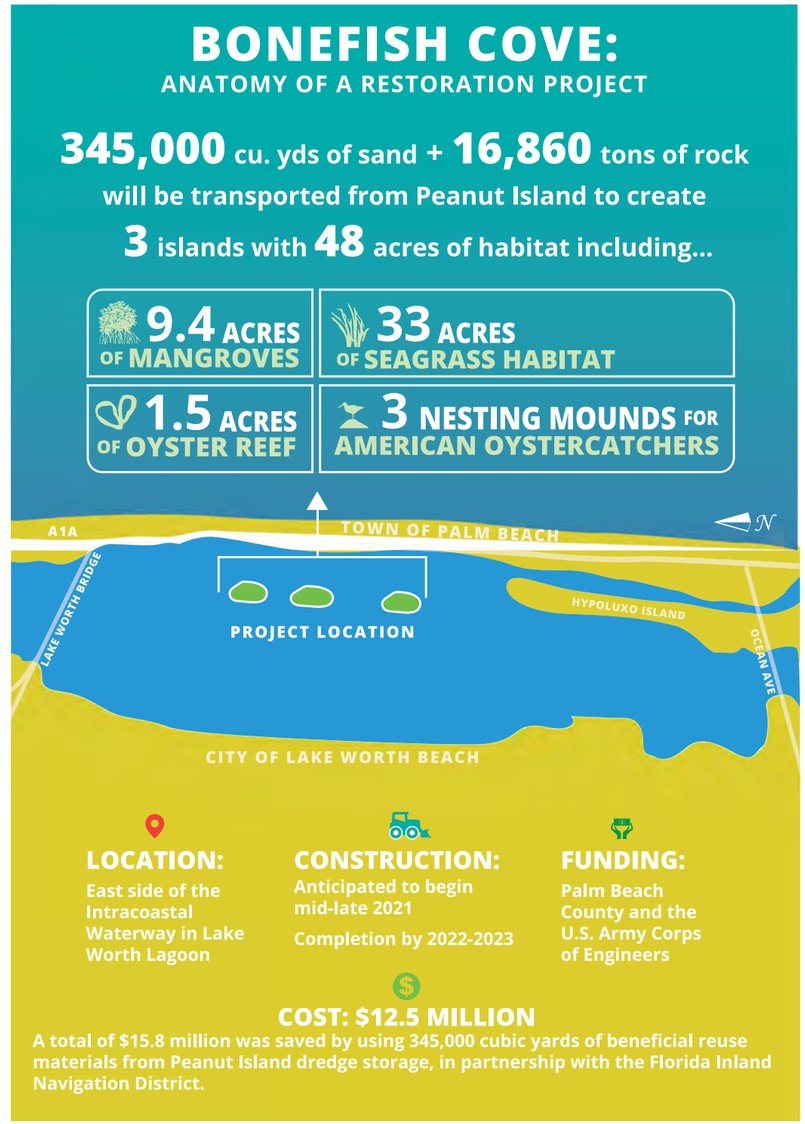
[1] Assessment of Freshwater Inflow and Water Quality for an Urbanized, Subtropical Estuary (Lake Worth Lagoon, Florida, USA). Buzzelli, C., et al. Marine Technology Society Journal. 2018.



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Mixed bed of shoal grass and Johnson's seagrass (Photo credit: PBC-ERM)

HE-3 MAINTAIN AND EXPAND SEAGRASS HABITATS

ACTION: Continue annual transect sampling and Lagoonwide mapping. Expand water quality monitoring to better understand factors impacting seagrass in the Lagoon. Update seagrass recovery targets for North, Central and Southern Lagoon segments, and pursue acquisition of submerged lands with dense seagrass beds in the Northern Lagoon.

IMPORTANCE:

Seagrass is an important ecological barometer of water quality and an essential habitat that provides food, shelter, and nursery areas for numerous marine and estuarine dependent species.

RELATED ACTIONS:

WQ-1, WQ-2, HE-2

BACKGROUND:

Seagrasses are a valuable and vulnerable habitat in the Lake Worth Lagoon. Although all seven seagrass species found in Florida occur in the Lagoon *(see Table 1.1)*, more than 83% of the total seagrass acreage is in the Northern Lagoon, from John D. MacArthur State Park to Singer Island, in close proximity to the Lake Worth (Palm Beach) Inlet.

Significant and troubling changes have occurred in overall seagrass cover and composition throughout the Lagoon since 2013.[1] These changes have been documented by annual sampling of 10 permanent transects to assess fine-scale data including seagrass species and abundance, supplemented by GIS analysis and field verification every five years.

GIS analysis and groundtruthing surveys show the overall extent of seagrass within the LWL decreased by 30 acres from 1,582 acres in 2013 to 1,552 acres in 2018 *(see Table 1.2)*. However, the declines were disproportional, with greater losses in the Southern and Central Lagoon, and dramatic thinning of seagrass and compositional shifts in canopy species in the Northern Lagoon *(see Figure 1.1)*. A major reduction in seagrass was documented in the Central Lagoon.

Among the specific changes observed in the 2013 and 2018 mapping:

- In 2018, only 1.2 acres of seagrass were found in the Central Lagoon, in shallow waters at Snook Islands and South Cove Natural Areas.
- A loss of nearly 100 acres of seagrass occurred from 2013-2018 between the Central/ Southern Lagoon boundary and the Ocean Boulevard Bridge.
- Seagrass cover increased by 94 acres in the north segment between 2013 (1,207 acres) and 2018 (1,301 acres). However, seagrass density experienced a seismic shift. The amount of moderate/high density seagrasses plummeted from 588

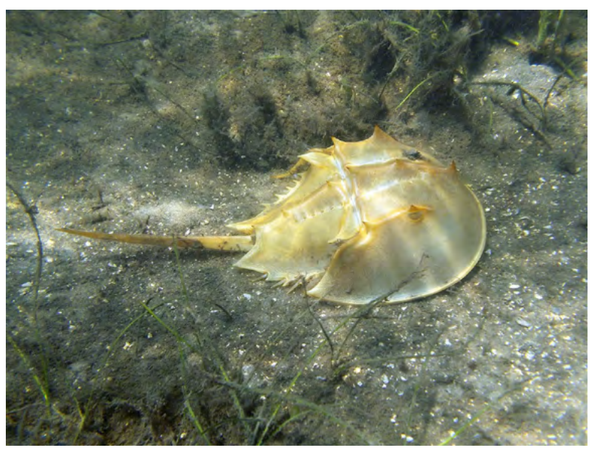
SEAGRASS SPECIES FOUND IN THE LAKE WORTH LAGOON

Shoal Grass *(Halodule wrightii)*
Manatee Grass *(Syringodium filiforme)*
Turtle Grass *(Thalassia testudinum)*
Widgeon grass *(Ruppia maritima)*
Star Grass *(Halophila engelmannii)*
Paddle Grass *(Halophila decipiens)*
Johnson's Seagrass *(Halophila johnsonii)**
**Listed as a threatened species under the Federal Endangered Species Act*

Table 1.1: Seagrass species found in Lake Worth Lagoon

acres in 2013 to 256 acres in 2018, a drop of 56%. The amount of low density/patchy seagrass habitat increased by nearly 67% increase during that period, from 528 acres to 881 acres. The greatest retraction has occurred in John D. MacArthur Beach State Park and Munyon Cove, home to the largest remaining seagrass beds in the Lagoon.

- MacArthur Beach State Park and Munyon Cove are now the only areas within the Lagoon that support the canopy species, *Syringodium filiforme* and *Thalassia testudinum*, important food sources for green sea turtles and manatees, and nursery areas for fish and invertebrates. But overall cover and distribution of these species declined between 2013 and 2018. The declines coincided with a transition from those larger, longer-lived seagrass species to small canopy species (e.g., *Halophila* spp.). Algal species also have increased; sea turtles now consume a higher proportion of Halophila and algae that they did prior to 2013 *(see Action FW-2)*.[2]
- The percentage of sites with no seagrass increased between 2013 and 2018, as did the percentage of sites with less than 5% cover. There were lagoon-wide declines in the number and percentage of sites with more than 5% seagrass cover.



Horseshoe crab molt, Northern Lagoon (Photo credit: PBC-ERM)

Transect sampling in 2019 and 2020 shows that the Northern Lagoon continues to support the highest seagrass cover and diversity of the three lagoon segments. However, overall frequency of seagrass occurrence continued to decline there and elsewhere in the Lagoon. In May 2020, five transects (all four transects in the Central Lagoon and one in the Southern Lagoon) had no seagrasses at all.

It is likely that multiple factors interacting synergistically, and not a single culprit, are responsible for the precipitous spatial and temporal changes in Lagoon seagrasses. Freshwater inflows, especially in the Central Lagoon, frequently lower salinities below tolerances for many seagrass species and contribute nutrients, sediments, and contaminants *(see Action WQ-6)*. Sediments carried in the freshwater discharges form thick layers of black muck ill-suited to seagrass growth *(see Action SE-1)*. Wind and boat wakes cause repeated resuspension of these sediments, increasing the light attenuation and severely reducing the light available for seagrasses to grow, let alone flourish.

A lagoon-wide seagrass restoration target of 2,000 acres was set in 2006. Verification of the methodology used and updated data is needed to accurately determine the maximum depth

TABLE 1.2 SEAGRASS ACREAGE IN LAKE WORTH LAGOON 2013 AND 2018

	North Segment	Central Segment	South Segment	LWL Total
2013 Acreage Summary				
2013 Seagrass Habitats				
Moderate to High Density Seagrass Habitat	588	-	2	590
Low Density/Patchy Seagrass Habitat	528	16	266	809
Zone of Seagrass Occurrence	91	12	82	184
Unvegetated Potential Seagrass Habitat	72	105	88	265
Unvegetated Softbottom	-	71	-	71
Not Surveyed	4	2	2	9
All Habitat Total	1283	205	439	1927
Total 2013 Seagrass Habitat	**1207**	**27**	**349**	**1582**
2018 Acreage Summary				
2018 Seagrass Habitats				
Moderate to High Density Seagrass Habitat	256	-	15	271
Low Density/Patchy Seagrass Habitat	881	-	121	1002
Emergent Shoal Low Density / Patchy Seagrass Habitat	1	-	-	1
Zone of Seagrass Occurrence	162	1	114	277
Unvegetated Potential Seagrass Habitat	150	109	101	360
Unvegetated Potential Seagrass Habitat (2013)	-	26	97	26
All Habitat Total	1451	137	448	2036
Total 2018 Seagrass Habitat	**1301**	**1**	**249**	**1552**
New Seagrass Habitats Added in 2018				
Moderate to High Density Seagrass Habitat	41	-	1	42
Low Density/Patchy Seagrass Habitat	34	-	1	35
Emergent Shoal Low Density / Patchy Seagrass	1	-		1
Zone of Seagrass Occurrence	16	-	0	16
Unvegetated Potential Seagrass Habitat	2	-	0	2
All Habitat Total	**94**	**0**	**2**	**96**
Total New Seagrass Habitat	**92**	**0**	**2**	**94**

SOURCE: Coastal Eco-Group, Inc.

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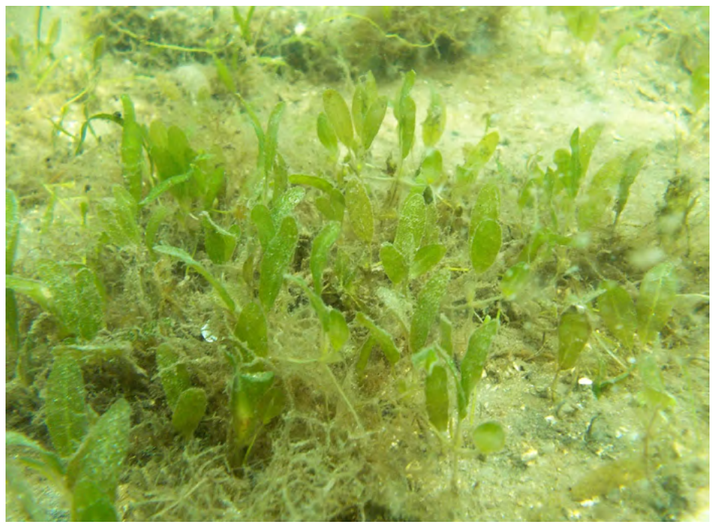
at which seagrass will recruit in each lagoon segment.

More importantly, additional research and monitoring is needed to evaluate which environmental parameters are driving current declines in seagrass cover throughout the lagoon.

Since 2013, an additional 30 acres of potential seagrass habitat has been added through the construction of five habitat restoration projects, each containing a seagrass component: Grassy Flats and Bryant Park Island, Jewell Cove Living Shorelines, Snook Islands Natural Area Phase II and Tarpon Cove Phase I Restoration *(see Action HE-2)*. Another 29 acres of seagrass habitat will be created by Phase 2 of the Tarpon Cove Restoration project, followed by 35 acres from the Bonefish Cove Restoration, slated for completion in 2023. Acquisition of privately owned submerged lands, from interested sellers, in the Northern Lagoon is also important for protecting existing seagrasses *(see Action HE-4)*.



Paddle grass in the Northern Lagoon (Photo credit: PBC-ERM)

In 2018, ERM staff began routinely filling new habitat restoration sites to a shallower depth (from -5 feet to -4 feet) to increase the probability of seagrass recruitment. This practice is an interim approach based on best available information and can be modified with more precise knowledge of growth and natural recruitment requirements for seagrasses in the north, central and south Lagoon sections.

APPROACH:

STEP 1 Continue annual transect sampling and Lagoonwide mapping every 5 years.

STEP 2 Expand water quality monitoring for additional environmental parameters affecting SAV (temperature, turbidity, light, seasonality, wind-boat wakes, sedimentation) to better understand factors impacting seagrass in the Lagoon *(See Action WQ-1)*.

STEP 3 Install photosynthetically active radiation (PAR) sensors to understand light requirements for seagrass to flourish at different depths in the Lagoon.

STEP 4 Identify causes of seagrass declines and species shifts in the Northern Lagoon.

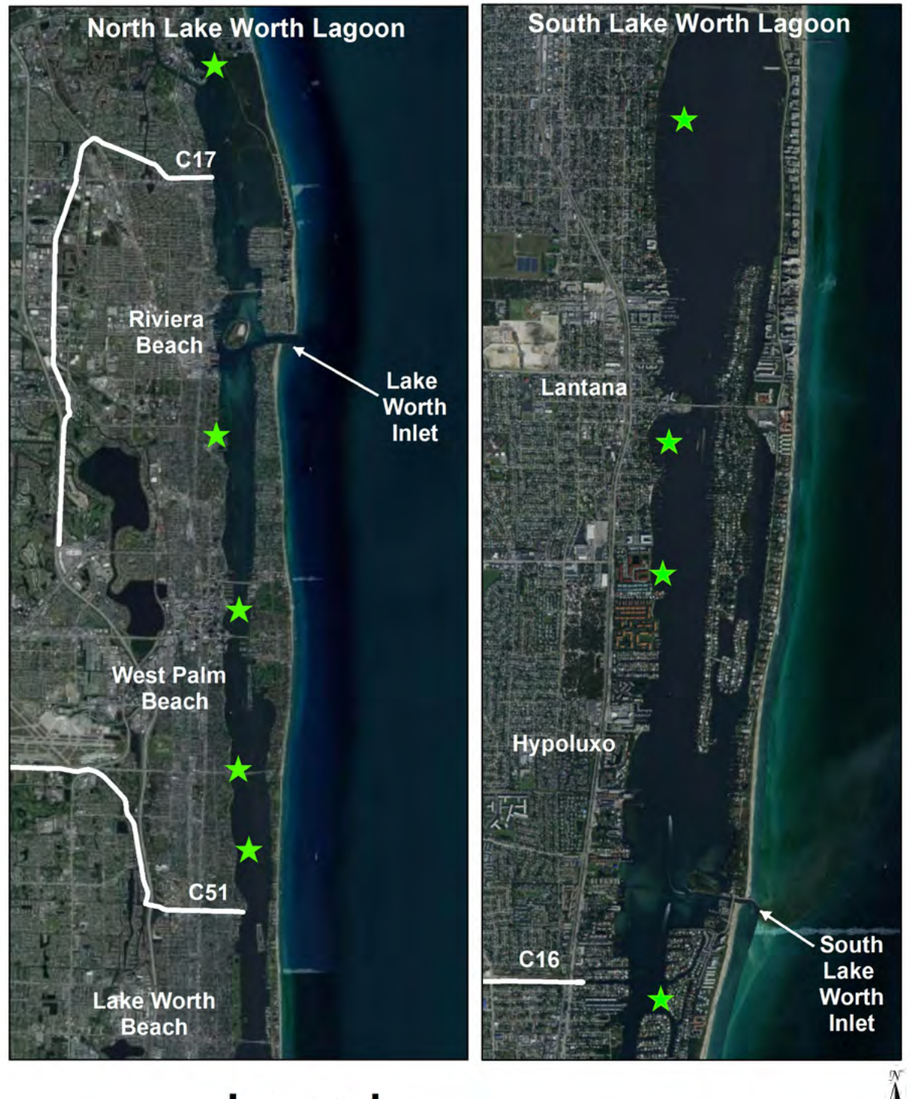
STEP 5 Update seagrass recovery targets for Lagoon segments based on light attenuation, sediment types and other factors.

STEP 6 Pursue acquisition of important seagrass resources in the Northern Lagoon *(See Action HE-4)*.

TIMEFRAME:

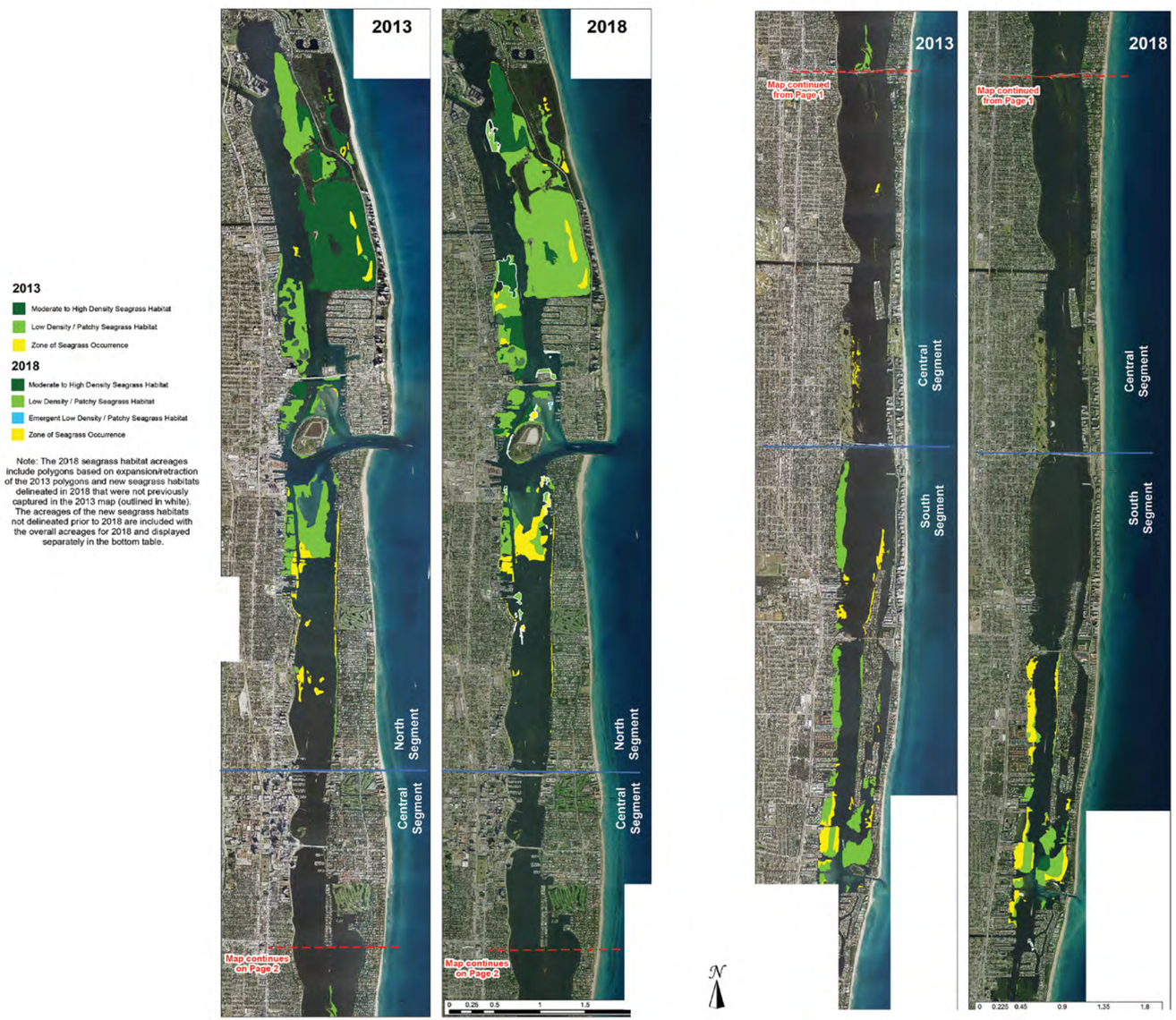
Transect sampling in STEP 1 occurs annually. Lagoonwide seagrass mapping next scheduled in 2023.

FIGURE 1.1 LWL TRANSECT MONITORING



SOURCE: PBC-ERM

FIGURE 1.2
2013 & 2018 LAKE WORTH LAGOON SEAGRASS HABITAT MAPS



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SOURCE: Coastal Eco-Group Inc.

STEP 2 is dependent on completion of hydrodynamic model and funds to add monitoring components *(see Action WQ-2)*.

STEP 3 can occur in 2022 if funds available to acquire sensors.

STEP 4 is ongoing as enhanced monitoring provides insights into dynamics of factors affecting seagrass growth and species distribution throughout the Lagoon.

STEP 5 can occur once light attenuation needs are better understood and hydrodynamic modeling adds to knowledge of sediment deposition, transport, and type.

STEP 6 County acquisition of submerged lands from willing sellers or donors can begin in 2022, contingent upon available funds and willing sellers.

COST ESTIMATE:

STEP 1 $$

STEP 2 $$-$$$

STEP 3 $

STEP 4 $$$-$$$$

STEP 5 $

STEP 6 $$$$$

EVALUATING PROGRESS:

Increases in seagrass recruitment per target goals for each Lagoon segment.

Acres of seagrass documented in restoration areas.

Acquisition of privately owned submerged lands supporting seagrass beds from willing sellers or donors.

REGULATORY NEEDS:

None

FUNDING:

LWLI Legislative Funding Request, recurring or special county/city budget allocations, grants to assist with research and land acquisition

POTENTIAL PARTNERS:*

PBC-ERM, SFWMD, Local Municipalities, FIND, FWC, HBOI/FAU, FDEP

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

[1] 2018 Lake Worth Lagoon Seagrass Status and Annual Transect Monitoring Report. Coastal Eco-Group, Inc. Cumulative Report 2018.

[2] Assessment of Marine Turtles in Lake Worth Lagoon 2017-2018. Inwater Research Group. 2019.

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Mixed segarass bed at Singer Island (Photo credit: PBC-ERM)

HE-4 ACQUIRE ECOLOGICALLY SIGNIFICANT SUBMERGED AND INTERTIDAL LANDS

ACTION: Acquire and/or protect privately owned submerged and intertidal lands of particular ecological value from willing sellers or donors throughout the Lagoon.

IMPORTANCE:

Seagrass beds in the Northern Lagoon are among the healthiest and most dense in the estuary and provide critical habitat for a multitude of species. Protection of existing seagrasses is considerably more cost-effective than fostering new seagrass growth through habitat restoration. Other submerged lands throughout the Lagoon also support valuable habitat and could be acquired as opportunities become available.

RELATED ACTIONS:

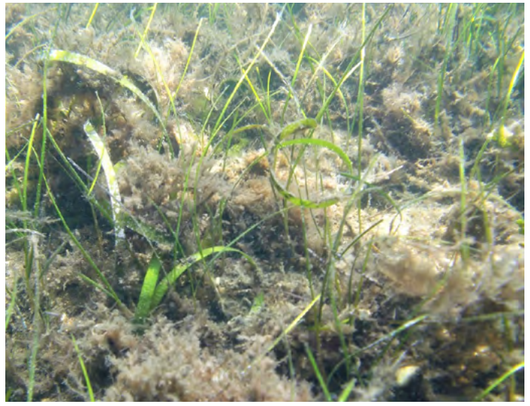
HE-3, FW-1, FW-2, FW-3

BACKGROUND:

Seagrass meadows are an ecologically valuable and vulnerable habitat in the Lake Worth Lagoon *(See Action HE-3)*. Submerged lands harboring some of the Lagoon's healthiest remaining seagrasses are in private ownership, placing them at risk of development impacts.

In particular, 29 parcels of submerged land comprising 152 acres near Singer Island are the highest priority for acquisition and conservation *(see Figure 1.1)*. These lands, primarily located within the City of Riviera Beach, range in size from 1.13 acre to 23.05 acres and are owned by various private entities. Together, the parcels contain the largest and most dense beds of turtle grass and manatee grass in the Lagoon. The seagrasses are a nursery for dozens of species of fish and shellfish, mating grounds for horseshoe crabs, and an important food source for manatees and juvenile green sea turtles *(See Action FW-2)*.

Conservation of these ecologically sensitive lands through public ownership or other private protection measures is supported by Palm Beach County and the City of Riviera Beach, who have previously committed up to $250,000 in matching funds for their purchase. In 2020, the Florida Legislature allocated $150,000 toward acquisition, but the funds were vetoed at the end of the State's budget process. The County resubmitted the proposal as part of the 2021 LWLI Legislative Funding Request.



Shoal grass and turtle grass in Northern Lagoon (Photo credit: PBC-ERM)

The County desires to acquire the lands through donations or fee-simple purchases with willing sellers, but could also pursue other strategies such as conservation easements. Currently, the average cost of creating suitable substrate and elevations to recruit an acre of seagrass in the Lagoon is about $500,000. Acquisition of submerged lands with existing seagrass, or shallow waters suitable for seagrass, would be considerably less costly than restoring deep-water areas to foster seagrass recruitment which is not guaranteed.

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APPROACH:

STEP 1 Continue to maintain contact with willing property owners regarding interest in sale or donation of lands. Resubmit funding request for Singer Island submerged lands to Legislature, and galvanize public support for funding from conservation organizations, recreational user groups and citizens. Once funding is secured, develop an acquisition timetable.

STEP 2 Work with regulatory agencies to ensure the protection of submerged resources with ecologically valuable submerged and intertidal lands are fully considered when processing permit applications. Encourage permitting agencies to consider acquisition and preservation of these properties as partial mitigation for unavoidable impacts when evaluating permits.

TIMEFRAME:

STEP 1 can be initiated in 2021 with LWLI funding request and a concerted effort to galvanize support for acquisition of lands. Acquisition of priority submerged lands near Singer Island is expected to take several years, and is contingent on willingness of property owners to sell or place lands under conservation easements.

STEP 2 can be initiated in 2021 and continue thereafter as long as ecologically important submerged lands remain in private ownership.

COST ESTIMATE:

STEP 1 $-$$$$ for acquisition of priority lands over time

STEP 2 $ Staff time

EVALUATING PROGRESS:

Parcels acquired from willing sellers or donated.

Acres of seagrass protected or enhanced.

Marine species utilization of acquired lands.

REGULATORY NEEDS:

Limited entry or boating speed zones may be needed to protect seagrass beds. Regulatory oversight required to prevent impacts to priority submerged lands, and to authorize mitigation credits or other permitting incentives in exchange for placement of conservation easements on submerged lands by property owners or third parties.

