OFFICE OF RESILIENCE AND COASTAL PROTECTION

Florida Coastal Water Quality Assessment and Integration Report

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Matlacha Pass Aquatic Preserve

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Florida Coastal Management Program

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

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And most importantly, we would like to thank the aquatic preserves staff. Without all of you, this project would not have been possible. Managing a continuous water quality program is not easy, and all your hard work and dedication to collecting the best data possible really showed. We are so immensely grateful for all you do.

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Great blue heron (Ardea herodias) perched in Charlotte Harbor Aquatic Preserve.

Executive Summary

The Florida Department of Environmental Protection's (DEP) Office of Resilience and Coastal Protection (RCP) was awarded a grant from the National Oceanic and Atmospheric Administration (NOAA) for the Florida Coastal Water Quality Assessment and Integration Project (project). The goal of the project was to assess estuarine water quality data collected at 28 stations by eight aquatic preserves (AP) offices in Florida and to provide the data in a format that facilitates the identification of ecosystem indicators supporting the Section 309 strategy, Statewide Ecosystem Assessment program of Florida's Coastal Aquatic Managed Areas, known as the Statewide Ecosystem Assessment of Coastal and Aquatic Resources (SEACAR) project.

The project developed a statewide data collection and dissemination framework for the aquatic preserve system, making it consistent with the nationwide National Estuarine Research Reserves System (NERRS) System-Wide Monitoring Program (SWMP).

The purpose of this report is to provide an overview of the Project and to analyze trends in water temperature, salinity, dissolved oxygen concentration (DO), pH, and turbidity data at 28 fixed continuous water quality monitoring stations at eight AP offices: Northwest Florida, Central Panhandle, Big Bend Seagrasses, Tampa Bay, Charlotte Harbor, Estero Bay, Northeast Florida and Indian River Lagoon.

Near continuous (15-minute) water quality data was collected at these sites since 2003. Over 4.25 million data records went through the NERRS Centralized Data Management Office (CDMO) quality evaluation and were hosted through a publicly available data portal. Data analyzed in this report depict summaries and long-term trends for estuarine water quality.

Water temperature and salinity were the most commonly measured parameters (28 stations) followed by pH and turbidity (26 stations) and dissolved oxygen (25 stations). Charlotte Harbor AP had the greatest number of individual data values (4,871,951) used for the analysis and Tampa Bay AP had the least number (115,288). Approximately 34% of possible tests for long-term trends were statistically significant ($p<0.05$).

Long-term trends were observed in all five water quality parameters. The parameter with least number of stations (three) that exhibited statistically significant long-term trends was water temperature, while salinity had the greatest number of stations (16) that exhibited a long-term trend.

Eleven stations exhibited decreasing trends in salinity and five stations exhibited statistically significant increasing trends. Five stations exhibited long-term trends in DO concentrations. Two stations exhibited statistically significant increasing trends in DO concentrations while three stations exhibited decreasing trends. Nine stations exhibited statically significant long-term trends ($p<0.05$) in pH. Six stations indicated decreasing trends in pH, while three stations showed increasing trends. Six stations exhibited statistically significant long-term trends ($p<0.05$) in turbidity data. Two stations indicated decreasing trends while four stations showed increasing trends in turbidity.

The findings in this report are based solely on the continuous water quality data collected by the AP system. Data underwent rigorous Quality Assurance/Quality Control (QA/QC) reviews: Metadata files were reviewed and standardized; training modules were developed; and AP staff attended the 18th annual SWMP technician training workshop hosted by the CDMO to learn SWMP protocols.

AP water quality data are downloadable in a format that is compatible with the 15 Florida NERRS water quality stations, as well as the stations managed by 29 NERRS nationwide, and can be integrated into important national and regional initiatives such as the Integrated Ocean Observing System (IOOS) and the Southeast Coastal Ocean Observing Regional Association (SECOORA). The AP data, metadata and training modules are available to the public through an online data portal, which is a valuable tool that can inform

plans and efforts to restore and maintain the services provided by coastal ecosystems on a regional and statewide scale.

The continuous water quality data collected by the Florida APs and NERRS will be seamlessly combined and incorporated into the SEACAR data discovery portal to assess the status and trends of coastal habitats, to support state and local programs, and to provide a research-based understanding of the health of Florida's estuarine habitats. Florida AP data is available for download at www.FloridaAPData.org, and the Florida NERRS data is available at www.NERRSdata.org.

Introduction

Florida's coast is host to a variety of habitats including seagrass beds, salt marshes, oyster reefs, mangroves, coral reefs, beaches and open ocean. These valuable habitats support a variety of commercial and recreational species of fish and invertebrates and serve as foraging and nesting habitats for shorebirds, migratory birds, and threatened and endangered species.

These rich biodiverse habitats attract both tourists and residents for recreation. As the public use demand increases in these areas, there is a greater need for monitoring the conditions and resiliency of these habitats. Recognizing this need, RCP manages sites in Florida for the conservation and protection of natural and historical resources and helps guide a resource-based public use that is compatible with the conservation and protection of critical habitats.

Overall, RCP manages more than 4.9 million acres of submerged and coastal upland habitats and oversees a variety of programs including 41 aquatic preserves; three national estuarine research reserves; Florida Coastal Management Program; Clean Boating Program; Clean Vessel Act Grant Program; Florida Resilient Coastlines Program; Florida Coral Reef Conservation Program; Florida Keys National Marine Sanctuary; Statewide Ecosystem Assessment of Coastal and Aquatic Resources Program; Florida Coastal Access Guide; Beach Field Services Program; Beach Management Funding Assistance Program; Beaches, Inlets and Ports Program; Coastal Construction Control Line Program; and the Coastal Engineering and Geology Group. RCP also reviews activities on the Outer Continental Shelf for federal consistency.

RCP is a strong supporter of the nationwide National Estuarine Research Reserve System, a network of 29 sites in 23 states and one U.S. territory designated to protect and study estuarine systems, and their approach to coastal ecosystem management. In Florida, RCP manages the three NERRS in partnership with NOAA. Each NERR encompasses at least one aquatic preserve within its boundaries. Rookery Bay NERR includes Rookery Bay Aquatic Preserve and Cape Romano - Ten Thousand Islands Aquatic Preserve; Apalachicola NERR includes Apalachicola Bay Aquatic Preserve; and Guana Tolomato Matanzas NERR includes Guana River Marsh Aquatic Preserve and Pellicer Creek Aquatic Preserve. Florida's aquatic preserves provide discrete areas designated for additional protection beyond that of the surrounding NERR and may afford a foundation for additional protective zoning in the future.

Florida's 41 aquatic preserves encompass roughly 2.2 million acres and offer a window into the state's natural and cultural heritage. In 1975, Florida enacted the Aquatic Preserve Act to ensure the continuation of aquatic preserve's natural conditions, so "their aesthetic, biological and scientific values may endure for the enjoyment of future generations" (Florida Aquatic Preserve Act of 1975, §258.36, F.S.).

Florida's natural beauty always has been an attraction for both tourists and residents, and as demand on Florida's coastal resources increases, the need for collecting long-term water quality data also increases. Understanding this importance, eight AP offices were supplied with water quality instruments (hereafter, data sondes) in late 2003 and throughout 2004 with the goal of improving the availability of long-term continuous estuarine water quality data. These data sondes were the same instruments used by the NERRS SWMP, so that the data collected across multiple sites were comparable statewide. The project contributed to meeting

the objectives of the State Ecosystem Assessment Program by ensuring the aquatic preserves' continuous water quality data underwent consistent quality assurance checks and were available in a format like that of the SWMP.

The goal of this report is to provide a summary of the continuous water quality data collected at eight AP offices: Northwest Florida, Central Panhandle, Big Bend Seagrasses, Tampa Bay, Charlotte Harbor, Estero Bay, Northeast Florida, and Indian River Lagoon for the Florida Coastal Water Quality Assessment and Integration Project. Since many of the AP stations have more than 10 years of continuous monitoring data, state-wide long-term trend assessments in water quality can provide a research-based understanding of the health of Florida's estuarine habitats and can lead to more informed management decisions.

Northwest Florida Aquatic Preserves

The Northwest Florida Aquatic Preserves are in the western Florida Panhandle and include three aquatic preserves: Fort Pickens, Rocky Bayou and Yellow River Marsh.

Figure 1. Continuous water quality station managed by Northwest Florida Aquatic Preserves.

These aquatic preserves are host to forest wetlands, salt and freshwater marshes, submerged grasses, oyster reefs and open water. These communities are important to commercial and recreational fishermen. Snapper, mullet, sheepshead, flounder, blue crabs, shrimp and redfish all live a portion of their lives within the shallow areas of the aquatic preserves.

Additionally, Rocky Bayou State Park Aquatic Preserve is recognized as an exceptional water resource of the state and supports a large variety of fish and shellfish, including the federally endangered Okaloosa darter.

In an effort to gain a better understanding of the water quality conditions within Yellow River Marsh Aquatic Preserve, a long-term continuous water quality program was established in 2015 (Figure 1). Collecting long-term water quality data within the watershed helps inform decision-making for improving the degraded water quality in the Pensacola Bay Watershed (PBW). YSI 6600 EDS data sondes were deployed at one monitoring station, YRMAP1, from 2015 to 2017, using methods outlined in the YSI Operating and Service Manual and the NERRS SWMP YSI 6-Series Multi-parameter Water Quality Monitoring Procedure SOP. Data was collected in 15-minute intervals and instruments were exchanged every three to four weeks.

Central Panhandle Aquatic Preserves

The Central Panhandle Aquatic Preserves are located along the northeastern coast of the Gulf of Mexico and include three aquatic preserves: Alligator Harbor Aquatic Preserve, Apalachicola Bay Aquatic Preserve and St. Joseph Bay Aquatic Preserve.

Figure 2. Continuous water quality stations managed by Central Panhandle Aquatic Preserves.

The communities found within these aquatic preserves include seagrass meadows, salt marshes, oyster reefs and beaches and serve as important nursery and foraging grounds for commercial and recreational fish and invertebrates, sea turtles, scallops and birds. Alligator Harbor is also one of the world's largest feeding grounds for the endangered Kemp's Ridley sea turtle.

Recognizing the ecological importance of the area, Central Panhandle Aquatic Preserves began collecting continuous water quality data in 2005 with the goal of collecting baseline water quality data and to study the effects that large storms have on the diverse habitats in the aquatic preserves (Figure 2). YSI 6600 EDS data sondes were deployed at Richardson's Hammock (CPRH) station from 2005 to 2011, Windmark (CPWM) station from 2006 to 2007 in St. Joseph Bay AP, and Alligator Harbor (CPAH) station from 2007 to 2008 in Alligator Harbor AP, using methods outlined in the YSI Operating and Service Manual and the NERRS SWMP YSI 6-Series Multi-parameter Water Quality Monitoring Procedure SOP. Data was collected in 30-minute intervals and were downloaded every two to four weeks.

Big Bend Seagrasses Aquatic Preserves

Big Bend Seagrasses Aquatic Preserves include Big Bend Seagrasses Aquatic Preserve and St. Martins Marsh Aquatic Preserve and are located along the Gulf of Mexico. Big Bend Seagrasses Aquatic Preserve is the largest aquatic preserve in Florida, encompassing over 945,000 acres.

Figure 3. Continuous water quality stations managed by Big Bend Seagrasses Aquatic Preserves. Asterisks (*) denote newly established water quality station.

The communities found within these aquatic preserves include seagrass beds, salt marshes, oyster reefs, hard-bottom sponge and coral communities, Sargassum meadows, spring-fed rivers and open water.

These communities provide essential habitats to a variety of sea and shore birds and support recreational and commercial shellfish industries, including Cedar Key clams, oysters, scallops, pink shrimp and blue crab. Additionally, the area provides an important nursery ground for commercial, recreational and threatened fish species, including the Gulf sturgeon.

Recognizing the importance of the diverse habitats found within these aquatic preserves, staff from Big Bend Seagrasses APs began collecting continuous water quality data in early 2004 with the goal of quantifying the spatial/temporal variability and trends, both seasonally and as a function of tidal forcing of abiotic parameters within the aquatic preserves (Figure 3). YSI 600 OMS data sondes were deployed in St. Martins Marsh AP at three monitoring stations: Crystal River (BBSCR) (2004 to 2015), King's Bay (BBSKB) (2004 to 2006), and Homosassa River (BBSHS) (2004 to 2016) and at two monitoring stations in Big Bend Seagrasses AP, Bennett Creek (BBSBC) (2004 to 2015) and Withlacoochee (BBSWT) (2004 to 2016). YSI 6600 EDS data sondes were deployed in St. Martins Marsh AP at Kings Bay (BBSKB) (2007 to 2016) and Homosassa River (BBSHS) (2016) water quality stations and in Big Bend Seagrasses AP at Dekle Beach (BBSDB) (2007 to 2016), Suwannee River (2009 to 2016) and Seahorse Key (2004 to 2015) water quality stations. Stations were established using methods outlined in the YSI Operating and Service Manual and the NERRS SWMP YSI 6-Series Multi-parameter Water Quality Monitoring Procedure SOP. Data was collected in 30-minute intervals from 2004 to 2009 and 15-minute intervals 2009 to 2016 and were downloaded every two to four weeks.

Tampa Bay Aquatic Preserves

The Tampa Bay Aquatic Preserves office manages four aquatic preserves: Boca Ciega Bay Aquatic Preserve, Pinellas County Aquatic Preserve, Cockroach Bay Aquatic Preserve and Terra Ceia Aquatic Preserve in the St. Petersburg – Tampa area. These aquatic preserves are ecologically important, providing wildlife habitats, protection from storms and land stabilization.

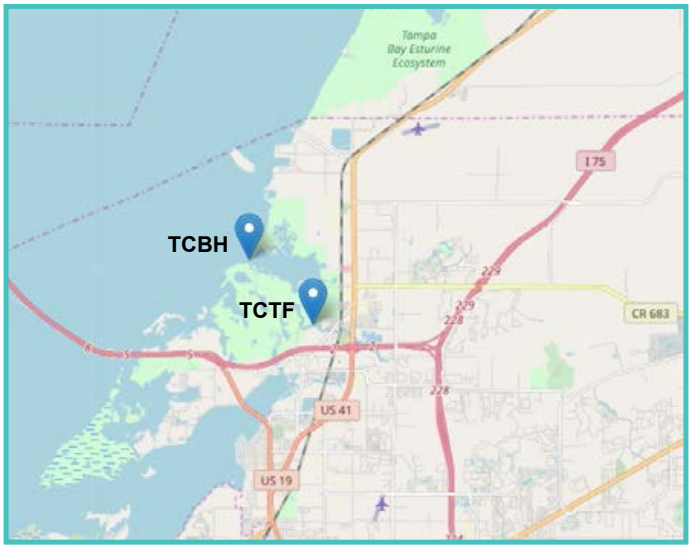


Figure 4. Continuous water quality stations managed by Tampa Bay Aquatic Preserves.

The communities found within these aquatic preserves include mangroves, oyster reefs, seagrass beds, coral communities, spring-fed caves, canals, freshwater lakes, beaches and open water.

The areas support a variety of fishes, invertebrates and shorebirds, and serve as important feeding grounds and nurseries for many listed and commercial and recreational fish species.

Water quality has long been of interest to the Tampa Bay environmental community. Tampa Bay Aquatic Preserves in partnership with the University of South Florida (USF) strategically placed water quality stations in Frog Creek and at the mouth of Bishop Harbor in Terra Ceia Aquatic Preserve to gain insight into the status and trends of water conditions (Figure 4).

YSI 6600 data sondes were deployed at two monitoring stations, Frog Creek (TCFC) and Bishop Harbor (TCBH), from 2008 to 2011; however, data included in this report are only from 2008 to 2009. Instruments were maintained and deployed by USF using methods outlined in the YSI Operating and Service Manual and were exchanged every two to four weeks. Data was collected in 15-minute intervals and radio telemetered.

Charlotte Harbor Aquatic Preserves

The Charlotte Harbor Aquatic Preserves include five aquatic preserves: Lemon Bay Aquatic Preserve, Cape Haze Aquatic Preserve, Gasparilla Sound-Charlotte Harbor Aquatic Preserve, Pine Island Sound Aquatic Preserve and Matlacha Pass Aquatic Preserve.

The Charlotte Harbor Aquatic Preserves protect more than 180,000 acres of mangrove forests and seagrass beds that provide rich habitats for shellfish, crustaceans, fish and birds. Additionally, the mangroves help stabilize substrates and shorelines.

