Data Discovery for a Meta-Analysis of Water Quality, Fish, and Benthic Data within the Kristin Jacobs Coral Reef Ecosystem Conservation Area

Florida Department of Environmental Protection
Coral Reef Conservation Program

Southeast Florida Coral Reef Initiative

Fishing, Diving, and Other Uses Focus Area
Local Action Strategy Project #51

Data Discovery for a Meta-Analysis of Water Quality, Fish, and Benthic Data within the Kristin Jacobs Coral Reef Ecosystem Conservation Area

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Executive Summary

The Southeast Florida Coral Reef Ecosystem Conservation Area was officially established on July 1, 2018, and was subsequently renamed the Kristin Jacobs Coral Reef Ecosystem Conservation Area (Coral ECA) on July 1, 2021. The Coral ECA includes the sovereign submerged lands and state waters offshore of Martin, Palm Beach, Broward and Miami-Dade Counties from the St. Lucie Inlet in Martin County, to the northern boundary of the Biscayne National Park in the south. The Southeast Florida Coral Reef Initiative (SEFCRI) was formed in 2003 and includes a SECFRI Team composed of 64 Coral ECA stakeholders tasked with developing local action strategies (LAS) to protect the coral reef resources in the region. These LAS are short-term, locally driven projects for cooperative action among federal, state, and non-governmental partners that identify and implement priority actions needed to assess or reduce key threats to coral reef resources in the Coral ECA. The SEFCRI Team identified five focus areas for immediate local action to address threats to the Coral ECA that included (*i*) land-based sources of pollution (LBSP), (*ii*) maritime industry and coastal construction impacts, (*iii*) fishing, diving, and other uses (FDOU), (*iv*) lack of awareness and appreciation, and (*v*) reef resilience.

One of those LAS projects is FDOU-51, *A Meta-Analysis of Water Quality, Fish, and Benthic Data*. Numerous recurring monitoring programs exist within the Coral ECA, collecting data on either water quality, fish, or benthic habitats and organisms, and the ultimate goal of FDOU-51 is to conduct some form of holistic or meta-analysis of these data to identify patterns and trends within them. Additionally, this project seeks to frame these analyses within the scope of selected resource management and research priorities, and it will identify knowledge gaps within the Coral ECA to help better inform future data collection, survey, or monitoring efforts. This report for FDOU-51 is limited to the initial data discovery aspect of this project.

An extensive review and metadata collection effort was undertaken for FDOU-51 in order to identify data related to three specific components that form the Coral ECA – the water quality, fish, and benthic habitat subsystems. In each case, data that were collected throughout the full spatial extent of the management area were prioritized, as were those programs that maintain a relatively long-term time series of data, and which have funding in place to continue their collection efforts at this time. These constraints were required in order to facilitate the ultimate objective of FDOU-51 which is to uncover and describe long-term and/or large-scale patterns and trends within the Coral ECA and its constituent parts. Thus, in addition to meeting these spatiotemporal prerequisites, comprehensive survey and monitoring programs with robust experimental designs that can accommodate inquiries at the scale of the Coral ECA were also desirable.

The water quality subsystem is an integral part of the Coral ECA, and the mechanisms that influence it are not limited to those activities that take place within the marine environment. It is important to understand both the aquatic and terrestrial elements that can affect water quality including, sedimentation and construction impacts, freshwater inputs, nutrients and toxicological fluxes, pathogenic and microbial inhabitants, chemical concentrations, and various other pollutants (e.g., petroleum-based inputs from boating). In addition to understanding these critical inputs, it is also important to account for the physical locations of sources (e.g., sewage outfalls, inlet contributing areas), and the hydrological conditions of the environments into which they are introduced.

Two programs monitor and survey a number of water quality attributes *in situ*, the Coral Ecosystem Conservation Area Water Quality Assessment (ECA-WQA) and the National Coral Reef Monitoring Program (NCRMP). The ECA-WQA uses a fixed monitoring design and focuses on inlet canals and sewage outfalls, but NCRMP employs a random stratified experimental design, and both programs survey the entire extent of the Coral ECA. Additionally, the U.S. Environmental Protection Agency maintains their STOrage and RETrieval (STORET) data warehouse, and DEP also coordinates another statewide warehouse called the Water Information Network (WIN). Both STORET and WIN house a variety of monitoring programs' and research investigations' water quality data outputs, and together with the regular data collected by the ECA-WQA and NCRMP, a relatively comprehensive collection of parameters covering large areas and temporal ranges can be obtained for the Coral ECA. Additionally, other programs compile water quality data related to LBSP as well as detailed hydrological information, such as the U.S. Geological Survey (USGS)'s National Water Information Network (NWIS) and the South Florida Water Management District (SFWMD)'s hydrological database, DBHYDRO.