FUNDING:

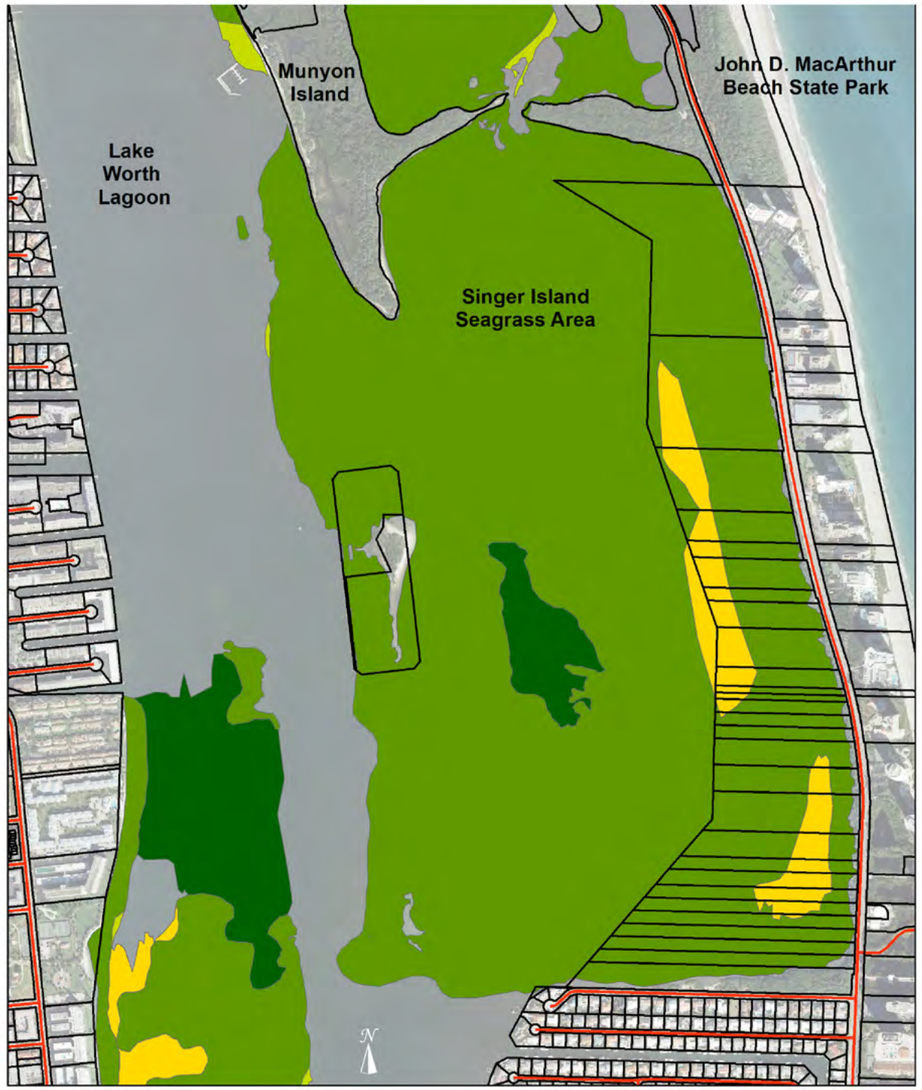
ERM, LWLI Legislative Request, Local Municipalities, USFWS National Coastal Wetlands Conservation Grant Program, NOAA Coastal and Estuarine Land Conservation Program

POTENTIAL PARTNERS:*

PBC-ERM and Property and Real Estate Management Departments, City of Riviera Beach, FDEP, FWC, USFWS

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

FIGURE 1.1 LAND ACQUISITION MAP



SOURCE: PBC-ERM

FISH AND WILDLIFE MONITORING AND PROTECTION
ACCOMPLISHMENTS AT A GLANCE

From 2013-2020, law enforcement agencies provided **11,250 hours of on-water enforcement** of seasonal manatee protection zones.

SEE ACTION FW-1

920 sea turtle observations were reported in the North Lagoon from 2005-2018. The vast majority were **juvenile green sea turtles about the size of a dinner plate.**

SEE ACTION FW-2

22 commercially important species of fish and shellfish have been documented in the lagoon since monitoring began in 2014. The most abundant fish collected is the **Bay Anchovy,** a baitfish that compromised 38.3% of the total Lagoon catch.

SEE ACTION FW-3

American Oystercatchers successfully fledged **35 chicks** at restoration sites in the Lagoon from 2005-2020. **Least Terns, Black Skimmers, and American Oystercatchers**—all protected—use restored areas for both nesting and foraging.

SEE ACTION FW-4

New research utilizing drones indicates that the coastal waters of Southeast Florida are **a nursery area for Manta Rays.** Juvenile Manta Rays have been observed at the **Blue Heron Bridge and feeding in the South Lake Worth Inlet.**

SEE ACTION FW-5

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FW-1 CONTINUE IMPLEMENTING PALM BEACH COUNTY'S MANATEE PROTECTION PLAN

ACTION: Continue implementation of PBC-MPP and improve manatee protection in and around the Lake Worth Lagoon.

IMPORTANCE:

Continued implementation of the County's Manatee Protection Plan and boat facility siting component will provide a unified, countywide approach to manatee conservation.

RELATED ACTIONS:

HE-3, PO-1, PU-2, FW-5

BACKGROUND:

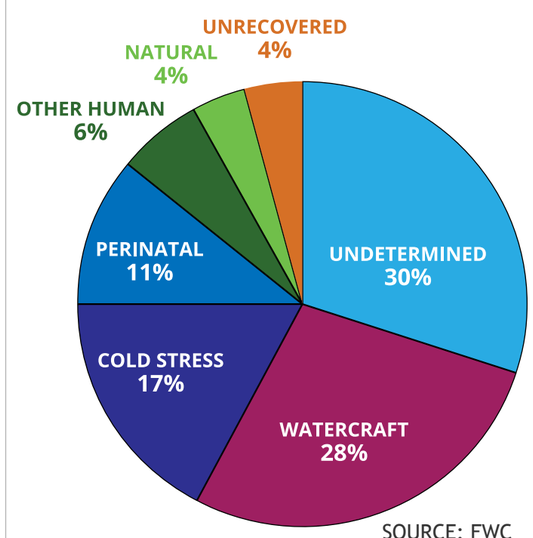
As one of 13 designated "Key" Counties for manatees in Florida, Palm Beach County continues to implement a Manatee Protection Plan (MPP) that requires siting restrictions on marinas and docks, enforcement of boating speed zones, community education, and data collection and monitoring. The Plan was approved in 2007; the County's Department of Environmental Resources Management (ERM) has primary implementation responsibility.

The County dedicates $750,000 a year in ad valorem revenues to implementing the MPP *(see Table 1.1)*. The bulk of that, $575,000, is used for habitat restoration that benefits manatees as well as other wildlife, in conjunction with state and federal matching funds. The restored habitats provide various recreational opportunities for residents and tourists, in addition to their fundamental wildlife value. About $150,000 is devoted to enforcing boating speed zones and $25,000 to public education.

Program goals are to:

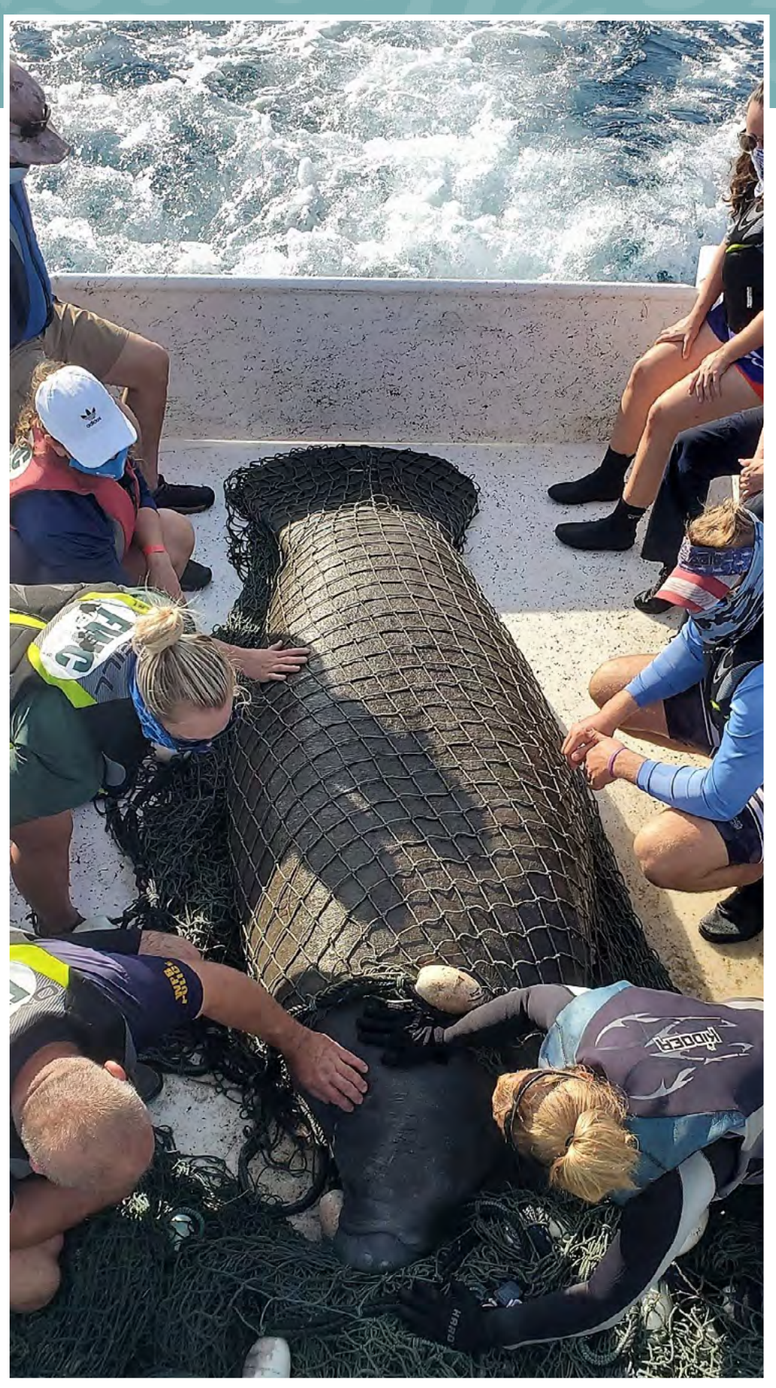
- Reduce manatee injuries and mortalities due to watercraft collisions.
- Assess manatee populations and use of the Lagoon to track conservation success and identify important habitats. The Florida Fish and Wildlife Conservation Commission (FWC) typically conducts annual statewide synoptic surveys of manatees, usually after a winter cold front when manatees are aggregated at warm-water refuges. However, weather conditions and FWC's staffing constraints mean that Palm Beach County is not always surveyed.
- Provide public education relating to manatees and safe boating practices to avoid injury.

FIGURE 1.1
2014-2019 MANATEE MORTALITY IN PALM BEACH COUNTY BY CAUSE



SOURCE: FWC

- Address waterway sign installation, maintenance and replacement in a timely manner.
- Assist FWC with manatee strandings in the Lagoon.
- Support additional research by partner agencies to monitor manatee occurrence, health and habitat utilization within the Lagoon.



FWC and Palm Beach County staff work to rescue an injured manatee in the Lagoon (Photo credit: PBC-ERM)

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TABLE 1.1 SUMMARY OF MANATEE LAW ENFORCEMENT PROGRAM 2007-2018

Manatee Season	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	Total
Educational Contacts	789	2,321	3,276	4,868	3,341	2,226	2,150	1,244	1,464	1,025	989	1,071	978	25,742
Total Citations	255	370	239	292	232	227	183	147	125	125	104	93	57	2,449
Manatee Zone Citations	153	215	151	178	137	202	152	118	100	101	87	70	46	1,710
Total Written Warnings	293	1,152	815	1,409	1,002	591	931	621	670	698	762	656	444	10,044
Manatee Zone Warnings	165	712	872	1,589	649	283	467	349	362	392	538	417	393	7,188
TOTAL HOURS	**1,000**	**2,179**	**2,341**	**2,193**	**1,669**	**1,604**	**1,717**	**1,643**	**1,657**	**1,573**	**1,635**	**1,559**	**1,466**	**22,236**

SOURCE: PBC-ERM

As winter sets in, large numbers of manatees gather near the Florida Power and Light (FPL) Next Generation Clean Energy Center in Riviera Beach to take advantage of the power plant's warm-water discharges. More than 500 manatees have been counted there during cold-weather periods. FPL's Manatee Lagoon Eco-Discovery Center has an observation deck and educational exhibits that annually offer visitors the chance to learn about and view manatees up close. In 2019, FPL's Manatee Lagoon Eco-Discovery Center welcomed 162,422 visitors.

Palm Beach County has an active on-water law enforcement presence, especially during the winter "Manatee Season," which runs from November 15 to March 31. During this period, seasonal slow-speed zones are in effect and the population of manatees swells in the Lagoon as they migrate from colder regions in north and central Florida in search of warmer waters. These slow speed zones are intended to protect manatees as they traverse shallow waters and busy boating channels throughout the County's waterways.

Manatees at FPL Riviera Beach power plant outfall (Photo credit: FWC)

Year-round slow speed zones also are in effect in waters heavily trafficked by resident and visiting boaters. These regulations help protect the small year-round resident manatee population that feeds on seagrass adjacent to Munyon and Peanut Islands, and rests around the South Cove and Snook Islands Natural Areas. Manatees have also been spotted visiting the newly constructed Tarpon Cove Islands.

For the 2018-2019 manatee season, the County's coordinated Manatee Law Enforcement (MLE) Program provided funding for an additional 1,559 hours of on-water patrols throughout the County's waterways. Nine local law enforcement agencies participated in the program: Tequesta, Jupiter, North Palm Beach, Riviera Beach, West Palm Beach, Lantana, Boynton Beach, Boca Raton and the Palm Beach County Sheriff's Office.

This partnership operates under a series of 5-year Interlocal Agreements that provide overtime funding for on-water enforcement personnel during manatee season. The current agreements expire on March 31, 2023.

Officers with the Florida Fish and Wildlife Conservation Commission also enforce the speed zones and are an additional visible presence on Lagoon waters.

Three watercraft-related manatee mortalities were reported during the 2018-2019 manatee season. From 2014-2019, 15 of the 53 manatee deaths in the County (28%) were a result of watercraft collisions *(see Figure 1.1)*.

Palm Beach County staff occasionally ride along with law enforcement officers for a firsthand look at how existing protections are working and to assess potential new problem areas.

Education targeting boaters and the general public supplements and enhances law enforcement efforts: Since 2013, informational kiosks at 12 local boat ramps have been redesigned and updated, and new educational materials

MANATEE MORTALITY VIA WATERCRAFT 2013-2019 (654 TOTAL MANATEES STATEWIDE)

County	Number of Manatees	%
Lee	126	19.3%
Brevard	69	10.6%
Palm Beach	19	2.9%

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Law enforcement officer enforcing manatee slow speed zones in Palm Beach County (Photo credit: PBC-ERM)

have been created and displayed at numerous boating and environmental events, including the annual LagoonFest and Manatee Fest at Manatee Lagoon Eco-Discovery Center. Print and video news releases routinely provide public updates on manatee issues and manatee season reminders.

As part of the educational outreach, officers instruct boaters to obey posted speed zones and be alert for manatees that travel the Intracoastal Waterway (ICW) to reach warm waters as far south as Broward and Dade counties in winter, and back again in spring. Officers also hand out laminated information cards with manatee protection tips *(see Figure 1.2)*.

The MPP was incorporated in the County's Comprehensive Plan. The County also encouraged local municipalities to adopt the MPP into their respective Comprehensive Plans. The cities of West Palm Beach and Boynton Beach adopted the MPP in 2008 and 2009, respectively.

APPROACH:

STEP 1 Continue implementing the Manatee Protection Plan. Maintain funding for MPP implementation at existing levels.

STEP 2 Continue to utilize funding for overtime hours for law enforcement during manatee season. Add municipalities to the LE program, and encourage agencies to increase regional multi-agency manatee enforcement patrols like "Operation Mermaid" in PBC and adjacent Counties. As resources permit, return funding of the MLE program to 2007 levels ($200,000 per year).

STEP 3 Continue to raise public awareness of the importance of the Lagoon to manatees through education about critical habitats and manatee-friendly boating. Support education efforts at the Manatee Lagoon FPL Eco-Discovery Center and other facilities.

FIGURE 1.2
WHAT CAN YOU DO TO PROTECT MANATEES?

- Be mindful when boating
- Obey posted manatee protection areas, know speed zones for the areas you travel to
- Travel slowly giving manatees a chance to get out of your way
- Wear polarized sunglasses help to see manatees in the water
- Minimize your interactions with manatees: Keep wild creatures wild
- Never pursue a manatee with your boat, kayak or paddleboard for a better look
- Report damaged or missing Manatee Speed Zone signs -866-405-Buoy (2869) or waterway.management@myfwc.com
- Report injured or distressed manatees to FWCC's Wildlife Hotline

STEP 4 Continue Seagrass and Water Quality Monitoring. Consider engaging a contractor to survey manatees in the Lagoon as part of FWC's annual statewide synoptic counts. Support additional research, including remote sensing technology if proposed by FWC or USFWS to better understand manatee utilization and distribution in the Lagoon. (*See FW-5*)

Officer enforcing manatee slow speed zones (Photo credit: PBC-ERM)

STEP 5 Identify opportunities to create or enhance habitat for manatees within the Lagoon. *(See HE-2, HE-3)*

TIMEFRAME:

STEP 1 Ongoing.

STEP 2 Ongoing. ERM requests annual funding allocations through the County's budget process.

STEP 3 Ongoing.

STEP 4 Ongoing. Seagrass transects sampled annually. Water quality monitoring occurs monthly. Funding to conduct annual synoptic surveys of manatees in the Lagoon could be requested in 2022-2023.

STEP 5 Ongoing, through restoration that includes seagrass habitats. Acquisition of seagrass beds near Singer Island (*See HE-4*) would protect an important year-round feeding area for manatees.

COST ESTIMATE:

STEP 1 $

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Manatee cow and calf (Photo credit: PBC-ERM)

Rescue of manatee at Bird Island 2018 (Photo credit: PBC-ERM)

STEP 2 $$$

STEP 3 $

STEP 4 $$$

STEP 5 $-$$$$$

EVALUATING PROGRESS:

Increased creation, enhancement or preservation of manatee foraging or refugia habitat.

Reduction in manatees injured/killed by watercraft.

Increase in compliance with regulatory speed zones.

REGULATORY NEEDS:

Continued implementation of on-water law enforcement and marina/boat siting facility restrictions in Manatee Protection Plan.

FUNDING:

Recurring County budget allocations (for law enforcement and habitat restoration); Grants (for education programs)

POTENTIAL PARTNERS:*

ERM, FWC, FDEP, municipalities, FPL Manatee Lagoon Eco Discovery Center, environmental education centers

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

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Researcher measuring width of turtle carapace (Photo credit: Inwater Research Group)

FW-2 CONTINUE SEA TURTLE MONITORING

ACTION: Monitor the health and abundance of sea turtles utilizing the Lake Worth Lagoon by continuing to perform annual monitoring, including visual surveys and captures. Acquire more information on sea turtle growth rates, spatial distribution, and movements in the Lagoon. Explore potential relationships between seagrass fluctuations, water quality, and turtle dietary shifts. Determine whether, and what, environmental factors contribute to the presence of fibropapilloma (FP) virus in turtles in the Lagoon.

IMPORTANCE:

Sea turtles are an important indicator species of estuarine health. Monitoring their health, abundance and distribution in the Lagoon is important to overall assessments of water quality and habitat conditions. Green sea turtles, the most prevalent species in the Lagoon, are federally listed as an endangered species.

RELATED ACTIONS:

WQ-1, HE-3, HE-4, FW-5, PO-1

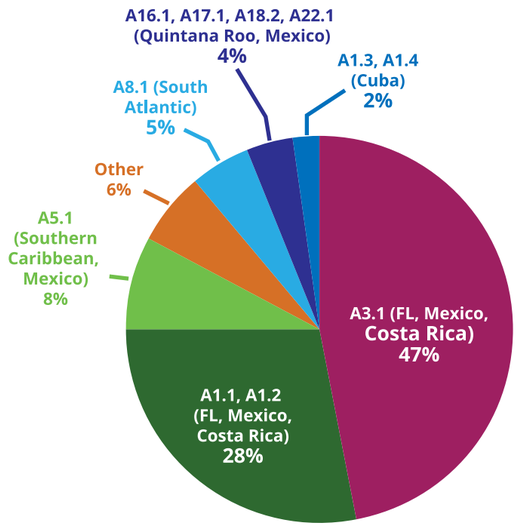
BACKGROUND:

Turtle monitoring has been conducted in the Northern Lagoon since 2005. This work, performed by Inwater Research Group under contract to Palm Beach County's Department of Environmental Resources Management (ERM), provides critical baseline information on species, size, and abundance. The surveys have revealed many more turtles than expected utilizing the Lagoon, particularly juvenile green turtles *(Chelonia mydas)*. In 2018, a density of 37.4 turtles/km2 was reported in the Munyon Island area, markedly higher than other study sites in the Florida Keys, Indian River Lagoon, and offshore areas of Palm Beach County.[1]

Among the highlights of this long-term data collection:

- Munyon Cove, with its rich seagrass beds, was identified as a hot spot for juvenile green sea turtles. The vast majority of the 920 sightings of sea turtles from 2005-2018 were juvenile greens observed in the North Lagoon, east of Little Munyon Island. The average size of turtles captured in surveys was 33 cm, about the size of a large dinner plate.
- DNA sampling traced the birthplace of the 179 turtles captured in the Lagoon to nesting beaches in Florida, Cuba, Mexico, Costa Rica, southern Caribbean, and the South Atlantic. Some of the home beaches are more than 5,000 miles away. About 75% of the Lagoon turtles surveyed were hatched on beaches in Florida, Mexico, or Costa Rica *(see Figure 1.1)*.
- Nearly half (48.3%) of the 179 turtles captured (or recaptured) exhibited the presence of benign but debilitating external tumors associated with fibropapillomatosis (FP), a virus that occurs primarily in green turtles *(see Figure 1.2)*. By

FIGURE 1.1 HOME BEACHES OF LWL SEA TURTLES 2005-2017



SOURCE: Inwater Research Group

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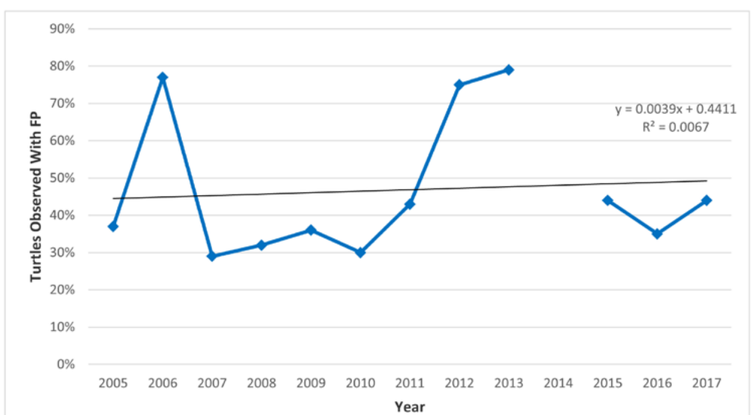
comparison, the presence of FP in turtles found in offshore waters is around 3%-4%.

- All but three of 22 recaptured turtles were originally tagged in the Lagoon. The three from elsewhere were initially tagged at the Kennedy Space Center, the St. Lucie Power Plant, and Cape Lookout, NC. The maximum interval between recaptures of a single individual was five years, indicating the importance of the Munyon Island area to the growth of green turtles utilizing the Lagoon.
- Dietary analysis indicates a significant shift in the diets of turtles near Munyon Island since 2014. Prior to then, turtles mostly consumed seagrasses like turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*) with little to no algae. From 2014-2018, their diets shifted largely to shoal grass (*Halodule wrightii*), with *Thalassia* almost absent from the samples. Analysis also showed a significant increase in algal species. These dietary shifts generally coincide with changes in seagrass abundance and benthic species composition in the Northern Lagoon.

The dietary shift observed in Lagoon green turtles coincides with a dramatic retraction of seagrass beds beginning in 2014. The percent of high- and moderate-density seagrass

FIGURE 1.2 FP OCCURRENCE IN LWL SEA TURTLES 2005-2018



SOURCE: Inwater Research Group

cover dominated by *Thalassia* and *Syringodium* declined significantly, while the percent of low-density, patchy seagrass cover dominated by Halodule increased. In 2013, for example, scientists documented 588 acres of high-density seagrass and 528 acres of patchy seagrass. By 2018, they documented 881 acres of patchy seagrass and just 256 acres of high-density seagrass.[2] The reduced acreage of seagrass allowed for increased coverage of algae.

The potential link between seagrass fluctuations, shifts in turtle forage preferences and the high incidence of FP in Lagoon green turtles warrants a closer look.

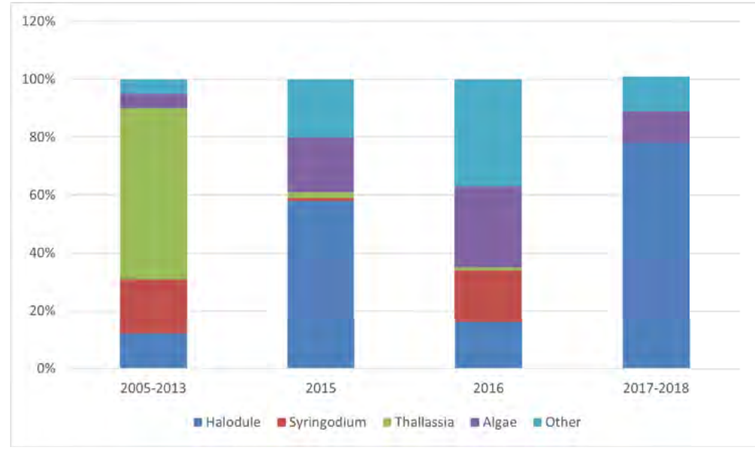
In 2019, sampling efforts included collection of blood samples from individual turtles for analysis by partners at Harbor Branch Oceanographic Institute, through grant funds from sales of the Helping Sea Turtles Survive specialty license plate. Results, when available, may provide important clues for assessing impacts of changing food sources and other environmental factors on turtle health. Augmenting this information with GPS or acoustic tracking to document short- and long-term movements would enhance our knowledge of how turtles use Lagoon resources and adjacent reef habitats at various life stages and seasons.

These monitoring efforts may prove even more valuable in the future; sea turtle researchers anticipate an increase in juvenile recruitment to Lake Worth Lagoon and other coastal estuaries over the next decade, as a result of record nesting on Caribbean beaches in recent years.[3]

Whether suitable habitat and sufficient food will be available to accommodate increased populations is uncertain. Adequate monitoring can drive timely management strategies to improve overall habitat conditions for sea turtles.

Continued educational efforts also are needed to increase community awareness of the Lagoon's significance to sea turtles, and to encourage support for conservation measures,

FIGURE 1.3 DIETARY COMPOSITION OF LWL SEA TURTLES 2005-2018



CLICK IMAGE TO ZOOM IN. CLICK AGAIN TO ZOOM OUT.

SOURCE: Inwater Research Group

such as acquisition or protection of critical seagrass habitats, and restoration that fosters seagrass growth in new areas.

APPROACH:

STEP 1 Continue to conduct annual sea turtle monitoring. This effort will continue to capture and tag new turtles and provide information on turtle abundance, diet, rate of FP disease, and associated changes over time.

STEP 2 Design and implement seagrass surveys to determine and track any correlations between sea turtle dietary shifts and changes in seagrass species and cover. At a minimum, seagrass monitoring frequency should coincide with turtle capture surveys and stomach content collection.

STEP 3 Expand water quality monitoring and sample collection in tandem with turtle surveys and consider expanding parameters to evaluate constituents

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Juvenile green turtle with papilloma tumors (Photo credit: Inwater Research Group)

identified by sea turtle researchers as possibly associated with FP.

STEP 4 Initiate an acoustic telemetry program to tag and track the movements of individual turtles throughout the Lagoon. An acoustic array network would be beneficial for tracking multiple species of fish and wildlife about which more information is needed to direct management actions.

STEP 5 Expand a health assessment program, including blood samples and chemical analysis, to evaluate the overall health of the turtles in the Lagoon and understand relationships with food availability and presence of FP.

STEP 6 Continue educational initiatives to promote community awareness of the Lagoon's importance to sea turtles. Promote community participation in water quality improvement, habitat restoration, ethical angling practices and other activities that benefit sea turtles as well as all marine life in the Lagoon.

TIMEFRAME:

STEPS 1-2 Continue turtle surveys quarterly or more often if funding is available. Continue seagrass surveys, ideally in the same months that turtle dietary sampling occurs.

STEPS 3, 4 and 5 require collaborative partnerships with local universities, governmental and non-governmental organizations, beginning in 2022. The length of time will be determined by funding/grant sources.

STEP 6 Ongoing.

COST ESTIMATE:

STEPS 1-2 $$

STEP 3 $-$$ Cost dependent on additional monitoring parameters and analysis required.

STEP 4 $ -$$ Cost varies according to the number of receivers and tags deployed. Acoustic receivers cost $1,700-$2,200 each, depending on quality. Battery life is 9-12 months, with replacement batteries costing $25. Acoustic tags cost about $350 each.

STEP 5 $-$$

STEP 6 $ (mainly staff time)

FUNDING:

Funding is available through the county budget process and the Sea Turtle License Plate Grants. Matching funds are provided by Palm Beach Atlantic University and Harbor Branch when applicable for specific research objectives. Additional funding sources will be investigated.

POTENTIAL PARTNERS:*

PBC-ERM, FWC, Inwater Research Group, Sea Turtle Conservancy, Sea Turtle License Plate Grants Program, USFWS, Palm Beach Atlantic University, Harbor Branch Oceanographic Institute, National Save The Sea Turtle Foundation

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

[1] Assessment of Marine Turtles in Lake Worth Lagoon 2017-2018. Inwater Research Group. 2019

[2] 2018 Lake Worth Lagoon Seagrass Status and Annual Transect Monitoring Report. Coastal Eco-Group, Inc. Cumulative Report 2018.

[3] C. Mott, Personal Communication. October 2020.