Birds utilize the mangroves as nesting habitat, and fish use the mangrove roots as nursery grounds and protection from predators. Seagrass beds are the most abundant vegetated habitat type within the Charlotte Harbor Aquatic Preserves. This area also serves as an important source for commercial clam aquaculture and crabbing in the local community.

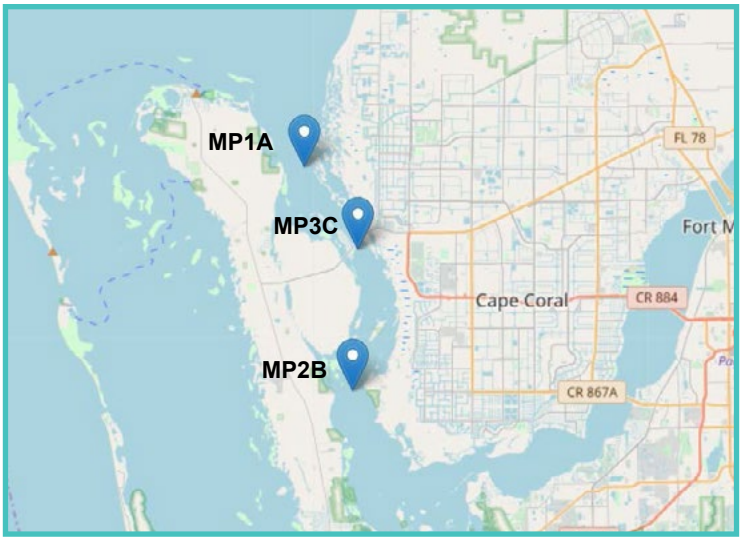


Figure 5. Continuous water quality stations managed by Charlotte Harbor Aquatic Preserves.

In 2005, two long-term continuous water quality stations, Matlacha Pass 1A (MP1A) and Matlacha Pass 2B (MP2B), were established in Matlacha Pass Aquatic Preserve with the goal of monitoring the extent of the tidal node that is between Charlotte Harbor to the north and the Caloosahatchee River and San Carlos Bay to the south (Figure 5). Charlotte Harbor Aquatic Preserves expanded its continuous water quality program in 2009 by adding a third water quality station, Matlacha Pass 3C (MP3C), to collect information on how the tide influences the Caloosahatchee River. Instruments were maintained and deployed using methods outlined in the YSI Operating and Service Manual and were exchanged every two to four weeks. Data was collected in 15-minute intervals.

Estero Bay Aquatic Preserve

The Estero Bay Aquatic Preserve was established in 1966 as Florida's first aquatic preserve and is located in the southwest region of Florida along the Gulf of Mexico.

The dominant community type in Estero Bay is the mangrove forest, but seagrass beds, salt marshes, tidal flats, oyster bars and others are also present.

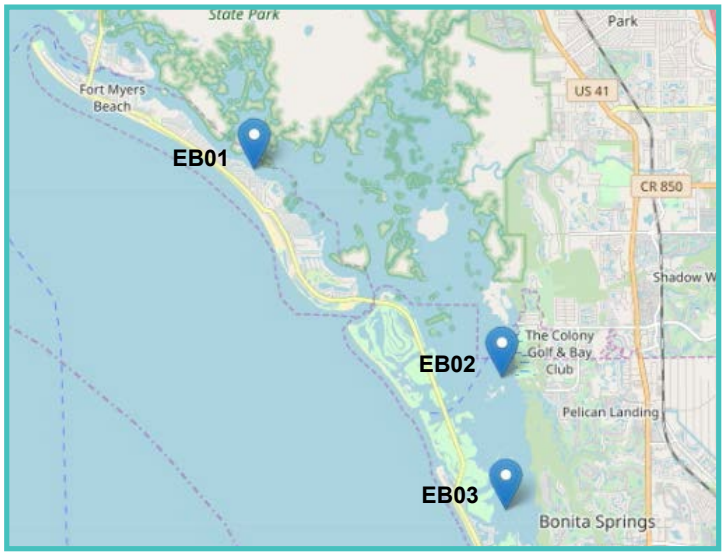


Figure 6. Continuous water quality stations managed by Estero Bay Aquatic Preserve.

Approximately 40 percent of the state's species that are listed as endangered and threatened are found within this area. The estuary supports important nursery grounds for a variety of commercial and recreational fish species, as well as stopover habitat for migratory birds and nesting habitat for wading and diving birds, including imperiled species.

The Estero Bay Aquatic Preserve established a continuous water quality data program in 2004 at three fixed monitoring stations, EB01 (Tom Winter), EB02 (Spring Creek) and EB03 (Fish Trap Bay). The purpose was to collect baseline data to evaluate daily, seasonal and long-term trends in water quality, to assess developmental impacts on the aquatic preserve and to inform management decisions (Figure 6).

YSI 6600 EDS data sondes were deployed at the three stations using methods outlined in the YSI Operating and Service Manual and the NERRS SWMP YSI 6-Series Multi-parameter Water Quality Monitoring Procedure SOP. Data was collected in 15-minute intervals from 2004 to 2016 and was downloaded every two to four weeks.

Northeast Florida Aquatic Preserves

The Northeast Florida Aquatic Preserves in northeast Florida include four aquatic preserves: Fort Clinch Aquatic Preserve, Nassau River-St. Johns Rivers Marshes Aquatic Preserve, Guana River Marsh Aquatic Preserve and Pellicer Creek Aquatic Preserve.

This area consists of numerous interconnecting tidal creeks, rivers, a freshwater-to-brackish water lagoon, a portion of a barrier island, salt marshes, oyster reefs, beaches, open water and uplands.

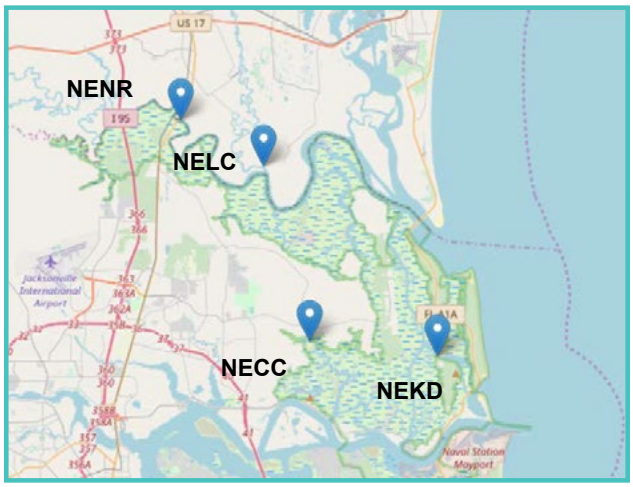


Figure 7. Continuous water quality stations managed by Northeast Florida Aquatic Preserves.

These communities provide habitats to a variety of resident and migratory wildlife and serve as important nursery and foraging grounds for fish, invertebrates, oysters, sea turtles and birds. This area also hosts a sizable breeding population of the endangered woodstork, provides habitat for ground-nesting shorebirds such as the threatened least tern, and provides important breeding and nesting habitats for sea turtles.

Northeast Florida Aquatic Preserves began a continuous water quality program in the Nassau River-St. Johns River Marshes Aquatic Preserve in 2004 with two water quality stations, Clapboard Creek (NECC) and Kingsley Plantation (NEKD), both collecting data from 2004 to 2011 (Figure 7). Northeast Florida Aquatic

Preserves expanded its continuous water quality program to include two additional stations, Lofton Creek (NELC) from 2005 to 2011 and Nassau River (NENR) from 2009 to 2011. YSI 6600 EDS data sondes were deployed at all four monitoring stations using methods outlined in the YSI Operating and Service Manual and the NERRS SWMP YSI 6-Series Multi-Parameter Water Quality Monitoring Procedure SOP. Data was collected in 30-minute intervals and were downloaded every two weeks.

Indian River Lagoon Aquatic Preserves

The Indian River Lagoon Aquatic Preserves office manages seven aquatic preserves stretching over 150 miles and covering 40 percent of the length of Florida's Atlantic Coast. It extends from the Banana River, down to the Jupiter Inlet, the North Fork of the St. Lucie River and the Loxahatchee River-Lake Worth Creek.

Figure 8. Continuous water quality stations managed by Indian River Lagoon Aquatic Preserves.

These aquatic preserves are host to mangrove forests, salt marshes, tidal flats, oyster reefs and seagrass beds. The communities provide important habitats for a variety of recreational and commercial fish species and migratory wildlife, and provides habitat for state- or federally-designated endangered or threatened species.

The Indian River Lagoon Aquatic Preserves established four long-term water quality monitoring stations — C-54 Canal/Fellsmere Canal (IRC54), North Prong (IRNP), Donald McDonald/South Prong (IRDM) and US 1/Main Drainage Basin (IRUS1) — in late 2003 along three prongs of the St. Sebastian River. The goal was to collect data on the St. Sebastian River's drainage basin in order to improve understanding of how watershed inputs are affecting water quality and aquatic resources in the area. The St. Sebastian River is the primary freshwater tributary within the Indian River-Malabar to Vero Beach Aquatic Preserve.

YSI 6600 EDS data sondes were deployed at four monitoring stations: C-54 Canal/Fellsmere Canal (IRC54) (2003 to 2007); North Prong (IRNP) (2003 to 2008); Donald McDonald/South Prong (IRDM) (2003 to 2007); and US 1/Main Drainage Basin (IRUS1) (2003 to 2008), using methods outlined in the YSI Operating and Service Manual and the NERRS SWMP YSI 6-Series Multi-parameter Water Quality Monitoring Procedure SOP. Data was collected in 30-minute intervals and instruments were exchanged every two to four weeks.

Project Overview

The Florida Department of Environmental Protection's Office of Resilience and Coastal Protection received funding from the National Oceanic and Atmospheric Administration Coastal Zone Management Act's (CZMA) Enhancement Program Projects of Special Merit for the Florida Coastal Water Quality Assessment and Integration Project (project). This project of special merit supplements the Section 309 Strategy of the Statewide Ecosystem Assessment program, known as SEACAR, by providing necessary water quality data in a format that facilitates the identification of ecosystem indicators.

By adopting NERRS monitoring protocols and database management techniques, the existing AP water quality stations were seamlessly combined with the NERRS water quality stations for the identification of ecosystem indicators supporting the SEACAR project, thus making the AP data more readily available for resource managers, planners, permitting agencies, educators and scientists to address specific coastal management needs.

The main objectives of the project were to:

1. Assess historical near-continuous water quality data collected at 28 stations by eight AP offices: Northwest Florida, Big Bend Seagrasses, Central Panhandle, Tampa Bay, Charlotte Harbor, Estero Bay, Northeast Florida and Indian River Lagoon (Figure 9)

2. Create an inventory of data from the AP program and perform Quality Assurance/Quality Control procedures on the data as outlined by the NERRS Central Data Management Office

3. Create a database to house the AP water quality data and provide user-friendly, web-based access to the database through the development of a monitoring data portal

4. Develop publicly available water quality data collection and management protocols and training modules

To meet the objectives of this project, RCP collaborated with the NERRS Centralized Data Management Office for the assessment of the continuous water quality program, development of the database, and the development of the instructional protocols, making the statewide data collection and dissemination framework for the aquatic preserves consistent with the NERRS System-Wide Monitoring Program, which began in Florida at the Apalachicola NERR in 1995.

Estero Bay Aquatic Preserve water quality technician inspects a data sonde after deployment while a colleague records notes.

Estero Bay Aquatic Preserve water quality technician prepares to inspect a retrieved data sonde and deploy another instrument.

YSI EXO3 data sonde before its first deployment in Estero Bay Aquatic Preserve.

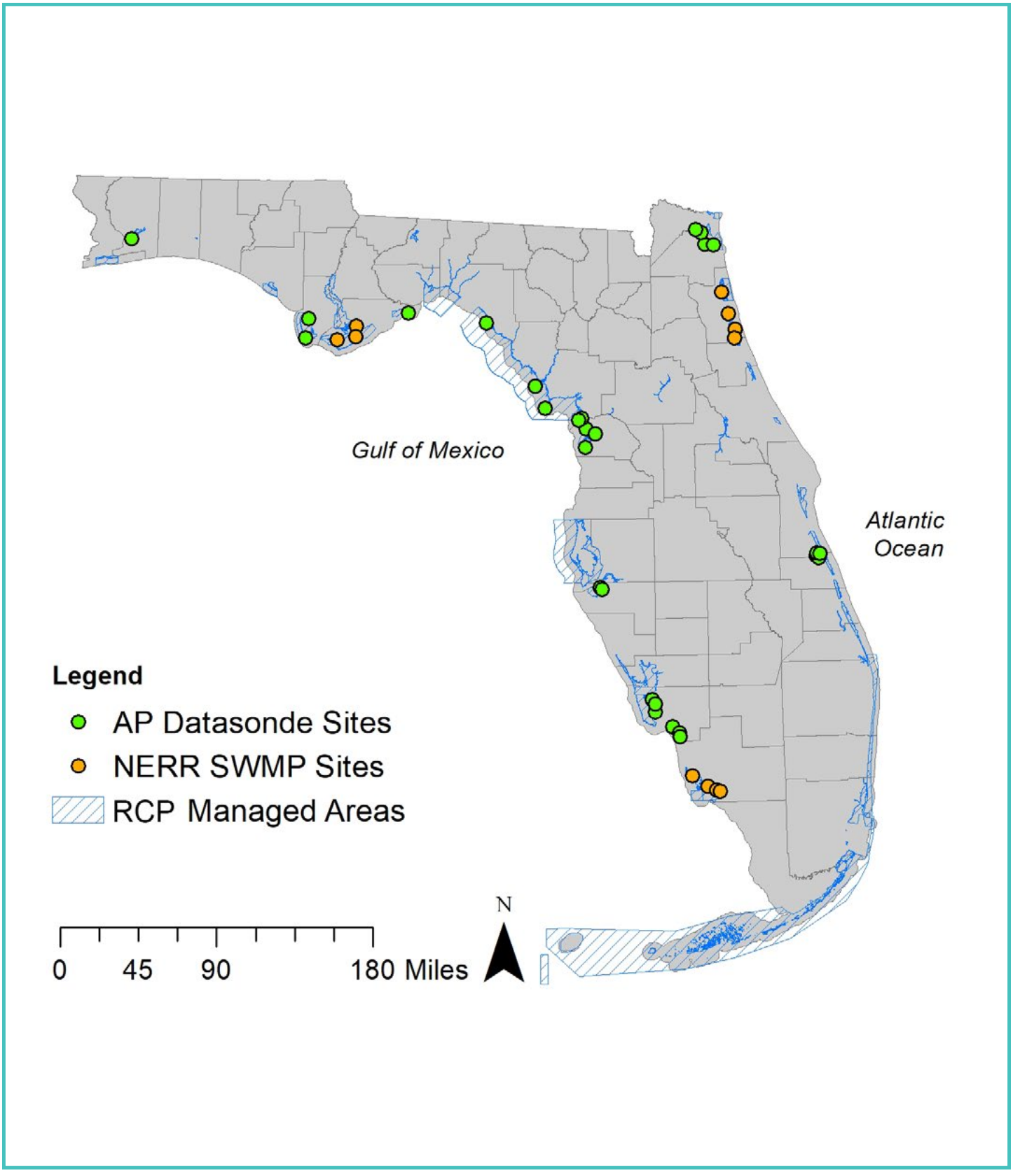


Figure 9. The map features locations where data sondes were used continuously to monitor water quality within NERRS and APs for the study period. Green dots represent AP stations and orange dots represent NERR stations.

Most of the AP offices have collected water temperature (°C), specific conductivity (mS/cm), salinity (ppt), dissolved oxygen percent (%), dissolved oxygen saturation (mg/L), pH, depth (m), and turbidity (NTU) data since 2004 when they were equipped with YSI 6-Series multiparameter data sondes in an effort to improve the availability of continuous estuarine water quality data in Florida.

This project reviewed and evaluated the data collected by the AP offices (approximately 4.25 million data records) using Quality Assurance/Quality Control methods as outlined in the CDMO Data Management Manual, as well as created a relational database to store historical and future AP data and a user-friendly, publicly accessible online data portal for hosting the data, www.FloridaAPData.org. Aquatic preserves staff also attended the NERRS 18th Annual SWMP Technician Training Workshop hosted by the CDMO to learn the latest water quality data collection and management procedures. The CDMO created instructional protocols and training modules for improved data collection and management of the AP continuous water quality program. Furthermore, the CDMO provided RCP with recommendations for program improvements.