The fish subsystem is a very important subsystem in the Coral ECA due not only to its biological and ecological impact, but also due to the socioeconomic implications of the resource. Fish and fishing play an oversized role in the food, tourism, and recreation industries of Florida, and to some degree have become a part of the cultural identity of the region. Thus, there are many and varied reasons to monitor and maintain these important marine resources sustainably. The Coral ECA has only one fisheries independent monitoring (FIM) program that operates within its boundaries – NCRMP. These data are useful and relatively comprehensive, although the bi-annual survey schedule is not idea. The NCRMP program performs visual censuses of fish in a randomly stratified sampling design employed to characterize the community composition and abundance of reef fish species residing with the Coral ECA in water < 30 m deep. In addition, these efforts are performed in conjunction with the NCRMP water sampling (described above) and their benthic sampling (described below), and NCRMP is the only program with the distinction of surveying all three Coral ECA subsystems identified for this FDOU-51 project.

On the other hand, fisheries dependent monitoring (FDM) programs are numerous within the Coral ECA, but they are spatially limited due the reporting resolution of available data (e.g., county-level, aggregated by legal reporting area). One commercial FDM program that provides data which may be useful to researchers is the Accumulative Landings System (ALS) that includes the Florida State Trip Ticket Program and a cooperative effort between the National Oceanic and Atmospheric Administration (NOAA) and the Florida Fish and Wildlife Conservation Commission (FWC) called the Trip Interview Program (TIP). Together, the Trip Ticket Program and TIP collect information about the catch and effort related to the landed (and discarded) specimens, and they record more detailed meristic information about the size and weight as well.

Recreational FDM data are available through several programs and they collect data regarding headboat, charter for-hire, private, and shore-based angling modes. In most cases both biological samples and interview-based trip data are collected. Biological data focuses on otoliths, tissue samples, and other fish parts, along with meristic measurements such as length and weight, and because these FDM programs are typically fisheries-management focused, they also often collect (or model) data related to sex, fecundity, and population growth factors for various target species and managed populations to inform their life history characteristics. In the Coral ECA, the Southeast Regional Headboat Survey (SRHS) and the Marine Recreational Information Program (MRIP) – itself comprising the Florida For-Hire Survey (FHS) and the Access Point Angler Intercept Survey (APAIS) – regularly capture recreational fishing data for management decision making. In addition, the FWC At-Sea Observer Program (ASOP) also collects data by placing trained observers on headboats and charter boats to record the on-water activities that account for recreational removals. These data are often more spatially resolved and can usually be assigned to specific geographic coordinates where the fishing events occurred. The ASOP observers record species and meristic data for all fish captured, and they also obtain data from a subset of anglers related to hook type, size, and placement.

The benthic subsystem in the Coral ECA is the subsystem that precipitated the creation of SEFCRI and represents a prized resource for the region given that it includes the northern portion of the Florida Reef Tract (FRT). The FRT is a known socioeconomically and ecologically important factor for the state of Florida and its coastal and marine habitats, and it is arguably even more ingrained into the cultural identity of south and southeastern Florida than fish and fishing were described to be above. The importance of the coral reef ecosystem to the region cannot be overstated. Thus, it is encouraging that three different monitoring programs regularly survey and census the coral reefs and other benthic hardbottom habitats within the Coral ECA, the Southeast Coral Reef Evaluation and Monitoring Project (SECREMP; annual sampling), Disturbance Response Monitoring (DRM; annual), and NCRMP (bi-annual). SECREMP samples 22 fixed monitoring sites

(< 20 m deep) across the entire Coral ECA, while both DRM (< 20 m) and NCRMP (< 30 m) employ larger sample sizes and randomly stratified experimental designs.

All three programs perform extensive coral demographic surveys and capture detailed information about species present (adults and juveniles), size, bleaching, disease (presence, type, and physical effects), and other predation and disturbance concerns. The DRM effort obtains a fair bit more detail about disease impacts since that is the primary focus of the program, while both DRM and NCRMP also include data collection about macroinvertebrates of concern (e.g., *Diadema antillarum*) and other Endangered Species Act listed coral species (e.g., *Acropora cervicornis*, *A. palmata*). Furthermore, SECREMP and NCRMP both perform image and line point-intercept surveys, respectively, to obtain information about the proportions of cover attributed to a variety of hardbottom categories including, coral *spp.*, algae, octocorals/gorgonians, sponges, sand, rubble, and others.