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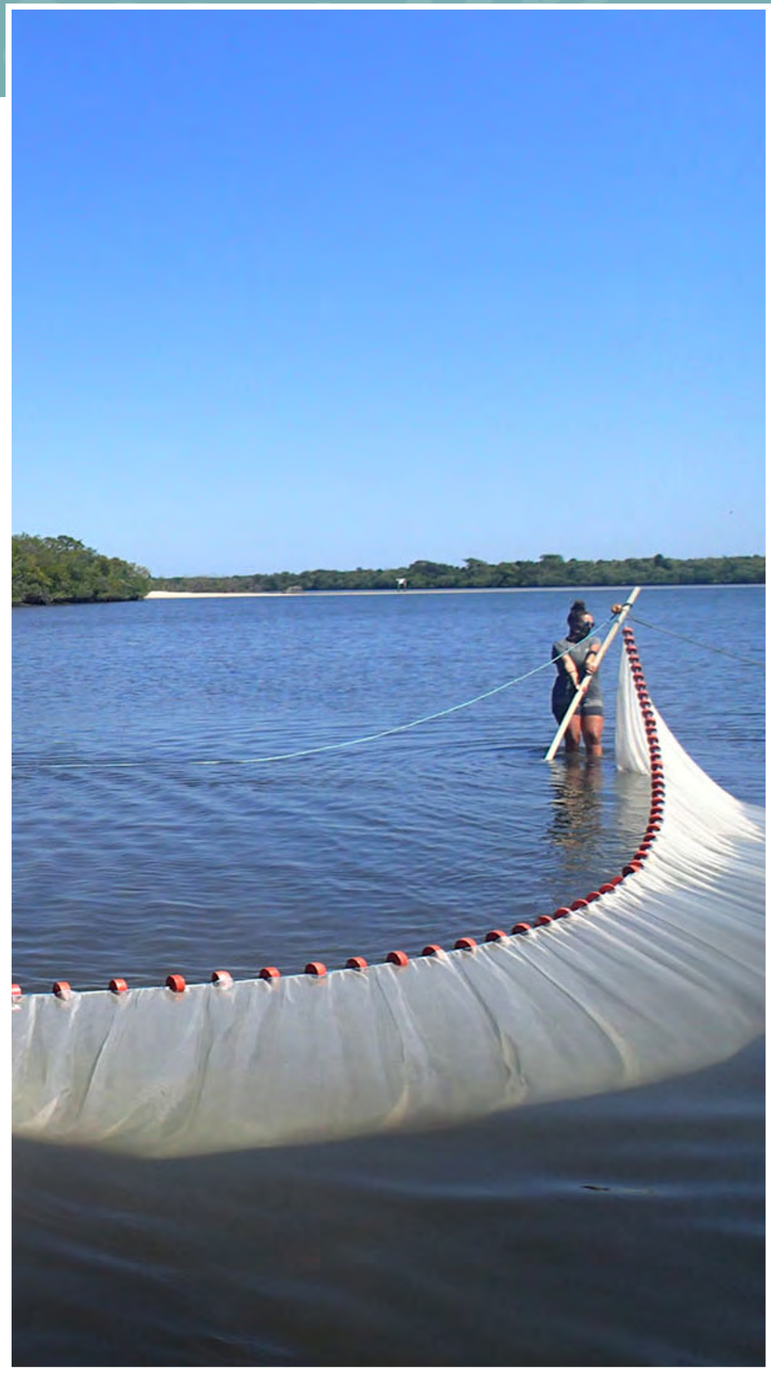


Sampling crew using a seine net (Photo Credit: FWC)

FW-3 CONTINUE FISHERIES MONITORING

ACTION: Continue fisheries sampling in the Northern and Central Lagoon to evaluate overall status and trends and assess fisheries utilization of restored habitats. Expand monitoring throughout the entire Lagoon. Update the species list for fish and selected invertebrates documented in the Lagoon. Expand use of acoustic telemetry to better document movement of fish and habitat utilization. Continue the Lake Worth Lagoon Fishing Challenge and explore other citizen-science initiatives to supplement fisheries-independent data.

IMPORTANCE:

Fisheries monitoring informs management decisions supporting habitat enhancement and protection, water quality improvements and stock assessments for economically important species.

RELATED ACTIONS:

FW-5, HE-1, HE-2, HE-3, HE-4, HE-5.

BACKGROUND:

The Florida Fish and Wildlife Conservation Commission's Fisheries Independent Monitoring Program (FWC-FIM) began sampling Lake Worth Lagoon in late 2014. The initial effort focused on fisheries utilization of waters adjacent to restored habitats in the Central Lagoon. Sampling was expanded in 2016 to incorporate sites in the Northern Lagoon, where the Lagoon's healthiest seagrass beds comprise an important and vulnerable habitat *(See Figure 1.1)*.

Palm Beach County (PBC) contracts with the FIM program for fisheries sampling. A new 3-year monitoring contract for the Northern and Central Lagoon will extend monitoring from Jan 2021 to Dec 2023.

Multiple fishing gear types are used to determine the abundance and distribution of adult and juvenile species. Samples are collected at randomly selected sites stratified by habitat and depth, and in both wet and dry seasons. Surveys record the number, species and length of fish captured, as well as environmental parameters such as salinity, temperature and dissolved oxygen.

The most abundant fish collected in the Lagoon is the Bay Anchovy *(Anchoa mitchilli)*, a ubiquitous baitfish that is the most prevalent species caught in FIM surveys across all Florida estuaries. In 2019, Bay Anchovy accounted for 38.3% of the total Lagoon catch.

Central Lagoon

From 2014-2020, quarterly sampling in the Central Lagoon provided a comparative evaluation of fish usage of a mature restoration site (Snook Island), a then-new restoration site (Grassy Flats) and an unimproved control site *(see Table 1.1)*.

TABLE 1.1 SUMMARY OF CATCH AND EFFORT DATA AT LAKE WORTH LAGOON RESTORATION SITES AUG 2014 - AUG 2018

	21.3-m Bay Seine		40-m Boat Seine		TOTALS	
	Animals	Hauls	Animals	Hauls	Animals	Hauls
Control	10,495	68	2,599	51	13,094	119
Grassy Flats	31,125	68	1,252	51	32,377	119
Snook Island	17,668	68	2,456	51	20,124	119
Totals	**59,288**	**204**	**6,307**	**153**	**65,595**	**357**

Source: FWC

African pompano collected during survey (Photo credit: FWC)

The assessments have demonstrated the value of created habitats to fish and shellfish in the Central Lagoon. The recurring presence of juveniles of economically important species such as commercial shrimp *(Farfantepenaeus spp.)*, Spot *(Leiostomus xanthurus)*, Striped Mullet *(Mugil cephalus)*, and others indicates that restoration areas may provide nursery habitat. The presence of both juvenile and adult Common Snook *(Centropomus undecimalis)* and Sheepshead *(Archosargus probatocephalus)* suggests that the sites serve as foraging grounds for resident species.[1]

For the 2021-2023 period, Central Lagoon fisheries sampling will include Snook Islands, Grassy Flats and the new Tarpon Cove-Phase I restoration, completed in 2019. Tarpon Cove was created by filling and capping a deep dredge hole to facilitate restoration of seagrasses and intertidal habitat, including mangroves, oyster bars and artificial reefs.

Northern Lagoon

Monthly fisheries assessments conducted in the Northern Lagoon since 2016 align with FIM's statewide sampling protocols. Sampling in this segment of the Lagoon contributes data toward species-specific stock assessments and provides valuable baseline information about the ecological contributions of the seagrasses found in the Northern Lagoon.

This effort has documented a more diverse fish community in the Northern Lagoon than in the Central Lagoon. Sampling shows many juvenile reef species (e.g., snappers and grunts) not found in abundance in the Central Lagoon restoration sites; barracuda, permit and green sea turtles also are frequently captured in net trawls there. These findings are not surprising considering the presence of seagrass beds and the proximity of Lake Worth Inlet to the northern sampling area.[2] In Summer 2020, a juvenile African pompano was collected, which was the first time this pelagic species has been collected by the FIM program anywhere in Florida.[3]

Additionally, there is limited fisheries data collected by the Palm Beach County Reef Research Team at artificial reefs monitored in the north Lagoon where visibility allows for visual surveys, such as at Sugar Sands and John Rybovich Reefs.

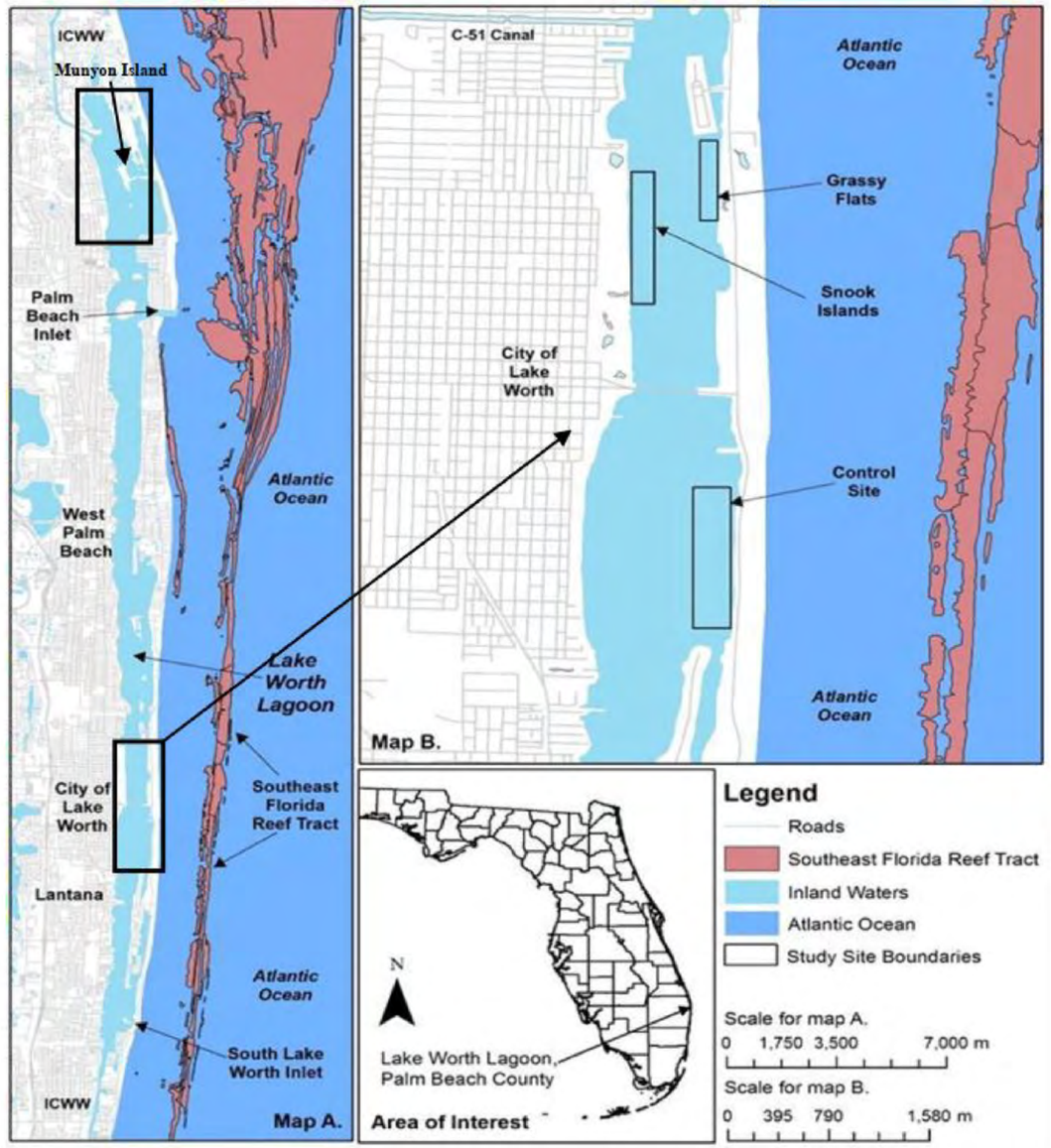
Southern Lagoon

Expanding FIM surveys to the Southern Lagoon is a logical extension of a comprehensive monitoring program, and would provide a valuable comparison with fisheries in the two other segments. Fisheries sampling in this area could support an overall assessment of the effects of large-scale stormwater discharges on local fish populations.

Lagoonwide

In addition to traditional sampling methods, ERM staff are exploring options for expanding use of

FIGURE 1.1 FISHERIES SAMPLING LOCATIONS IN LWL



SOURCE: FWC

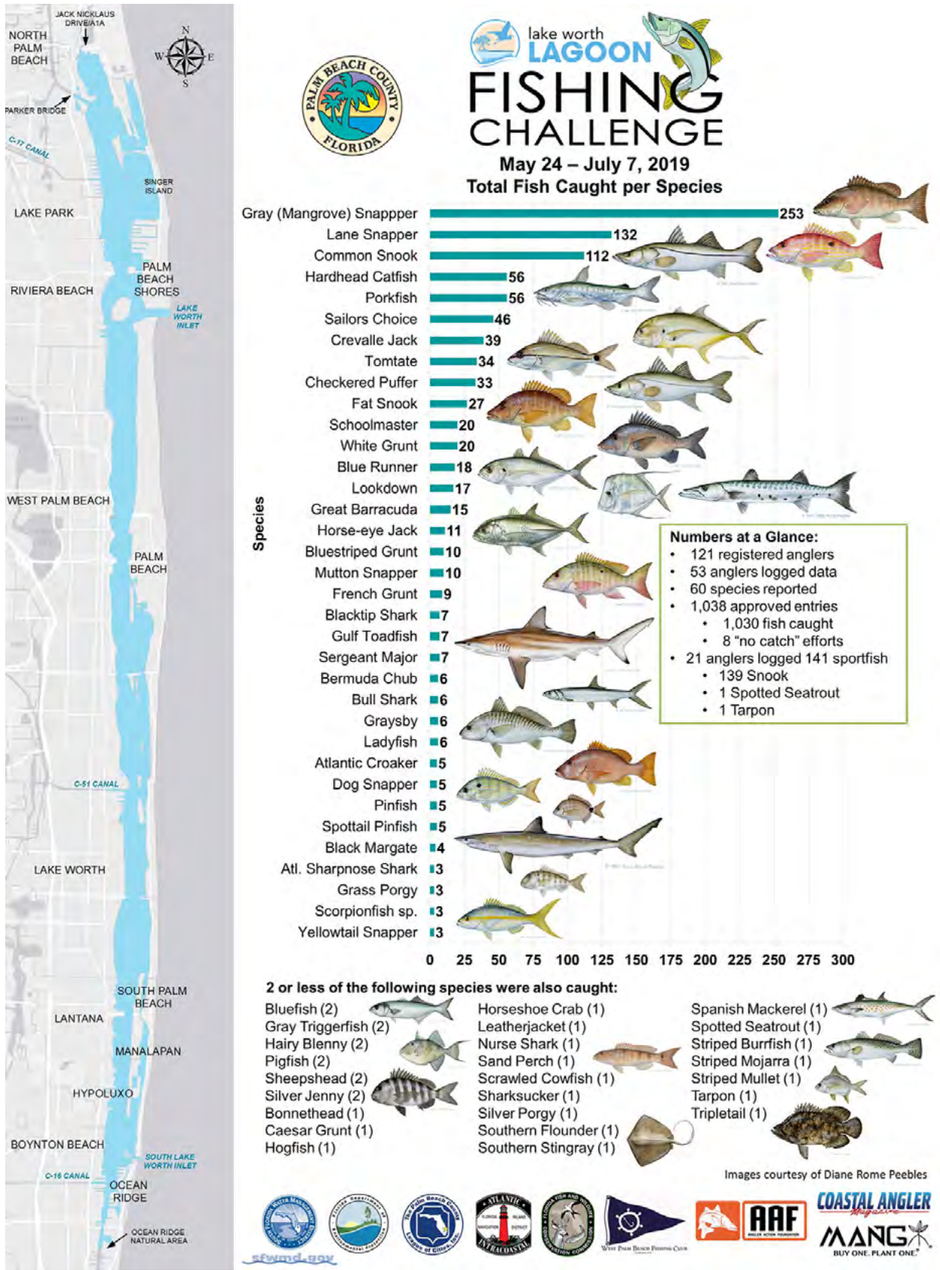


Figure 1.2 2019 Lake Worth Lagoon Fishing Challenge result poster (Photo credit: PBC-ERM)

acoustic telemetry to better document movement of fish between estuarine and ocean and overall habitat utilization of targeted species throughout the Lagoon *(See Action FW-5)*.

Recreational anglers also provide important data that contributes to knowledge of Lagoon fisheries. The annual Lake Worth Lagoon Fishing Challenge enlists anglers to photo-document fish caught anywhere in the Lagoon, using the iAngler app, with prizes sponsored by local businesses and organizations *(see Figure 1.2)*. The tournament provides information about fish usage of Lagoon areas not currently monitored by FIM, including the South Lagoon and canals. It should continue as a supplement to fisheries-independent surveys, or as a valuable stopgap measure if funding for expanded monitoring cannot be secured.

Fish Health

The FIM program serves as an early warning system to detect diseases, abnormalities and toxins such as mercury in fish. All fish (≥ 75 mm Standard Length) and selected invertebrates collected in the Lagoon were visually examined; specimens with external abnormalities were sent to the FWC's Fish and Wildlife Health (FWH) group in St. Petersburg for detailed diagnosis. Mercury samples were collected from economically important species. Juvenile Snook and Sheepshead were the most common species collected for mercury analysis, with mean concentrations within acceptable limits.

APPROACH:

STEP 1 Continue monthly/quarterly fisheries sampling in the Northern and Central LWL. Starting in 2021, the Tarpon Cove-Phase I restoration site is being added to the areas sampled in the Central Lagoon.

STEP 2 Expand sampling, employing statewide FIM protocols, to the Southern Lagoon.

STEP 3 Update the species list for fish and selected invertebrates documented in the Lagoon.

STEP 4 Expand acoustic tagging of fish and install an acoustic telemetry network in the Lagoon.

STEP 5 Continue the Lake Worth Lagoon Fishing Challenge.

Snook collected from Central Lagoon (Photo credit: FWC)

TIMEFRAME:

STEP 1 Funding for current monitoring programs to continue through 2023. STEP 2 can occur concurrently if funds are secured.

STEP 3 Completed in 2021, and updated as needed, or

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no less than every five years.

STEP 4 Contingent on available funds and/or research partners.

STEP 5 Annually.

COST ESTIMATE:

STEP 1 $$

STEP 2 $$$

STEP 3 Staff time only

STEP 4 $

STEP 5 $ (mainly staff time)

EVALUATING PROGRESS:

Monitoring surveys completed in each Lagoon segment.

Abundance and diversity of economically important species documented.

Number of acoustic telemetry receivers deployed in Lagoon.

Number of anglers participating and catches reported in Lake Worth Lagoon Fishing Challenge.

REGULATORY NEEDS:

None anticipated.

FUNDING:

County Budget, Direct and in-kind contributions from partners for acoustic telemetry and Fishing Challenge

POTENTIAL PARTNERS:*

ERM, FWC, NOAA / NMFS, West Palm Beach Fishing Club, Angler Action Foundation, Coastal Angler Magazine, FACT Network, PBAU, HBOI/FAU

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

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[1] Lake Worth Lagoon Fisheries Monitoring Program. Annual Report for Palm Beach County. Jan. 2019 – Dec.2019. Florida Fish and Wildlife Conservation Commission. 2020.

[2] Same as above

[3] Richard Paperno, FWC, pers. comm.

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Banding oystercatcher chick 2020 (Photo credit: PBC-ERM)

FW-4 MANAGE AND MONITOR SHOREBIRD HABITAT

ACTION: Continue to provide additional habitat for shorebirds via restoration and habitat enhancement projects in the Lake Worth Lagoon.

IMPORTANCE:

Shorebird populations are a valuable barometer of the biodiversity of the Lagoon. Monitoring shorebirds offers another tool for measuring the value of county-sponsored restoration projects to Lagoon fish and wildlife. Shorebirds also provide economic benefits through ecotourism that supports tour providers, hotels, restaurants and other businesses.

RELATED ACTIONS:

HE-2, HE-3, HE-5, PO-1, PU-2

BACKGROUND:

Despite its highly urban shoreline, the Lake Worth Lagoon attracts a variety of migratory, wintering and resident shorebirds, including imperiled species like the Black Skimmer (state listed as threatened); the American Oystercatcher (state listed as threatened); the Least Tern (state listed as threatened); and Piping Plover (federally listed as threatened). These species, along with others that nest directly on beaches, are extremely vulnerable to predation and human disturbance.

With less than 30% of natural shorelines left in the Lagoon, Palm Beach County (PBC) has made an extraordinary commitment to providing sheltered, protected foraging and nesting for shorebirds. Since 2014, 34 acres of habitat that benefits shorebirds has been created, including mangroves, seagrass areas, oyster reefs, cordgrass, intertidal shorelines, islands and maritime hammocks. Rock mounds specifically designed to support nesting American Oystercatchers have been installed as part of intertidal island creations such as Tarpon Cove. These projects have significantly boosted options for nesting, roosting and foraging throughout the Lagoon.

Investment in shorebird habitats has quickly paid dividends. Immediately upon completion of the Snook Islands Natural Area in the Central Lagoon in 2005, an American Oystercatcher pair began nesting there. They nested at Snook Islands every year until 2015, when they moved to the Grassy Flats restoration project. To date, this pair has produced 17 chicks, with 15 successfully fledged. Nesting of American Oystercatchers has now been documented at four restoration sites: Snook Islands, Grassy Flats, Bryant Park Wetlands and Tarpon Cove, producing a total of 35 fledglings since 2005 *(see Table 1.1)*.

Routine monitoring of shorebirds at restoration projects began in 2015 when the County's Environmental Resources Management (ERM) Department began

TABLE 1.1 AMERICAN OYSTERCATCHER NESTING SUCCESS

Location	Years	Chicks	Successfully fledged
Snook Islands NA and Grassy Flats	2005-2015	17	15
Bryant Park Wetlands Project	2014-2020	17	11
Snook Islands NA	2017-2020	8	7
Tarpon Island (Phase I)	2020	4	2

SOURCE: PBC ERM

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participating in the Florida Shorebird Alliance breeding bird surveys and annual shorebirds surveys coordinated by the Florida Fish and Wildlife Conservation Commission (FWC). The surveys continue to reinforce the value of restored habitats to a variety of year-round and migratory species, including the Piping Plover and Red Knot (both federally threatened), Least Tern, and Black Skimmer, along with the American Oystercatcher.

In 2019, five oystercatcher chicks were tagged by FWC biologists at Snook Islands and Tarpon Cove. Resighting of tagged birds provides additional information on fledgling success and overall utilization of the Lagoon for foraging, roosting and nesting. In 2019, a chick tagged at Tarpon Cove was sighted multiple times foraging along the oyster reefs by Johns Island, along with another juvenile tagged in 2019 in the Indian River Lagoon.

APPROACH:

STEP 1 Continue to provide and manage nesting and foraging habitat for shorebirds in the Lake Worth Lagoon through habitat creation, restoration and enhancement. Ensure island elevations are appropriate to provide nesting and wintering habitat above the high tide line.

Oystercatcher in flight (Photo credit: PBC-ERM)

STEP 2 Actively manage island habitats to ensure shorebird success:

- Control vegetation on islands through trimming, weed pulling and removal of trash.
- Strategically place gravel, shell hash, or sand to improve the nesting substrate.
- Monitor and maintain decoys put in place to attract nesting least terns. Remove or deter invasive/ exotic species such as green iguanas and Egyptian geese with potential to disrupt nesting or prey on eggs or chicks. Treat areas for fire ants.
- Post educational signage on islands during nesting season to alert the public to keep their distance and minimize disturbance of nesting and fledging birds.

STEP 3 Continue to monitor shorebird utilization of the Lagoon.

STEP 4 Evaluate and identify important, publicly accessible bird “hot spots” within the Lagoon worthy of nomination to the Great Florida Birding Trail.

STEP 5 Continue banding American Oystercatcher chicks and adults to track habitat utilization and fledgling success.

TIMEFRAME:

STEPS 1,2, 3 and 5 are ongoing

STEP 4 can occur in FY 2021-2022

COST ESTIMATE:

STEP 1-2 $$$$$

STEPS 3-5 $ Mainly staff time

Oystercatcher with two chicks (Photo credit: PBC-ERM)

EVALUATING PROGRESS:

Annual surveys of foraging adults, nesting pairs, chicks and fledglings.

Resighting of birds tagged in the Lagoon.

REGULATORY NEEDS:

Possible ordinance to prohibit drone flyovers of nesting areas.

FUNDING:

Recurring County and state budget allocation, Lake Worth Lagoon Initiative request to Florida Legislature (for habitat creation), in-kind support from Audubon and Florida Shorebird Alliance

POTENTIAL PARTNERS:*

PBC-ERM, FWC, USFWS, FIND, Florida Shorebird Alliance, Audubon

**Listed Agencies have not committed funds and are subject to Agencies’ budget approvals*

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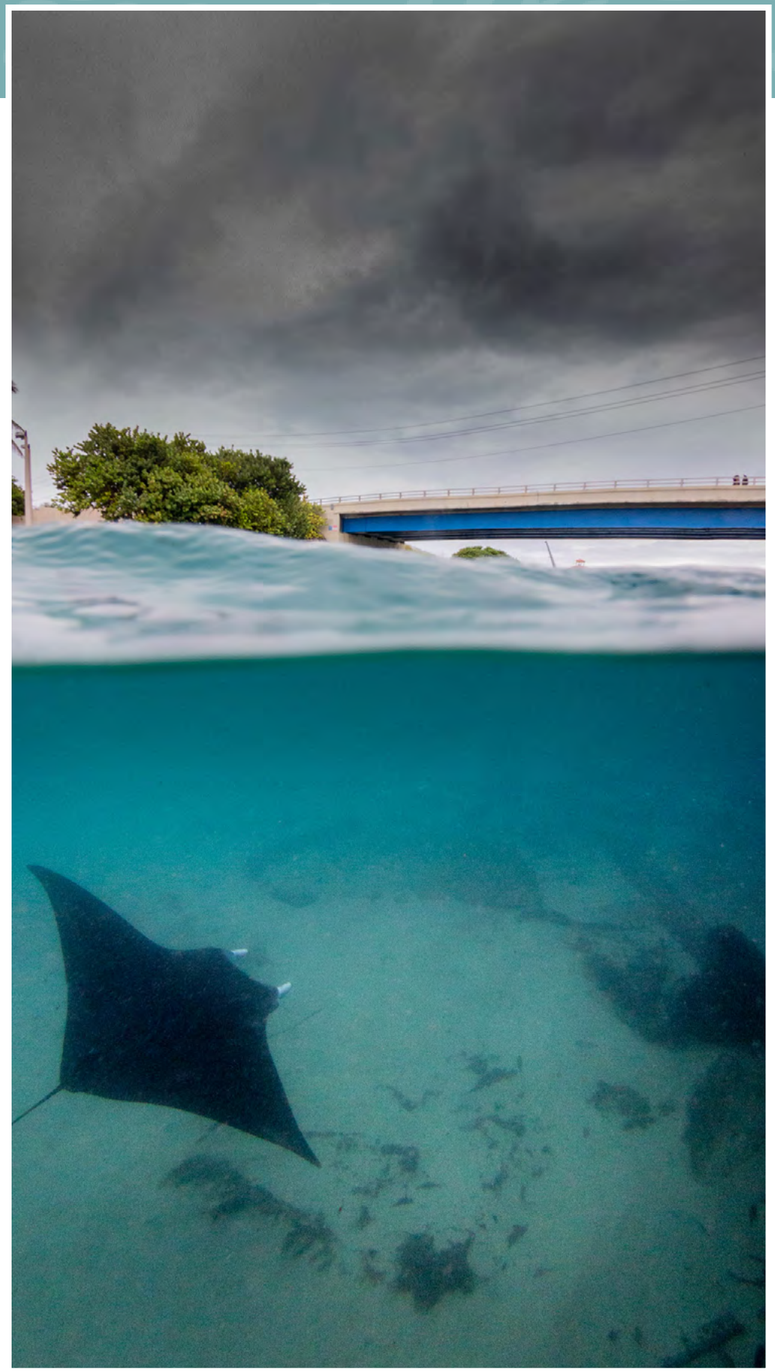

Manta Ray in South Lake Worth Inlet (Photo credit: Bryan Turffs)

FW-5 IMPLEMENT REMOTE TRACKING TECHNOLOGIES FOR FISH AND WILDLIFE MONITORING

ACTION: Design and implement a collaborative acoustic telemetry network to track species of special management interest within the Lagoon.

IMPORTANCE:

Documenting the spatial and temporal distribution of fish, sea turtles, manta rays and other species will provide insights into estuarine-marine connections, migration patterns, and critical habitats at various life stages, contributing to informed management strategies on a watershed scale.

RELATED ACTIONS:

FW-1, FW-2, FW-3, FW-4, WQ- 5

BACKGROUND:

Remote tracking technologies enable resource managers to document where and when animals travel, and what pathways they use. They can help determine exactly where an animal is at any moment in time and often what that animal is doing.

The technologies can be used for a wide variety of purposes, from following the movements of large marine animals like manatees and sharks to tracking how marine pollution travels through the environment. Information gained from these remote tracking systems can be used to identify, map and protect critical foraging and nursery habitats, fill in missing life cycle data, and better manage human activities such as commercial and recreational fishing that may impact a species.

Examples of tracking technologies include acoustic, GPS and satellite tags. The choice of technology depends on the length of time the animal will be monitored; how data will be transmitted; and funds available for tracking equipment. Satellite tags, for example, are mainly useful on animals that come to the surface to breathe, such as manatees or whales.