Assessment

Training

Staff from six aquatic preserve offices (Rebecca Cray - Estero Bay; Mary McMurray - Charlotte Harbor; Claire Burgett - Biscayne Bay; Zach Schang - Northwest Florida; Trisha Green - Big Bend Seagrasses; and Silas Tanner - Guana River Marsh) had the opportunity to attend the 18th annual NERRS SWMP Technician Training Workshop hosted by the CDMO in South Carolina. Aquatic preserves staff received hands-on training in water quality data collection and data management procedures used by the NERRS. Staff had the opportunity to network and share unique user experiences with each other that provided a broader understanding of monitoring applications and techniques. Water quality training materials were developed for AP staff, including protocol documents, data management manuals, metadata templates, QA/QC checklists, quick reference guides, sensor inventory tracking, data submission procedures, maintenance procedures and video training tutorials. These resources are available on the data portal website, www.FloridaAPData.org. In addition to the training resources, a centralized data coordinator position was created to assist AP staff with applying data management procedures used by the NERRS.

Interviews

To assess the historical and current AP water quality monitoring activities, CDMO staff (Dr. Dwayne Porter and Jeremy Cothran) and RCP staff (Katie Petrinec) interviewed AP managers and technicians from the eight AP offices included in the Project. Interviews also were expanded to include Biscayne Bay AP, which began a continuous water quality program in 2018. The goal of the interviews was to assess the quality of the data collected by each office, to identify their needs, to offer insight into potential causes of data loss and to provide recommendations for improving data collection.

AP staff emphasized the importance of partnerships and the need to perform a gap analysis, so that monitoring efforts are not duplicated across state and federal agencies. The interviewees recognized the importance of standardizing the AP continuous water quality program for data collection and management methods; expressed the need for RCP to host an annual in-person training workshop to maintain the consistency of the data collection and management methods implemented with this project; and stressed the importance of having long-term support for the program to help with data management for all of the AP offices. Lastly, they all saw the value in having a database to house the AP data and a web-based portal to host the data.

Recommendations

The CDMO provided a series of recommendations for RCP based on their assessment as well as feedback from the APs. The CDMO recommended that RCP design and implement a system-wide AP continuous water quality program consistent with the NERRS SWMP and provide long-term support to maintain the program.

The following list are recommendations and other considerations provided by the CDMO:

- Establish a centralized data management office through the establishment of a data coordinator
- Provide access to a variety of different types of data and integrate these data with AP-collected data
- Create a relational database structure that allows for rapid and customizable data queries
- Perform QA/QC protocols that identify spurious data and/or data anomalies
- Maintain a metadata strategy that ensures that all aspects of data collection, management and QA/QC are documented and meet ISO 19115-2 metadata standards
- Create a data portal to provide public access to the data, metadata and derived products
- Create web-based tools to include map-based products that enable spatial visualization of data and derived information
- Establish staff training and develop a community of regional data management experts
- Establish a Data Management Committee (DMC) to provide guidance, oversight and support
- Implement the use of telemetry for near-real-time delivery of water quality data

To view a full copy of the report, Florida Coastal Water Quality Monitoring Data Assessment, Access and Training, please visit: https://floridadep.gov/rcp/fcmp/documents/florida-coastal-water-quality-monitoring-data-assessment-access-and-training.

Data

The water quality data set spans over 10 years of sampling events at 28 water quality stations managed by eight AP offices: Northwest Florida; Big Bend Seagrasses; Central Panhandle; Tampa Bay; Charlotte Harbor; Estero Bay; Northeast Florida; and Indian River Lagoon. Over the 10 years, there were variations in instruments, data collection intervals, duration of deployments and recorded parameters (Table 1). Additionally, seven stations experienced gaps (> 6 months) in data and 21 stations were discontinued. These differences imposed limitations on how data could be evaluated.

Stations were established using methods similar to the NERRS SWMP. Data was collected in fixed station locations 0.5 meters off the bottom. The data was evaluated by comparing the calibration methods, post-deployment readings, and reconditioning of the data sondes and sensors after deployments. The data collection methods performed were in accordance with methods outlined by the YSI 6-Series Multiparameter Water Quality Sondes User Manual and, therefore, it was determined that the data files were useable.

Station data was imported into a common relational database from CSV or Microsoft Excel files that were collected from each AP at the beginning of the project. Some of the challenges encountered by the CDMO while importing the data included differences in measured parameters, data collection time periods, column headers between the data files, data contained in multiple spreadsheets, and filler values in some datasets that were assigned to missing data values. Once the issues were corrected, the CDMO successfully imported roughly 4.25 million data records into the database.

Table 1. Data collection periods for the aquatic preserves' 28 continuous water quality stations. Plus sign (+) represents stations that experienced data gaps that were longer than six months. Asterisk denotes currently inactive stations.

Region	AP Office	Station	Station Code	Data Collection Period
Northwest	Northwest	Yellow River Marsh AP1	YRMAP1	1/2015 - 7/2017
	Central Panhandle	Richardson's Hammock	*CPRH	7/2005 - 6/2011
	Central Panhandle	Windmark	*CPWM	8/2006 - 8/2007
	Central Panhandle	Alligator Harbor	CPAH	1/2008 - 8/2008
	Big Bend Seagrasses	Bennett Creek	*BBSBC	1/2004 - 1/2014, 3/2015 - 12/2015, 5/2016 - 7/2016
	Big Bend Seagrasses	Crystal River	*BBSCR	1/2004 - 1/2015
	Big Bend Seagrasses	Dekle Beach	*BBSDB	3/2007 - 12/2015
	Big Bend Seagrasses	Homosassa River	*BBSHS	+1/2004 - 12/2004, 3/2006 - 1/2015, 4/2016 - 7/2016
	Big Bend Seagrasses	Kings Bay	*BBSKB	3/2009 - 12/2015, 2/2016 - 7/2016
	Big Bend Seagrasses	Seahorse Key	*BBSSK	+4/2004 - 2/2005, 8/2006 - 4/2015
	Big Bend Seagrasses	Suwannee River	*BBSSW	3/2009 - 12/2015, 2/2016 - 7/2016
	Big Bend Seagrasses	Withlacoochee	*BBSWT	+1/2004 - 7/2014, 3/2015 - 12/2015, 5/2016
Southwest	Tampa Bay	Bishop Harbor	*TCBH	4/24/2008 - 3/3/2009
	Tampa Bay	Frog Creek	*TCFC	9/26/2008 - 2/26/2009
	Charlotte Harbor	Matlacha Pass 1A	MP1A	10/2005 - 12/2016
	Charlotte Harbor	Matlacha Pass 2B	MP2B	9/2005 - 12/2016
	Charlotte Harbor	Matlacha Pass 3C	MP3C	3/2009 - 12/2016
	Estero Bay	Tom Winter	EB01	7/2004 - 4/2017
	Estero Bay	Spring Creek	EB02	7/2004 - 4/2017
	Estero Bay	Fish Trap Bay	EB03	11/2004 - 4/2017
Northeast	Northeast	Clapboard Creek	NECC	9/2004 - 6/2011
	Northeast	Lofton Creek	*NELC	7/2005 - 5/2011
	Northeast	Kingsley Plantation	*NEKD	1/2004 - 5/2011
	Northeast	Nassau River	*NENR	7/2009 - 5/2011
	Indian River Lagoon	C-54 Canal/Fellsmere Canal	*IRC54	+9/2003 - 1/2004, 1/2006 - 12/2007
	Indian River Lagoon	Donald McDonald/South Prong	*IRDM	+9/2003 - 2/2004, 12/2004 - 12/2007
	Indian River Lagoon	North Prong	*IRNP	+9/2003 - 1/2004, 11/2004 - 12/2008
	Indian River Lagoon	US1/Main Drainage Basin	*IRUS1	+9/2003 - 1/2004, 2/2004 - 12/2008

Data was then evaluated using a two-step (primary and secondary) QA/QC process as outlined in the NERRS CDMO Data Management Manual (NERRS, 2015). The primary QA/QC process was performed by the CDMO and was an automated process applying standardized metadata flags to data that were missing or outside sensor specifications as determined by YSI, the instrument manufacturer. Individual flag columns for each water quality parameter collected also were added to the data files during the primary QA/QC process. The yearly data files were then exported from the project database and sent to the RCP data coordinator for the secondary QA/QC process.

The yearly data files were evaluated during the secondary QA/QC process, and standardized flags and codes were applied to the flag columns contained within the primary quality checked data files using an Excel macro distributed by the CDMO. Anomalous data was flagged and coded using metadata documents provided by the AP offices when applicable. For offices that did not previously maintain metadata documents, the RCP data coordinator created those documents, quality checked the data, and applied the flags and codes to the data. Metadata documents were created in a standardized format. Moving forward, AP offices will create annual metadata reports following the standardized format and will include information about the data set that will be valuable to the user and aid in interpreting the data. Data that completed the secondary QA/QC process were then sent to the CDMO and were uploaded to the AP database.

The AP database served as a backbone for making the AP data available through a publicly accessible data portal. The data portal, www.FloridaAPData.org, provides a map-based, user-friendly interface for station selection and provides data users the ability to graph data from multiple AP water quality stations for regional or statewide comparisons. With the option to download station data and metadata documents, the data portal also makes the AP data more readily available for resource managers, planners, permitting agencies, educators and scientists.

Trend Analysis

The data files used in this report have completed QA/QC reviews and are considered valid data. Data was compiled using both 15-minute and 30-minute data collection intervals and five out of eight water quality parameters — water temperature, salinity, dissolved oxygen concentration, pH and turbidity — were evaluated, summarized and analyzed for long-term trends. Water quality data was aggregated into monthly averages, and the nonparametric Seasonal Mann-Kendall test was used for detecting the monotonic long-term trend direction. Estimated slopes use Hirsch et al.'s modification of the Theil/Sen Estimator and the estimated Confidence Intervals use Gilbert's modification of the Theil/Sen method. Datasets that contained a minimum of three consecutive years were analyzed for significant ($p<0.05$) increasing or decreasing trends based on all available data for each water quality parameter. Stations that did not include sufficient data are reported as NR. Stations that did not pass the Heterogeneity Test ($p>0.05$) do not have Trend Test results and are reported as NA.

All statistical analyses and graphics included in this report were created using RStudio 1.0.44 (RStudio Team, 2015) and Microsoft Excel (2016). RStudio is an integrated development environment (IDE) for R; an open source language that uses packages that are applied to data to create data summaries and advanced statistical analyses.

The SWMPr package provides several functions that facilitate data retrieval, organization and analysis of time series data in the reserve estuaries (Beck, 2016). SWMPr was used for evaluating all the AP water quality data files and creating data summaries. EnvStats (Millard, 2013), lubridate (Grolemund et al., 2011), and SWMPr packages were used for performing the Seasonal Mann-Kendall tests.

Results

The following subsections provide general information about the measured parameters, summary statistics and long-term trend results for each water quality parameter summarized by station. Long-term trends with p-values less than 0.05 are indicated with an increasing or decreasing trend notation. P-values that are less than 0.01 are indicative of a stronger trend and p-values that are greater than 0.05 are not considered significant.

Water Temperature

All 28 continuous water quality monitoring stations collected water temperature data with varying data collection periods (Table 1). Mean water temperature values ranged from 21.17°C to 25.75°C at the 28 stations, with NENR (Northeast Florida AP) having the lowest mean value and EB03 (Estero Bay AP) having the highest mean. BBSSK station (Big Bend Seagrasses AP) had the lowest minimum temperature at 0.05°C and TCFC (Tampa Bay AP) had the highest minimum temperature at 15.20°C. CPRH (Central Panhandle AP) had the highest maximum water temperature of 38.45°C, and the lowest maximum water temperature, 31.07°C, was at BBSKB station (Big Bend Seagrasses AP) (Table 2).

Three stations exhibited significant long-term trends in water temperature: BBSSK (Big Bend Seagrasses AP) and EB01 and EB02 (Estero Bay AP). Seahorse Key (BBSSK) exhibited a strong decreasing trend, while EB01 and EB02, both located in the Estero Bay AP, exhibited a statistically significant increasing trend. Long-term trends in water temperature were not observed at 22 stations, and there were not enough data for long-term trend analysis at three stations: CPAH (Central Panhandle AP) and TCBH and TCFC (Tampa Bay AP) (Table 2).

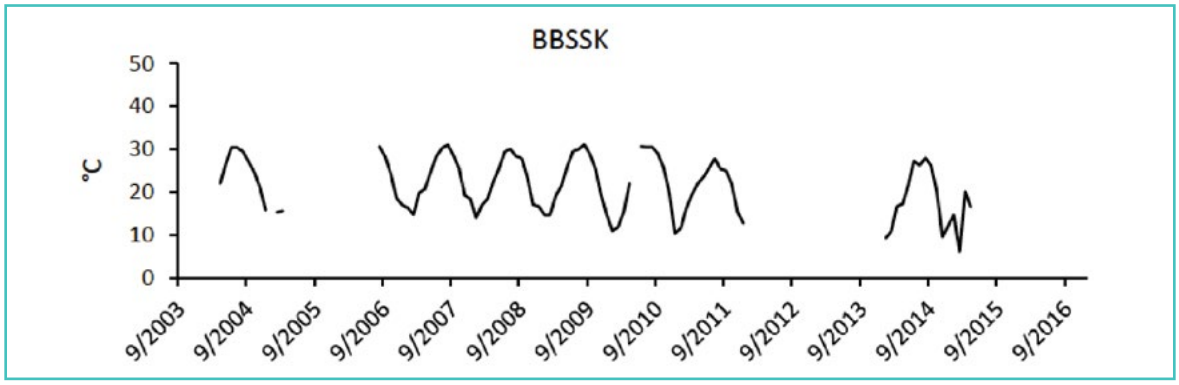
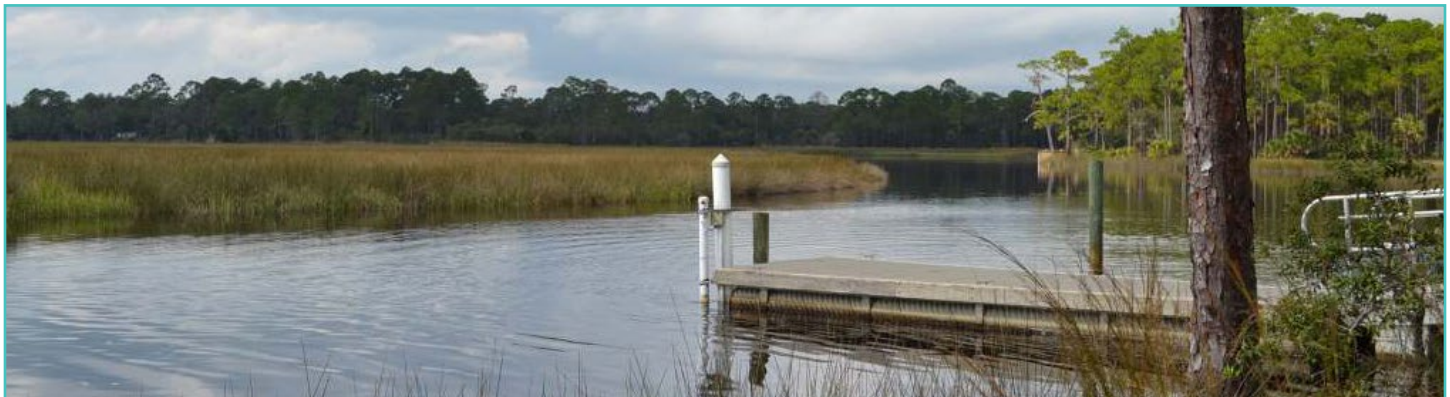


Figure 10. Average monthly water temperature recorded at BBSSK water quality station in Big Bend Seagrasses APs. BBSSK exhibited decreasing long-term trend in water temperature. Breaks in data indicate missing or omitted data.



A continuous water quality monitoring station located in Pellicer Creek Aquatic Preserve.