Together, these programs comprise the most comprehensive set of long-term and spatially large-scale efforts that collect data within the Coral ECA related to water quality, fish, and benthic habitats and organisms. They will be useful in fulfilling the goals of FDOU-51 to uncover the long-term and large-scale patterns and trends that underly the unique coral reef ecosystem, and its various subsystems and the components that define them. There are still data pretreatment and compatibility concerns that must be considered prior to analyses, however, and they are best addressed by first developing detailed definitions of the research questions that are important to managers and stakeholders. Once Coral ECA-related questions are defined, the data exploration process can begin, and this report will serve as a reference resource in that regard. Further, this document will help to resolve questions about the compatibility of various monitoring efforts' data products, and will aid in the analytical design and method selection processes for such efforts. Thus, this report completes the first step toward a holistic review of the water quality, fish, and benthic subsystems in the Coral ECA as defined by FDOU-51.

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This work was the product of collaboration among data providers and other stakeholders working throughout the Kristin Jacobs Coral Reef Ecosystem Conservation Area (Coral ECA). In particular, I would like to thank Katie Lizza, the Fishing, Diving, and Other Uses (FDOU) Coordinator from the Florida Department of Environmental Protection (DEP)'s Coral Reef Conservation Program who was immensely helpful in the organization of resources and logistics, as well as in the metadata collection effort, for this FDOU-51 project. Other DEP staff who were also instrumental to this review include Mollie Sinnott, Kristi Kerrigan, and Alycia Shatters. Additional thanks go out to the following people who took extra time to help describe various aspects of their data collection programs, and without which this compilation would not have been as detailed: Nick Alcaraz, Nicole Besemer, Sarah Groves, and Dominique Lazarre. Finally, I'd like to acknowledge the FDOU-51 Project Team who have provided advice and guidance along the way in preparation for this report as well as for all of the follow-up activities and collaborative meetings for FDOU-51. I truly appreciate all of the people that have helped bring this data discovery report together.

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List of Acronyms

ALS	Accumulative Landings System
APAIS	Access Point Angler Intercept Survey
ASOP	At-Sea Observer Program
BC	Broward County
CDOM	Chromophoric Dissolved Organic Matter
Coral ECA	Kristin Jacobs Coral Reef Ecosystem Conservation Area
CPUE	Catch per Unit Effort
CRCP	Coral Reef Conservation Program
CREMP	Coral Reef Evaluation and Monitoring Project
DBHYDRO	SFWMD Hydrographic Database
DC	Miami-Dade County
DEP	Florida Department of Environmental Protection
DNA	Deoxyribonucleic Acid
DPSER	Drivers, Pressures, States, Ecosystem Services, and Responses
DRM	Disturbance Response Monitoring
EBM	Ecosystem-Based Management
ECA-WQA	Coral Ecosystem Conservation Area Water Quality Assessment
eDNA	Environmental Deoxyribonucleic Acid
EPA	U.S. Environmental Protection Agency
FDM	Fisheries Dependent Monitoring
FDOU	Fishing, Diving and Other Uses
FDOU-51	FDOU LAS Project #51
FHS	For-Hire Survey
FIM	Fisheries Independent Monitoring
FRT	Florida Reef Tract
FWC	Florida Fish and Wildlife Conservation Commission
FWRI	FWC's Fish and Wildlife Research Institute
GIS	Geographic Information System