Remote tracking technologies utilizing satellites, GPS and acoustic telemetry mean scientists don't have to be near the animal to pick up its signal. Data is transmitted from the animal, or a receiving station, to a computer.

In recent years acoustic telemetry has been widely used by scientists studying fish and sea turtles *(See Figure 1.1)*. This system uses sound (acoustics) to relay information across open space (telemetry). Information is gathered by attaching acoustic transmitters, or "tags," to the fish or turtles. Each tag emits a unique sound pulse that is relayed by tracking stations (receivers) placed underwater at strategic intervals. When a tagged animal passes in range of the receiver, a unique "ping" identifies the animal and its location. Receivers can typically detect signals within a radius of 500-1000 meters.

The collaborative, open access Florida Atlantic Coast Telemetry (FACT) Network, has established a system of 900 tracking stations from North Carolina to the Bahamas *(See Figure 1.2)*. This acoustic array supports research conducted by state and federal wildlife agencies, universities, not-for-profit and private marine research organizations. More than 83 species, comprising 4,700 individuals,

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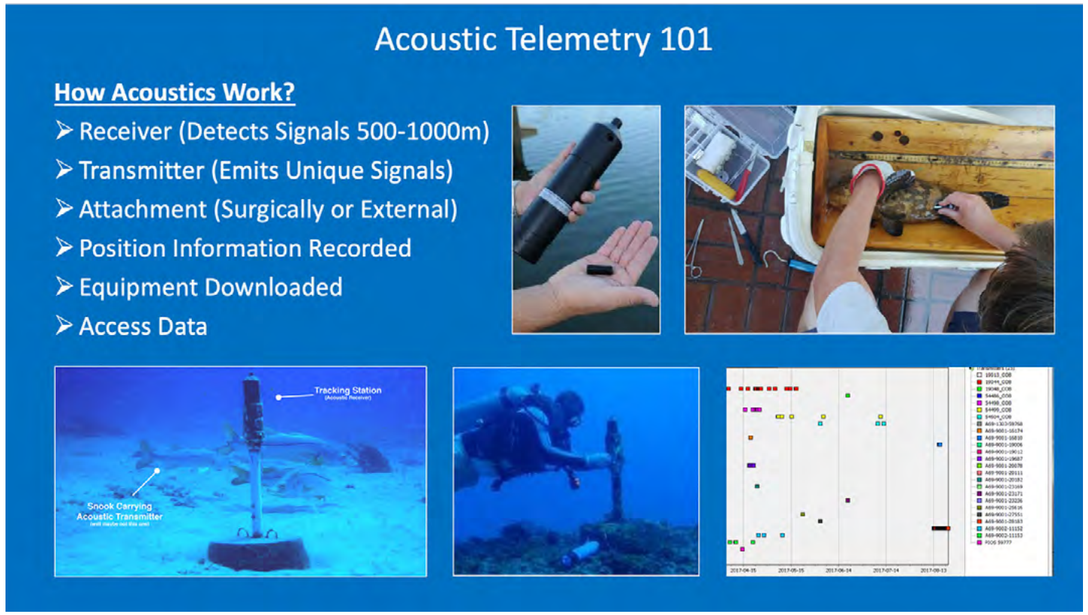

Figure 1.1: How acoustic telemetry works (SOURCE: FWC)

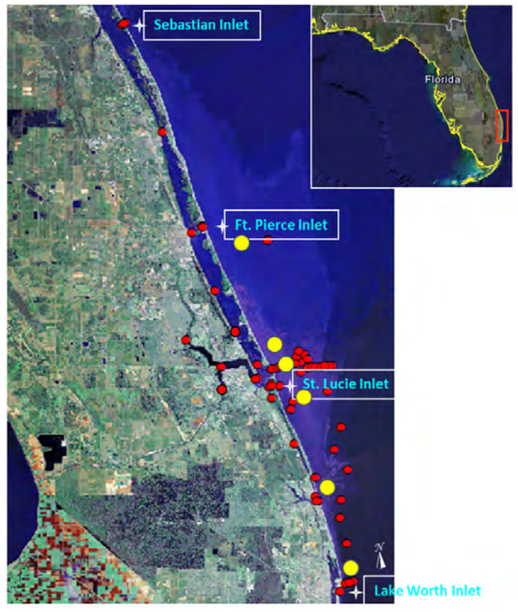

Figure 1.2: Florida East Coast Acoustic Array Network

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have been tracked since 2007. Members of the FACT Network already maintain receivers at reef sites offshore of Palm Beach County, within the Loxahatchee River and Jupiter Inlet, and within the Indian River Lagoon. Acoustic receivers installed off Singer Island have detected more than 400 acoustic signals from 33 individual animals utilizing repurposed concrete poles (called "Reef Darts") installed by the West Palm Beach Fishing Club and the County's Department of Environmental Resources Management (ERM). Among the tagged animals were small-toothed sawfish, great white sharks, tiger sharks, great hammerheads, a cownose ray and a cobia that was originally tagged in Pensacola.

The installation of an acoustic array within the Lagoon itself would be beneficial to researchers studying multiple marine species. For example, the ability to document movement of fish between estuarine and ocean habitats would add to our understanding of relationships between restored and natural habitats. Understanding the movement of sea turtles within the Lagoon is important for documenting population dynamics over time, especially given the Lagoon's status as an important nursery habitat for the species.

Acoustic telemetry could potentially play a role in tracking the movement of microplastics or other marine debris in the Lagoon.

Recent research conducted by the Marine Megafauna Foundation indicates the coastal waters of south Florida, including Palm Beach County, are a potential nursery ground for giant manta rays *(Mobula birostris),* an endangered species.[1] Evidence indicates that manta rays are using the Lake Worth Lagoon. They have been seen three times by divers at the Blue Heron Bridge, in 2015 and 2020. They have also been documented feeding and resting within South Lake Worth Inlet.

Up to six mantas have been observed inside the South Lake Worth Inlet at one time. Survey data showed young manta rays with embedded fishing line and tackle suggesting impacts from living in a highly urbanized coastal area.

Use of acoustic telemetry to track mantas would help to understand the importance of the Lagoon to these charismatic creatures and contribute to development of conservation strategies for this federally listed species.

APPROACH:

STEP 1 Identify a funding source to purchase and maintain equipment within Lagoon.

STEP 2 Collaborate with universities, researchers, non-profits and other interested partners to direct tagging efforts and data analysis to understand species utilization of Lagoon habitats, and the environmental and biological factors that influence their movement.

Researcher Jessica Pate approaches a juvenile Manta Ray (Photo credit: Bethany Augliere)

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A Manta Ray swims close to shore (Photo credit: Jessica Pate)

TIMEFRAME:

Initial acoustic array installed in 2022, pending availability of funds for receivers and tags.

COST ESTIMATE:

STEP 1 $ Acoustic receivers cost $1,700-$2,200 each, depending on quality. Battery life is 9-12 months, with replacement batteries costing $25. Acoustic tags cost about $350 each. Ongoing staff time to coordinate this program is a recurring cost.

STEP 2 $

EVALUATING PROGRESS:

Number of receivers installed.

Number of Species and Individuals Tagged and Tracked.

REGULATORY NEEDS:

None

FUNDING:

Direct and in-kind funding provided by Palm Beach County ERM, West Palm Beach Fishing Foundation, FAU, FWC, state and federal grants.

POTENTIAL PARTNERS:*

PBC-ERM, FWC, West Palm Beach Fishing Club, USFWS, Marine Megafauna Foundation, ANGARI Foundation, Palm Beach Atlantic University

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

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[1] Urban Manta Rays: Potential Manta Ray Nursery Habitat along a Highly Developed Florida Coastline. Pate. J and Marshall, A. ENDANGERED SPECIES RESEARCH. 2020.

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CLIMATE CHANGE AND SEA LEVEL RISE ACCOMPLISHMENTS AT A GLANCE

Palm Beach County and seven municipalities formed a **Coastal Resilience Partnership** in 2019 to work cooperatively on strategies to **mitigate and adapt to sea levels** expected to rise by 17 inches by 2040.

SEE ACTION CC-1

Completion of a **vulnerability assessment** in early 2021 will examine risks to critical community assets, including **natural resources and water infrastructure,** from climate change.

SEE ACTION CC-1

Living Shorelines **that use native plants and natural materials to improve resiliency** have been installed at five locations since 2013: Bryant Park, Currie Park, Osprey Park, Jewell Cove and Lyman Kayak Park.

SEE ACTION CC-2

A shoreline characterization study completed in 2020 shows that 70% of the Lagoon shoreline has been **hardened by seawalls, bulkheads or other armoring.**

SEE ACTION CC-2

Flooded street in West Palm Beach during September 2020 King Tide (Photo credit: PBC-ERM)

CC-1 CONDUCT A VULNERABILITY ASSESSMENT OF RESOURCES AT RISK FROM CLIMATE CHANGE

ACTION: Identify living resources, infrastructure and community assets vulnerable to sea level rise and climate change, and implement appropriate adaptive strategies to reduce impacts.

IMPORTANCE:

Identification of natural and societal resources most vulnerable to climate change will guide critically important decisions about mitigation and adaptation strategies, bolstering the resilience of the Lake Worth Lagoon watershed.

RELATED ACTIONS:

WW-1, WW-2, HE-1, HE-2, SW-2

BACKGROUND:

The Southeast Florida Regional Climate Change Compact's 2019 unified sea level rise projections estimate that seas will rise by approximately 10 to 17 inches by 2040 and 21 to 40 inches by 2070 as the rate of rise accelerates in the four Southeast Florida counties that comprise the partnership: Broward; Miami-Dade; Monroe; and Palm Beach County.1 With one foot of sea level rise (SLR), extensive areas of the Lake Worth Lagoon shoreline are at risk of inundation *(see Figure 1.1)*.

Rising sea levels are expected to elevate groundwater, increase infiltration, corrode infrastructure, and alter the effectiveness of wastewater treatment systems. Higher water levels may also shrink or even eliminate habitats that do not have room to migrate landward as waters rise (*see Actions HE-1 and HE-2*). Similarly, anticipated increases in storm intensity may increase stormwater inflow and overwhelm sewer system capacity (*see Action WW-1*).

Impacts are already occurring, most recently with sanitary sewer overflows in West Palm Beach in October 2020 caused by extremely high "king" tides, compounded by rain, wind and infrastructure failures. Additionally, sunny day flooding is becoming more and more routine in communities along the Lagoon and within its watershed, as extreme rain events overwhelm the conveyance capacity of existing stormwater systems.

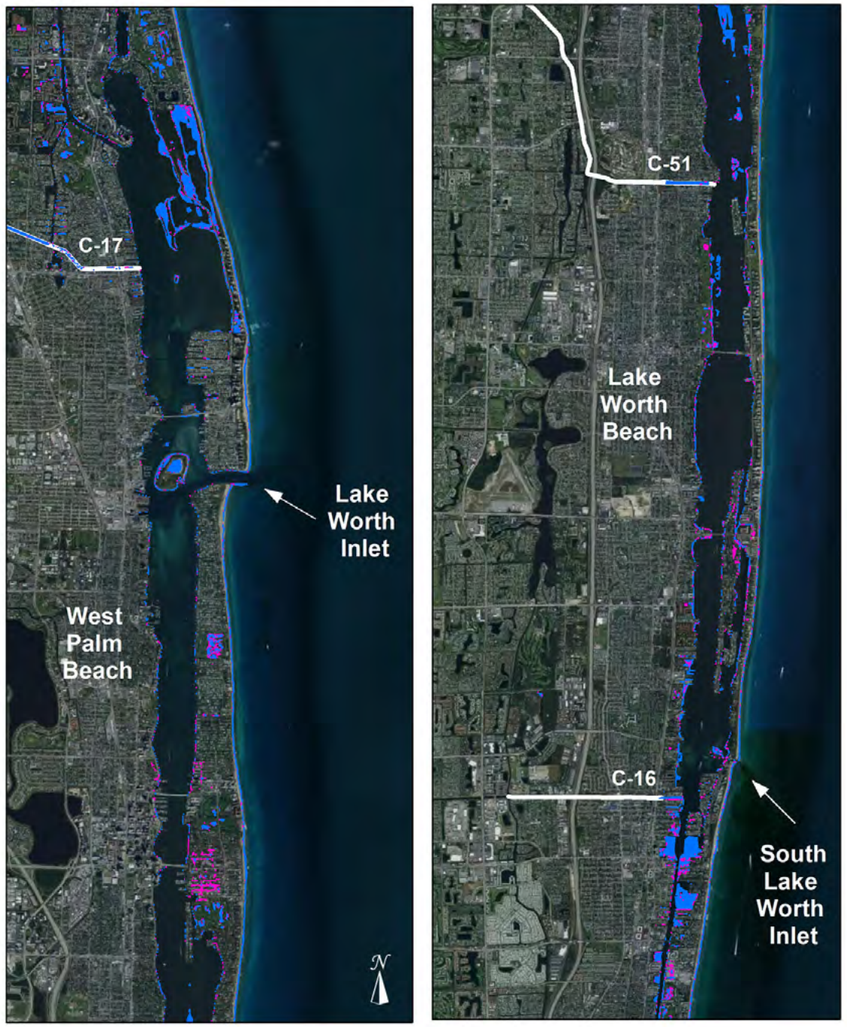
Other far-reaching effects of climate change include increasing

Flooded street in West Palm Beach during September 2020 King Tide (Photo credit: PBC-ERM)

temperatures, changing precipitation patterns, fluctuating water availability, and increases in waterborne illnesses, storm intensity, and the spread of invasive species, all with potential negative impacts to the Lagoon's resources and residents.

A 2020 report commissioned by the Southeast Florida Regional Climate Change Compact and other partners found that if the region does not adapt to climate change, daily tidal inundation by 2070 could threaten $53.6 billion in property, affect 17,800

FIGURE 1.1 SEA LEVEL RISE PROJECTION MAP (1 FOOT)



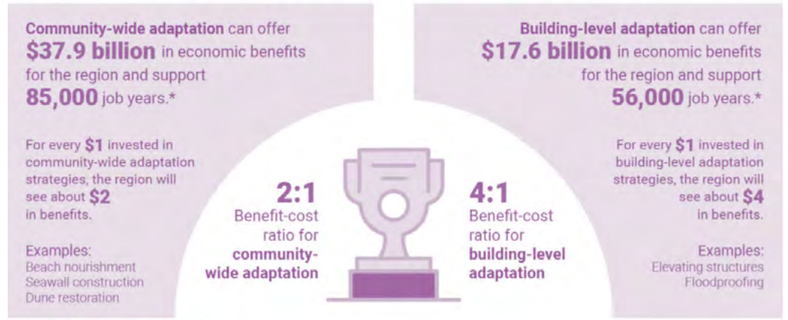
SOURCE: PBC-ERM

jobs, and cause $384 million in fiscal losses.[2] The report also found that, regionally, the benefits outweigh the costs for climate adaptation projects studied in the report. For every $1 invested in community-wide adaptations such as raising the height of seawalls, nourishing beaches, or restoring natural dunes, the counties would gain $2 in economic benefits. For every $1 invested in building-level adaptation strategies, such as elevating or flood proofing structures, the region will see $4 in benefits *(see Figure 1.2)*.

King tides, or exceptionally high spring tides that occur when the moon is at its closest point to Earth, provide a worrying glimpse of the future. While only a temporary phenomenon, king tides demonstrate the potential impacts of rising seas on critical coastal resources and infrastructure such as roads, hospitals, drinking water, and wastewater treatment facilities. They are also a valuable educational tool for helping citizens visualize future shoreline conditions, and may encourage the public to take proactive steps to make their own homes and landscapes more resilient (*see Action SW-1*). For municipal and county planners, areas flooded by king tides may be prioritized for stormwater retrofits or Green Infrastructure installations (e.g., permeable pavement, rainwater gardens, etc.)

Palm Beach County created an Office of Resilience (OOR) in 2017 to advance the County's climate resilience and sustainability efforts. OOR helps coordinate climate vulnerability assessments for the County in partnership with other County departments. PBC, together with the municipalities of Boca Raton, Boynton Beach, Delray Beach, Highland Beach, Lake Worth Beach, Lantana and Ocean Ridge, formed the Coastal Resilience Partnership (CRP) of Southeast Palm Beach County to conduct a micro-regional climate change vulnerability assessment. Supported by funding from the Florida Department of Environmental Protection's Florida Resilient Coastlines

FIGURE 1.2 ECONOMIC BENEFITS OF RESILIENCY STRATEGIES



SOURCE: Urban Land Institute

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Program, the assessment is examining how various climate threats such as flooding, high winds, extreme heat, pests, and harmful algal blooms will affect major community assets in the study area *(see Figure 1.3)*. Assets to be studied include:

- Critical Facilities, such as hospitals, fire and police stations, utilities and government facilities
- Water Infrastructure, including stormwater, wastewater, and potable water systems
- Businesses and Industries
- Natural Resources, including beaches, parks, preserves, intertidal habitats, and tree canopy
- People, including populations that may be disproportionately vulnerable to climate threats
- Commercial, cultural,

FIGURE 1.3 CLIMATE CHANGE VULNERABILITY ASSESSMENT

and residential property
- Transportation and mobility networks

The CRP of Southeast Palm Beach County's climate change vulnerability assessment is a critical first step in identifying elements most vulnerable to climate threats and developing equitable adaptation strategies for each participating jurisdiction to consider. Results will help inform actions that can be taken in areas of the Lagoon watershed within the study area, and provide a valuable foundation for future Lagoonwide assessments and adaptive management.

Building on this success, the County plans to develop a vulnerability assessment of all unincorporated areas of the County and a resilience action plan by 2025. An $800,000 Rebuild Florida grant from the state Department of Economic Opportunity will jump-start this process. Additionally, the County is developing an internal policy requiring that climate change and sea level rise impacts be considered in all future capital improvement projects. At the state level, a bill passed by the Florida Legislature in 2020 requires state, local governments, and other public entities to conduct a Sea Level Impact Projection Study before construction of any new state-funded project in a coastal building zone.

King Tides at Flagler Drive with West Palm Beach and Lake Worth Lagoon in background (Photo credit: PBC-ERM)

The County and several municipalities are already embracing the use of Living Shorelines as one cost-effective resilience strategy. Living Shorelines use natural elements like coastal plants, rock and sand to stabilize and protect shorelines instead of hardening them with seawalls (*see Action SW-2*). A system of "mangrove planters" at Currie Park in West Palm Beach is one successful example: Here, Palm Beach County and the City of West Palm Beach collaborated to install a series of connected planters containing mangroves waterward of the park's existing seawall. West Palm Beach recently applied for a $21 million grant from the Florida Department of Economic Opportunity's Rebuild Florida Infrastructure Repair Program to expand the Currie Park Living Shoreline with more mangrove planters, a higher seawall, improved stormwater capacity, walkways, landscaping, lighting and other features to make the park more resilient.

APPROACH:

STEP 1 Once the CRP of Southeast Palm Beach County's Climate Change Vulnerability Assessment is complete, encourage the incorporation of resilience adaptations into the comprehensive plans or other planning initiatives of all municipalities within the Lagoon's watershed.

STEP 2 Identify current and potential flooding impacts to low-lying communities throughout the watershed due to king tides and future sea level rise. Assess the need for new check valves, retrofits and/or pumps in stormwater management systems to minimize flooding.

STEP 3 Enhance community understanding of the far-ranging impacts of climate change, to build support for individual and collective actions to help adapt to or mitigate effects.

STEP 4 Consider managed retreat from areas chronically impacted by flooding, storm surge, and SLR, where use is not sustainable because of high maintenance or repair costs, or threats to public safety.

TIMEFRAME:

STEPS 1-3 Can begin in 2021, upon completion of the CRP of Southeast Palm Beach County's Climate Change Vulnerability Assessment.

STEP 4 Policies and Decision Tools to determine when, where and whether managed retreat should be considered can be initiated in 2025.

COST ESTIMATE:

STEP 1 $

STEP 2 $$

STEP 3 $

STEP 4 $$$$$

EVALUATING PROGRESS:

Number of communities within Lagoon watershed incorporating resilience adaptations into comp plans.

Modifications or upgrades to existing critical infrastructure assets in the Lagoon watershed.

Increase in community support for adaptation and mitigation strategies.

REGULATORY NEEDS:

Updates to comprehensive plans and other land use development guidelines.

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FUNDING:

LWLI Legislative Funding Request, Recurring or special county/ city budget allocations, federal or state grants

POTENTIAL PARTNERS:*

PBC-Office of Resilience, South Florida Regional Climate Compact, FDEP, PBC-ERM, local municipalities, SFWMD, local and special drainage districts, EPA, NOAA

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

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[1] Unified Sea Level Rise Projection: 2019 Update. Southeast Florida Regional Climate Change Compact Sea Level Rise Work Group (Compact). February 2020.

[2] The Business Case for Resilience in Southeast Florida: Regional Economic Benefits of Climate Adaptation. Urban Land Institute. 2020.

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Living Shoreline at Bryant Park (Photo credit: PBC-ERM)

CC-2 IMPROVE RESILIENCY OF CRITICAL HABITATS TO CLIMATE CHANGE AND SEA LEVEL RISE

ACTION: Enhance resilience to climate change within the Lake Worth Lagoon through Living Shorelines and habitat restoration and enhancement. Foster community awareness of the potential impacts of a changing climate on Lagoon habitats, and encourage individual and collective actions to mitigate those effects.

IMPORTANCE:

Critical habitats in the Lagoon provide significant climate mitigation benefits including sequestration of carbon, absorption of wave energy and tidal flows, protection against storm surge, and preservation of fish and wildlife species that are an integral part of this unique estuary. Mangroves, cordgrass, maritime hammocks, seagrass beds, oyster reefs, artificial reefs, and breakwaters not only perform important ecological services, but also support valuable commercial and recreational activities.

RELATED ACTIONS:

CC-1, HE-1, HE-2, HE-3, HE-4

BACKGROUND:

Climate change presents a significant threat to fish, wildlife, and natural ecosystems that will likely exacerbate other ecological threats such as habitat loss, invasive species, and water pollution. Preparing for the future impacts of climate change is an urgent concern for the Lagoon that requires planning, implementation of adaptive measures, and long-term monitoring.

Coastal habitats including mangroves and seagrass beds provide critical nursery and foraging areas for fish, oysters and waterbirds. They are among the first to experience climate change impacts, but are also an important first line of defense in mitigating their effects *(see Figure 1.1)*. In addition to absorbing and buffering the impacts of storm surge, intertidal wetlands are highly effective carbon sinks, removing carbon from the atmosphere and storing it in their biomass or in the sediments below at roughly 10 times the rate of tropical forests.[1] Conversely, destruction or degradation of these habitats releases the carbon they have stored to become a source of greenhouse gases that perpetuate and compound climate change.

FIGURE 1.1
CRITICAL STORAGE
OCEAN + COASTAL HABITATS

83%	2%	50%
GLOBAL CARBON	COVERAGE	SEDIMENT CARBON

83% of the global carbon cycle is circulated through the ocean. Coastal habitats cover less than 2% of the total ocean area, but account for approximately half of the total carbon sequestered in ocean sediments.

The Lagoon has been dramatically altered by development, with seawalls, bulkheads or other armoring along 70% of the shoreline *(see Action HE-2)*. These hardened, artificial shorelines increase erosion, harm water quality, provide poor habitat, and can magnify storm damage and flooding. Preserving the remaining natural areas and enhancing armored shores through use of Living Shorelines is a cost-effective tool for improving habitat resiliency *(see Table 1.1)*.

Living Shorelines use "softer," more natural materials that buffer the effects of increased storms and floods, shield critical coastal infrastructure, and provide habitat for a variety of fish and wildlife *(see Figure 1.2)*. They

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TABLE 1.1 PROJECTS THAT CONTRIBUTE TO HABITAT RESILIENCY IN THE LAKE WORTH LAGOON

Breakwaters, Artificial Reefs and Oyster Reefs	Year(s)
Peanut Island Reef Complex	2007-2014 (Multiple projects)
Phil Foster Park Snorkel Trail Enhancement	2015
Old Bridge Park Restoration and Dock	2016
Sugar Sands Reef	2017
Southern Boulevard Bridge Reef	2018
Intertidal Habitat Creation	
Snook Islands Natural Area	2015, 2017
Peanut Island Reef Complex	2016
Bryant Park Islands	2014, 2017
Grassy Flats Natural Area	2015
Living Shorelines with Intertidal Wetland Planters	
Bryant Park Living Shorelines	2015, 2017
West Palm Beach- Currie Park and Osprey Park Living Shorelines	2017

SOURCE: PBC-ERM

can be installed in place of or as an enhancement to armored shorelines *(see Figure 1.3)*.

Institutional and educational barriers currently discourage the use and acceptance of Living Shorelines by both the public and private sector. For example, regulatory agencies often lack institutional support for permitting alternatives to traditional shoreline stabilization techniques. Additionally, shoreline management is often viewed in a site-specific vacuum that overlooks the cumulative effects of shoreline hardening, rather than on a watershed basis that prioritizes ecological continuity and connectedness. A general lack of awareness and support for Living Shorelines among waterfront homeowners, developers and planning organizations hampers more widespread use, a shortcoming that initiatives like the Southeast Florida Regional Climate Compact and The Nature Conservancy (TNC) seek to address.

Changes in coastal management policies and rules at the federal, state and local level would help to even the playing field for Living Shorelines. For example, in 2017 the U.S. Army Corps of Engineers authorized a simpler nationwide permit for certain types of Living Shorelines. State regulators could adopt a similar streamlined permit for natural shoreline solutions. Recently, Palm Beach County adopted changes to its Comprehensive Land Use Plan to encourage the use of Green Infrastructure, including Living Shorelines.

Changes also could include tax incentives to replace seawalls with Living Shorelines, and regulations that prioritize ecologically beneficial re-use of clean, dredged materials *(see Action HE-5)*.

Incorporation of sea level rise projections in all Lagoon intertidal habitat restoration projects would ensure that public investments continue to pay dividends by providing opportunities for created or restored habitats to adapt and evolve over time.

Public education efforts could include workshops for marine contractors and demonstration projects that involve citizens in installation and monitoring. The Bryant Park and Jewell Cove Living Shoreline projects are existing examples of "SLR Community Stewardship Sites." Bryant Park is used as a youth education site for the Lake Worth Waterkeeper's "Lagoonies" program, and Jewell Cove hosts "Scientist For A Day" activities coordinated by the County's Environmental Resources Management (ERM) staff. The Palm Beach Resilient Islands, a joint project of ERM and The Nature Conservancy, is an upcoming education-stewardship site.

Finally, a publicly funded, willing-seller land acquisition program would create a sustainable funding mechanism for preserving critical habitats that perform vital services by sequestering carbon, absorbing storm surges, and filtering pollutants.

APPROACH:

STEP 1 Measure sea level rise in the Lagoon watershed to identify and prioritize habitats at greatest risk of inundation and in greatest need of protection. Install a tide gauge at the Port of Palm Beach and/or document SLR at targeted areas in the Lagoon.

STEP 2 Support funding and implementation of one or more demonstration projects to provide diverse and tangible examples of the ecological and aesthetic attributes of Living Shorelines.

STEP 3 Support life-cycle analysis and monitoring of current and future living shoreline projects to quantify costs

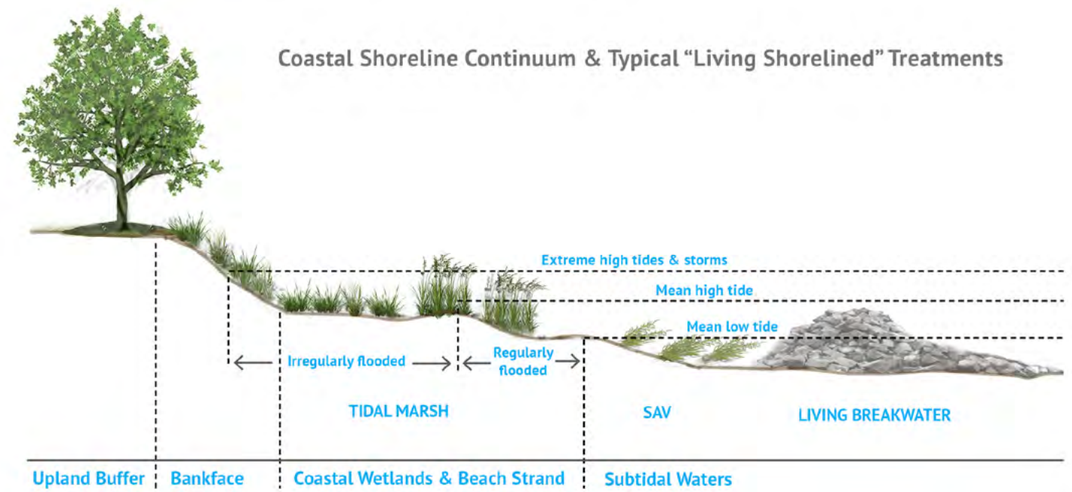

Figure 1.2: Diagram of a living shoreline. (SOURCE: Burke Environmental Associates)

CLICK IMAGE TO ZOOM IN. CLICK AGAIN TO ZOOM OUT.

and benefits versus traditional seawalls.

STEP 4 Host workshops in Living Shoreline design and installation, to boost the pool of qualified consultants and contractors that can design, permit and install living shorelines.