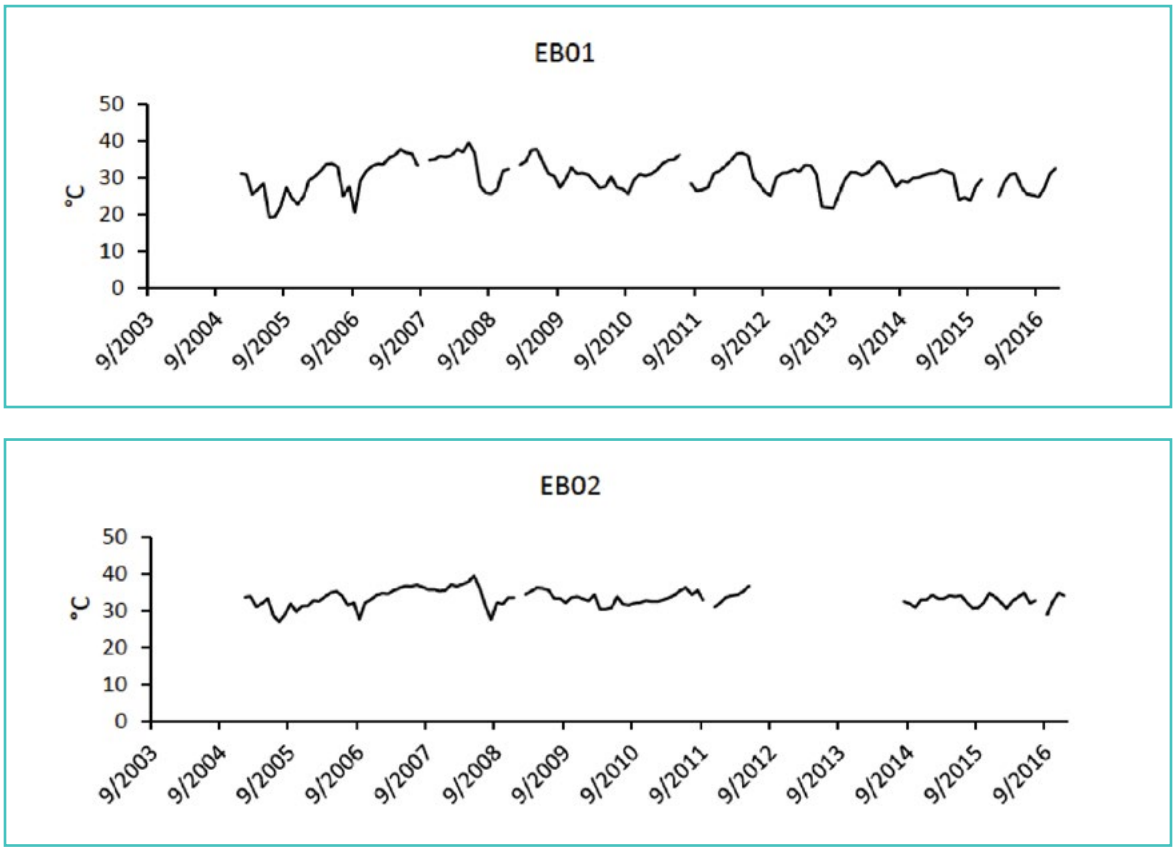


Figure 11. Average monthly water temperature recorded at EB01 and EB02 water quality stations in Estero Bay AP. Both stations exhibited increasing long-term trends in water temperature. Breaks in data indicate missing or omitted data.

A white grunt (Haemulon plumierii). White grunt is a common fish species in many aquatic preserves.

Table 2. Summary statistics for water temperature (°C) collected by aquatic preserves staff at 28 continuous water quality stations in Florida.

Region	AP Office	Station	Station Code	N	Min	Median	Mean	Max
Northwest	Northwest	Yellow River Marsh AP1	YRMAP1	101647	4.70	23.10	22.30	32.70
	Central Panhandle	Richardson's Hammock	CPRH	97320	1.52	22.57	22.00	38.45
	Central Panhandle	Windmark	CPWM	16875	9.02	26.18	24.84	34.88
	Central Panhandle	Alligator Harbor	CPAH	13034	2.75	20.88	21.50	32.99
	Big Bend Seagrasses	Bennett Creek	BBSBC	243369	5.22	24.35	23.56	35.07
	Big Bend Seagrasses	Crystal River	BBSCR	224487	5.16	22.92	22.84	36.56
	Big Bend Seagrasses	Dekle Beach	BBSDB	281179	1.97	23.24	22.35	34.16
	Big Bend Seagrasses	Homosassa River	BBSHS	244109	4.34	24.52	23.71	34.43
	Big Bend Seagrasses	Kings Bay	BBSKB	274210	12.09	24.29	23.80	31.07
	Big Bend Seagrasses	Seahorse Key	BBSSK	179207	0.05	21.74	21.47	36.43
	Big Bend Seagrasses	Suwannee River	BBSSW	227993	4.62	23.70	22.93	35.78
	Big Bend Seagrasses	Withlacoochee	BBSWT	261422	4.18	25.35	24.17	35.97
Southwest	Tampa Bay	Bishop Harbor	TCBH	8305	10.16	20.00	21.71	32.18
	Tampa Bay	Frog Creek	TCFC	15152	15.20	22.93	24.38	31.12
	Charlotte Harbor	Matlacha Pass 1A	MP1A	391357	4.66	23.14	22.32	32.74
	Charlotte Harbor	Matlacha Pass 2B	MP2B	381246	7.22	25.70	25.27	37.45
	Charlotte Harbor	Matlacha Pass 3C	MP3C	263923	7.09	26.30	25.56	34.27
	Estero Bay	Tom Winter	EB01	404556	7.87	26.37	25.70	34.43
	Estero Bay	Spring Creek	EB02	325455	5.54	25.85	25.41	35.19
	Estero Bay	Fish Trap Bay	EB03	389629	4.74	26.41	25.75	35.47
Northeast	Northeast	Clapboard Creek	NECC	114229	4.49	22.90	22.48	35.94
	Northeast	Lofton Creek	NELC	100339	4.54	22.70	22.14	33.94
	Northeast	Kingsley Plantation	NEKD	118328	5.83	22.08	21.75	32.40
	Northeast	Nassau River	NENR	31438	5.62	22.04	21.17	31.78
	Indian River Lagoon	C-54 Canal / Fellsmere Canal	IRC54	30454	9.98	25.16	25.09	34.28
	Indian River Lagoon	Donald McDonald / South Prong	IRDM	43791	11.61	23.48	23.86	35.57
	Indian River Lagoon	North Prong	IRNP	60036	11.16	24.89	24.58	33.97
	Indian River Lagoon	US1/Main Drainage Basin	IRUS1	57148	12.53	24.98	24.93	37.13

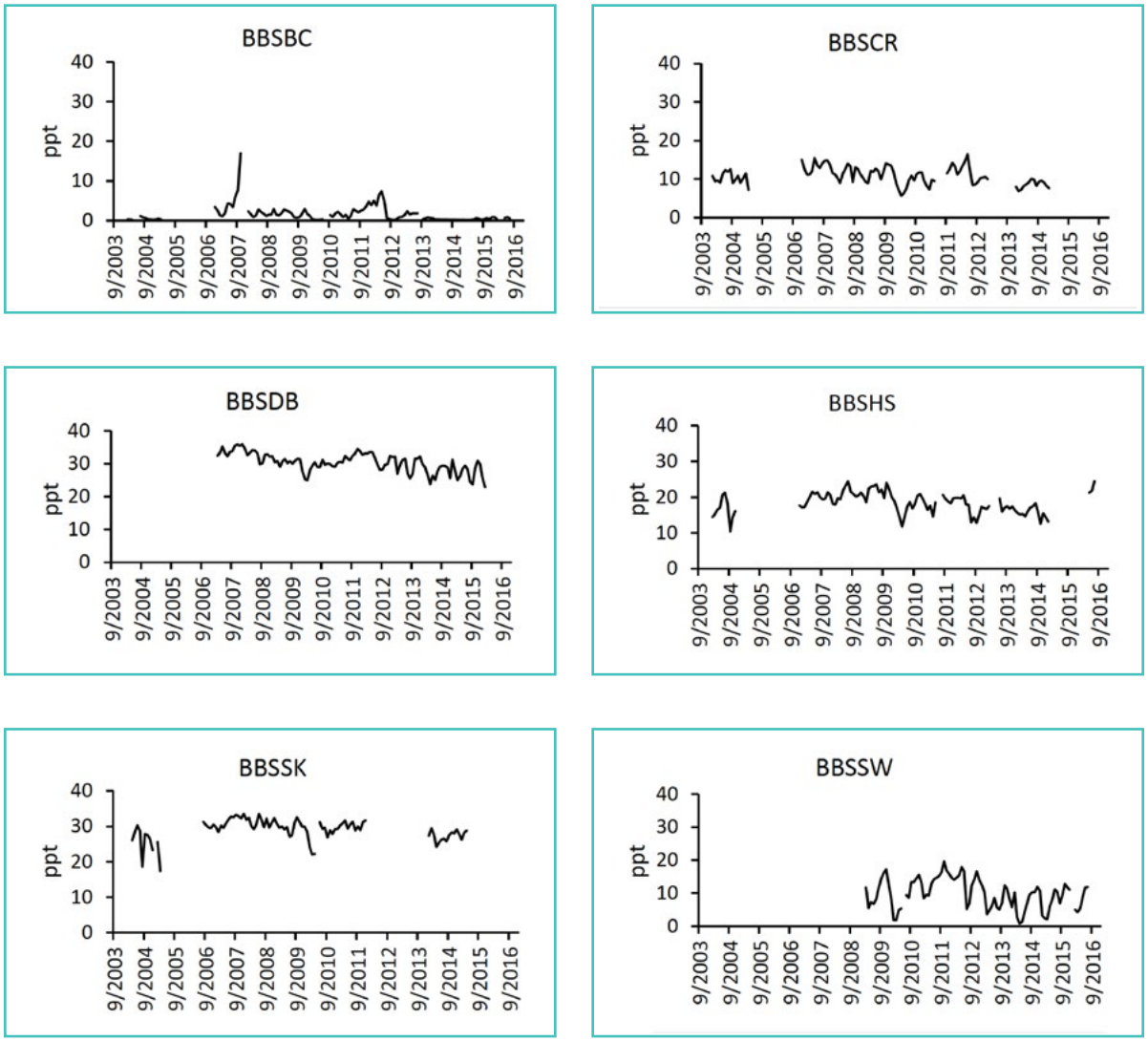
Table 3. Long-term trends in water temperature (°C) collected at 28 continuous water quality stations in Florida. Long-term trends were determined using the Seasonal Mann-Kendall Test. Estimated slopes use Hirsch et al.'s modification of the Theil/Sen Estimator and the estimated Confidence Intervals use Gilbert's modification of the Theil/Sen method. Datasets that contained a minimum of three consecutive years were analyzed for significant ($p<0.05$) increasing or decreasing trends based on all available data for water temperature. Stations that did not include sufficient data are reported as No Result (NR). Stations that did not pass the Heterogeneity Test ($p>0.05$) do not have Trend Test results and are reported as NA. Results that could not be calculated are reported as NC.

AP Office	Station Code	Heterogeneity Test			Trend Test				
		Code	df	p	τ	Slope	95% CI	z	p
Northwest	YRMAP1	13.091	11	0.287	-0.333	-0.464	[-0.877, 0.274]	-1.658	0.097
Central Panhandle	CPRH	8.110	11	0.703	-0.065	-0.069	[-0.303, 0.112]	-0.662	0.508
Central Panhandle	CPWM	0.000	1	1.000	1.000	0.751	NC	0.707	0.480
Central Panhandle	CPAH	NR	NR	NR	NR	NR	NR	NR	NR
Big Bend Seagrasses	BBSBC	10.279	11	0.505	0.085	0.059	[-0.026, 0.109]	1.188	0.235
Big Bend Seagrasses	BBSCR	4.814	11	0.940	0.063	0.029	[-0.050, 0.102]	0.771	0.441
Big Bend Seagrasses	BBSDB	6.652	11	0.827	0.083	0.038	[-0.048, 0.143]	1.053	0.292
Big Bend Seagrasses	BBSHS	8.611	11	0.658	0.047	0.029	[-0.051, 0.108]	0.637	0.524
Big Bend Seagrasses	BBSKB	13.673	11	0.252	0.021	0.016	[-0.026, 0.060]	0.548	0.584
Big Bend Seagrasses	BBSSK	7.830	11	0.728	-0.339	-0.371	[-0.545, -0.185]	-3.785	0.000
Big Bend Seagrasses	BBSSW	12.077	11	0.358	0.017	0.011	[-0.155, 0.207]	0.122	0.903
Big Bend Seagrasses	BBSWT	10.242	11	0.509	0.091	0.057	[-0.020, 0.116]	1.402	0.161
Tampa Bay	TCBH	NR	NR	NR	NR	NR	NR	NR	NR
Tampa Bay	TCFC	NR	NR	NR	NR	NR	NR	NR	NR
Charlotte Harbor	MP1A	5.385	11	0.911	0.122	0.048	[-0.003, 0.094]	1.824	0.068
Charlotte Harbor	MP2B	4.782	11	0.941	0.111	0.051	[-0.005, 0.106]	1.653	0.098
Charlotte Harbor	MP3C	7.653	11	0.744	0.108	0.058	[-0.022, 0.156]	1.211	0.226
Estero Bay	EB01	9.909	11	0.539	0.133	0.045	[0.002, 0.093]	2.038	0.042
Estero Bay	EB02	10.035	11	0.527	0.264	0.087	[0.0445, 0.137]	3.568	0.000
Estero Bay	EB03	10.356	11	0.499	0.059	0.028	[-0.019, 0.077]	0.919	0.358
Northeast	NECC	16.512	11	0.123	0.007	0.015	[-0.172, 0.134]	0.045	0.964
Northeast	NELC	9.896	11	0.540	0.051	0.042	[-0.197, 0.173]	0.331	0.741
Northeast	NEKD	9.189	11	0.604	-0.037	-0.013	[-0.205, 0.106]	-0.246	0.806
Northeast	NENR	9.600	9	0.384	0.200	0.420	[-1.293, 2.962]	0.316	0.752
Indian River Lagoon	IRC54	10.248	10	0.419	0.043	0.040	[0.612, 0.956]	0.000	1.000
Indian River Lagoon	IRDM	14.202	10	0.164	0.293	0.341	[-0.226, 1.070]	1.308	0.191
Indian River Lagoon	IRNP	7.544	11	0.753	0.234	0.597	[-0.007, 1.074]	1.823	0.068
Indian River Lagoon	IRUS1	21.180	11	0.032	NA	NA	NA	NA	NA

Salinity

All 28 continuous water quality monitoring stations collected salinity data with varying data collection periods (Table 1). Mean salinity values ranged from 1.63 ppt at BBSBC (Big Bend Seagrasses APs) to 33.59 ppt at EB02 (Estero Bay AP). BBSKB (Big Bend Seagrasses APs) experienced the lowest overall salinity levels with a minimum of 0.01 ppt and a maximum of 10.25 ppt; however, both BBSHS (Big Bend Seagrasses APs) and IRNP (Indian River Lagoon APs) stations recorded the lowest minimum value of 0.00 ppt. The highest minimum salinity values were 20.13 ppt and 20.10 ppt, recorded at CPRH and CPWM respectively. These two stations within the Central Panhandle AP also had a low overall range in salinity levels, with a maximum salinity level of 40.34 ppt at CPRH and 39.7 ppt at CPWM. The highest maximum value was 46.94 ppt at the EB03 (Estero Bay) station (Table 3).

Sixteen stations exhibited significant long-term trends ($p<0.05$) in salinity, which was the most for any one parameter. Eleven stations exhibited significant decreasing trends: six stations managed by Big Bend Seagrasses APs (BBSBC, BBSCR, BBSDB, BBSHS, BBSSK and BBSSW); three stations managed by Charlotte Harbor APs (MP1A, MP2B and MP3C); and two stations managed by Estero Bay AP (EB01 and EB03). Six stations exhibited significant increasing trends: three stations managed by Northeast Florida APs (NECC, NEKD and NENR) and two stations managed by Indian River Lagoon APs (IRNP and IRUS1). Nine stations showed no trends at all, and three stations - CPAH (Central Panhandle APs) and TCBH and TCFC (Tampa Bay APs) - did not have enough data for long-term trend analysis (Table 3).