STEP 5 Consider tax incentives or mitigation credits for Living Shorelines.

STEP 6 Support education about Living Shorelines and "climate-friendly" landscapes featuring drought-tolerant native groundcovers, shade-producing trees, rain gardens and other elements that reduce emissions from lawn mowers, power tools and air conditioners.

TIMEFRAME:

STEPS 1, 3, 4 and 5 can be initiated in FY 2021-2022

STEPS 2 and 6 are ongoing

COST ESTIMATE:

STEP 1 $

STEP 2 $ if using existing or already budgeted Living Shoreline projects as demo sites.

STEP 3 $-$$ depending on number of sites, length of monitoring and depth of cost analysis.

STEP 4 $

STEP 5 No additional cost; Staff time only.

STEP 6 $

EVALUATING PROGRESS:

Number/Acres of Living Shoreline and Intertidal Restoration projects.

Figure 1.3: Currie Park Living Shoreline before and during September 2020 King Tide (Photo credit: PBC-ERM)

Number of Participants in activities at SLR Stewardship Sites.

Number of Participants in training workshop(s).

Updated rules, policies and codes.

Number of citizens receiving education about Living Shorelines and climate-friendly landscaping.

REGULATORY NEEDS:

Revisions to permitting rules, land development codes, property tax assessments or comprehensive plan schedules.

FUNDING:

County budget allocations, potential climate resilience or habitat restoration grants from NOAA, USFWS, or EPA, FDEP (Florida Resilient Coastlines Program) and National Fish and Wildlife Foundation (National Coastal Resilience Fund Request)

POTENTIAL PARTNERS:*

PBC-ERM and the Office of Resilience, local municipalities, SE Florida Regional Climate Compact, UF/IFAS Extension and Florida Sea Grant, Treasure Coast Regional Planning Council, Florida Department of Environmental Protection, local chapters of the Florida Marine Contractors Association and American Society of Civil Engineers, regional academic and research institutions, and The Nature Conservancy.

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

[i] What is eutrophication? National Ocean Service website, https://oceanservice.noaa.gov/facts/eutrophication.html, 10/05/17.

PUBLIC OUTREACH AND ENGAGEMENT ACCOMPLISHMENTS AT A GLANCE

The annual LagoonFest community celebration of the Lagoon's beauty and value **attracted 5,000 attendees and 80 exhibitors** in 2019.

SEE ACTION PO-1

The Lake Worth Lagoon Initiative **website was revamped** in 2019 and **received 8,500 visits** from April 2019-Nov. 2020.

SEE ACTION PO-1

More than **10,500 pounds of trash was removed** from nine restoration sites from 2014-2020.

SEE ACTION PO-1

900 citizen-scientists participated in an ANGARI Foundation project **to deploy and track small wooden "drift cards"** from 2017-2019 to improve understanding of **how surface currents disperse marine pollution.**

SEE ACTION PO-1

26 interns from 2017-2019 **graduated from the Green Futures mentoring program** that provides first-hand experience and training in the environmental science field.

SEE ACTION PO-2

Virtual field trips to the Lagoon and natural areas were expanded from 45 students in Spring 2020 to 70+ students in Fall 2020 in response to COVID-19 safety measures.

SEE ACTION PO-2

LagoonFest 2019, held on Flagler Drive in downtown West Palm Beach (Photo credit: PBC-ERM)

PO-1 FOSTER PUBLIC AWARENESS AND ENGAGEMENT

ACTION: Increase direct citizen involvement and awareness of the intrinsic natural value of LWL. This direct connection may foster stewardship to protect and restore the Lagoon. Expand efforts to reach underserved audiences, including communities of color as well as those with disabilities. Accelerate use of digital technology and communications tools to broaden reach and leverage efforts.

IMPORTANCE:

Informed and engaged citizens are empowered to make changes in their own lives and in their communities that benefit the Lagoon.

RELATED ACTIONS:

WQ-4, SW-1, HE-2, PO-2, PU-1

BACKGROUND:

Public outreach plays a critical role in galvanizing support for protecting and improving the Lake Worth Lagoon. Educational efforts coordinated by the Environmental Resources Management (ERM) Department encompass mediums as diverse as print, web, social media, community events and person-to-person interactions *(see Figure 1.1)*. ERM's professional staff regularly shares information about the Lagoon through presentations to community groups, educational venues, interactive, experiential events, media interviews, content creation shared through social and web platforms and through collaborative partnerships with governmental and nongovernmental organizations.

Among key outreach achievements since 2013:

Lagoon Fest

LagoonFest is an annual festival that connects and engages attendees with the natural wonders in Lake Worth Lagoon. Celebrating what makes the Lagoon special, it is held each November since 2014 on the West Palm Beach waterfront. LagoonFest invites residents and visitors to interact with eco-themed exhibitors to learn about the Lagoon's habitats and inhabitants and what actions they can take to impact the lagoon in a positive way. The 2019 LagoonFest attracted 5,000 attendees, and featured more than 80 vendors with interactive, marine-themed displays, demonstrations, live animals, giveaways, kayaking/boat tours and more. This event is produced in partnership with the City of West Palm Beach, The Palm Beaches and the Lake Worth Lagoon Initiative partners. The Covid-19 pandemic forced cancellation of the 2020 LagoonFest.

LagoonFest is scheduled to return beginning in 2021.

Discover A Local Treasure campaign

In partnership with Palm Beach County's tourism development arm, *The Palm Beaches*, ERM staff continue to support the "Discover A Local Treasure" marketing campaign to encourage residents to explore and enjoy their home waters. The campaign's branding includes a Lagoon-specific logo, and a costumed spotted eagle ray mascot called Laguna who appears at community events and children's programs. Multiple short, compelling videos produced for the

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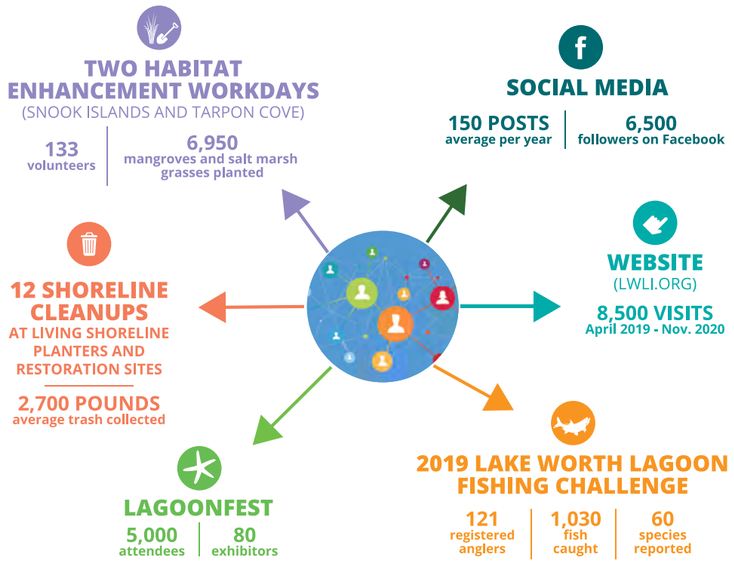
FIGURE 1.1
2019-2020
COMMUNITY OUTREACH HIGHLIGHTS
PALM BEACH COUNTY ENVIRONMENTAL RESOURCES MANAGEMENT



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campaign showcase environmental restoration projects and the value of the Lagoon as seen through the eyes of people who live, work and play in, on and around it. The videos, including the introductory "Lake Worth Lagoon: A Lake Worth Saving" are housed on ERM's YouTube, where they have been viewed 7,500 times as of 2020. They also are shared via Facebook and Instagram channels, with more than 25,000 views from 2015-2020.

Volunteer Opportunities

- ERM Public Outreach staff coordinates approximately 10 cleanup and planting events per year at Lagoon restoration sites. Additionally, partners such as LagoonKeepers.org, Lake Worth Lagoon Waterkeeper and Cultivating Lake Worth Lagoon (a Homeschool group) conduct dozens more cleanup and planting efforts.
- In 2020, ERM staff coordinated a volunteer planting of 6,100 mangroves on a newly created island at Tarpon Cove Natural Area, with participation from 90 local residents and students. Partners included the Florida Department of Environmental Protection, National Oceanic and Atmospheric Administration, and the West Palm Beach Fishing Club. MANG LLC is an official "adopter" of Tarpon Cove Restoration Project. MANG has and continues to donate mangroves, coordinate volunteer planting projects and regular trash cleanups at the site.
- In 2019, ERM also hosted a community restoration event at Snook Islands Natural Area, with 850 mangroves planted by 43 volunteers participating along with the local company 4Ocean. The event was filmed and posted to YouTube.

Citizen-Science Opportunities

- ANGARI Foundation's Drift Card Study in the LWL. This project enlisted volunteers to assist in deployment of small biodegradable floating cards to improve understanding of how currents and associated marine pollution flow within the Lagoon. More than 1,260 citizen scientists have participated in the study since it commenced in 2017, including those who decorated, released, or reported the location of the drift cards and those who provided access to drift card release sites. Although most of the recovered drift cards were retrieved inside the Lagoon, more than one-third were recovered outside along Atlantic beaches *(see Action WQ-5)*.
- The Lake Worth Lagoon Fishing Challenge encourages anglers to document their catches over 2-week and 6-week tournaments with prizes awarded in several categories. This event, started in 2016, has contributed valuable information about the Lagoon's sport fish stocks, especially fish caught in canals, reefs and areas throughout the Lagoon that are not sampled by the fisheries monitoring program. A record 121 anglers participated in 2019, reporting catches of 139 snook, one tarpon and one spotted seatrout.
- ERM staff regularly coordinate marine debris cleanups at restoration sites during the Great American Cleanup and International Coastal Cleanup, where volunteers record the amount and types of trash they collect.

Above: Drift card

Right: Volunteers tossing drift cards into Lagoon (Photo credit: Palm Beach Post)

Digital Communications Tools

The Lake Worth Lagoon Initiative website (LWLI.org) was overhauled in 2019 with fresh images, improved navigation and an updated design compatible with mobile devices. Additionally, the Lake Worth Lagoon page on the County's website is regularly populated with new, user-friendly content. ERM outreach staff also actively maintain Facebook and Instagram platforms. ERM's quarterly Environmental Times Newsletter includes updates on Lagoon news and activities. Interested parties can subscribe via LWLI.org.

Despite these successes, more can be done to foster stewardship that is truly reflective of the diversity of the Lagoon watershed's residents. A concentrated commitment is needed to reach and engage disadvantaged communities often far removed from glitzy, sophisticated waterfront entertainment and residential areas. More educational messages and materials should be translated into Spanish to connect with the growing population of county residents with limited English language skills. Access to recreational, educational and volunteer activities in the Lagoon should be expanded to provide opportunities for those with physical

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Screenshot of Lake Worth Lagoon Initiative website

disabilities or developmental challenges *(see Action PO-2)*. These diverse communities influence the health of the Lagoon, yet often have limited knowledge of its value and fewer opportunities to directly connect with and be inspired by it.

APPROACH:

STEP 1 Increase multicultural outreach and education to underserved communities. Improve awareness and enjoyment of the Lagoon through the many free recreational activities and facilities available to all County residents, and promote specific activities and values important to different cultures and communities.

STEP 2 Expand availability of educational messaging and materials in Spanish, Creole or other languages as appropriate to target key audiences in the Lagoon watershed. Produce outreach materials listing public use facilities and activities, as well as project Fact Sheets, in various languages. Provide electronic versions for posting/distribution at schools, libraries, community centers.

STEP 3 Enhance use of social media campaigns to deliver targeted, repeated, consistent educational messages that promote direct behavior changes to benefit the Lagoon (such as reducing single-use plastics, creating Lagoon-friendly landscapes, or practicing responsible recreational use.

STEP 4 Enlist support and assistance from Lagoon-dependent businesses, recreational groups and community service organizations to disseminate educational messages and materials. Consider a "Friend of the Lagoon" partnership recognition program utilizing the "Laguna" spotted eagle ray mascot *(see Action PU-1)*.

STEP 5 Increase opportunities for residents of all ages and abilities to participate in hands-in volunteer projects and citizen-science initiatives, such as the Adopt A Living Shoreline initiative *(see Action CC-2)*.

TIMEFRAME:

STEPS 1 and 3 are ongoing, especially via outreach efforts to youth throughout Palm Beach County *(see Action PO-2)*.

STEP 2 can occur as educational materials are revised and updated, beginning in FY 2021-2022.

STEP 4 is ongoing through partner fishing clubs and businesses involved in the Lake Worth Lagoon Fishing Challenge. Formal development of a "Friend of the Lagoon" program could begin in FY 2021-2022, and be expanded over time.

STEP 5 is ongoing through programs like LagoonFest, Lake Worth Lagoon Fishing Challenge and Adopt a Natural Area and can occur at any time. A logical first action is to identify local organizations that provide services to specific target audiences such as seniors or citizens with special needs to discuss appropriate activities for participation.

COST ESTIMATE:

STEP 1 $

STEP 2 $-$$

STEP 3 $

Lake Worth Lagoon Fishing Challenge poster

STEP 4 $ Staff time to engage businesses; expenditures required for decals, tent cards and other collaterals associated with a formal partnership program.

STEP 5 $

EVALUATING PROGRESS:

Number of participants in volunteer events, citizen-science activities and LagoonFest.

Number of participants representing special target audiences.

Website metrics, including visitors and time spent on website.

Social Media Metrics, including Facebook/ Instagram followers, post reach and engagement rates over time.

Number of business partners.

REGULATORY NEEDS:

None

FUNDING:

Recurring county budget allocation; possible grant funding for specific programs; private sector donations or in-kind contributions

POTENTIAL PARTNERS:*

PBC-ERM, Local non-profit organizations such as ANGARI Foundation, Lagoon Keepers.org, Lake Worth Waterkeeper; MANG; Manatee Lagoon Eco-Discovery Center, special interest groups such as fishing, paddling or hiking clubs; Florida Fish and Wildlife Conservation Commission (through its Becoming an Outdoorswoman and Fishing/Hunting outreach programs)

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

Volunteers installing shoreline plants at the South Cove natural area (Photo credit: PBC-ERM)

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A young Lagoon resident plants a mangrove during a "Growing Up Wild" workshop (Photo credit: PBC-ERM)

PO-2 PROMOTE YOUTH EDUCATION AND ENGAGEMENT

ACTION: Continue and expand formal and informal learning experiences and hands-on volunteer and career mentoring opportunities for youth throughout the Lagoon watershed.

IMPORTANCE:

The future health of the Lagoon depends on nurturing younger generations who understand and appreciate its value and are committed to protecting it.

RELATED ACTIONS:

PO-1, PU-2

BACKGROUND:

With increasing evidence that experiential learning is the most effective way to deliver impactful environmental education, Palm Beach County's Environmental Resources Management (ERM) Department has refocused its limited resources to create more direct hands-on learning opportunities.

In 2020 with the arrival of the Covid-19 coronavirus, and subsequent remote learning and social distancing mandates, ERM staff pivoted to create new experiential learning opportunities. Using only an iPhone and linking into science classrooms with a teacher moderator, staff scientists were able to explore and enthusiastically share their intimate knowledge of the County's unique natural areas and restoration sites though live virtual field trips.

Using Google Meet in Spring 2020, then transitioning to YouTube Live in Fall 2020, the virtual fields trips showcased diverse habitats from freshwater swamps and hardwood hammocks to mangrove-fringed tidal flats and large-scale restoration projects. In January 2021, ERM hosted a virtual event at Tarpon Cove for 55 students in 8th and 9th grade pre-Chemistry and Biology to learn about water quality, sediments, and marine life in the Lagoon. The magic of live video allowed the students to visually accompany ERM staff, discovering plants and animals simultaneously, ask questions and even make special requests to look more closely at natural artifacts found along the way.

In addition to being "Covid-19 Safe," the virtual field trips provided an unexpected opportunity to connect with children who had never before

PBC-ERM staff conducting a virtual field trip

seen a mangrove or a gopher tortoise, or even ventured much outside their rural communities in the western part of the county. Even students in urban areas are often unaware of the unique natural resources in their own backyard.

In 2020-2021, the virtual experiences expanded from one teacher and 20 students to multiple teachers and more than 200 students.

In addition to this formal classroom outreach, ERM staff also coordinates the following informal education and internship activities, all of which were temporarily suspended in 2020 due to the pandemic:

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- **The Tri-City Trailblazers,** launched in 2018, provides hands-on outdoor experiences to youth in the Glades Area communities of Pahokee, Belle Glade and South Bay, a population far removed from the Lagoon geographically and culturally. Participants explore and learn about the Lagoon over four different field days working alongside professional scientists, as they encourage and inspire a positive connection with nature. Partners include the South Florida Water Management District and Palm Beach County Youth Services. As of 2020, 35 students had participated. In 2021, the program was expanded to include the PBC-supported Youth Empowerment Centers in Riviera Beach and Lake Worth, with the goal of reaching and connecting disadvantaged youth throughout the county to nature and exposing them to new interests, activities and career paths.
- **The Adventure Awaits/Growing up Wild series** connects children under 14 and their parents/guardians to the natural wonders within the LWL through a variety of immersive activities. All the Lagoon-centered adventures are led by ERM staff scientists. Important Natural Areas such as Snook Islands are featured in this series. Four Growing Up Wild events have been held since the program's launch in 2018, with 85 children participating.
- **The Green Futures Summer Internship/Mentoring Program** began in 2017 through a partnership with Palm Beach County Youth Services. The Green Futures program pairs graduating high school and college-aged youth with environmental science professionals working in the LWL and throughout Palm Beach County. During a 4-week paid internship, participants between the ages of 17 and 22 assist ERM staff in duties such as water quality monitoring, mangrove planting and relocations, wetland vegetation and seagrass surveys, bird counts and site cleanups at restoration sites. To date, 26 interns have graduated from the program.
- **The Annual LagoonFest event** *(see Action PO-1)* features many interactive exhibitors, touch tanks and a popular Kids Zone with customized eco-themed activities for youngsters, as well as appearances by a costumed spotted eagle ray mascot named "Laguna," along with several of her friends from partner agencies, who serve as engaging ambassadors for introducing children to the treasures found in the Lagoon.

The three teens featured in the "Hidden Wild" documentary film kayaking in the Lagoon (Photo credit: PBC-ERM)

- **"Hidden Wild" Documentary Film.** ERM, in partnership with The Palm Beaches, contracted with Day's Edge Productions to complete a documentary film called "Hidden Wild." It follows an adult expedition leader and three youth explorers on a 70-mile, 7-day journey through the County's wildest environments. The film will serve as both an eco-tourism tool/asset as well as a curriculum component for 7th and 10th grade science classes in the Palm Beach County School District beginning in 2021. ERM worked with a team of teachers and administrators from the school district to craft the lesson plans associated with the film. The project seeks to inspire the deeper connections required to develop an understanding and sense of "place" in the community. These connections will lead to personal actions that have a positive effect on the environment. In addition to its use in schools, the film will be aired on South Florida PBS channels, and made available for streaming online.

APPROACH:

STEP 1 Expand science-based K-12 education for youth in Palm Beach County, especially for underserved communities in the western basin and highly urbanized areas along the coast. Expand the number of schools participating in virtual field trips during the school year.

STEP 2 Continue hands-on opportunities to learn and contribute to Lake Worth Lagoon improvements through the Adventure Awaits and Tri-City Trailblazers programs.

STEP 3 Continue to model and promote career opportunities in STEM fields through the Green Futures Internships. Expand participation as staff resources allow.

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STEP 4 Encourage other organizations offering youth education programs – including municipalities, Florida Power & Light's Manatee Lagoon, the Loggerhead Marine Life Center, Loxahatchee River Center, Lake Worth Lagoon Waterkeeper, and John D. MacArthur Beach State Park – to utilize the strategies and steps presented in this Action to leverage and strengthen our collective impact.

STEP 5 Maximize distribution of the "Hidden Wild" documentary film through environmental education centers, community groups, private schools, home-school groups and online streaming on multiple platforms.

TIMEFRAME:

STEPS 1-3 Ongoing and should be maintained and expanded over time.

STEP 4 Programs to target specific youth communities and interests can be incorporated in existing summer camps and regular children's programming beginning in 2021.

STEP 5 Classroom use of film starting in Spring 2021, along with broadcast on public television. Reach can be expanded throughout 2021 and beyond.

COST ESTIMATE:

STEPS 1, 2 and 3 $ Generally staff time only, although some additional materials, equipment or supplies may be required.

STEP 4 $ Primarily staff time, as existing programs can be adapted to meet the needs of specific groups.

Production of targeted educational materials, such as translations to Spanish, Creole or other languages, would entail direct costs.

STEP 5 $$

EVALUATING PROGRESS:

Number of participants in virtual field trips and other education programs.

Number of Green Futures interns who complete the program.

Number of youth who volunteer for ERM restoration/cleanup events.

Number of Community Service Hours awarded to high school students annually.

Number of youth from underserved communities such as the Tri-City area who participate in Lagoon-related education and recreation activities.

Number of 7th and 10th graders who view eco-adventure film (Hidden Wild) annually.

REGULATORY NEEDS:

None

FUNDING:

Recurring county budget allocation; possible grant funding for specific programs; direct or in-kind services provided by key public or private partners.

Photo montage: Snook Islands Natural Area

POTENTIAL PARTNERS:*

Palm Beach County School District, PBC Youth Services, ANGARI Foundation, SFWMD, Local municipalities, Florida Power & Light's Manatee Lagoon, the Loggerhead Marine Life Center, Lake Worth Lagoon Waterkeeper, and John D. MacArthur Beach State Park, public and private organizations that provide youth education

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

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PUBLIC USES OF THE LAGOON
ACCOMPLISHMENTS AT A GLANCE

The economic value of boating, fishing, snorkeling and birdwatching in the Lagoon **is estimated at $199.8 million a year.**

More than 120 anglers caught more than **1,000 fish of 60 species in the 2019 Lake Worth Lagoon Fishing Challenge** showcasing the Lagoon's value for sportfishing.

More than 162,000 people visited FPL's Manatee Lagoon Eco-Discovery Center in 2019 to view the **hundreds of manatees that gather near the power plant outfall in winter.**

Palm Beach County **ranked sixth in the state in 2019 in registered boats,** with 36,358.

Fourteen marinas located within the Lake Worth Lagoon are **designated by the state as Clean Marinas,** along with two Clean Boatyards.

From 2014 to 2019, **34 derelict vessels were removed** from the Lake Worth Lagoon.

SEE ACTION PU-1

Exploring marine life along the Phil Foster Snorkel Trail (Photo credit: The Palm Beaches)

PU-1 ENSURE ADEQUATE, AND APPROPRIATE ACCESS TO THE LAGOON

ACTION: Provide adequate and equitable access for fishing, boating, paddling, diving and other recreational uses while safeguarding the Lake Worth Lagoon's natural resources from overuse and degradation.

IMPORTANCE:

Facilitating responsible recreational use will create a community of engaged stakeholders with a vested interest in protecting the Lagoon, while reducing impacts to living resources and building a foundation of trust important to successful resolution of conflicting uses.

RELATED ACTIONS:

PO-1, FW-1, FW-4, HE-1, HE-2, HE-3

BACKGROUND:

As one of Florida's wealthiest counties, with a per capita income of $71,946 a year, Palm Beach County benefits from a large seasonal influx of well-heeled winter residents and a thriving year-round tourism industry valued at $7.7 billion in 2019.[1] The County hosted more than eight million visitors that year, who supported 70,000 jobs in tourism-related businesses such as hotels, restaurants, stores, and transportation services.

The Lake Worth Lagoon plays an underappreciated but vital role in the County's economic underpinning. Its contribution was confirmed in an economic valuation commissioned by the Everglades Law Center in 2020 *(see Figure 1.1)*. The report concluded that the overall economic value of the Lagoon is $5.37 billion – a figure that includes water-dependent activities and the commerce they support; the value of waterfront property and the increased spending tied to those higher property values; and the intrinsic worth of services such as improved water quality and erosion control provided by the Lagoon ecosystem.[2]

The value of outings to boat, fish, dive, snorkel or watch birds in the Lagoon is estimated at $199.8 million a year. Residents who repeatedly enjoy Lagoon recreation account for almost two-thirds of that spending, compared with tourists who may only engage in one recreational activity during their stay.

Managing the Lagoon's resources requires a delicate balance of two disparate and sometimes diverging goals: Ensuring adequate access to the Lagoon's bounty for all who wish to enjoy it, while safeguarding it from overuse and degradation. Achieving this balance is further complicated by the geographic scale of the Lagoon itself: There is simply not enough space for everyone to enjoy unrestricted access without compromising the welfare of the humans and wildlife who share the waters, or the ecological integrity of the natural system.

Aerial view of fishing pier and kayak launch at Snook Islands Natural Area (Photo credit: PBC-ERM)

Equitable access – particularly for underserved communities – is another important consideration. Both socio-economic and physical mobility limitations can serve as barriers to enjoyment of Lagoon amenities and resources that contribute to overall quality of life.

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Ensuring Adequate, Appropriate and Equitable Access

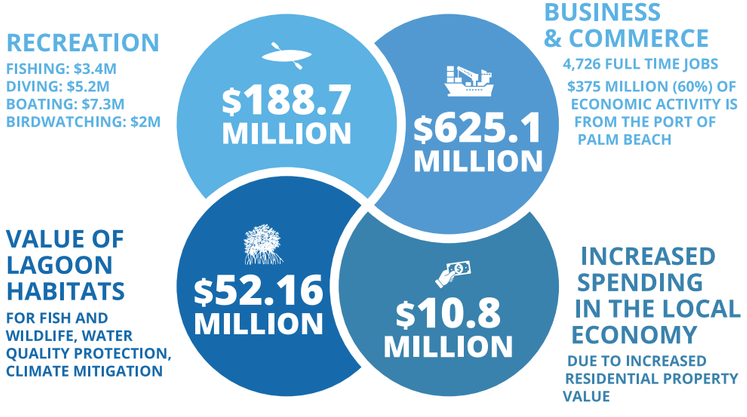
Extensive armoring of the Lagoon shoreline with seawalls, along with the sheer density of private waterfront development, make sufficient public access challenging. Despite this, the County and municipalities bordering the Lagoon have created an impressive network of free public parks and natural areas, many with amenities such as picnic areas, fishing piers, boat ramps, floating day use docks, kayak launches, boardwalks and gazebos *(see Table 1.1)*. These facilities are often constructed in partnership with other public and private entities such as the Florida Inland Navigation District. Examples include:

- The highly acclaimed Snorkeling Trail at Phil Foster Park near Blue Heron Bridge in the City of Riviera Beach. In 2018, close to 478,000 people visited this marked underwater route along artificial reefs constructed of rock, concrete and limestone, in addition to numerous whimsical underwater statues. Protected snorkeling opportunities also are available at Peanut Island Park near the Palm Beach Inlet. Both of these popular snorkeling sites are free to visit, easily accessed off a beach entry to the water, and have on-site lifeguards. Unregulated collection of tropical marine life for aquariums prompted FWC in 2019 to ban specimen collecting Heron Bridge.

Typical weekend crowd near Phil Foster Park (Photo credit: Palm Beach Post)

- Peanut Island Park is a popular destination for boaters, offering fishing, swimming, snorkeling, picnicking and even overnight camping (for a small fee). Day trippers can catch a ferry or kayak over from Phil Foster Park to the 80-acre island created from material dredged from the Intracoastal Waterway, and several ecotour providers offer boat, kayak and paddleboard tours. The park itself is free to visit. Peanut Island recorded 240,930 visitors in 2018.
- Florida Power and Light's Manatee Lagoon Eco-Discovery Center offers residents and tourists an opportunity to view the hundreds of manatees who congregate in the Riviera Beach power plant's warm-water outfall in the winter. The Center also hosts exhibits and a variety of educational programs for school and camp groups, daily walking tours of the center's exhibits, yoga on the waterfront observation deck, and story and craft time for toddlers. More than 162,000 people visited the Center in 2019.
- Snook Islands Natural Area is a series of islands created from dredge spoil and restored to provide intertidal habitats for fish and wildlife. The area is leased to the County by the City of Lake Worth Beach and managed for passive recreational uses such as birdwatching, kayaking and boating, with boardwalks and a dedicated fishing pier used by an estimated 19,386 people in 2018.
- The South Cove Natural Area in downtown West Palm Beach offers a wheelchair-accessible boardwalk for watching

MEASURING THE LAGOON'S WORTH
(ANNUAL FIGURES)



SOURCE: Everglades Law Center and PFM Group Consulting LLC

TABLE 1.1 VISITATION AT PUBLIC USE FACILITIES AT NATURAL AREAS AND PARKS IN LAKE WORTH LAGOON

Boat Ramps and Parks	Annual Visitors	Daily Use Boat Trailer Permits
Jim Barry Light Harbor Park		2744
Phil Foster Park	478,000	6924
Annual Permits for all County Boat Ramps		4740

Parks, Natural Areas and Educational Centers	Annual Visitors
Peanut Island Park	240,930
FPL Manatee Lagoon Eco-Discovery Center	162,000
Snook Islands Natural Area	19,386
South Cove Natural Area	42,766

All numbers from 2018 except FPL-Manatee Lagoon numbers from 2019

SOURCE: PBC ERM

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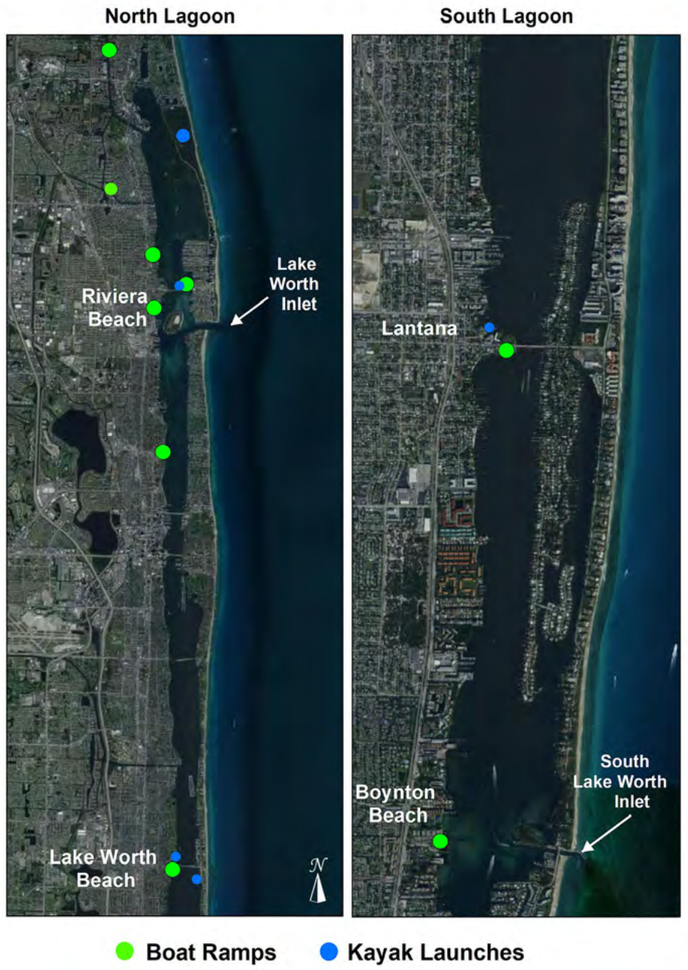
FIGURE 1.2 PUBLIC BOAT RAMPS AND KAYAK LAUNCHES



SOURCE: PBC-ERM

wildlife on three small manmade islands covering six acres of the Lagoon just north of the Royal Palm Bridge. Visitor use was estimated at 42,766 in 2018.

- Bryant Park in the City of Lake Worth Beach offers a boat ramp, shaded picnicking and sitting areas, and a meandering waterfront promenade with sweeping views of the Lagoon.
- Summa Beach Park, in West Palm Beach, is the terminus of the scenic Flagler Drive linear waterfront park. It has a grassy open space with benches and beautiful views of the Lagoon. Numerous other parks are located within the overall Flagler Drive linear park.
- Eight public boat ramps and five dedicated kayak launches offer direct access to the Lagoon, along with several privately owned launch sites *(see Figure 1.2 and Table 1.2)*. In 2018, the County sold 4,740 annual boat trailer permits, which grant unlimited access to all five County-owned boat ramps. Additionally, some 2,744 daily permits were issued at the Jim Barry Light Harbor Park, and 6,924 for Phil Foster Park.
- Paddling opportunities abound throughout the Lagoon, starting in the north with John D. MacArthur State Park, Munyon Island, Peanut Island, and Audubon Islands; and including restoration projects at Tarpon Cove, Grassy Flats, Snook Islands, Jewell Cove and Bryant Park in the central and south Lagoon.
- Recreational opportunities should be accessible to residents of all physical abilities and income levels. For example, ADA-compliant fishing areas serve wheelchair-bound anglers at Snook Islands Natural Area, Ocean Inlet, Phil Foster, Jim Barry Light Harbor, and Peanut Island Parks.

Managing Marine Debris

The non-profit LagoonKeepers.org has conducted quarterly marine debris cleanups at restoration areas since 2014. The County has funded this effort with $100,000 from fines paid to the Pollution Recovery Trust Fund for pollution violations. Cleanups from 2014-2017 removed trash from the South Cove and Snook Islands Natural Areas, Ibis Isles Restoration and Bryant Park Islands. As new Living Shorelines were constructed and additional areas restored, Bryant Park, Jewell Cove, Osprey Park, Currie Park and the Grassy Flats Natural Area were added to the schedule. LagoonKeepers.org removed approximately 10,570 pounds of trash from all sites from 2014-2019.

The County's Environmental Resources Management (ERM) also hosts monthly cleanups at several restoration projects throughout the Lagoon *(see Action PO-1)*.

Promoting Responsible Boating

State records show Palm Beach County ranked sixth in the state in 2019 in registered boats, with 36,358. That is a decline of 4.7% from 2013. The Lagoon is a popular fishing

TABLE 1.2 PUBLIC BOAT RAMPS AND KAYAK LAUNCHES

Public Boat Ramps	City
Juno Park Boat Ramp	North Palm Beach
Anchorage Park Marina	North Palm Beach
Jim Barry Light Harbor Park	Riviera Beach
Sportsman Park Boat Ramp	Lantana
Harvey Oyer Jr. Park	Boynton Beach
Lake Park Harbor Marina	Lake Park
Bryant Park Boat Ramp	Lake Worth Beach
Currie Park and Boat Ramp	West Palm Beach
Phil Foster Park Boat Ramp	Riviera Beach
Dedicated Kayak Launches	**City**
John D. MacArthur Beach State Park	North Palm Beach
Phil Foster Park	Riviera Beach
Snook Islands Natural Area	Lake Worth Beach
Jewell Cove Natural Area	Lake Worth Beach
Lyman Kayak Park	Lantana

Juno Park Boat Ramp not in the Lagoon proper but just north in North Palm Beach included in side by side map for boat ramps and kayak launches.

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and boating destination itself, and a prime launching area for boaters bound for offshore waters via the Lake Worth (Palm Beach) and South Lake Worth (Boynton) Inlets.

The 125-foot-wide Intracoastal Waterway runs the entire length of the Lagoon, generating congestion especially on weekends and holidays. Slow speed zones have been established around inlets, bridges, boat ramps and other areas identified as safety concerns. Minimum or no wake zones also have been created to protect manatees, recreation areas like Peanut Island, and natural areas. A robust multi-jurisdictional law enforcement coalition enforces speed restrictions during the November 15-March 31 manatee season (*see Action FW-1*). In 2019, 85 manatees were killed by watercraft strikes statewide, with 3 of those, or 3.5%, in Palm Beach County.

Projected population growth will undoubtedly bring more people who want to enjoy boating, and commensurate challenges in protecting the Lagoon's living resources. Seagrasses, for example, are particularly vulnerable to both direct (propeller scarring) and indirect (wave-generated re-suspension and scouring of bottom sediments) impacts from boating (*see Action HE-3*). Shorebirds require quiet, protected areas off-limits to people and pets to successfully raise chicks (*see Action FW-4*). User conflicts – between boaters, personal watercraft users, anglers, and paddlers, for instance – also are likely to increase.

Fishing piers, some with wheelchair access, provide fishing opportunities for residents of all abilities (Photo credit: PBC-ERM)

Sustained education efforts would help reduce resource impacts resulting from increased recreation in the Lagoon.

Clean Boating Facilities and Sewage Pumpouts

There are 94 marine facilities in Palm Beach County, including marinas, boatyards, and retailers. The Florida Department of Environmental Protection (FDEP) has designated 22 of them as Clean Boating facilities, signifying adherence to Best Management Practices to protect habitats, manage waste and stormwater, prevent spills, and prepare for emergencies. Fourteen marinas located within the Lake Worth Lagoon are recognized as Clean Marinas, as well as two Clean Boatyards *(see Table 1.3)*. Eight of the facilities offer sewage pumpouts for boaters. FDEP continues to offer funding assistance through the federal Clean Vessel Act (CVA) for the purchase, installation, and maintenance of pumpout equipment in marinas.

Additional public and private marinas throughout the County offer pumpouts, but are not designated as Clean Marinas – pointing to opportunities to provide technical assistance to help them apply for pumpout grants and achieve formal recognition.

Derelict Vessels

Abandoned and derelict vessels can cause environmental damage by physically impacting sensitive coastal habitats or by leaking sewage, oil, and fuel.

It is unlawful in Florida to store, leave or abandon any derelict

TABLE 1.3 DESIGNATED CLEAN MARINAS AND BOATYARDS IN THE LAGOON

	Facility Name	City	Pumpout Type	Land Ownership
Marina	North Palm Beach Marina	North Palm Beach	Stationary	Private
Marina	Old Port Cove Marina	North Palm Beach	Vacuum	Private
Marina	Lake Park Harbor Marina	Lake Park	Vacuum	Public
Marina	Loggerhead Marina - South Lantana	Lantana	NONE	Private
Marina	Rybovich Marina	West Palm Beach	Vacuum	Private
Marina	Rybovich Marine Center	Riviera Beach	NONE	Private
Marina	Loggerhead Marina - Lantana	Lantana	NONE	Private
Marina	Palm Harbor Marina	West Palm Beach	Stationary	Private
Marina	Sailfish Marina Resort	Palm Beach Shores	NONE	Private
Marina	New Port Cove Marine Center	Riviera Beach	Stationary	Private
Marina	Palm Beach Town Docks	Palm Beach	Stationary	Private
Boatyard	Viking Yacht Service Center	Riviera Beach	NONE	Private
Boatyard	Rybovich Marina	West Palm Beach	NONE	Private
Marina	Loggerhead Marina - Riviera Beach	Riviera Beach	Vacuum	Private

SOURCE: Florida Department of Environmental Protection

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Derelict vessel in water at Grassy Flats Restoration project (Photo credit: PBC-ERM)

vessel in state waters, but removal can be a long, drawn-out and costly process. From 2014 to 2019, 34 derelict vessels were removed from the Lake Worth Lagoon in partnership with LagoonKeepers.org. Costs for removal and disposal were shared by Palm Beach County, the Florida Inlet Navigation District (FIND), and the Florida Fish and Wildlife Conservation Commission (FWC). Palm Beach County annually dedicates $20,000 from the Pollution Recovery Trust Fund for this purpose. In 2020, the County received two grants totaling $93,450 from FWC to remove five derelict vessels in the Lagoon. The contract with LagoonKeepers.org to assist with future derelict vessels was extended to 2023.

FWC and the City of Riviera Beach both have websites documenting the location and status of derelict, at risk and abandoned vessels.

Mooring Fields

Mooring fields provide a mechanism for both increasing and managing boating access. By concentrating boats where essential services are more easily provided, they help to reduce boating-related impacts such as waste discharges and damage to seagrasses or reefs from anchoring.

Appropriate siting of mooring fields is critical. FDEP recently adopted a new environmental resource general permit for public mooring fields. This rule allows public mooring fields for up to 100 boats under certain conditions, including a demonstration of minimal adverse environmental effect on water resources.

The City of Riviera Beach is working on permitting three mooring fields in the northern lagoon with a total of 180 mooring buoys. Potential locations include near Phil Foster Park, along the Intracoastal Waterway between the city marina and Blue Heron Bridge, and south of Peanut Island. The city will also provide sewage pumpout service and a water taxi to ferry boaters to and from shore. The project is anticipated to begin in 2021. ERM staff will provide input on potential locations away from seagrasses or important shorebird areas.

Promoting Responsible Ecotourism

Millions of tourists from all over the nation and world visit Palm Beach County. Oceanside beaches, watersports, and waterfront dining and lodging are a major lure for visitors. Fishing, paddling or a stroll along a boardwalk are often part of the tourism experience. These visitors may stay only a short time but their influence on the health of the Lagoon is outsized because of the network of businesses they support.

Kayaking is a popular recreational activity in the Lagoon (Photo credit: PBC-ERM)

Ecotourist providers that offer tours and rentals of boats, kayaks, paddleboards, and personal watercraft have a particular interest and opportunity in promoting ethical enjoyment of the Lagoon. Many already provide education about Lagoon wildlife and habitats as part of their services; this initiative could be formalized and expanded through a “Lagoon Steward” or “Lagoon-Friendly Business” certification for businesses who complete a training program and commit to ethical nature-based tourism experiences. Such a program would help to amplify consistent messages about Lagoon stewardship for both tourists and residents who patronize the businesses.

LagoonFest already offers a visible forum for residents to interact with ecotourism providers and for those businesses to showcase their commitment to eco-ethics. The one-day festival could also serve as an opportunity for the County to jump-start an ongoing partnership with ecotour companies.

The “Discover a Local Treasure” program developed by the County’s tourism marketing arm, *The Palm Beaches*, was launched in 2019 to promote summer staycations for residents. The marketing effort proved especially timely in 2020 by motivating residents to explore their own home waters. Spending by locals also provided some financial respite for tourist-dependent businesses hard hit by the economic slowdown during the worldwide pandemic. “Discover A Local Treasure” is an ideal foundation for ongoing initiatives aimed at inspiring community commitment to protecting the Lagoon.

APPROACH:

STEP 1 Continue to provide opportunities for residents and

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tourists to experience the Lagoon. Ensure that people of all ages, physical abilities and income levels have access to recreational activities.

STEP 2 Continue to support partnerships to remove marine debris and derelict vessels from Lagoon waters.

STEP 3 Encourage all marinas, boatyards and retail facilities in the Lagoon to achieve designation through FDEP's Clean Boating program. Support additional marina applications for assistance in funding sewage pumpouts.

STEP 4 Actively participate in development of criteria for siting and design of mooring fields to minimize risks to critical habitats.

STEP 5 Implement a certification program for ecotour businesses to foster community commitment to ethical enjoyment of the Lagoon.

TIMEFRAME:

STEPS 1,2 and 4 are ongoing.

STEP 3 can begin in 2021 and continue thereafter.

STEP 5 Certification program can be developed in 2021, for implementation beginning in 2022.

COST ESTIMATE:

STEP 1 $-$$$$$ depending on size and scope of access facility.

STEP 2 $-$$$ for annual removal of marine debris and derelict vessels via contract with LagoonKeepers.org and ERM-coordinated volunteer cleanups.

STEP 3 $ staff time only.

STEP 4 $ staff time only.

STEP 5 $-$$ for promotion of marketing of certification program, development of training materials, workshops, and marketing collaterals (decals, signs, etc.). These tasks could be performed by a contractor, with support and assistance from staff.

EVALUATING PROGRESS:

Number of boat ramps, waterfront parks, fishing piers, paddling trails.

Number of Handicapped-accessible boardwalks, trails and piers.

Derelict Vessel Removed Annually.

Marine Debris Removed Annually.

Increase in Clean Marinas and Clean Boatyards.

Number of Certified Ecotourism Businesses.

REGULATORY NEEDS:

Mooring Fields-permitting compliance for proper sitting and approval by FDEP.

FUNDING:

Recurring or special county/city budget allocations, FIND, FDEP

POTENTIAL PARTNERS:*

PBC-ERM and Parks and Recreation, The Palm Beaches, Local Municipalities, LagoonKeepers.org, FIND, FDEP, FWC

**Listed Agencies have not committed funds and are subject to Agencies' budget approvals*

1 https://www.thepalmbeaches.com/record-breaking-822-million-visitors-palm-beaches-2019

2 ECONOMIC VALUATION OF LAKE WORTH LAGOON, PALM BEACH COUNTY, FL. Everglades Law Center & PFM Group Consulting LLC. 2020.

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RESEARCH AND MONITORING

American Oystercatcher fledgling being tagged, weighed and measured (Photo credit: PBC-ERM)

This update of the Lake Worth Lagoon Management Plan identifies the following specific needs for additional Research, Monitoring, Modeling and Mapping initiatives important for Plan implementation. Palm Beach County and the Lake Worth Lagoon Initiative welcome partnerships with government, university and non-profit organizations to address these needs.

RESEARCH NEEDS:

- Factors influencing the growth, persistence and distribution of Harmful Algal Blooms. *(see Action WQ-4)*
- Identify sources and pathways for bacterial contaminants that affect recreational use of Lagoon waters. *(see Action WQ-4)*
- Occurrence, transport and fate of microplastics and/or pharmaceuticals and personal care products (PPCPs) in treated effluent, septic and landfill leachate, agricultural runoff, and in downstream receiving waters in the Lagoon watershed. *(see Action WQ-5)*
- Lagoon-wide sediment transport, characterization and sourcing. *(see Action SE-1)*
- Feasibility study to identify strategies for reducing sediment loads within the C-51 Canal. *(see Action SE-1)*
- Quantify reductions in water, fertilizer, and pesticide use, and associated cost savings, for one or more golf courses in the Lagoon watershed that follow the FDEP Manual of BMPs or are certified through Audubon International. *(see Action SW-1)*
- Cost-benefit analyses of one or more local Green Infrastructure and Low Impact Development projects versus traditional "gray" stormwater treatment. *(see Action SW-2)*
- Cost-benefit analyses of one or more Living Shoreline projects versus armored shoreline stabilizations. *(see Action CC-2)*
- Identify causes of seagrass declines and species shifts throughout the Lagoon. *(see Action WQ-3)*
- Assess vulnerability of natural resources at risk from climate change and sea level rise. *(see Action CC-1)*

MONITORING NEEDS:

- Increase water quality monitoring stations throughout the Lagoon, increase frequency of monitoring at existing stations and add monitoring of specific parameters necessary to support modeling efforts, pinpoint impairments or identify specific issues of concern related to water quality. *(see Actions WQ-1, WQ-2, WQ-4, WQ-5 and WQ-6)*
- Assess the scope, scale and distribution of microplastics in the watershed. *(see Action WQ-5)*
- Develop quantifiable criteria for measuring the long-term success of habitat restoration. *(see Action HE-2)*
- Expand monitoring for additional environmental parameters affecting seagrass health and density, such as freshwater discharges, temperature, turbidity, light, seasonality, wind-wave-boat wakes, and sedimentation. *(see Action HE-3)*
- Assess seasonal manatee use of the Lagoon including abundance, distribution, and habitat utilization. *(see Action FW-1)*
- Expand health assessment of sea

Spotted eagle ray (Photo credit: PBC-ERM)

turtles in the Lagoon to evaluate overall condition and explore potential connections with food availability and presence of Fibropapilloma virus. *(see Action FW-2)*

- Conduct fisheries sampling in the Southern Lagoon, using statewide Fisheries Independent Monitoring protocols. *(see Action FW-3)*
- Assess bird utilization throughout the Lagoon and identify publicly accessible areas worthy of nomination to the Great Florida Birding Trail. *(see Action FW-4)*
- Implement a collaborative acoustic telemetry network to track species of interest within the Lagoon (fish, turtles, manta rays, etc.). *(see Action FW-5)*
- Install a tide gauge at the Port of Palm Beach and/or document Sea Level Rise at targeted areas in the Lagoon. *(see Actions CC-2)*
- Increase opportunities for residents of all ages and abilities to participate in hands-on volunteer projects and citizen-science monitoring programs. *(see Actions PO-1 and PO-2)*

MODELING NEEDS:

- A pollutant loading model to estimate contributions of nutrients and other pollutants currently entering the Lagoon, and potential reductions from implementation of BMPs and other water quality improvements. *(see Actions WQ-2, SW-, WW-1, WW-2)*
- A hydrodynamic estuary model assessing physical and meteorological influences on Lagoon ecology, to assist in evaluating the effects of freshwater inflow, tidal flushing, sedimentation, sea level rise and other environmental stressors. *(see Actions WQ-2, WQ-6 and SE-1)*
- Comprehensive shoreline characterization study incorporating wind and wave modeling to determine most suitable locations for restoration and living shoreline enhancements.
- Update seagrass recovery targets for Lagoon segments based on light attenuation, sediment types, impact of freshwater discharges, and effect of wind and waves on the resuspension of sediments and other factors. *(see Action HE-3)*
- Identify current and potential flooding impacts to low-lying communities throughout the watershed due to king tides and future sea level rise. *(see Action CC-1)*

Manatee rescue in the Lake Worth Lagoon (Photo credit: PBC-ERM)

New mangroves at Snook Islands Natural Area (Photo credit: PBC-ERM)

MAPPING NEEDS:

- Inventory and map all natural hardbottom areas to characterize communities and identify monitoring and management needs. *(see Action HE-1)*
- Map "hot spots" of chronic sewer overflows and problem areas, in conjunction with identification of environmental risk factors that increase probability of wastewater spills and overflows. *(see Action WW-1)*
- Inventory and map septic systems with greatest potential to contribute problematic nutrients to the Lake Worth Lagoon based on proximity to Lagoon, age of system, density, soil conditions, depth of groundwater table, potential for denitrification, vulnerability to sea level rise and other relevant factors. *(see Action WW-2)*
- Map muck and sediments throughout the Lagoon *(see Action SE-1)*

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FINANCING AND IMPLEMENTATION

This chapter describes how the Lake Worth Lagoon Management Plan will be implemented and funded in partnership with the Florida Legislature; the Lake Worth Lagoon Initiative; Palm Beach County; municipal governments; state, regional and local agencies; non-governmental organizations; and other stakeholders with a vested interest in the health of the Lagoon.

Starfish and seagrass (Photo credit: PBC-ERM)

THE ROLE OF THE LAKE WORTH LAGOON INITIATIVE

The Lake Worth Lagoon Initiative (LWLI) has primary responsibility for implementing the Management Plan. LWLI is an informal forum for stakeholders to facilitate information-sharing and develop research, restoration and education strategies to improve Lagoon health. A Steering Committee and three topic-driven Working Groups (Habitat, Water, and Public Outreach) meet three times each year. The 5-member Steering Committee is composed of representatives from Palm Beach County Board of County Commissioners and the League of Cities; the Florida Inland Navigation District (FIND); a Governing Board member of the South Florida Water Management District; and the Southeast District Director of the Florida Department of Environmental Protection (FDEP) *(see Figure 1.1)*.

Palm Beach County's Environmental Resources Management (ERM) staff provide administrative support and coordination for the LWLI.

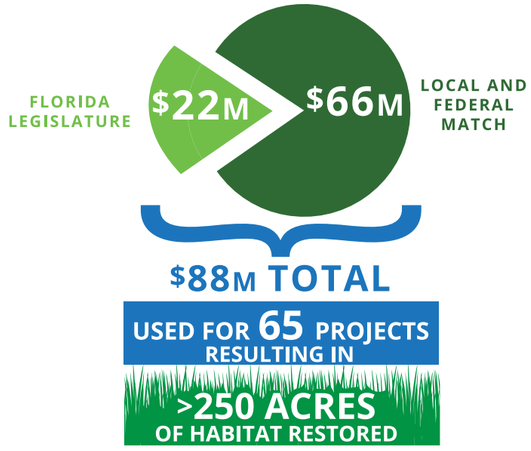
LWLI partner responsibilities include:

- Submitting the annual request from the Lake Worth Lagoon Initiative (LWLI) to the Florida Legislature to finance priority projects such as habitat restoration, storm water retrofits and septic-to-sewer conversions. Palm Beach County coordinates the application and project ranking process.

  Projects submitted for Legislative consideration are reviewed and forwarded by the LWLI Steering Committee to the Palm Beach County Board of County Commissioners. Adoption of the Lagoon Management Plan by formal resolution is required of entities offering projects for consideration. Partners and applicants are encouraged to advocate on behalf of the LWLI funding request.

  - From 2013-2020, the Legislature allocated $5.9 million in grant funds, matched by $5.9 million in local funds, for a total of $11.9 million in restoration and water quality projects. The Legislature approved project-specific funding for the Lagoon in FY 2021, but the funds were vetoed by the Governor *(see Table 1.1)*.

FINANCING LAGOON IMPROVEMENTS



  - Identifying grant opportunities to achieve Plan objectives.
    - From 2014-2020, FIND awarded $1.2 million in grant funds from its Waterway Assistance Program for County-sponsored projects within the LWL.[1] These grants were matched 1-to-1 by local funds to leverage $2.5 million for LWL habitat and public access projects *(see Table 1.2)*.
    - Also, during this timeframe, FIND provided $8.1 million in grant funds, matched by $37.9 million in local funds, to construct municipal public use facilities,

TABLE 1.1 PROJECTS FUNDED BY THE LWL INITIATIVE LEGISLATIVE FUNDING REQUEST FROM 2013-2021

FY	PROJECT NAME	AMOUNT REQUESTED	FUNDING AWARD	MATCHING FUNDS	TOTAL PROJECT COST
2021	4 projects received a preliminary allocation of $850,000*				
2018	City of Riviera Beach - Singer Island South	$1,183,000	$750,000	$750,000	$1,500,000
2017	Lost Tree Village-Septic to Sewer	$1,646,750	$1,000,000	$1,000,000	$2,000,000
2016	Lake Worth Lagoon Living Shorelines	$500,000	$500,000	$500,000	$1,000,000
2016	Tarpon Cove Mangrove Islands and Seagrass	$1,500,000	$1,300,000	$1,300,000	$2,600,000
2016	Monitoring and Administration	$200,000	$200,000	$200,000	$400,000
2014	Peanut Island Reef Complex in Riviera Beach	$75,000	$90,000	$90,000	$180,000
2014	West Palm Beach Currie Park Living Shoreline	$300,000	$360,000	$360,000	$720,000
2014	Palm Beach Grassy Flats Restoration	$900,000	$960,000	$960,000	$1,920,000
2014	Bryant Park & Old Bridge Park Living Shorelines in Lake Worth	$400,000	$515,000	$515,000	$1,030,000
2014	Monitoring and Administration	$400,000	$150,000	$150,000	$300,000
2013	Monastery Artificial Reef at Peanut Island	$250,000	$150,000	$150,000	$300,000
	TOTALS	**$7,354,750**	**$5,975,000**	**$5,975,000**	**$11,950,000**

*Preliminary allocation vetoed in final state budget

SOURCE: PBC-ERM

marinas, and waterfront enhancements *(see Action PU-1)*.