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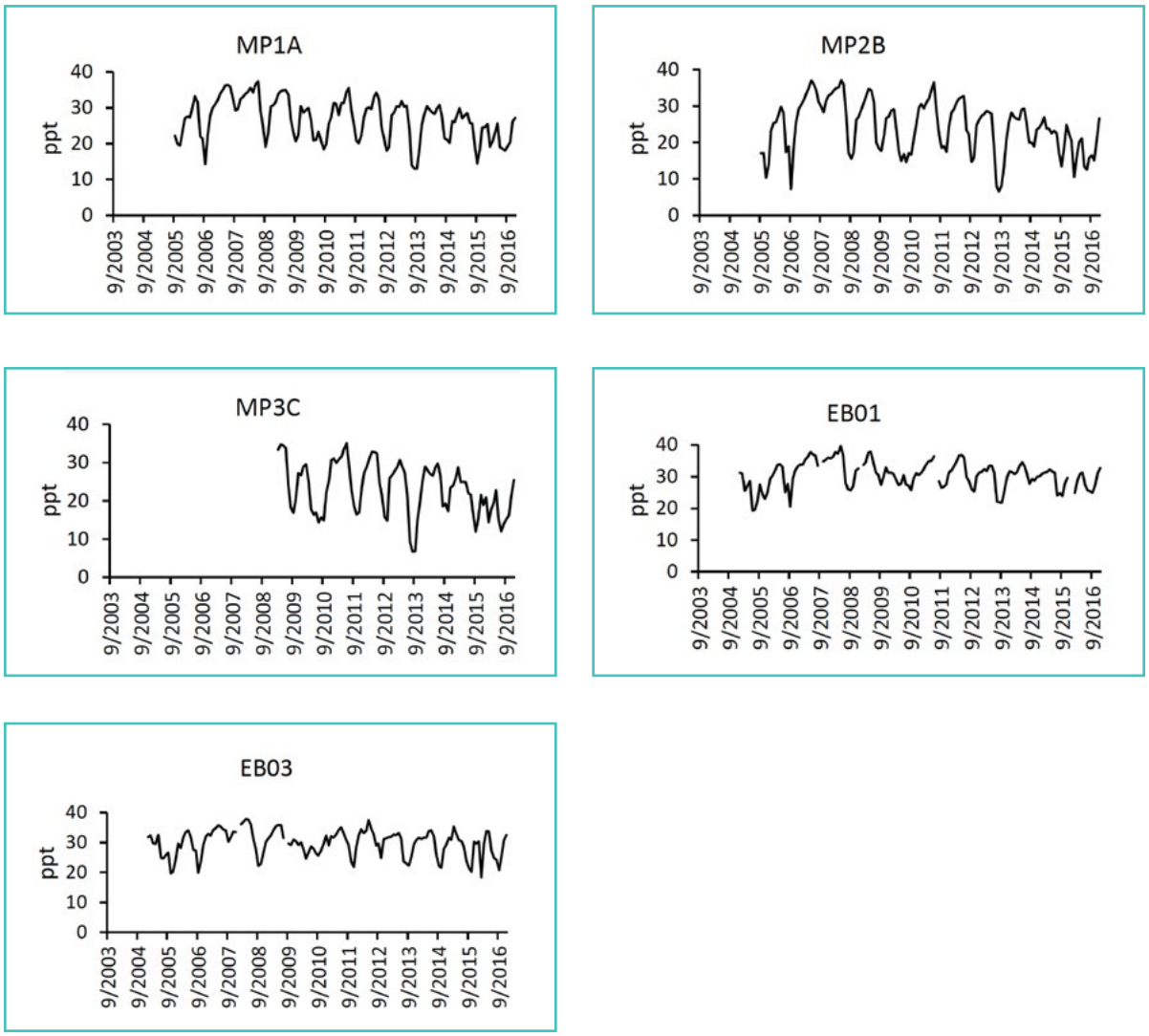

Figure 12. Average monthly salinity recorded at BBSBC (Big Bend Seagrasses AP); BBSCR (Big Bend Seagrasses AP); BBSDB (Big Bend Seagrasses AP); BBSHS (Big Bend Seagrasses AP); BBSSK (Big Bend Seagrasses AP); BBSSW (Big Bend Seagrasses AP); MP1A (Charlotte Harbor AP); MP2B (Charlotte Harbor AP); MP3C (Charlotte Harbor AP); and EB01 and EB03 (Estero Bay AP). These stations exhibited decreasing long-term trends in salinity. Breaks in data indicate missing and/or omitted data.

A tiger shark (Galeocerdo cuvier) swimming through seagrasses in Big Bend Seagrasses Aquatic Preserve.

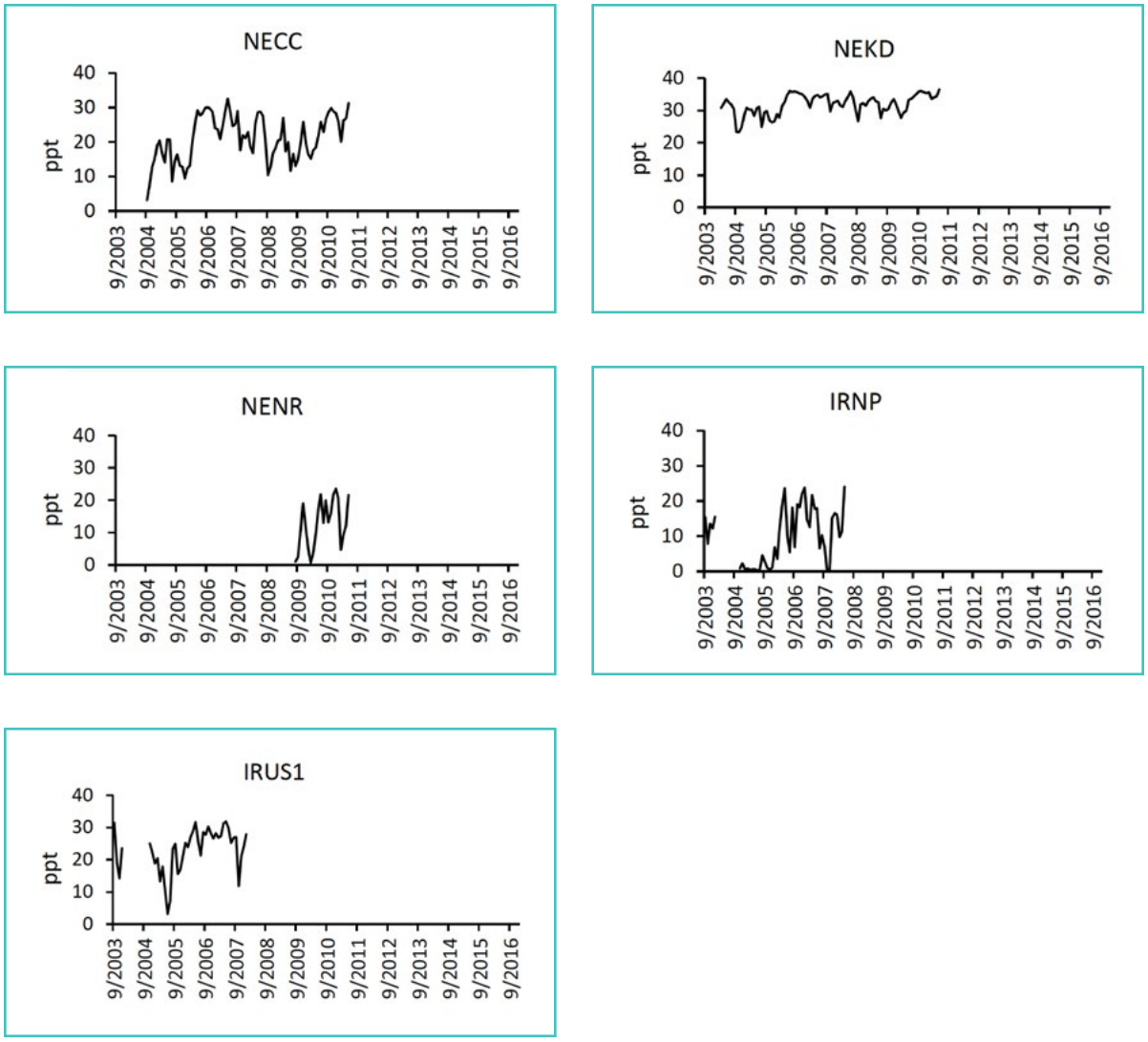

Figure 13. Average monthly salinity recorded at NECC (Northeast Florida AP); NEKD (Northeast Florida AP); NENR (Northeast Florida AP); IRNP (Indian River Lagoon AP); and IRUS1 (Indian River Lagoon AP) water quality stations. These stations exhibited increasing long-term trends in salinity. Breaks in data indicate missing and/or omitted data.

Mangroves lining the shoreline in Indian River Lagoon Aquatic Preserve.

Table 4. Summary statistics for salinity (ppt) collected by aquatic preserves staff at 28 continuous water quality stations in Florida.

Region	AP Office	Station	Station Code	N	Min	Median	Mean	Max
Northwest	Northwest	Yellow River Marsh AP1	YRMAP1	95268	0.10	13.20	12.90	28.90
	Central Panhandle	Richardson's Hammock	CPRH	90746	20.13	32.38	32.23	40.34
	Central Panhandle	Windmark	CPWM	16823	20.10	32.06	32.49	39.70
	Central Panhandle	Alligator Harbor	CPAH	13034	0.03	34.02	33.51	38.24
	Big Bend Seagrasses	Bennett Creek	BBSBC	229319	0.01	0.26	1.63	39.96
	Big Bend Seagrasses	Crystal River	BBSCR	212293	0.04	10.38	13.61	27.27
	Big Bend Seagrasses	Dekle Beach	BBSDB	265541	12.31	30.56	30.05	37.13
	Big Bend Seagrasses	Homosassa River	BBSHS	235670	0.00	18.42	18.23	33.30
	Big Bend Seagrasses	Kings Bay	BBSKB	271388	0.01	1.76	1.89	10.25
	Big Bend Seagrasses	Seahorse Key	BBSSK	178350	5.82	29.64	28.93	35.88
	Big Bend Seagrasses	Suwannee River	BBSSW	221693	0.04	7.48	9.96	35.10
	Big Bend Seagrasses	Withlacoochee	BBSWT	248847	0.01	11.93	11.59	35.25
Southwest	Tampa Bay	Bishop Harbor	TCBH	8303	0.42	32.56	32.41	34.01
	Tampa Bay	Frog Creek	TCFC	15150	0.17	12.63	12.72	27.56
	Charlotte Harbor	Matlacha Pass 1A	MP1A	384978	0.10	13.20	12.93	28.85
	Charlotte Harbor	Matlacha Pass 2B	MP2B	378154	2.17	25.05	24.29	39.21
	Charlotte Harbor	Matlacha Pass 3C	MP3C	263090	0.30	23.52	23.02	36.56
	Estero Bay	Tom Winter	EB01	364919	0.14	30.86	30.28	41.07
	Estero Bay	Spring Creek	EB02	296910	8.50	33.84	33.59	41.24
	Estero Bay	Fish Trap Bay	EB03	350960	0.01	31.30	29.87	46.94
Northeast	Northeast	Clapboard Creek	NECC	114229	0.42	21.81	21.29	34.84
	Northeast	Lofton Creek	NELC	100335	0.05	27.89	25.40	39.05
	Northeast	Kingsley Plantation	NEKD	118328	0.05	33.19	31.89	38.02
	Northeast	Nassau River	NENR	31438	0.01	12.38	12.50	46.16
	Indian River Lagoon	C-54 Canal / Fellsmere Canal	IRC54	29851	0.57	12.61	12.89	33.05
	Indian River Lagoon	Donald McDonald / South Prong	IRDM	43791	0.00	3.92	5.11	40.61
	Indian River Lagoon	North Prong	IRNP	58886	0.08	3.12	10.00	32.72
	Indian River Lagoon	US1/Main Drainage Basin	IRUS1	57148	0.17	24.53	22.98	40.42

Table 5. Long-term trends in salinity (ppt) collected at 28 continuous water quality stations in Florida. Long-term trends were determined using the Seasonal Mann-Kendall Test. Estimated slopes use Hirsch et al.'s modification of the Theil/Sen Estimator and the estimated Confidence Intervals use Gilbert's modification of the Theil/Sen method. Datasets that contained a minimum of three consecutive years were analyzed for significant ($p<0.05$) increasing or decreasing trends based on all available data for salinity. Stations that did not include sufficient data are reported as No Result (NR).

AP Office	Station Code	Heterogeneity Test			Trend Test				
		Code	df	p	τ	Slope	95% CI	z	p
Northwest	YRMAP1	11.909	11	0.371	-0.389	-3.048	[-5.174, -0.192]	-1.960	0.050
Central Panhandle	CPRH	3.208	11	0.988	-0.121	-0.158	[-0.597, 0.201]	-1.104	0.270
Central Panhandle	CPWM	0.000	1	1.000	1.000	5.566	NA	0.707	0.480
Central Panhandle	CPAH	NR	NR	NR	NR	NR	NR	NR	NR
Big Bend Seagrasses	BBSBC	7.820	11	0.729	-0.172	-0.074	[-0.158, -0.001]	-2.042	0.041
Big Bend Seagrasses	BBSCR	7.056	11	0.795	-0.307	-0.364	[-0.497, -0.199]	-3.674	0.000
Big Bend Seagrasses	BBSDB	1.261	11	1.000	-0.528	-0.752	[-0.904, -0.547]	-6.832	0.000
Big Bend Seagrasses	BBSHS	5.332	11	0.914	-0.218	-0.384	[-0.585, -0.115]	-2.807	0.005
Big Bend Seagrasses	BBSKB	5.851	11	0.883	-0.013	-0.003	[-0.033, 0.043]	-0.137	0.891
Big Bend Seagrasses	BBSSK	4.432	11	0.956	-0.218	-0.208	[-0.375, -0.045]	-2.332	0.020
Big Bend Seagrasses	BBSSW	8.659	11	0.653	-0.234	-0.650	[-0.965, -0.214]	-2.409	0.016
Big Bend Seagrasses	BBSWT	5.970	11	0.875	-0.075	-0.121	[-0.355, 0.143]	-0.930	0.352
Tampa Bay	TCBH	NR	NR	NR	NR	NR	NR	NR	NR
Tampa Bay	TCFC	NR	NR	NR	NR	NR	NR	NR	NR
Charlotte Harbor	MP1A	2.452	11	0.996	-0.375	-0.643	[-0.811, -0.422]	-5.602	0.000
Charlotte Harbor	MP2B	3.882	11	0.973	-0.371	-0.665	[-0.959, -0.459]	-5.516	0.000
Charlotte Harbor	MP3C	3.831	11	0.975	-0.416	-1.095	[-1.496, -0.601]	-4.809	0.000
Estero Bay	EB01	1.753	11	0.999	-0.156	-0.200	[-0.356, -0.038]	-2.428	0.015
Estero Bay	EB02	7.285	11	0.776	-0.042	-0.044	-0.143, 0.071]	-0.602	0.547
Estero Bay	EB03	5.477	11	0.906	-0.127	-0.132	[-0.275, -0.002]	-1.956	0.050
Northeast	NECC	6.247	11	0.856	0.221	0.979	[0.0999, 1.985]	2.409	0.016
Northeast	NELC	5.276	11	0.440	0.087	0.534	[-0.571, 1.913]	0.773	0.917
Northeast	NEKD	5.618	11	0.897	0.313	0.522	[0.209, 0.842]	3.444	0.000
Northeast	NENR	0.000	9	1.000	1.000	5.448	[2.902, 15.661]	2.846	0.004
Indian River Lagoon	IRC54	10.074	10	0.434	0.130	0.376	[-2.491, 6.363]	0.000	1.000
Indian River Lagoon	IRDM	3.534	10	0.966	0.455	1.453	[-0.105, 3.027]	1.890	0588
Indian River Lagoon	IRNP	8.690	11	0.650	0.340	2.749	[-0.001, 5.130]	2.021	0.043
Indian River Lagoon	IRUS1	8.154	11	0.699	0.512	2.070	[0.510, 3.796]	2.603	0.009

Dissolved Oxygen

Twenty-five of the 28 continuous water quality monitoring stations collected dissolved oxygen (DO) data with varying data collection periods (Table 1). Dissolved oxygen data was not collected at three stations managed by Big Bend Seagrasses APs (BBSBC, BBSCR and BBSWT) due to limitations in the type of instrument deployed during the station collection period.

All 25 of the stations that collected DO data had minimum DO concentrations in the hypoxic range (<4 mg/L); however, mean values were greater than 4 mg/L at 24 of the water quality stations. One station, TCFC (Tampa Bay AP), had mean DO concentrations below 4 mg/L (Table 4).

Five stations exhibited long-term trends in DO concentrations. Two stations, BBSSK (Big Bend Seagrasses AP) and EB03 (Estero Bay AP), exhibited statistically significant increasing trends in DO concentrations, while three stations, NECC and NELC (Northeast Florida AP) and IRNP (Indian River Lagoon AP), exhibited decreasing trends (Table 4).

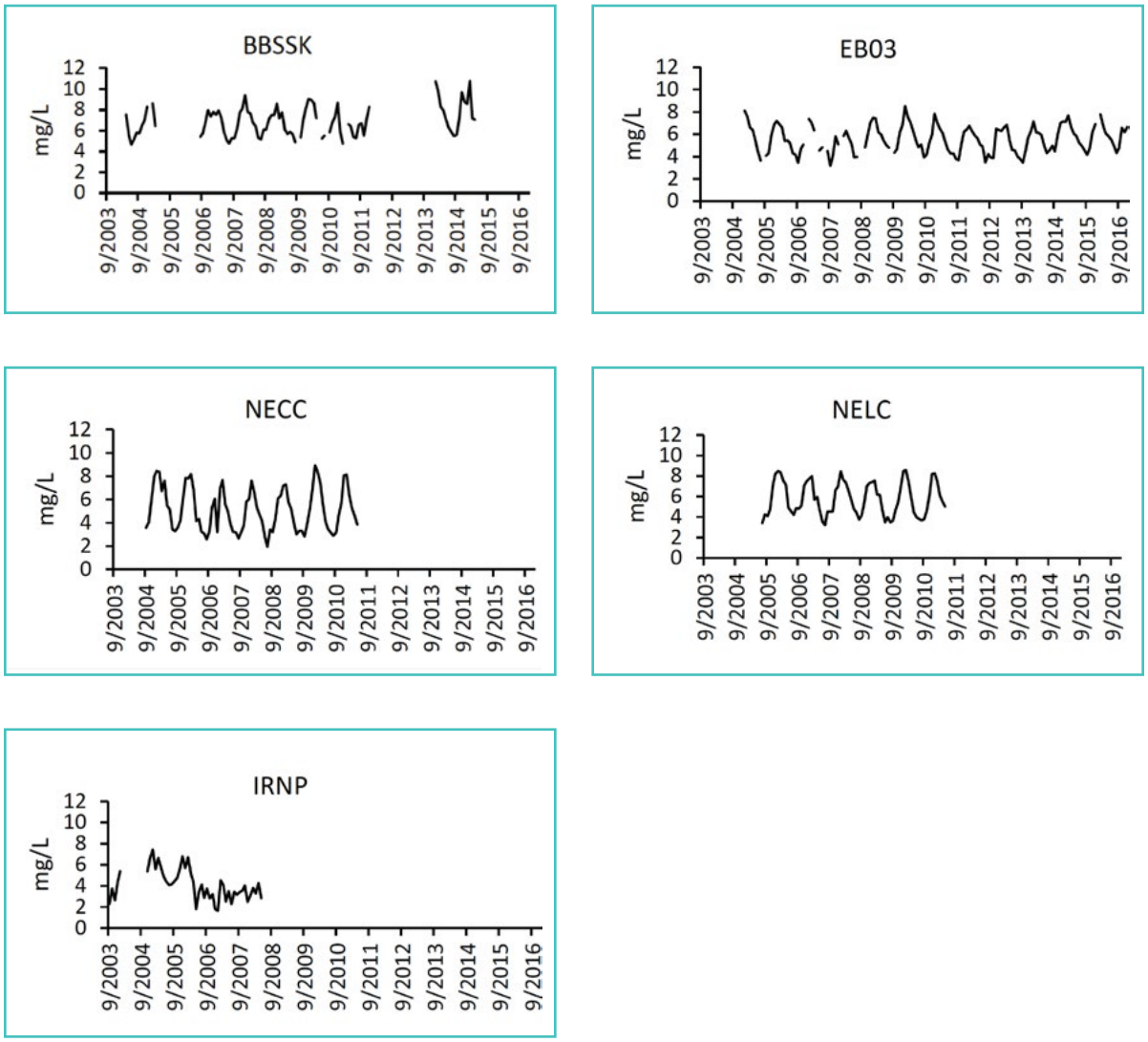

Figure 14. Average monthly dissolved oxygen concentrations recorded at BBSSK (Big Bend Seagrasses AP); EB03 (Estero Bay AP); NECC (Northeast Florida AP); NELC (Northeast Florida AP); and IRNP (Indian River Lagoon AP) water quality stations. BBSSK and EB03 exhibited increasing long-term trends in dissolved oxygen concentrations, while NECC, NELC and IRNP exhibited decreasing trends. Breaks in data indicate missing and/or omitted data.

Table 6. Summary statistics for dissolved oxygen (mg/L) collected by aquatic preserves staff at 28 continuous water quality stations in Florida.

Region	AP Office	Station	Station Code	N	Min	Median	Mean	Max
Northwest	Northwest	Yellow River Marsh AP1	YRMAP1	86865	0.00	7.00	6.80	16.30
	Central Panhandle	Richardson's Hammock	CPRH	73588	0.02	7.27	7.30	14.95
	Central Panhandle	Windmark	CPWM	12768	2.17	6.78	6.71	12.19
	Central Panhandle	Alligator Harbor	CPAH	11557	0.86	8.02	7.76	14.39
	Big Bend Seagrasses	Bennett Creek	BBSBC	NR	NR	NR	NR	NR
	Big Bend Seagrasses	Crystal River	BBSCR	NR	NR	NR	NR	NR
	Big Bend Seagrasses	Dekle Beach	BBSDB	184324	0.43	7.27	7.17	13.11
	Big Bend Seagrasses	Homosassa River	BBSHS	6555	2.11	5.68	5.74	9.67
	Big Bend Seagrasses	Kings Bay	BBSKB	203899	0.53	7.24	7.22	12.02
	Big Bend Seagrasses	Seahorse Key	BBSSK	132868	0.77	7.12	7.06	14.53
	Big Bend Seagrasses	Suwannee River	BBSSW	182324	0.06	6.19	6.26	13.23
	Big Bend Seagrasses	Withlacoochee	BBSWT	NR	NR	NR	NR	NR
Southwest	Tampa Bay	Bishop Harbor	TCBH	8153	1.12	4.16	4.91	12.42
	Tampa Bay	Frog Creek	TCFC	14803	0.05	1.17	1.58	11.86
	Charlotte Harbor	Matlacha Pass 1A	MP1A	376575	0.01	7.04	6.82	16.25
	Charlotte Harbor	Matlacha Pass 2B	MP2B	372428	0.09	6.61	6.49	18.74
	Charlotte Harbor	Matlacha Pass 3C	MP3C	244756	0.01	5.51	5.36	13.51
	Estero Bay	Tom Winter	EB01	297188	0.00	5.34	5.24	12.86
	Estero Bay	Spring Creek	EB02	225024	0.00	5.83	5.67	10.82
	Estero Bay	Fish Trap Bay	EB03	268379	0.00	5.72	5.58	11.55
Northeast	Northeast	Clapboard Creek	NECC	106180	0.01	4.96	5.10	13.49
	Northeast	Lofton Creek	NELC	95856	0.02	5.64	5.77	10.53
	Northeast	Kingsley Plantation	NEKD	110958	0.02	6.40	6.32	11.70
	Northeast	Nassau River	NENR	31438	1.05	5.76	5.95	12.67
	Indian River Lagoon	C-54 Canal / Fellsmere Canal	IRC54	26779	0.07	5.90	5.79	11.33
	Indian River Lagoon	Donald McDonald / South Prong	IRDM	39746	0.17	6.52	6.50	11.94
	Indian River Lagoon	North Prong	IRNP	58850	0.01	4.17	4.17	11.32
	Indian River Lagoon	US1/Main Drainage Basin	IRUS1	53459	0.01	6.13	6.00	11.34

Table 7. Long-term trends in dissolved oxygen (mg/L) collected at 28 continuous water quality stations in Florida. Long-term trends were determined using the Seasonal Mann-Kendall Test. Estimated slopes use Hirsch et al.'s modification of the Theil/Sen Estimator and the estimated Confidence Intervals use Gilbert's modification of the Theil/Sen method. Datasets that contained a minimum of three consecutive years were analyzed for significant ($p<0.05$) increasing or decreasing trends based on all available data for dissolved oxygen. Stations that did not include sufficient data are reported as No Result (NR).

AP Office	Station Code	Heterogeneity Test			Trend Test				
		Code	df	p	τ	Slope	95% CI	z	p
Northwest	YRMAP1	16.004	11	0.141	0.200	0.143	[-0.229, 0.297]	0.778	0.437
Central Panhandle	CPRH	12.939	11	0.297	-0.096	-0.059	[-0.193, 0.067]	-0.650	0.516
Central Panhandle	CPWM	NR	NR	NR	NR	NR	NR	NR	NR
Central Panhandle	CPAH	NR	NR	NR	NR	NR	NR	NR	NR
Big Bend Seagrasses	BBSBC	NR	NR	NR	NR	NR	NR	NR	NR
Big Bend Seagrasses	BBSCR	NR	NR	NR	NR	NR	NR	NR	NR
Big Bend Seagrasses	BBSDB	10.045	11	0.526	-0.054	-0.010	[-0.057, 0.025]	-0.515	0.607
Big Bend Seagrasses	BBSHS	NR	NR	NR	NR	NR	NR	NR	NR
Big Bend Seagrasses	BBSKB	13.178	11	0.282	-0.130	-0.043	[-0.081, 0.013]	-1.563	0.118
Big Bend Seagrasses	BBSSK	8.267	11	0.689	0.263	0.081	[0.021, 0.126]	2.809	0.005
Big Bend Seagrasses	BBSSW	10.049	11	0.526	0.001	0.000	[-0.102, 0.095]	0.000	1.000
Big Bend Seagrasses	BBSWT	NR	NR	NR	NR	NR	NR	NR	NR
Tampa Bay	TCBH	NR	NR	NR	NR	NR	NR	NR	NR
Tampa Bay	TCFC	NR	NR	NR	NR	NR	NR	NR	NR
Charlotte Harbor	MP1A	5.929	11	0.878	-0.076	-0.022	[-0.057, 0.013]	-1.105	0.269
Charlotte Harbor	MP2B	4.441	11	0.955	-0.019	-0.006	[-0.034, 0.018]	-0.236	0.813
Charlotte Harbor	MP3C	2.600	11	0.995	-0.044	-0.014	[-0.094, 0.064]	-0.472	0.637
Estero Bay	EB01	12.559	11	0.323	0.026	0.005	[-0.044, 0.043]	0.303	0.762
Estero Bay	EB02	9.665	11	0.561	0.115	0.035	[-0.009, 0.068]	1.510	0.131
Estero Bay	EB03	11.511	11	0.401	0.138	0.029	[0.002, 0.061]	2.070	0.038
Northeast	NECC	10.042	11	0.527	-0.200	-0.079	[-0.145, -0.010]	-2.136	0.033
Northeast	NELC	5.143	11	0.924	-0.335	-0.114	[-0.217, -0.039]	-3.201	0.001
Northeast	NEKD	9.556	11	0.571	-0.045	-0.020	[-0.090, 0.049]	-0.582	0.561
Northeast	NENR	9.600	9	0.384	-0.200	-0.283	[-1.398, 0.234]	-0.316	0.752
Indian River Lagoon	IRC54	10.248	10	0.419	0.043	0.047	[-1.451, 0.853]	0.000	1.000
Indian River Lagoon	IRDM	12.366	10	0.261	0.152	0.158	[-0.139, 0.363]	0.727	0.467
Indian River Lagoon	IRNP	6.455	11	0.841	-0.383	-0.625	[-1.068, -0.261]	-2.406	0.016
Indian River Lagoon	IRUS1	16.426	11	0.126	-0.000	-0.044	[-0.307, 0.174]	-0.217	0.828

pH

Twenty-six of the 28 continuous water quality monitoring stations collected pH data with varying data collection periods (Table 1). pH data was not collected at two stations (BBSCR and BBSWT) managed by Big Bend Seagrasses AP.

Mean pH values ranged from 7.06 to 8.14 at the 26 stations, with NENR (Northeast Florida AP) having the lowest mean value and BBSDK having the highest mean value at 8.14 (Table 5). Seven continuous water quality stations — CPRH (Central Panhandle AP); MP2B (Charlotte Harbor AP); IRUS1 (Indian River Lagoon AP); CPAH (Central Panhandle AP); EB03 (Estero Bay AP); BBSSK (Big Bend Seagrasses AP); and EB03 (Estero Bay AP) — had minimum pH values that were less than 6.00 and maximum pH values greater than 9.00.

Nine stations exhibited statically significant long-term trends ($p<0.05$), and 12 stations showed no long-term trends in pH. Six stations total showed decreasing long-term trends in pH: BBSDB, BBSKB, BBSSK, BBSSW (Big Bend Seagrasses AP); NECC (Northeast Florida AP); and IRNP (Indian River Lagoon AP). Three stations — MP3C (Charlotte Harbor AP), NEKD (Northeast Florida AP) and IRUS1 (Indian River Lagoon AP) — showed increasing trends in pH (Table 5).

A shoreline view of St. Joseph Bay Aquatic Preserve from the St. Joseph Bay State Buffer Preserve.

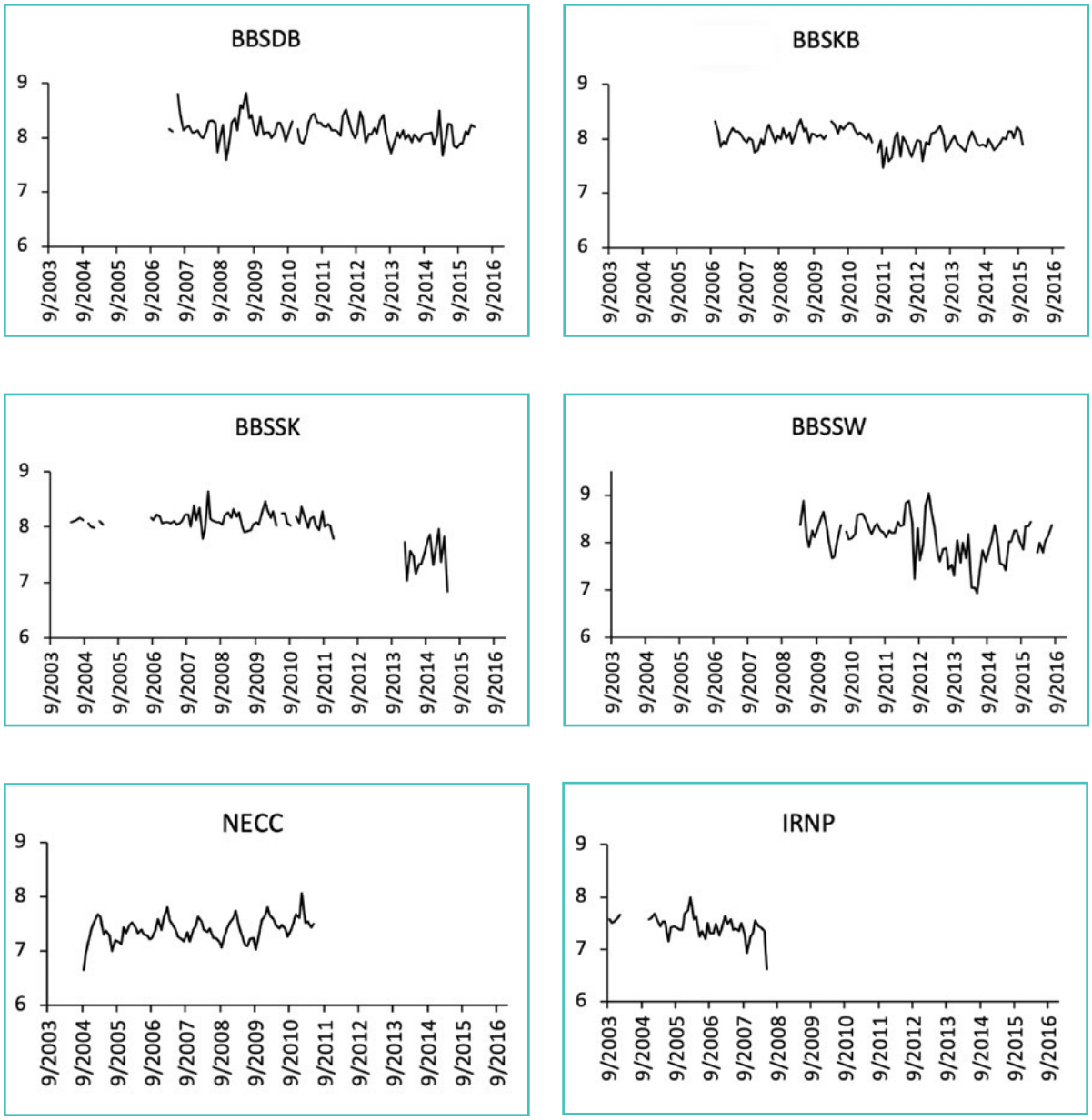

Figure 15. Average monthly pH recorded at BBSDB (Big Bend Seagrasses AP); BBSKB (Big Bend Seagrasses AP); BBSSK (Big Bend Seagrasses AP); BBSSW (Big Bend Seagrasses AP); NECC (Northeast Florida AP); and IRNP (Indian River Lagoon AP). These stations exhibited decreasing long-term trends in pH. Breaks in data indicate missing and/or omitted data.