- Working collaboratively with each other and additional partners to enhance the Lagoon *(see Table 1.3)*.
  - From 2014-2020, the Florida Department of Transportation contributed $3.9 million in Lagoon improvements through mitigation projects at Snook Islands and Bryant Park Islands.
  - Contributions from 10 agencies and organizations brought the $3.5 million Grassy Flats intertidal restoration to life. The project received a $960,000 legislative appropriation, matched by $842,000 from the U.S. Army Corps of Engineers, $794,000 from the County, and contributions from the Town of Palm Beach, City of Lake Worth, U.S. Fish & Wildlife Service, National Oceanic and Atmospheric Administration, Florida Fish and Wildlife Conservation Commission, Florida Department of Environmental Protection, Marine Industries Association, and West Palm Beach Fishing Club.
  - The Florida Department of Environmental Protection contributed $346,000 toward restoration at Grassy Flats, artificial reefs at Phil Foster Snorkel Trail and Sugar Sands, and Living Shoreline mangrove pods throughout the Lagoon.
  - FIND and local maritime contractors have provided critical support for restoration by donating lagoon-compatible material from dredging and marina projects to fill historic dredge holes and create intertidal habitat and islands *(see Action HE-2)*. This contribution resulted in an $10.8 million cost savings on the Tarpon Cove restoration project alone, and is expected to save $15.8 million on the Bonefish Cove restoration slated for completion by 2023.
  - The South Florida Water Management District provides sampling and laboratory analysis for monthly water quality monitoring and for assessment of the sediment trap installed on the C-51 Canal. SFWMD installed and maintains two automated water quality stations in the Central Lagoon and a nutrient analyzer at S155 to support data collection related to freshwater flow and sediment discharges to the Lagoon *(see Action WQ-1)*.
  - FWC provides significant direct and in-kind contributions to Lagoon management through fisheries, oyster and habitat monitoring, as well as for restoration via delegated funds from the U.S. Fish and Wildlife Service (USFWS). A total of $1.45 million in funding came from FWC, USFWS, NOAA and local partners between 2014-2020.
- Adopting rules, policies and ordinances that uphold and encourage responsible use of the lagoon.
  - SFWMD and local municipalities in the Lagoon watershed are formally requested to adopt a resolution supporting the restoration, monitoring, funding and education strategies presented in each Management Plan update.
  - As of 2020, Palm Beach County and 20 municipalities have enacted a state model ordinance that prohibits lawn fertilizer application when flood or storm watches are issued, or heavy rains are expected *(see Action SW-1)*.
  - Palm Beach County adopted a policy requiring that climate change/sea level rise impacts be factored

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TABLE 1.2 FLORIDA INLAND NAVIGATION DISTRICT WATERWAYS ASSISTANCE PROGRAM (WAP) PROJECTS IN LAKE WORTH LAGOON 2013-2020

Complete list-Florida Inland Navigation District- Waterways Assistance Program Projects in Lake Worth Lagoon 2013-2020. (Table adapted from FIND website)

PROJECT NAME	PROJECT NUMBER	PROJECT SPONSOR	GRANT AMOUNT	TOTAL COST
Old Bridge Park Natural Area	PB-14-182	Palm Beach County	$251,875	$503,750
Peanut Island Erosion Control & Reef Project	PB-14-184	Palm Beach County	$166,800	$333,600
West Palm Beach Living Shorelines	PB-15-186	Palm Beach County	$391,175	$782,350
Anchorage Park	PB-NPB-17-197	Village of North Palm Beach	$200,000	$400,000
Municipal Marina Construction - Phase B1	PB-RB-13-177	City of Riviera Beach	$750,000	$4,341,396
Riviera Beach Marina Construction - Part B, Phase I	PB-RB-14-185	City of Riviera Beach	$75,000	$150,000
Riviera Beach City Marina Dock G and Lifts	PB-RB-16-189	City of Riviera Beach	$1,157,500	$2,315,000
Riviera Beach Marina Pier F	PB-RB-17-196	City of Riviera Beach	$1,200,000	$2,400,000
Currie Park Boat Access, PH II	PB-WPB-16-190	City of West Palm Beach	$428,000	$856,000
Anchorage Park Part 2	PB-NPB-18-202	Village of North Palm Beach	$300,000	$600,000
Town of Palm Beach Docks Replacement Phase I	PB-PB-180-201	Town of Palm Beach	$325,000	$650,000
Riviera Beach Marina Final Docks Phase I	PB-RB-18-199	City of Riviera Beach	$325,000	$650,000
Ocean Inlet Park Marina Phase I	PB-18-200	Palm Beach County	$200,000	$400,000
Riviera Beach Municipal Marina Pier E		City of Riviera Beach	$250,000	$500,00
Riviera Beach Public Mooring Field Phase I		City of Riviera Beach	$75,000	$125,000
Lake Worth Inlet Flood Shoal Dredging Phase I		Palm Beach County	$140,000	$280,000
Town of Palm Beach Dock Replacement		Town of Palm Beach	$3,062,000	$32,300,000
		TOTALS	**$19,297,350**	**$47,087,096**

SOURCE: PBC-ERM

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TABLE 1.3 COMPLETED PROJECTS BY FUNDING SOURCE

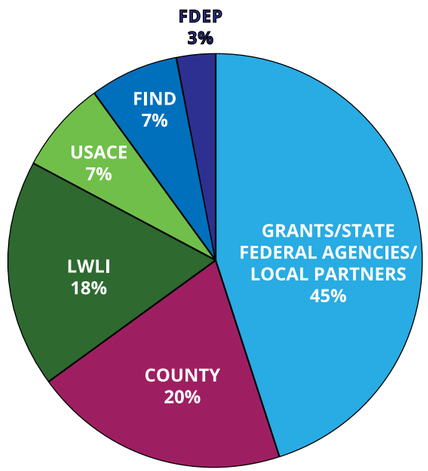
YEAR COMPLETED	PROJECT NAME	LWLI	FIND	FDOT	FDEP	FWC/USFWS/ NOAA/ TNC/LOCAL PARTNERS	USACE	PBC	DONATED MATERIAL	TOTAL PROJECT COST
2014	Bryant Park Islands			$3,674,983		$416,658		$340,000		$4,431,641
2015	Grassy Flats	$960,000			$110,000	$788,020	$842,000	$794,475		$3,494,495
2015	Bryant Park Living Shorelines (Phase I)	$64,908				$40,000		$64,908		$169,816
2015	Peanut Island Erosion Control & Reef Project	$90,000	$68,796							$158,796
2016	Peanut Island Reef Complex		$58,135					$58,135		$116,270
2016	Jewell Cove Living Shorelines	$150,000				$100,000		$150,362		$400,362
2017	Phil Foster Snorkel Trail and Sugar Sands Reef				$150,000			$4,918		$154,918
2017	Currie Park Living Shoreline	$303,502	$321,715					$45,542		$670,759
2017	Osprey Park Living Shoreline	$56,498	$34,377					$1,550		$92,425
2017	Bryant Park Living Shorelines (Phase II)	$168,954						$168,954		$337,908
2017	Old Bridge Park Restoration & Dock		$251,875					$157,925		$409,800
2018	Lyman Kayak Park Living Shoreline							$16,209	$3,960	$20,169
2018	Snook Island Modifications			$163,070						$163,070
2018	Grassy Flats Modifications							$62,754		$62,754
2018	Bryant Park Repairs			$64,994						$64,994
2018	Southern Boulevard Bridge Reef								100% donation of material and placement	
2019	Tarpon Cove (Phase I)	$331,073				$43,142		$444,320	$11.5 million	$818,535
2020	Lake Worth Inlet Flood Shoal Phase I - Modeling		$140,000			$70,000		$70,000		$280,000
2020	LWL Mangrove Pods				$86,963					$86,963
		$2,124,935	**$874,897**	**$3,903,047**	**$346,963**	**$1,457,820**	**$842,000**	**$2,380,052**	**> $11.5 million**	**$11,933,674**

SOURCE: PBC-ERM

into all future capital improvement projects *(see Action CC-1)*.

- FWC banned harvest of tropical aquarium species at the Blue Heron Bridge dive site effective April 1, 2019.
- The Town of Palm Beach enacted an ordinance prohibiting use of plastic straws and stirrers in 2019. Palm Beach and other coastal municipalities are working together on measures to restrict all single-use plastics.
- Increasing awareness and appreciation of the Lagoon's biological diversity and importance to regional quality of life.
  - LWLI partners actively support and promote the annual LagoonFest celebration and the Lake Worth Lagoon Fishing Challenge, along with shoreline cleanups and other hands-on volunteer opportunities *(see Action PO-1)*.

FIGURE 1.2 FUNDING BREAKDOWN - ALL AGENCIES ($11.9M TOTAL)



The Role of Palm Beach County

Palm Beach County is a driving and cohesive force for comprehensive Lagoon management. The County coordinates both the Lake Worth Lagoon Initiative and the Lake Worth Lagoon Management Plan, dedicating significant staff time and financial resources for Lagoon priorities. This commitment totaled nearly $2.4 million in funding for habitat restoration and enhancement projects alone from 2014-2020, 20% of expenditures from all sources *(see Table 1.4)*.

Additionally, the County funds all or part of major Lagoon monitoring programs – including water quality, seagrass, fisheries, sea turtles and oysters – at a prorated cost of $223,000 a year *(see State of the Lagoon chapter)*. Expanding those base monitoring programs to include shorebird surveys and creation of an Acoustic Telemetry Array in the north LWL, both recommended new actions in this Plan update, would add $40,000 to the County's annual monitoring costs (*see Figure 1.3)*.

ERM staff also develop and implement an array of innovative community education and involvement programs, such as virtual field trips for students launched in 2020 in response to COVID-19, and the Green Futures Summer Internship/ Mentoring Program *(see Actions PO-1 and PO-2)*.

FINANCING STRATEGY

The County pursues dedicated and variable funding for Lagoon priorities at all levels of government, and from private and non-profit sources. The Lake Worth Lagoon Initiative- Legislative Funding Request Program has been a critical component of many projects and partnerships, yet its dependence on legislative approval each year makes it difficult to activate the kind of multi-year, multi-scale projects needed to achieve watershed-wide restoration and monitoring.

The major objectives for the 2021-2031 timeframe of this Management Plan recognize this shortcoming and seek to diversity and identify dedicated, recurring, and durable funding for the Lagoon:

- Resume annual appropriations from the Florida Legislature for priority projects endorsed by the Lake Worth Lagoon Initiative Steering Committee.
- Secure funding in State agencies' (line item) budget.
- Secure Federal Legislative authorization through the Water Resources Redevelopment Act (WRDA) to support restoration initiatives through the U.S. Army Corps of Engineers.
- Aggressively pursue municipal, state, and federal grant partnerships for Lagoon improvement.
- Maintain local funding at existing levels to provide matching funds to accomplish more with public dollars.
- Continue partnerships with the maritime community to facilitate beneficial use of dredged material.
- Promote public-private partnerships with the potential for

TABLE 1.4 LWL MONITORING CURRENT CONTRACTS AND COST SCHEDULE

ACTIVITIES	TOTAL	ON ANNUAL BASIS
Fixed Transect Seagrass (2yr) 2020-2021	$118,530	$59,265
Sea Turtle Monitoring (2yr) 2020-2021	$76,000	$38,000
Oyster Monitoring (3 yr) 2020-2022	$198,000	$66,000
Fisheries Monitoring (3yr) 2021-2023	$179,549	$59,850
TOTAL	**$572,079**	**$223,115**
MONITORING THROUGH PARTNERSHIPS		
Bird Monitoring and tagging (ERM and FWC staff time and equipment)	$30,000	$30,000*
Acoustic Telemetry Array: WPB Fishing Foundation, PBC and FWC partnership	$28,000	$10,000*
TOTAL	**$58,000**	**$40,000**
GRAND TOTAL	**$630,079**	**263,115**

**Equipment and staff time estimate*

SOURCE: PBC-ERM

bottom-line benefits for LWL businesses, land trusts, environmental organizations and others.

- Establish a LWL Restoration Fund as a subset of FDEP's Florida Pollution Recovery Trust Fund to direct state fines collected from enforcement of environmental laws within the Lagoon watershed to Lagoon restoration.

IMPLEMENTATION STRATEGY

The 2021 Update of the LWL Management Plan presents specific Action Plans and strategies to build upon progress made in improving the Lagoon and address emerging issues that will require action in the coming decade.

This update of the Plan strategically embraces watershed management as a central theme, acknowledging that the health of the Lagoon is inextricably connected to the activities and inputs occurring in a voluminous watershed that is 42 times the size of the Lagoon itself.

Mechanisms for Implementation

Adoption of the Plan through a formal Resolution by its contributors will provide a confirmation of the consensus that is essential for securing future resource allocation and grant funding.

Local governments are encouraged to integrate the LWL Management Plan's goals and priorities into their comprehensive land use plans, to elevate and codify consideration of the Lagoon in their long-range blueprint for growth. Likewise, incorporating Plan strategies and actions into ordinances, land development codes, operating protocols, regional restoration plans and other guidance documents can lead to significant progress in Lagoon protection and enhancement.

Municipalities and additional agencies of the state (such as drainage districts) are required to adopt the 2021 Lake Worth Lagoon Management Plan Resolution *(see Figure 1.4)* to submit projects for the LWLI-Legislative Funding Request.

[1] The Waterway Assistance Program was established by the Florida Legislature and FIND to address problems associated with the Atlantic Intracoastal Waterway and other District-owned waterways.

Figure 1.4 DRAFT LWL RESOLUTION 2021

A RESOLUTION OF THE _____
IN SUPPORT OF THE 2021 LAKE WORTH LAGOON MANAGEMENT PLAN

WHEREAS, the Lake Worth Lagoon restoration efforts have been underway since 1998 and the State of Florida designated the lagoon a priority water body in 2004 in section 373.453, Florida Statutes; and

WHEREAS, in 2008, the Lake Worth Lagoon Initiative (LWLI) was established to provide interagency coordination with the purpose of seeking awareness, support and legislative funding assistance for projects that will improve and protect the natural resources within the watershed; and

WHEREAS, the LWLI provides partnerships between government agencies and stakeholders that incorporate and combine funding acquisition support, outreach and technical expertise, increase stakeholder and public awareness; and

WHEREAS, the 2021 Lake Worth Lagoon Management Plan Update (LWLMP) is a revision to the 1998, 2008 & 2013 LWL Management Plans, which outline actions and projects to restore the ecological health of the water body; and

WHEREAS, the _____
_ desires to support the 2021 LWLMP, which provides for the following elements:

Continue construction of priority environmental enhancement and restoration projects, increase stakeholder participation, increase partnering efforts for funding support and acquisition, complete Action Plans, increase public awareness and outreach efforts, and prioritize and combine data collection efforts to assess project successes and guide future management decisions; and

NOW THEREFORE, BE IT RESOLVED BY
_____:

Section 1: The foregoing recitals are hereby adopted and ratified.

Section 2: This Resolution shall take effect immediately upon adoption.

PASSED and ADOPTED this _____day of _____, 2021.

LAKE WORTH LAGOON INITIATIVE

MEMBERSHIP

The business of the LWLI shall be managed by a 5-member Steering Committee and 3 Working Group Leads.

The Steering Committee shall consist of one representative from each of the following entities:

- Palm Beach County Board of County Commissioners
- Governing Board member - South Florida Water Management District
- Director of the SE District Florida Department of Environmental Protection (FDEP)
- Palm Beach County League of Cities
- Florida Inland Navigation District (FIND)

MEMBERSHIP-WORKING GROUP LEADS

Working Groups shall cover major areas of emphasis:

- Water: An appointed technical representative by the Governing Board Member of SFWMD
- Habitat: An appointed technical representative by the Director of ERM.
- Public Outreach: An appointed representative by the Director of ERM
- Working Group Leads will organize and schedule Working Group meetings, prepare agendas, maintain minutes and be responsible for communicating, to the LWLI, information from their respective working group.

ACRONYMS AND ABBREVIATIONS

Oystercatchers hanging out in the Lake Worth Lagoon (Photo credit: PBC-ERM)

BMP Best Management Practice

CERP Comprehensive Everglades Restoration Plan

CWA U.S. Clean Water Act

DEO Department of Economic Opportunity

EPA U.S. Environmental Protection Agency

FDACS Florida Department of Agriculture and Consumer Services

FDEP Florida Department of Environmental Protection

FDOH Florida Department of Health

FWC Florida Fish and Wildlife Conservation Commission

FWC-FWRI FWC Fish and Wildlife Research Institute

FIND Florida Inland Navigation District

FPL Florida Power & Light

GIS Geographical Information Systems

HAB Harmful Algal Bloom

HBOI Harbor Branch Oceanographic Institute

HOA Homeowner Association

ICW Intracoastal Waterway

IRL Indian River Lagoon

LWDD Lake Worth Drainage District

LWL Lake Worth Lagoon

LWLI Lake Worth Lagoon Initiative

MPP Manatee Protection Plan

NNC Numeric Nutrient Criteria

NOAA National Oceanic and Atmospheric Administration

PBC Palm Beach County

PBAU Palm Beach Atlantic University

PBC-ERM Palm Beach County-Environmental Resources Management

SFWMD South Florida Water Management District

TMDL Total Maximum Daily Load

UF-IFAS University of Florida-Institute of Food and Agricultural Sciences

USACE United States Army Corps of Engineers

USFWS United States Fish and Wildlife Service

USGS United States Geological Survey

WAP Waterway Assistance Program

WWTP Wastewater Treatment Plant

SUMMARY ACTION PLAN COSTS AND TIMELINE

WATER AND SEDIMENT QUALITY SUMMARY

WATER QUALITY		
WQ-1 EXPAND WATER QUALITY MONITORING	**TIMELINE**	**ESTIMATED COST**
Step 1 Continue water quality monitoring and trend analysis	2021-2031	$$
Step 2 Increase frequency of monitoring or add parameters to pinpoint impairments or specific issues of concern	2022-2031	$$$
Step 3 Develop Additional Monitoring Plans to Address Management Needs	2022-2031	$$-$$$
WQ-2 DEVELOP A WATERSHED-BASED MODELING PROGRAM	**TIMELINE**	**ESTIMATED COST**
Step 1 Develop two predictive watershed models: model for estimating pollutant loading from the watershed and a hydrodynamic estuary model for the Lagoon	2022-2024	$$$
Step 2 Utilize Model to determine optimal water quality conditions and salinities and apply into water management decisions	2023-2031	$$
Step 3 Develop additional modeling tools as needed to address specific management needs	2023-2031	$$$
WQ-3 IMPLEMENT BEST MANAGEMENT PRACTICES FOR DRAINAGE CANALS	**TIMELINE**	**ESTIMATED COST**
Step 1 Establish working group to develop standardized guidelines for non-structural BMPs	2021-2023	$
Step 2 Adoption of BMPs by partner agencies and organizations	2022-2028	$
Step 3 Evaluate reductions in nutrients and sediments over time	2023-2031	$$
WQ-4 MONITOR AND ASSESS WAYS TO REDUCE BACTERIAL CONTAMINATION AND HARMFUL ALGAL BLOOMS	**TIMELINE**	**ESTIMATED COST**
Step 1 Sample for Harmful Algal Blooms, including blue-green algae and red tides, in addition to bacterial contaminants that could pose a health risk to marine life and the public	2021-2031	$-$$$
Step 2 Understand the current factors contributing to Harmful Algal Blooms in the Lagoon, and potential problem species in the future due to climate change	2023-2028	$$-$$$
Step 3 Identify sources of bacterial contamination at Phil Foster Park and other recreation areas in the Lagoon	2022-2031	$$-$$$
Step 4 Increase public education and awareness of Harmful Algal Blooms and waterborne pathogens, and ways to reduce exposure	2022-2031	$
WQ-5 IDENTIFY AND ASSESS THE IMPACTS OF EMERGING CONTAMINANTS	**TIMELINE**	**ESTIMATED COST**
Step 1 Implement sampling and analysis to assess scope and distribution of microplastics in the watershed and LWL	2021-2031	$-$$
Step 2 Track ongoing research on Emerging Contaminants and support localized research	2021-2031	$
Step 3 Support education on Emerging Contaminants, reduction of plastic pollution and pharmaceuticals and personal care products (PPCP's)	2021-2031	$
WQ-6 MANAGE FRESHWATER INFLOWS TO OPTIMIZE ENVIRONMENTAL BENEFITS	**TIMELINE**	**ESTIMATED COST**
Step 1 Evaluate and implement modifications to operational protocols for drainage canals and water control structures to reduce damaging freshwater pulses and velocities, as well as nutrient and sediment loading	2022-2031	$$
Step 2 Support modifications to canal operations to reduce dramatic fluctuations in flows that contribute to salinity extremes. Develop long-term water management plan to maintain optimal salinity ranges for oysters and seagrasses.	2023-2031	$$
Step 3 Support modifications to existing Stormwater Treatment Areas to improve storage capacity, nutrient reduction and sediment containment	2023-2031	$-$$
Step 4 Identify potential new Stormwater Treatment Areas and Water Conservation areas in the western C-51 basin and elsewhere in the LWL watershed to capture, treat and gradually release freshwater downstream	2023-2031	$-$$

ESTIMATED COSTS KEY:		
	$	$0-$25,000
	$$	$25,000-$100,000
	$$$	$100,000-$500,000
	$$$$	$500,000-$1,000,000
	$$$$$	More than $1,000,000

WASTEWATER		
WW-1 ASSESS AND REDUCE OCCURRENCE OF SEWER OVERFLOWS	**TIMELINE**	**ESTIMATED COST**
Step 1 Installation of emergency generators for continued operation of lift stations during power failures	2022-2024	$$$
Step 2 Create decision-support tool for prioritizing wastewater system improvements and identification of environmental risk factors	2023-2028	$$
Step 3 Encourage wastewater utilities within the Lagoon watershed to develop and implement a Capacity, Management, Operation and Maintenance program to address maintenance needs	2023-2031	$
Step 4 Educate on importance of maintaining privately owned lateral lines	2023-2029	$-$$$
WW-2 SEPTIC SYSTEM INVENTORY AND ASSESSMENT	**TIMELINE**	**ESTIMATED COST**
Step 1 Create an inventory and geographic database of septic systems with potential to contribute nutrients to the Laggon based on selected factors	2022-2025	$$
Step 2 Determine nutrient loading associated with leaching from septic systems by conducting a souce tracking study	2023-2028	$- $$$
Step 3 Create priority list for conversion of septic systems to central sewer and/or advanced or nutrient-reducing septic systems	2023-2028	$$$$-$$$$$
Step 4 Support State legislation to require regular maintenance and inspection of septic systems and stricter setbacks and standards for new septic systems in areas with impaired waters	2023-2029	$
STORMWATER RUNOFF		
SW-1 REDUCE STORMWATER RUNOFF FROM URBAN LANDSCAPES	**TIMELINE**	**ESTIMATED COST**
Step 1 Quantify estimates of nutrient loading from residential landscapes in the watershed	2024-2028	$$$
Step 2 Foster compliance with fertilizer ordinances and landscape Best Management Practices on County's properties and municipalities within the watershed	2021-2031	$
Step 3 Promote consistent educational messaging about fertilizers to foster compliance with local ordinances.	2021-2031	$
Step 4 Quantify reductions in water, fertilizer and pesticide use, and associated cost savings, for golf courses in the Lagoon watershed that follow DEP's manual of Best Management Practices or certified by Audubon International	2022-2025	$-$$
Step 5 Offer site visits to golf couses to identify improvements to maintenance programs to reduce impacts to Lagoon	2025-2031	$
Step 6 Continue promoting Florida Friendly Landscaping through programs and community events and Lake Worth Lagoon Initiative Outreach Working Group	2021-2031	$
SW-2 EXPAND USE OF GREEN INFRASTUCTURE AND LOW IMPACT DEVELOPMENT PRACTICES (GI/LID)	**TIMELINE**	**ESTIMATED COST**
Step 1 Encourage expanded use of GI/LID techniques to treat rainfall runoff	2021-2031	$
Step 2 Conduct cost-benefit analysis on benefits associated with local Green Infrastructure projects relative to traditional stormwater treatment	2021-2024	$
Step 3 Conduct Green Infrastructure workshop of stormwater professionals, landscape architects and water resource planners	2021-2031	$
Step 4 Education on benefits of Green Infrastructure, signage at demonstration project or webinar showcasing examples in the County	2021-2031	$
Step 5 Incorporate Support for Green Infrastructure in comprehensive plans and land use codes	2021-2031	$
Step 6 Consider incentives such as increasing density allowances with Green Infrastructure is used	2021-2031	$
Step 7 Creation of County and municipal stormwater utilities as a mechanism to finance ongoing water quality improvements	2021-2031	$
SEDIMENT MANAGEMENT		
SE-1 ASSESS AND MANAGE SEDIMENT LOADING	**TIMELINE**	**ESTIMATED COST**
Step 1 Continue annual surveys of C51 sediment trap and implement results of sediment trap efficiency study	2021-2031	$-$$$
Step 2 Assess sediment loads to the Lagoon along the main drainage canals and structures. Implement a Lagoon-wide sediment characterization and sourcing study	2022-2024	$$-$$$
Step 3 Conduct feasibility study to identify strategies for reducing sediment loads within the C-51	2022-2031	$$
Step 4 Implement projects to reduce sediment loading to the Lagoon and manage sediment within the Lagoon to improve habitat value via capping or removing muck deposits	2021-2031	$$$$-$$$$$

ESTIMATED COSTS KEY:		
	$	$0-$25,000
	$$	$25,000-$100,000
	$$$	$100,000-$500,000
	$$$$	$500,000-$1,000,000
	$$$$$	More than $1,000,000

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HABITAT ENHANCEMENT AND PROTECTION SUMMARY

HE-1 CREATE, PROTECT AND MONITOR HARDBOTTOM HABITATS	TIMELINE	ESTIMATED COST
Step 1 Continue and expand an oyster enhancement and monitoring plan that defines long term goals for oyster restoration in the Lagoon	2022-2031	$-$$
Step 2 Inventory and map all natural hardbottom areas to characterize communities and identify monitoring and management needs	2022-2031	$$-$$$
Step 3 Continue to pursue opportunities to create artificial reefs to provide habitat, reduce erosion and provide recreational areas	2022-2031	$$-$$$
Step 4 Encourage stakeholder involvement in creating an oyster gardening program	2022-2031	$
HE-2 RESTORE, CREATE AND PROTECT INTERTIDAL HABITATS	**TIMELINE**	**ESTIMATED COST**
Step 1 Complete shoreline characterization and suitability restoration modeling study and implement recommendations to enhance seawalls with Living Shorelines or focus restoration efforts in specific areas of the Lagoon determined most beneficial	2021-2024	$
Step 2 Continue to pursue beneficial reuse of lagoon compatible dregde material to expand or create new restoration sites	2021-2031	$$$-$$$$
Step 3 Develop criteria to determine long-term restoration success and expand post-construction monitoring	2022-2025	$
Step 4 Increase awareness of the value of coastal habitats, the economic contribution of ecosystem services provided by the Lagoon and the importance of community investment in habitat restoration and protection	2021-2031	$
HE-3 MAINTAIN AND EXPAND SEAGRASS HABITATS	**TIMELINE**	**ESTIMATED COST**
Step 1 Continue annual seagrass transect monitoring and Lagoon-wide mapping every 5 years	2021-2031	$-$$
Step 2 Expand water quality monitoring for additional environmental parameters affecting seagrass to better understand factors impacting seagrasses in the lagoon	2022-2031	$$-$$$
Step 3 Install photoshythetically active radiation (PAR) sensors to understand light requirements for seagrass to flourish at different depths in the Lagoon	2022-2028	$
Step 4 Identify causes of seagrass declines and species shifts in the Lagoon	2022-2028	$$$-$$$$
Step 5 Update seagrass recovery targets for Lagoon segments based on light attenuation, sediment types and other factors	2022-2028	$
Step 6 Pursue acquisition of important seagrass resources in the North Lagoon from willing sellers	2021-2031	$$$$$
HE-4 ACQUIRE ECOLOGICALLY SIGNIFICANT SUBMERGED AND INTERTIDAL LANDS	**TIMELINE**	**ESTIMATED COST**
Step 1 Continue to determine property owners interest in sale or donation of lands, resubmit funding request for Singer Islands submerged lands to Legislature	2021-2031	$-$$$$
Step 2 Work with regulatory agencies to ensure the protection of submerged resources with ecologically valuable submerged and intertidal lands are fully considered when processing permit applications	2021-2031	$

ESTIMATED COSTS KEY:		
	$	$0-$25,000
	$$	$25,000-$100,000
	$$$	$100,000-$500,000
	$$$$	$500,000-$1,000,000
	$$$$$	More than $1,000,000

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FISH AND WILDLIFE MONITORING AND PROTECTION SUMMARY

FW-1 CONTINUE IMPLEMENTING PALM BEACH COUNTY'S MANATEE PROTECTION PLAN	TIMELINE	ESTIMATED COST
Step 1 Continue Implementing the Manatee Protection Plan	2021-2031	$
Step 2 Continue funding the Manatee Law Enforcement Program and add municipalities to program	2021-2031	$$$
Step 3 Continue raising awareness of the importance of the Lagoon to manatees as critical habitat and encourage manatee friendly boating practices	2021-2031	$
Step 4 Continue seagrass and water quality monitoring. Participate in manatee surveys in the Lagoon to better track manatee utilization and distribution in the Lagoon	2021-2031	$$$
Step 5 Identify opportunities to create or enhance habitat for manatees	2021-2031	$-$$$$$
FW-2 CONTINUE SEA TURTLE MONITORING	**TIMELINE**	**ESTIMATED COST**
Step 1 Continue annual sea turtle monitoring	2021-2031	$$
Step 2 Design and implement seagrass surveys to determine and track correlations between sea turtle dietary shifts and changes in seagrass species and cover	2021-2031	$$
Step 3 Continue collecting water quality data and expand parameters to evaluate constituents that may be associated with fibropapillomatosis (FP)	2021-2031	$-$$
Step 4 Initiate an acoustic telemetry program to tag and track the movements of individual turtles throughout the Lagoon to direct potential management actions	2022-2031	$-$$
Step 5 Expand the turtle health assessment program, including blood samples and chemical analysis, to evaluate the overall health of turtles in the Lagoon	2022-2031	$-$$
Step 6 Continue educational initiatives to promote awareness of the Lagoon's importance to sea turtles	2022-2031	$
FW-3 CONTINUE FISHERIES MONITORING	**TIMELINE**	**ESTIMATED COST**
Step 1 Continue fisheries sampling in the North and Central Lagoon	2021-2031	$$
Step 2 Expand sampling, employing statewide Fisheries-Independent Monitoring protocols, to the South Lagoon	2021-2031	$$$
Step 3 Update the species list for fish and selected invertebrates documented in the Lagoon	2021-2031	$
Step 4 Expand acoustic tagging of fish and install an acoustic telemetry network in the Lagoon	2022-2031	$
Step 5 Continue the Lake Worth Lagoon Fishing Challenge	2021-2031	$
FW-4 MANAGE AND MONITOR SHOREBIRD HABITAT	**TIMELINE**	**ESTIMATED COST**
Step 1 Continue to provide and manage nesting and foraging habitat for shorebirds in the Lagoon	2021-2031	$-$$$$$
Step 2 Actively manage island habitats to ensure shorebird success	2021-2031	$
Step 3 Continue to monitor shorebird utilization of the Lagoon	2021-2031	$
Step 4 Evaluate and identify important, publicly accessible bird "hot spots" for nomination to the Great Florida Birding Trail	2021-2031	$
Step 5 Continue banding American Oystercatcher chicks and adults to track habitat utilization and fledgling success and add species to banding program	2021-2031	$
FW-5 IMPLEMENT REMOTE TRACKING TECHNOLOGIES FOR FISH AND WILDLIFE MONITORING	**TIMELINE**	**ESTIMATED COST**
Step 1 Identify a funding source to purchase and maintain equipment within the Lagoon	2021-2031	$-$$
Step 2 Collaborate with interested partners to direct tagging efforts and data analysis to understand species utlilization of Lagoon habitats, and the environmental and biological factors that influence their movements	2021-2031	$-$$

ESTIMATED COSTS KEY:		
	$	$0-$25,000
	$$	$25,000-$100,000
	$$$	$100,000-$500,000
	$$$$	$500,000-$1,000,000
	$$$$$	More than $1,000,000

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CLIMATE CHANGE AND SEA LEVEL RISE SUMMARY