A loggerhead sea turtle (Caretta caretta) swimming through seagrass in Big Bend Seagrasses Aquatic Preserve.

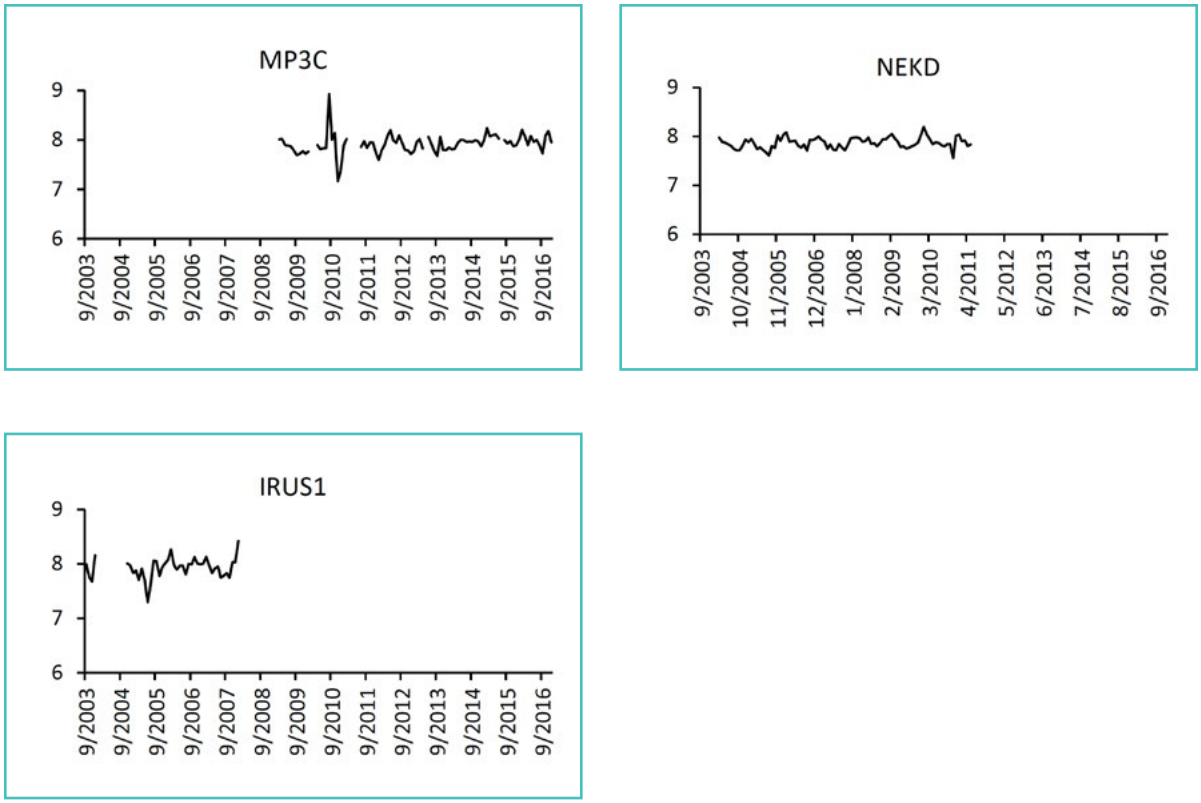

Figure 16. Average monthly pH recorded at MP3C (Charlotte Harbor AP), NEKD (Northeast Florida AP) and IRUS1 (Indian River Lagoon AP) water quality stations. These stations exhibited increasing long-term trends in pH. Breaks in data indicate missing and/or omitted data.

A sea star (Echinaster spinulosus) on a blade of seagrass in Estero Bay Aquatic Preserve.

Table 8. Summary statistics for pH collected by aquatic preserves staff at 28 continuous water quality stations in Florida.

Region	AP Office	Station	Station Code	N	Min	Median	Mean	Max
Northwest	Northwest	Yellow River Marsh AP1	YRMAP1	80628	5.60	7.60	7.60	8.90
	Central Panhandle	Richardson's Hammock	CPRH	92952	4.13	8.12	8.12	10.76
	Central Panhandle	Windmark	CPWM	15499	7.66	8.09	8.08	8.54
	Central Panhandle	Alligator Harbor	CPAH	13034	5.46	7.94	7.97	9.97
	Big Bend Seagrasses	Bennett Creek	BBSBC	31395	5.91	7.33	7.32	8.02
	Big Bend Seagrasses	Crystal River	BBSCR	NR	NR	NR	NR	NR
	Big Bend Seagrasses	Dekle Beach	BBSDB	250180	6.01	8.12	8.14	9.69
	Big Bend Seagrasses	Homosassa River	BBSHS	6555	7.09	8.04	7.95	8.51
	Big Bend Seagrasses	Kings Bay	BBSKB	231595	6.79	8.01	8.01	9.02
	Big Bend Seagrasses	Seahorse Key	BBSSK	168272	5.99	8.07	8.00	9.87
	Big Bend Seagrasses	Suwannee River	BBSSW	224730	5.74	7.63	7.58	9.11
	Big Bend Seagrasses	Withlacoochee	BBSWT	NR	NR	NR	NR	NR
Southwest	Tampa Bay	Bishop Harbor	TCBH	8306	7.45	8.10	8.10	8.66
	Tampa Bay	Frog Creek	TCFC	15152	6.14	7.40	7.37	8.07
	Charlotte Harbor	Matlacha Pass 1A	MP1A	370338	5.590	7.57	7.55	8.89
	Charlotte Harbor	Matlacha Pass 2B	MP2B	330236	4.66	8.01	8.00	9.73
	Charlotte Harbor	Matlacha Pass 3C	MP3C	209747	6.83	7.92	7.92	9.24
	Estero Bay	Tom Winter	EB01	366740	6.53	7.95	7.95	9.10
	Estero Bay	Spring Creek	EB02	290190	6.75	8.05	8.06	9.07
	Estero Bay	Fish Trap Bay	EB03	345441	5.50	7.96	7.96	9.17
Northeast	Northeast	Clapboard Creek	NECC	105500	5.75	7.40	7.41	8.53
	Northeast	Lofton Creek	NELC	96484	5.80	7.47	7.43	8.22
	Northeast	Kingsley Plantation	NEKD	113471	6.94	7.89	7.87	8.53
	Northeast	Nassau River	NENR	31438	5.69	7.10	7.06	7.99
	Indian River Lagoon	C-54 Canal / Fellsmere Canal	IRC54	24624	6.56	7.68	7.67	9.75
	Indian River Lagoon	Donald McDonald / South Prong	IRDM	38184	6.16	7.63	7.61	9.02
	Indian River Lagoon	North Prong	IRNP	51141	6.16	7.48	7.45	9.06
	Indian River Lagoon	US1/Main Drainage Basin	IRUS1	51259	4.68	7.95	7.91	9.39

Table 9. Long-term trends in pH collected at 28 continuous water quality stations in Florida. Long-term trends were determined using the Seasonal Mann-Kendall Test. Estimated slopes use Hirsch et al.'s modification of the Theil/Sen Estimator and the estimated Confidence Intervals use Gilbert's modification of the Theil/Sen method. Datasets that contained a minimum of three consecutive years were analyzed for significant ($p<0.05$) increasing or decreasing trends based on all available data for pH. Stations that did not include sufficient data are reported as No Result (NR).

AP Office	Station Code	Heterogeneity Test			Trend Test				
		Code	df	p	τ	Slope	95% CI	z	p
Northwest	YRMAP1	7.277	11	0.776	-0.200	-0.094	[-0.311, 0.025]	-0.778	0.437
Central Panhandle	CPRH	3.223	11	0.987	-0.245	-0.036	[-0.067, -0.008]	-2.318	0.020
Central Panhandle	CPWM	NR	NR	NR	NR	NR	NR	NR	NR
Central Panhandle	CPAH	NR	NR	NR	NR	NR	NR	NR	NR
Big Bend Seagrasses	BBSBC	0.000	1	1.000	1.000	1.062	NA	0.707	0.480
Big Bend Seagrasses	BBSCR	NR	NR	NR	NR	NR	NR	NR	NR
Big Bend Seagrasses	BBSDB	9.109	11	0.612	-0.272	-0.022	[-0.039, -0.010]	-3.486	0.000
Big Bend Seagrasses	BBSHS	NR	NR	NR	NR	NR	NR	NR	NR
Big Bend Seagrasses	BBSKB	4.737	11	0.943	-0.204	-0.017	[-0.029, -0.006]	-2.673	0.001
Big Bend Seagrasses	BBSSK	4.151	11	0.097	-0.367	-0.036	[-0.056, -0.018]	-4.065	0.000
Big Bend Seagrasses	BBSSW	5.014	11	0.930	-0.289	-0.056	[-0.091, -0.018]	-3.144	0.001
Big Bend Seagrasses	BBSWT	NR	NR	NR	NR	NR	NR	NR	NR
Tampa Bay	TCBH	NR	NR	NR	NR	NR	NR	NR	NR
Tampa Bay	TCFC	NR	NR	NR	NR	NR	NR	NR	NR
Charlotte Harbor	MP1A	5.805	11	0.886	-0.108	-0.006	[-0.011, 0.001]	-1.727	0.084
Charlotte Harbor	MP2B	7.774	11	0.733	0.091	0.006	[-0.002, 0.010]	1.354	0.176
Charlotte Harbor	MP3C	11.125	11	0.433	0.348	0.025	[0.014, 0.038]	3.765	0.000
Estero Bay	EB01	8.405	11	0.677	0.127	0.004	[-0.000, 0.010]	1.917	0.055
Estero Bay	EB02	8.344	11	0.682	0.107	0.003	[-0.001, 0.007]	1.400	0.162
Estero Bay	EB03	16.782	11	0.114	0.032	0.001	[-0.004, 0.005]	0.440	0.660
Northeast	NECC	11.819	11	0.377	0.370	0.294	[0.014, 0.045]	3.955	0.000
Northeast	NELC	5.750	11	0.890	0.006	0.000	[-0.015, 0.027]	0.000	1.000
Northeast	NEKD	7.167	11	0.785	0.200	0.008	[0.000, 0.016]	2.132	0.033
Northeast	NENR	3.6000	9	0.936	0.800	0.178	[0.048, 0.572]	2.214	0.027
Indian River Lagoon	IRC54	8.727	10	0.558	-0.455	-0.051	[-0.395, 0.020]	-1.206	0.228
Indian River Lagoon	IRDM	10.879	10	0.367	0.146	0.015	[-0.112, 0.182]	0.449	0.654
Indian River Lagoon	IRNP	13.904	11	0.238	-0.312	-0.064	[-0.092, -0.011]	-2.406	0.016
Indian River Lagoon	IRUS1	13.769	11	0.246	0.147	0.011	[-0.016, 0.080]	1.085	0.278

Turbidity

Twenty-six of the 28 continuous water quality monitoring stations collected turbidity data with varying data collection periods (Table 1). Turbidity data was not collected at two stations managed by Big Bend Seagrasses AP, BBSCR and BBSWT.

Mean turbidity values ranged from 4.02 NTU to 24.99 NTU at the 26 stations. BBSKB (Big Bend Seagrasses AP) had the lowest mean value (4.0 NTU) and NENR (Northeast Florida AP) had the highest (25.0 NTU). All 26 stations that collected turbidity data had minimum values near 0 NTU. Fifteen monitoring stations — YRMAP1 (Northwest Florida AP); BBSBC (Big Bend Seagrasses AP); BBSSK (Big Bend Seagrasses AP); CPAH (Central Panhandle AP); CPWM (Central Panhandle AP); CPAH (Central Panhandle AP); MP1A (Charlotte Harbor AP); MP2B (Charlotte Harbor AP); MP3C (Charlotte Harbor AP); TCBH (Tampa Bay AP); TCFC (Tampa Bay AP); EB03 (Estero Bay AP); NECC (Northeast Florida AP); NEKD (Northeast Florida AP); and NELC (Northeast Florida AP) — had maximum turbidity values greater than 500. The lowest maximum turbidity value (142 NTU) was observed at BBSHS station (Big Bend Seagrasses AP) (Table 6).

Six stations exhibited statically significant long-term trends ($p<0.05$), but long-term trends were not observed at 13 stations. Two stations IRNP (Indian River Lagoon AP) and BBSSW (Big Bend Seagrasses AP) indicated decreasing trends in turbidity, while four stations — MP1A (Charlotte Harbor AP), EB01 (Estero Bay AP), BBSDB (Big Bend Seagrasses AP) and IRUS1 (Indian River Lagoon AP) — showed increasing trends in turbidity (Table 6).

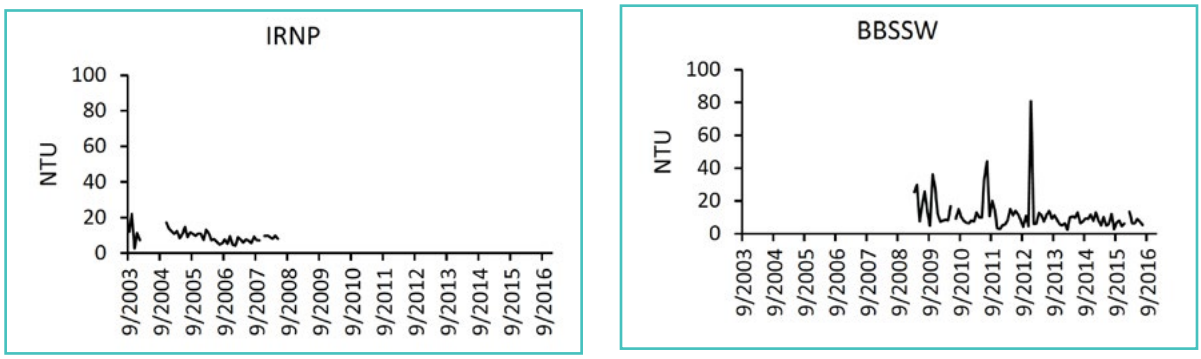

Figure 17. Average monthly turbidity recorded at IRNP (Indian River Lagoon AP) and BBSSW (Big Bend Seagrasses AP) water quality stations. These stations exhibited decreasing long-term trends in turbidity. Breaks in data indicate missing and/or omitted data.

A bay scallop (Argopecten irradians) in St. Joseph Bay Aquatic Preserve.

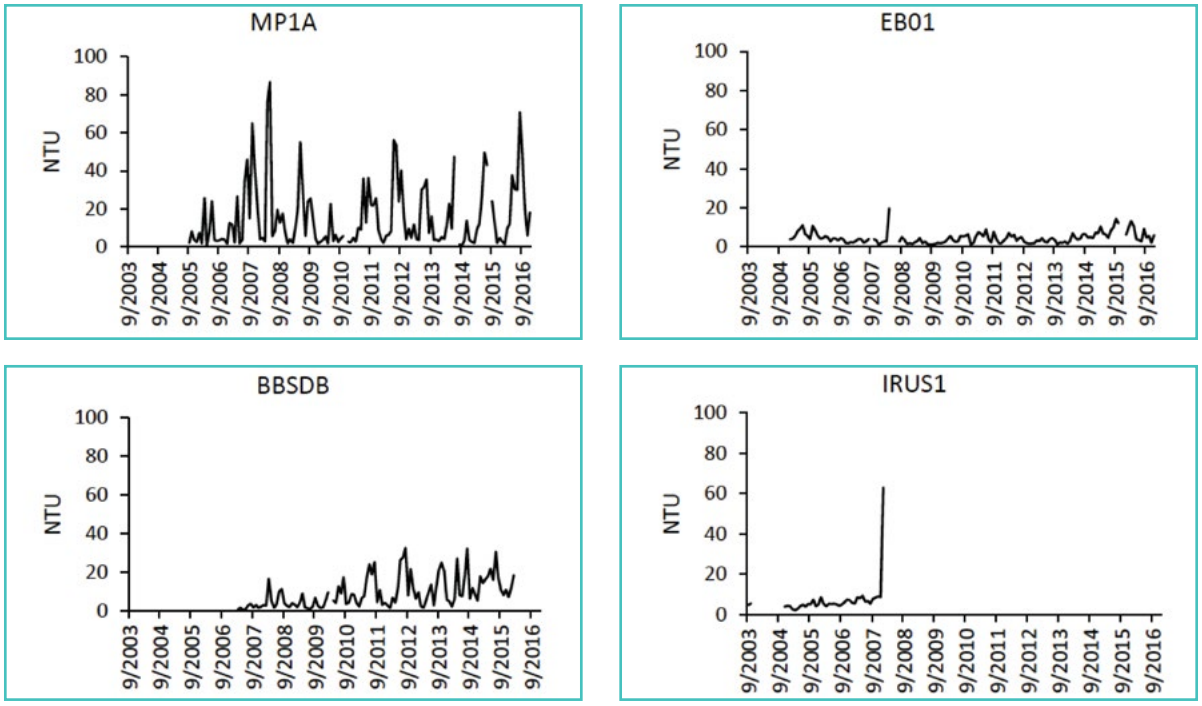

Figure 18. Average monthly turbidity recorded at MP1A (Charlotte Harbor AP), EB01 (Estero Bay AP), BBSDB (Big Bend Seagrasses AP), and IRUS1 (Indian River Lagoon AP) water quality stations. These stations exhibited increasing long-term trends in turbidity. Breaks in data indicate missing and/or omitted data.

A red mangrove growing on an oyster bar in Estero Bay Aquatic Preserve.

Table 10. Summary statistics for pH collected by aquatic preserves staff at 28 continuous water quality stations in Florida.

Region	AP Office	Station	Station Code	N	Min	Median	Mean	Max
Northwest	Northwest	Yellow River Marsh AP1	YRMAP1	98950	0.3	6.9	13.1	629.3
	Central Panhandle	Richardson's Hammock	CPRH	48559	0.0	1.1	4.1	816.2
	Central Panhandle	Windmark	CPWM	11426	0.0	2.10	4.5	912.1
	Central Panhandle	Alligator Harbor	CPAH	12448	0.0	10.2	18.1	998.9
	Big Bend Seagrasses	Bennett Creek	BBSBC	16607	0.0	4.8	11.4	955.9
	Big Bend Seagrasses	Crystal River	BBSCR	NR	NR	NR	NR	NR
	Big Bend Seagrasses	Dekle Beach	BBSDB	212168	0.0	1.6	9.5	150.0
	Big Bend Seagrasses	Homosassa River	BBSHS	6229	0.0	2.2	4.5	142.0
	Big Bend Seagrasses	Kings Bay	BBSKB	237595	0.0	1.9	4.0	149.7
	Big Bend Seagrasses	Seahorse Key	BBSSK	164128	0.0	5.3	15.1	999.2
	Big Bend Seagrasses	Suwannee River	BBSSW	202050	0.0	5.9	11.6	150.0
	Big Bend Seagrasses	Withlacoochee	BBSWT	NR	NR	NR	NR	NR
Southwest	Tampa Bay	Bishop Harbor	TCBH	8263	0.1	2.2	5.7	995.3
	Tampa Bay	Frog Creek	TCFC	13701	0.9	7.6	15.1	999.8
	Charlotte Harbor	Matlacha Pass 1A	MP1A	388660	0.3	6.9	13.1	629.3
	Charlotte Harbor	Matlacha Pass 2B	MP2B	310092	0.0	1.4	9.0	999.2
	Charlotte Harbor	Matlacha Pass 3C	MP3C	206371	0.0	1.5	5.3	999.1
	Estero Bay	Tom Winter	EB01	328524	0.0	3.2	4.6	340.1
	Estero Bay	Spring Creek	EB02	209827	0.0	4.3	9.2	490.7
	Estero Bay	Fish Trap Bay	EB03	267245	0.0	5.6	8.4	947.8
Northeast	Northeast	Clapboard Creek	NECC	112012	0.0	4.5	5.6	796.0
	Northeast	Lofton Creek	NELC	96144	0.0	14.6	18.8	981.2
	Northeast	Kingsley Plantation	NEKD	113945	0.0	4.3	7.8	999.5
	Northeast	Nassau River	NENR	31087	2.0	20.6	25.0	160.0
	Indian River Lagoon	C-54 Canal / Fellsmere Canal	IRC54	24960	0.0	4.6	7.9	149.7
	Indian River Lagoon	Donald McDonald / South Prong	IRDM	39116	0.0	5.4	8.9	201.0
	Indian River Lagoon	North Prong	IRNP	51257	0.0	7.5	9.5	183.0
	Indian River Lagoon	US1/Main Drainage Basin	IRUS1	49506	0.0	4.5	5.9	149.9

Table 11. Long-term trends in turbidity collected at 28 continuous water quality stations in Florida. Long-term trends were determined using the Seasonal Mann-Kendall Test. Estimated slopes use Hirsch et al.'s modification of the Theil/Sen Estimator and the estimated Confidence Intervals use Gilbert's modification of the Theil/Sen method. Datasets that contained a minimum of three consecutive years were analyzed for significant ($p<0.05$) increasing or decreasing trends based on all available data for turbidity. Stations that did not include sufficient data are reported as No Result (NR).

AP Office	Station Code	Heterogeneity Test			Trend Test				
		Code	df	p	τ	Slope	95% CI	z	p
Northwest	YRMAP1	17.727	11	0.088	-0.167	-0.474	[-3.162, 2.222]	-0.754	0.451
Central Panhandle	CPRH	9.692	11	0.558	0.143	0.108	[-0.038, 0.236]	1.292	0.196
Central Panhandle	CPWM	NR	NR	NR	NR	NR	NR	NR	NR
Central Panhandle	CPAH	NR	NR	NR	NR	NR	NR	NR	NR
Big Bend Seagrasses	BBSBC	9.600	9	0.384	-0.200	-2.092	[-16.231, 5.689]	-0.316	0.752
Big Bend Seagrasses	BBSCR	NR	NR	NR	NR	NR	NR	NR	NR
Big Bend Seagrasses	BBSDB	2.526	11	0.996	0.493	1.279	[0.886, 1.839]	6.368	0.000
Big Bend Seagrasses	BBSHS	NR	NR	NR	NR	NR	NR	NR	NR
Big Bend Seagrasses	BBSKB	2.585	11	0.995	-0.088	-0.054	[-0.156, 0.039]	-1.155	0.248
Big Bend Seagrasses	BBSSK	6.177	11	0.861	0.114	0.308	[-0.094, 0.653]	1.320	0.187
Big Bend Seagrasses	BBSSW	10.763	11	0.463	-0.332	-0.982	[-1.676, -0.446]	-3.797	0.000
Big Bend Seagrasses	BBSWT	NR	NR	NR	NR	NR	NR	NR	NR
Tampa Bay	TCBH	NR	NR	NR	NR	NR	NR	NR	NR
Tampa Bay	TCFC	NR	NR	NR	NR	NR	NR	NR	NR
Charlotte Harbor	MP1A	14.749	11	0.194	0.134	0.248	[0.009, 0.675]	1.991	0.046
Charlotte Harbor	MP2B	16.499	11	0.124	-0.021	-0.020	[-0.147, 0.140]	-0.193	0.847
Charlotte Harbor	MP3C	11.361	11	0.413	-0.136	-0.122	[-0.315, 0.017]	-1.474	0.140
Estero Bay	EB01	4.146	11	0.965	0.154	0.149	[0.018, 0.240]	2.374	0.018
Estero Bay	EB02	7.931	11	0.719	0.007	0.010	[-0.374, 0.274]	0.036	0.972
Estero Bay	EB03	6.847	11	0.811	0.086	0.095	[-0.086, 0.279]	1.178	0.239
Northeast	NECC	6.450	11	0.842	0.047	0.059	[-0.199, 0.382]	0.318	0.750
Northeast	NELC	6.348	11	0.849	0.158	0.629	[-0.152, 1.674]	1.435	0.151
Northeast	NEKD	4.734	11	0.943	0.036	0.046	[-0.344, 0.377]	0.328	0.743
Northeast	NENR	8.400	9	0.494	0.400	6.152	[-1.940, 12.058]	0.949	0.343
Indian River Lagoon	IRC54	8.032	9	0.531	-0.333	-0.753	[-5.630, 1.563]	-0.843	0.399
Indian River Lagoon	IRDM	15.011	10	0.132	0.051	-1.123	[-2.564, 1.482]	-0.145	0.884
Indian River Lagoon	IRNP	3.771	11	0.976	-0.370	-1.200	[-1.580, -0.333]	-2.300	0.021
Indian River Lagoon	IRUS1	1.775	11	0.999	0.865	1.411	[0.827, 1.809]	5.242	0.000

Discussion

These continuous water quality data are essential for the continued assessment of and response to environmental issues. Estuarine data (water temperature, salinity, dissolved oxygen, pH and turbidity) can be compared to various biological parameters to develop assessment indicators that lead to more informed management of Florida's estuarine habitats. The data also provide insight into cumulative and secondary impacts of activities surrounding coastal resources.

Water temperature is a key indicator for determining the health of an estuary. Many aquatic organisms thrive in specific temperature ranges, and temperature affects the amount of dissolved oxygen in the water and rates of photosynthesis. Increasing water temperature for long periods of time can negatively impact life in the estuary by causing harmful algal blooms. Changes in water temperature also can lead to changes in reproduction and migration for many aquatic species. Water temperature was one of the most commonly measured parameters collected by the aquatic preserves (all 28 AP stations). Overall, water temperature was directly influenced by air temperature, with the lowest water temperatures during the winter season and highest during the summer. Three stations exhibited significant long-term trends ($p<0.05$) in water temperature: BBSSK (Big Bend Seagrasses AP) and EB01 and EB02 (Estero Bay AP). BBSSK exhibited a strong negative trend while EB01 and EB02 exhibited a statistically significant increasing trend.

Salinity is often highly variable in an estuary because of tidal effects, weather events, and from variations in inputs from freshwater sources like creeks and rivers. However, as with water temperature, aquatic organisms can tolerate ranges in salinity only as defined by their species. If conditions occur outside their normal range for extended periods of time, stress or death can follow. Therefore, salinity is one of the many water quality parameters that can enhance our understanding of drivers that influence the health and condition of an estuary.

All 28 continuous water quality monitoring stations collected salinity data. Sixteen stations exhibited significant long-term trends ($p<0.05$) in salinity. Eleven stations exhibited significant decreasing trends: six stations managed by Big Bend Seagrasses AP (BBSBC, BBSCR, BBSDB, BBSHS, BBSSK, BBSSW); three stations managed by Charlotte Harbor AP (MP1A, MP2B, MP3C); and two stations managed by Estero Bay AP (EB01 and EB03). Six stations exhibited significant increasing trends: three stations managed by Northeast Florida AP (NECC, NEKD and NENR) and two stations managed by Indian River Lagoon APs (IRNP and IRUS1). Interestingly, the 11 stations that exhibited long-term decreasing trends in salinity were stations located in the northwest and southwest regions of Florida along the Gulf Coast. The five stations that experienced increasing trends in salinity were in the northeast region of Florida along the Atlantic Coast. More information is needed to support these observed regional differences. A more comprehensive synthesis will be performed in the SEACAR Assessment Report.

Dissolved oxygen concentrations are another valuable indicator in determining estuary health. Concentrations generally vary throughout the day due to photosynthesis, respiration and decomposition. Concentrations also vary seasonally as concentrations are generally higher in the winter months and lower in the summer months because of seasonal changes in water temperature. Maintaining consistency with the NERR SWMP, dissolved oxygen concentrations below 4 mg/L are considered hypoxic and can be stressful to marine life if DO levels remain low for prolonged periods of time.

All 25 of the stations that collected DO data had minimum DO concentrations in hypoxic range. One station, TCFC (Tampa Bay AP), had mean DO concentrations below 4 mg/L, with the lowest average at 1.58 mg/L.

Four stations exhibited long-term trends in DO concentrations. Two stations BBSSK (Big Bend Seagrasses APs) and EB03 (Estero Bay AP) exhibited statistically significant increasing trends in DO concentrations, while two stations, NELC (Northeast Florida AP) and IRNP (Indian River Lagoon AP), exhibited decreasing trends (Table 4).

pH is another water quality parameter that varies in an estuary. As with the other measured parameters in this report, aquatic organisms can tolerate ranges in pH only as defined by their species. Seven continuous water quality stations — CPRH (Central Panhandle AP); MP2B (Charlotte Harbor AP); IRUS1 (Indian River Lagoon AP); CPAH (Central Panhandle AP); EB03 (Estero Bay AP); BBSSK (Big Bend Seagrasses AP); and EB03 (Estero Bay AP) — had minimum pH values that were less than 6.00 and maximum pH values greater than 9.00. If pH levels fall below 6.0 or rise above 9.0 for extended periods of time, stress occurs in many aquatic organisms.

Nine stations exhibited statistically significant long-term trends in pH. Six stations total indicated decreasing long-term trends in pH – BBSDB, BBSKB, BBSSK, BBSSW (Big Bend Seagrasses AP), NECC (Northeast Florida AP) and IRNP (Indian River Lagoon AP). Three stations – MP3C (Charlotte Harbor AP), NEKD (Northeast Florida AP) and IRUS1 (Indian River Lagoon AP) – showed increasing trends in pH.

Turbidity measures the amount of suspended particles in the water and gives insight into how easily light can be transmitted through the water column; thus turbidity is another valuable indicator of estuary health. Areas that experience high amounts of runoff or algae can have increased turbidity levels, which decrease the amount of sunlight that can pass through the water column, negatively impacting aquatic plants like seagrasses.

Six stations exhibited statistically significant long-term trends. IRNP (Indian River Lagoon AP) and BBSSW (Big Bend Seagrasses AP) indicated decreasing trends in turbidity, while four stations – MP1A (Charlotte Harbor AP), EB01 (Estero Bay AP), BBSDB (Big Bend Seagrasses AP) and IRUS1 (Indian River Lagoon AP) – showed increasing trends in turbidity.

Increases in turbidity can result in less light penetration through the water column and can hinder photosynthesis, which is necessary for healthy aquatic plant growth and production of dissolved oxygen. Most of the aquatic preserves have active seagrass monitoring programs, including the four aquatic preserve offices (Charlotte Harbor, Estero Bay, Big Bend Seagrasses and Indian River Lagoon) that saw increasing long-term trends in turbidity. These stations could be negatively impacted by increasing long-term trends in turbidity and should continue assessing turbidity and its relationship to trends in seagrass health moving forward.

Conclusions

For more than a decade, the APs have been collecting high temporal continuous water quality data in three regions of Florida: northwest, southwest and northeast. Large datasets such as the AP continuous water quality data have enormous potential to support integrative state-wide assessments. Key water quality parameters (water temperature, salinity, dissolved oxygen, pH and turbidity) were analyzed for long-term trends. Significant trends were identified in all the water quality parameters.

The Florida Coastal Water Quality Assessment and Integration Project was successful in achieving many recommendations made by the CDMO. The project developed a statewide data collection and dissemination framework for the Florida Aquatic Preserves Continuous Water Quality Monitoring Program, making it consistent with the NERRS SWMP. Data collected by eight AP offices – Northwest Florida, Central Panhandle, Big Bend Seagrasses, Tampa Bay, Charlotte Harbor, Estero Bay, Northeast Florida and Indian River Lagoon – at 28 fixed continuous water quality stations were evaluated, and over 4.25 million data records passed the data quality assessments and are stored in a relational database that serves as the backbone for the web-based data portal. The data portal includes a map-based interface that enables spatial visualization of the data and provides access to the AP data through a publicly accessible data portal, www.FloridaAPData.org. RCP also established a continuous water quality data coordinator to assist with performing data management as these programs continue and expand.

Next Steps

The Florida aquatic preserves database currently houses continuous water quality data records ranging from 2003 to 2017, with much of the data ending in 2016. Efforts are being made to evaluate and incorporate more recent and current data collected by the AP offices. This data was not included in the project and needs to be processed through data management procedures to be incorporated into the database, making them available for download through the data portal. Additionally, the AP water quality program has expanded to include two new stations (BBSCH and BBSST) managed by Big Bend Seagrasses AP; three new stations (BBLR03, BBBB14 and BBJT71) managed by Biscayne Bay AP; and two new stations (CPAH2 and CPFS) managed by Central Panhandle AP. Incorporating this new data into the data portal is also a priority.

Plans also include adding data identity fields (provisional, provisional plus and authenticated) to the current data, as well as the new data, to make the data more compatible with the CDMO data portal; improving the availability of the AP data; improving the data portal import and upload options; enhancing data graphing capabilities; and enhancing the overall usability and accessibility of the data portal.

The Office of Resilience and Coastal Protection will develop a water quality technician certification training for AP staff. The training will be held in Florida and will provide a curriculum consistent with the annual NERRS SWMP technician training hosted
by CDMO.

The continuous water quality data collected by the AP is in the process of being combined with the Florida NERRS data and incorporated into the SEACAR assessment report. The statewide assessment of water quality can contribute to research-based understanding of the health of Florida's estuarine habitats and help guide management to protect them for the benefit of future generations.

A school of sardines swimming over seagrasses.

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Red mangroves in Rookery Bay Aquatic Preserve.