CC-1 CONDUCT A VULNERABILITY ASSESSMENT OF RESOURCES AT RISK FROM CLIMATE CHANGE	TIMELINE	ESTIMATED COST
Step 1 Complete Climate Change Vulnerability Assessment and encourage incorporation of resilience adaptations into comprehensive plans for other municipalities in the watershed	2021-2022	$
Step 2 Identify current and potential flooding impacts to low-lying communities throught the watershed	2021-2031	$$
Step 3 Education on far-ranging impacts of climate change for individual and collective action to adapt or mitigate effects	2021-2031	$
STEP 4 Consider managed retereat from chronically impacted areas where use is not sustainable or there are threats to public safety	2028-2031	$$$$$
CC-2 IMPROVE RESILIENCY OF CRITICAL HABITATS TO CLIMATE CHANGE AND SEA LEVEL RISE	**TIMELINE**	**ESTIMATED COST**
Step 1 Measure sea level rise in the Lagoon's watershed to identify and prioritize habitats at greatest risk	2021-2024	$
Step 2 Support implementation of one or more demonstration projects with examples of living shorelines	2021-2031	$
Step 3 Conduct analysis and monitoring of current and future living shoreline projects to quantify costs and benefits versus traditional seawalls	2021-2024	$-$$
Step 4 Promote workshops for Living Shoreline design and installation, to boost the number of qualified consultants and contractors that can design, permit and install living shorelines	2021-2024	$
Step 5 Tax incentives or mitigation credits for Living Shorelines	2021-2024	$
Step 6 Continue education about Living Shorelines and climate friendly landscapes	2021-2031	$

ESTIMATED COSTS KEY:		
	$	$0-$25,000
	$$	$25,000-$100,000
	$$$	$100,000-$500,000
	$$$$	$500,000-$1,000,000
	$$$$$	More than $1,000,000

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PUBLIC OUTREACH AND ENGAGEMENT SUMMARY

PO-1 FOSTER PUBLIC AWARENESS AND ENGAGEMENT	TIMELINE	ESTIMATED COST
Step 1 Increase muticultural outreach and education to underserved communities	2022-2031	$
Step 2 Expand availability of educational messaging and materials in Spanish, Creole or other languages as appropriate to target key audiences in the Lagoon watershed	2021-2031	$-$$
Step 3 Enhance use of social media campaigns to deliver targeted and consistent educational messages that promote direct behavior changes to benefit the Lagoon	2022-2031	$
Step 4 Enlist assistance from Lagoon-dependent businesses, recreational groups and community service organizations to disseminate educational messages and materials	2022-2031	$
Step 5 Increase opportunities for residents of all ages and abilities to participate in hands-on volunteer projects and citizen-science initiatives	2021-2031	$
PO-2 PROMOTE YOUTH EDUCATION AND ENGAGEMENT	**TIMELINE**	**ESTIMATED COST**
Step 1 Expand science-based K-12 education for youth in Palm Beach County, especially for underserved communities	2021-2031	$
Step 2 Continue hands-on opportunities to learn and contribute to Lagoon improvement through Adventure Awaits and Tri-City Trailblazers programs	2021-2031	$
Step 3 Continue to model and promote career opportunities in STEM fields through the Green Futures Interships	2021-2031	$
Step 4 Encourage other organizations offering youth education programs to utilize the strategies and steps presented in the Action to leverage and strengthen our collective impact	2021-2031	$
Step 5 Maximize distribution of the “Hidden Wild” documentary film through environmental education centers, community groups, private schools, home-school groups and online streaming on multiple platforms	2021-2031	$$

ESTIMATED COSTS KEY:		
	$	$0-$25,000
	$$	$25,000-$100,000
	$$$	$100,000-$500,000
	$$$$	$500,000-$1,000,000
	$$$$$	More than $1,000,000

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PUBLIC USES OF THE LAGOON SUMMARY

PU-1 ENSURE ADEQUATE AND APPROPRIATE ACCESS TO THE LAGOON	TIMELINE	ESTIMATED COST
Step 1 Continue to provide opportunities for residents and tourists to experience the LWL	2021-2031	$-$$$$$
Step 2 Continue to support partnerships to remove marine debris and derelict vessels from LWL waters	2021-2031	$-$$$
Step 3 Encourage all marinas, boatyards and retail facilities in the Lagoon to achieve designation through FDEP's Clean Boating program	2022-2031	$
Step 4 Actively participate in development of criteria for siting and design of mooring fields to minimize risks to critical habitats	2021-2031	$
Step 5 Implement a certification program for ecotour businesses to foster community commitment to ethical enjoyment of the Lagoon	2022-2031	$-$$

ESTIMATED COSTS KEY:		
	$	$0-$25,000
	$$	$25,000-$100,000
	$$$	$100,000-$500,000
	$$$$	$500,000-$1,000,000
	$$$$$	More than $1,000,000

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COMPLETED PROJECTS

BRYANT PARK ISLANDS (2014 AND 2018)

More than 5 acres of habitat created including seagrass, oysters and three intertidal islands planted with mangroves and cordgrass. Limestone rocks placed along the eastern and southern shorelines serve as breakwaters to stabilize the island and provide oyster habitat. Birds nest and forage in the restored area. Modifications in 2018 added more limestone rock and shell for shoreline protection and nesting bird habitat.

GRASSY FLATS NATURAL AREA (2015 AND 2018)

Thirteen acres of muck sediments were capped with sand creating two intertidal islands. Limestone rock was placed along the western edge of the islands for stabilization and to provide oyster reef habitat. Created wetland habitat includes salt marsh, mangrove vegetation, and tidal flats used as food and nursery habitat for fish and wildlife. This project provides additional recreational opportunities, including fishing, birding and kayaking.

Enhancements in 2018 added more than 750 tons of shell hash and smaller rock for increased oyster reef habitat on the eastern edges and foraging areas for American Oystercatchers on both intertidal islands.

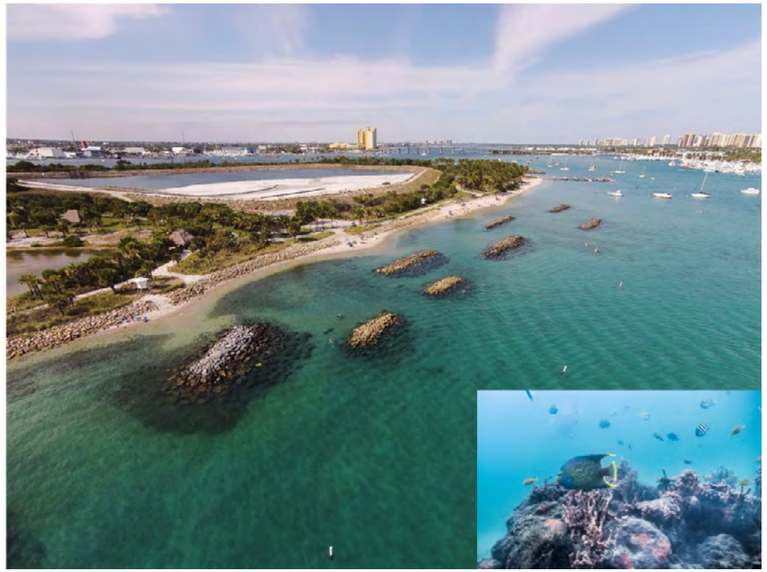
BRYANT PARK LIVING SHORELINES PHASE I AND II (2015 AND 2017)

In Phase I a 575-foot long Living Shoreline planter designed and sculpted by a local artist was installed as a unique integration of art and ecology. Sculptural elements offered openings for fish to swim in and out of the structure at high tide, while supporting mangroves and cordgrass. The outside shelf/ledges also provide oyster reef habitat.

For Phase II, more than 1,160 linear feet of living shoreline was created along the barren seawall at Bryant Park in the City of Lake Worth Beach, including four wetland planters made of limestone rock. Together, the planters buffer wave action and storm surge along the seawall and provide valuable habitat for oysters, fish and other wildlife.

PEANUT ISLAND EROSION CONTROL AND REEF COMPLEX PROJECTS (2015 AND 2016)

Multiple reef breakwaters were installed to reduce wave energy and provide shoreline protection on the southeastern shoreline of Peanut Island. These emergent artificial reef structures provide valuable habitat for numerous fish and invertebrate species, making it a premier snorkeling location within the Lake Worth Lagoon.

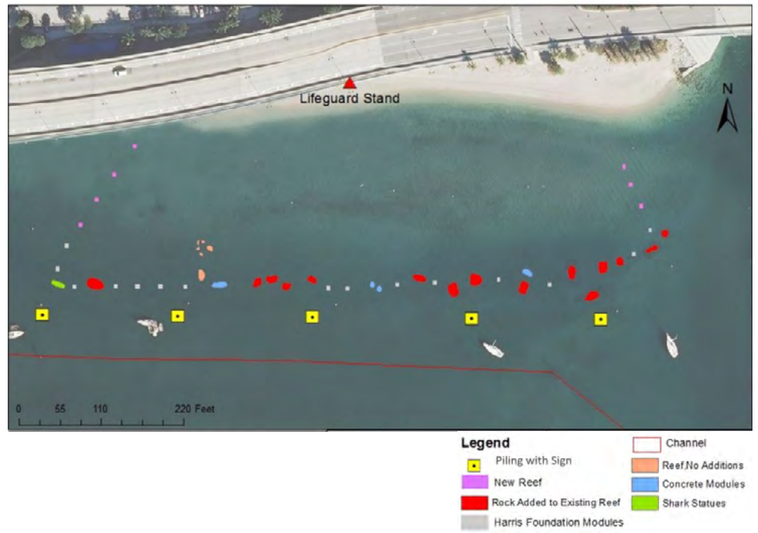


JEWELL COVE LIVING SHORELINE (2016)

This project restored 11.4 acres of natural shoreline along the Lake Worth Lagoon by removing invasive vegetation and planting native maritime hammock species such as Royal palms, Gumbo Limbo trees, coontie, and coral bean along 1,100 linear feet of upland. Additionally, 700 feet of limestone rip rap helps stabilize the shoreline and provide mangrove, cordgrass and oyster reef habitat. The project provides recreational and environmental education opportunities for visitors, local students and residents.

PHIL FOSTER SNORKEL TRAIL (2017)

An 800-foot-long snorkel trail was created on the south side of Phil Foster Park in Lake Worth Lagoon. This location is bathed in clear oceanic water with each incoming tide due to its proximity to Lake Worth Inlet. The underwater trail includes concrete modules, boulder mounds and shark sculptures, as well as smaller rocks that serve as markers to guide snorkelers between the larger features. The trail is located in 6 to 10 feet of water and accessible from the beach at Phil Foster Park. The reef components include ledges and small spaces that attract a variety of sea life.



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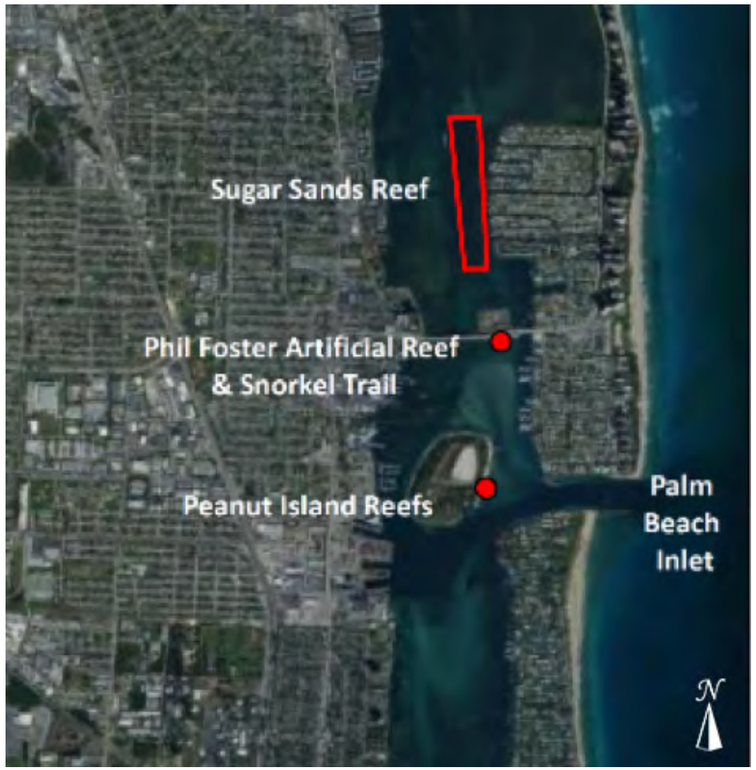
SUGAR SANDS REEF (2017)

This artificial reef complex is located in a deep dredged hole spanning 7.5 acres north of the Blue Heron Bridge and east of the Intracoastal Waterway. The site features pyramid modules, limestone boulders, and reused concrete which provide habitat complexity and support a diverse fish assemblage. More than six placements of reef material have occurred since 1991.



CURRIE AND OSPREY PARKS LIVING SHORELINES (2017)

Together, these two projects created more than 1,400 feet of Living Shoreline along a barren seawall at Currie Park and another 130 feet at Osprey Park. Seven wetland planters were built at Currie and one at Osprey Park. These were planted with mangroves and cordgrasses to increase nursery areas and habitat for fish and other wildlife. The limestone planters also provide shoreline protection.

Currie Park

Osprey Park

OLD BRIDGE PARK RESTORATION (2017)

This project replaced the failing seawall along Old Bridge Park. A new seawall stabilizes the shoreline, and rip rap placed waterward of the seawall reduces wave energy and creates habitat for benthic organisms, invertebrates and fish. A new sidewalk, fishing pier and floating dock significantly enhance access for recreational anglers.

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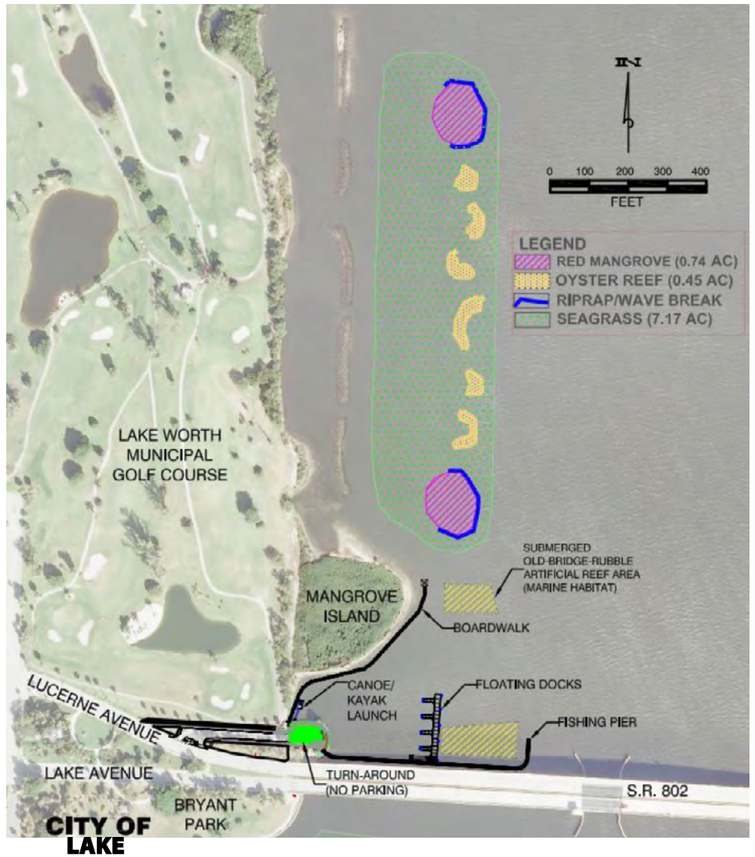
LYMAN KAYAK PARK LIVING SHORELINE (2018)

Two wetland planters were constructed using limestone rock, creating 148 linear feet of Living Shoreline and providing oyster habitat. Red mangroves and cordgrass placed behind the planters provide nursery and foraging areas for fish and birds while stabilizing the shoreline. This park also has a kayak ramp that allows direct access to the Lagoon.

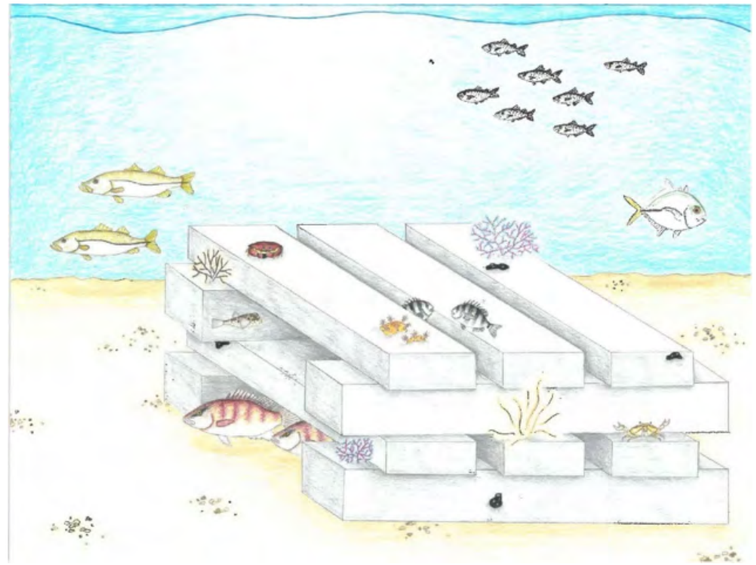
SNOOK ISLANDS PHASE II MODIFICATIONS (2018)

More than 7 acres of additional wetland habitat was added to the 100 acres successfully restored since 2005. New islands were planted with mangrove and cordgrass, along with oyster reefs and submerged habitat for seagrass recruitment. The restoration resulted in increased nursery and foraging grounds for birds, fish, and manatees. Snook Islands is a popular fishing and kayaking destination in the Central Lake Worth Lagoon.



SOUTHERN BOULEVARD BRIDGE REEF (2018)

This 1.7-acre reef is composed of 6,000 tons of reused concrete from the Southern Boulevard Bridge replacement, and placed by hardhat divers in an old dredge hole just to the south of the bridge. The dredge hole ranged in depth from 14-30 feet. Material was stacked to create ledges in discrete pods. After the new bridge is constructed, the site will receive additional material from the dismantling of the temporary bridge.



Southern Boulevard bridge reef: A depiction of the material stacked on the bottom, creating ledges and additional fish habitat.

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LAKE WORTH LAGOON MANGROVE PODS (2020)

These mangrove pods were installed waterward of Jewell Cove Natural Area as a pilot project to demonstrate the construction of low-profile wetland habitat for additional oyster and mangrove habitat in the Lake Worth Lagoon. The project involves planting mangroves in discretely placed limestone rock mounds to provide additional oyster and mangrove habitat, testing the feasibility of this cost-effective technique versus traditional methods (intertidal island creation, mangrove planters, etc.). Benefits include water quality improvements, improved fishing and wildlife-watching opportunities, increased shoreline protection, and increased carbon storage to mitigate the effects of climate change. The mangrove pods serve as a model for waterfront homeowners seeking eco-friendly options for enhancing habitat and climate resiliency of armored shorelines.

Pilot mangrove pod at Jewell Cove Natural Area (Photo credit: PBC-ERM)

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ONGOING PROJECTS

ONGOING AND POTENTIAL PROJECTS

TARPON COVE PHASE I (2019) AND PHASE II

When completed, Tarpon Cove will provide 46 acres of tidal and intertidal habitats in the Central Lagoon. The enhancements include 5 intertidal islands with 2.7 acres of mangrove and tidal marsh, 2.1 acres of oyster reef habitat, 34 acres of potential seagrass habitat and 0.3 acres of shorebird nesting habitat. Multiple partners are working together to reuse beneficial sand sources from the Rybovich Marina expansion, the Town of Palm Beach maintenance dredging, FIND's dredging of the Intracoastal Waterway and additional waterway improvement projects within the Lagoon. Approximately 418,600 cubic yards of sand and 24,000 tons of rock are needed to complete the project.

During Phase I, two islands were created by capping organic-rich muck sediments in a historic dredge hole. In Phase II, three more islands will be created and rock breakwaters installed for additional habitat and protection against waves and storm surge.

Tarpon Cove (Photo credit: Lake Worth Waterkeeper)

Tarpon Cove under construction (Photo credit: PBC-ERM)

MONCEAUX PARK LIVING SHORELINES

This project will create 200 linear feet of Living Shoreline along the barren seawall at Monceaux Park in the City of West Palm Beach. Work includes construction of three wetland planters using limestone rock to provide shoreline protection and habitat for fish and wildlife.

LAKE WORTH INLET FLOOD SHOAL DREDGING PROJECT

Local Sponsors: Palm Beach County/Marine Industries Association

The flood shoal north of Peanut Island continues to accrete sand, creating both environmental and navigational concerns. The project will dredge a portion of the flood shoal to reduce sedimentation at Phil Foster Park Snorkel Trail, increase areas for recreational boat use, and improve navigation and safety by providing easier access for first responders.

BONEFISH COVE

Local Sponsors: Palm Beach County/U.S. Army Corps of Engineers Section 1135 Project

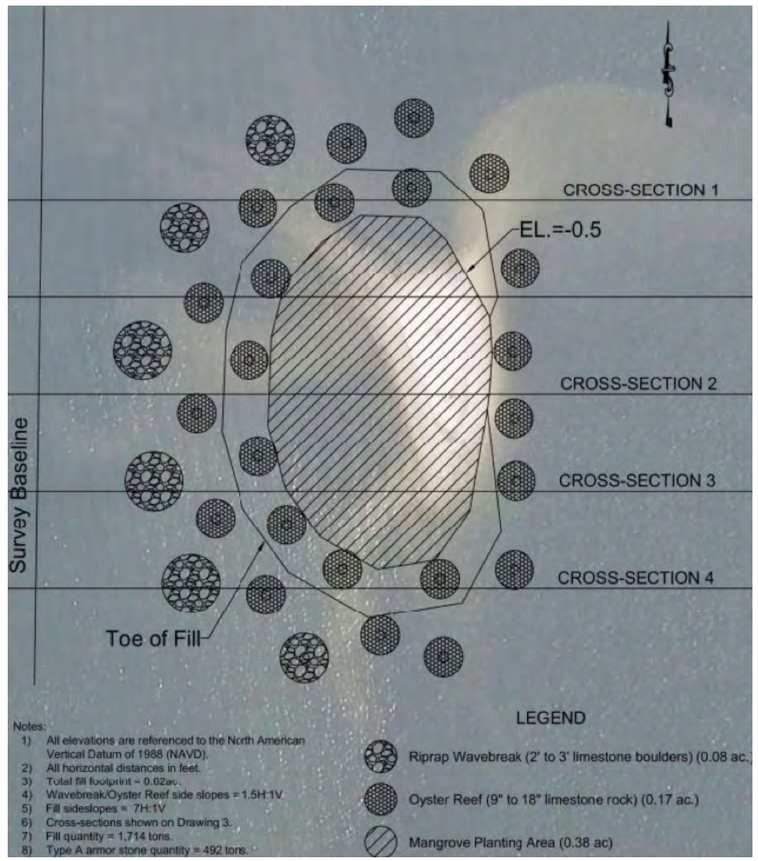
This project encompasses 48 acres in the Central Lagoon along the Town of Palm Beach. It will create 3 intertidal mangrove islands with a footprint of 9.4 acres, 1.5 acres oyster reefs, 33 acres of potential seagrass habitat and 3 nesting mounds for American Oystercatchers. Beneficial reuse of sand includes 345,000 cubic yards of fill to be transported from Peanut Island for construction. Construction is expected to begin mid to late 2021.

Bonefish Cove will provide additional intertidal and tidal habitat for numerous species of birds, fish and invertebrates in an area that has otherwise been lost to shoreline hardening. The islands will also provide recreational opportunities such as kayaking, boating, fishing and bird watching.

PALM BEACH RESILIENT ISLANDS

Local Sponsors: Palm Beach County/The Nature Conservancy

Located in the Central Lagoon, the first phase of this project will create an 0.8-acre oyster reef and mangrove intertidal island surrounded by limestone rocks to act as a wavebreak. This project will serve as a valuable education and stewardship site for the public to experience first-hand the benefits of Living Shoreline restoration projects, while providing important habitat to support fish and wildlife in the Lagoon.



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PROVIDENCIA CAY RESTORATION

This project in West Palm Beach will create an intertidal island, oyster reef and seagrass habitat, restoring a total of 6 acres in a historic dredge hole area. Enhancements will support recreational activities and improved water quality and habitat for fisheries, birds, oyster, manatees, and sea turtles. The island will provide an "Ecotourism Destination" to view and visit estuarine habitats.

LAKE WORTH LAGOON FUTURE PROJECT PLANNING

LOCATION	CATEGORY	NAME	DESCRIPTION	ACTION PLAN
Lake Worth Lagoon	Living Shoreline	LWL Living Shorelines	Location TBD- living shorelines incorporating oysters, cordgrass, mangroves and other living shoreline components	HE-1, HE-2, CC-2
Lake Worth Lagoon	Artificial Reefs	LWL Artificial Reefs	Location TBD- artificial reef projects to add habitat for fisheries, invertebrates, etc.	HE-1, HE-2, FW-3
Lake Worth Lagoon	Mangroves	LWL Mangrove Pods	Location TBD- Mangrove pods (rocks placed at intertidal elevations planted with red mangroves) to add habitat for birds, fish and invertebrates	HE-2
Lake Worth Lagoon	Islands	LWL Island Restoration	Location TBD- Intertidal islands created with lagoon compatible sand and rock breakwaters; incorporating oyster, seagrass, mangrove, cordgrass and bird habitat, as well as other living shoreline components	SE-1, HE-1, HE-2, HE-3, FW-1, FW-3, FW-4, CC-2, PO-1, PU-1
North Lagoon	Submerged Land Purchase	Singer Islands Submerged Land Acquisition	Purchase submerged lands from willing sellers for seagrass conservation	HE-4, HE-3, FW-1, FW-2 and FW-3
North Lagoon	Navigation/ Safety/Beneficial Reuse Material	Lake Worth Inlet Flood Shoal	Dredge the Lake Worth Inlet flood shoal to improve boater safety/navigation. Beneficial reuse of material for intertidal island creation and/or capping muck sediments	SE-1, PU-1
North Lagoon	Living Shoreline	Palm Beach Country Club Living Shoreline	Living shoreline improvements	HE-1, HE-2, CC-2
North Lagoon	Breakwater/Island/ Living Shoreline	Providencia Cay Restoration	Place sand/rock for intertidal island- mangroves and wetland vegetation	HE-1, HE-2, HE-3, FW-1, CC-2
North Lagoon	Living Shoreline	Kelsey Park Living Shoreline	Living shoreline improvements	HE-1, HE-2, CC-2
North Lagoon	Living Shoreline	Lake Park Marina Living Shoreline	Living shoreline improvements	HE-1, HE-2, CC-2
North Lagoon	Artificial Reef	Sugar Sands Reef	Rock substrate added for reef	HE-1, PU-1, CC-2
Central Lagoon	Ongoing/Dredged Hole/Island/ Living Shoreline/ Breakwater	Tarpon Cove Restoration	Islands, seagrass, oyster, breakwaters and bird habitat	HE-1, HE-2, HE-3, FW-1,FW-3, FW-4, CC-2, PO-1

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A sea robin glides across the Lagoon (Photo credit: PBC-ERM)

LAKE WORTH LAGOON FUTURE PROJECT PLANNING *(Continued)*

LOCATION	CATEGORY	NAME	DESCRIPTION	ACTION PLAN
Central Lagoon	Islands and Living Shoreline	Bird Islands and Oyster Habitat Restoration From Everglades to John's Islands	Mangrove/Oyster Habitat Restoration; Place sand, oyster and mangrove pods between Everglades and John's Islands	HE-1, HE-2, HE-3, FW-4, CC-2, PO-1, PU-1
Central Lagoon	Artificial Reef	Everglades Reef	Rock substrate added for reef/fish habitat	HE-1, FW-3, CC-2
Central Lagoon	Living Shoreline	Monceaux Park Living Shoreline	Living shoreline improvements	HE-1, HE-2, CC-2
Central Lagoon	Island Restoration/ Living Shoreline	Palm Beach Resilient Islands	Add mangrove island with breakwater, oyster reefs and bird nesting habitat	HE-1, HE-2, FW-4, CC-2, PO-1
Central Lagoon	Seagrass Habitat	Currie Park Dredge Hole EAST	Add sand to dredge hole and bring to -5 MHW elevation and encourage natural recruitment of seagrass	HE-2, HE-3
Central Lagoon	Manage Sediment	C-51 Sediment Trap Dredging	Dredge existing sediment trap to reduce sediments entering the Lagoon and negatively impacting water quality and resources such as oysters and seagrasses	SE-1, WQ-1, WQ-3
Central Lagoon	Artificial Reef	Southern Blvd Bridge Artificial Reef	Create fish and invertebrate habitat using demolition materials from Southern Blvd Bridge	HE-1, FW-3, CC-2
Central to South Lagoon	Islands and Rock	Bird Islands and Oysters from Ibis Isle to Bonefish Cove	Add rock, sand & mangroves along rock spine to enhance/build upon existing islands and oyster habitat	HE-1, HE-2, FW-4, CC-2, PO-1
South Lagoon	Dredged Hole/ Islands/ Living Shoreline/ Breakwater	Bonefish Cove	Fill dredge hole offshore to improve seagrass habitat; add mangrove island with rock breakwater, oyster reefs and bird nesting habitat	HE-1, HE-2, HE-3, FW-1,FW-3, FW-4, CC-2, PO-1, PU-1
South Lagoon	Living Shoreline	Intracoastal Park Living Shoreline	Removal of upland exotic plants and addition of living shoreline improvements	HE-2, CC-2, PO-1

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