GPS	Geographic Positioning System
HAB	Harmful Algal Bloom Monitoring
HABMON	Harmful Algal Bloom Monitoring
HB	House Bill
ICA	Inlet Contributing Area
ID	Identification
LAS	Local Action Strategy
LBSP	Land-Based Sources of Pollution
LPI	Line Point-Intercept
MC	Martin County
MRFSS	Marine Recreational Fisheries Statistics Survey
MRIP	Marine Recreational Information Program
NCEI	NOAA National Centers for Environmental Information
NCRMP	National Coral Reef Monitoring Program
NOAA	National Oceanic and Atmospheric Administration
NRC	Nearshore Ridge Complex
NS&T	NOAA's National Status and Trends
NWIS	National Water Information System
OFR	Our Florida Reefs
PAHs	Polycyclic Aromatic Hydrocarbons
PB	Palm Beach County
PCBs	Polychlorinated Biphenyls
RVC	Reef Visual Census
SAV	Submerged Aquatic Vegetation
SCTLD	Stony Coral Tissue Loss Disease
SCUBA	Self-Contained Underwater Breathing Apparatus
SEACAR	Statewide Ecosystem Assessment of Coastal and Aquatic Resources
SECREMP	Southeast Florida Coral Reef Evaluation and Monitoring Project
SEFCRI	Southeast Florida Coral Reef Initiative
SFWMD	South Florida Water Management District
SRHS	Southeast Regional Headboat Survey
STORET	STOrage and RETreieval Data Warehouse
TIP	Trip Interview Program
USGS	U.S. Geological Survey
WIN	Water Information Network
WQP	Water Quality Portal
WQX	Water Quality Exchange

1. INTRODUCTION

1.1. Background

The Southeast Florida Coral Reef Ecosystem Conservation Area was officially established on July 1, 2018. HB 53 passed the House on Jan. 25, 2018, and subsequently passed the Senate on Feb. 7, 2018 (Florida-Senate 2018). This area was renamed the Kristin Jacobs Coral Reef Ecosystem Conservation Area (Coral ECA) on July 1, 2021, and includes the sovereign submerged lands and state waters offshore of Martin, Palm Beach, Broward and Miami-Dade Counties from the northern boundary of the Biscayne National Park in the south, to the St. Lucie Inlet in Martin County at the northern extent (Figure 1). Although this boundary was only recently established, collaborative action and research among marine resource professionals, scientists, and stakeholders from government agencies and other organizations has been ongoing within the Coral ECA at least since the formation of the Southeast Florida Coral Reef Initiative (SEFCRI) in 2003 (DEP 2004). The SEFCRI Team comprises 64 stakeholders and was formed to develop local action strategies (LAS) to protect the coral reef resources in the northern portion of the Florida Reef Tract (FRT) that spans approximately 160 km linear coastline (Finkl and Andrews 2008; Banks et al. 2007). These LAS are short-term, locally driven projects or roadmaps for cooperative action among federal, state, and non-governmental partners, which identify and implement priority actions needed to assess or reduce key threats to coral reef resources in the Coral ECA (DEP 2004). The Florida Department of Environmental Protection (DEP) Coral Reef Conservation Program (CRCP) was established in 2004 to support and manage the SEFCRI Team and overall progress towards completion of LAS projects (DEP 2004). The SEFCRI Team identified five focus areas for immediate local action to address threats to the Coral ECA that included (*i*) land-based sources of pollution (LBSP), (*ii*) maritime industry and coastal construction impacts, (*iii*) fishing, diving, and other uses (FDOU), (*iv*) lack of awareness and appreciation, and (*v*) reef resilience. Each of these focus areas have specific LAS projects that are implemented and managed by DEP coordinators within the CRCP.

1.2. Study Goals

One of those LAS projects is FDOU-51, *A Meta-Analysis of Water Quality, Fish, and Benthic Data*. Numerous recurring monitoring programs exist within the Coral ECA, collecting data on either water quality, fish, or benthic habitats and organisms, and the ultimate goal of FDOU-51 is to conduct some form of holistic or meta-analysis of these data to identify patterns and trends within them. Additionally, this project seeks to frame these analyses within the scope of selected resource management and research priorities, and it will identify knowledge gaps within the Coral ECA to help better inform future data collection or research and management efforts.

The first phase of FDOU-51 is directed toward data discovery and the scoping of priorities to be explored in the ultimate meta-analysis of the Coral ECA. The FDOU-51 team operated within the framework of conceptual models previously developed to describe the south Florida coastal ecosystem and its related subsystems (Fletcher et al. 2013), and attempted to incorporate aspects of ecosystem-based management (EBM; Christensen et al. 1996; Lubchenco & Sutley 2010) and the DPSER (drivers, pressures, states, ecosystem services, and responses) model for data organization (Bowen and Riley 2003; Tscherning et al. 2012; Kelble et al. 2013). Thus, the first action taken was to subdivide the Coral ECA into the three primary subsystems of interest to FDOU-51: (*i*) water quality, (*ii*) fishes, and (*iii*) benthic coral and hardbottom habitats. Next, a data discovery process was undertaken to catalog relevant data sources that could inform a meta-analysis of the Coral ECA to identify patterns and trends manifest over time and across the space designated to the conservation area.

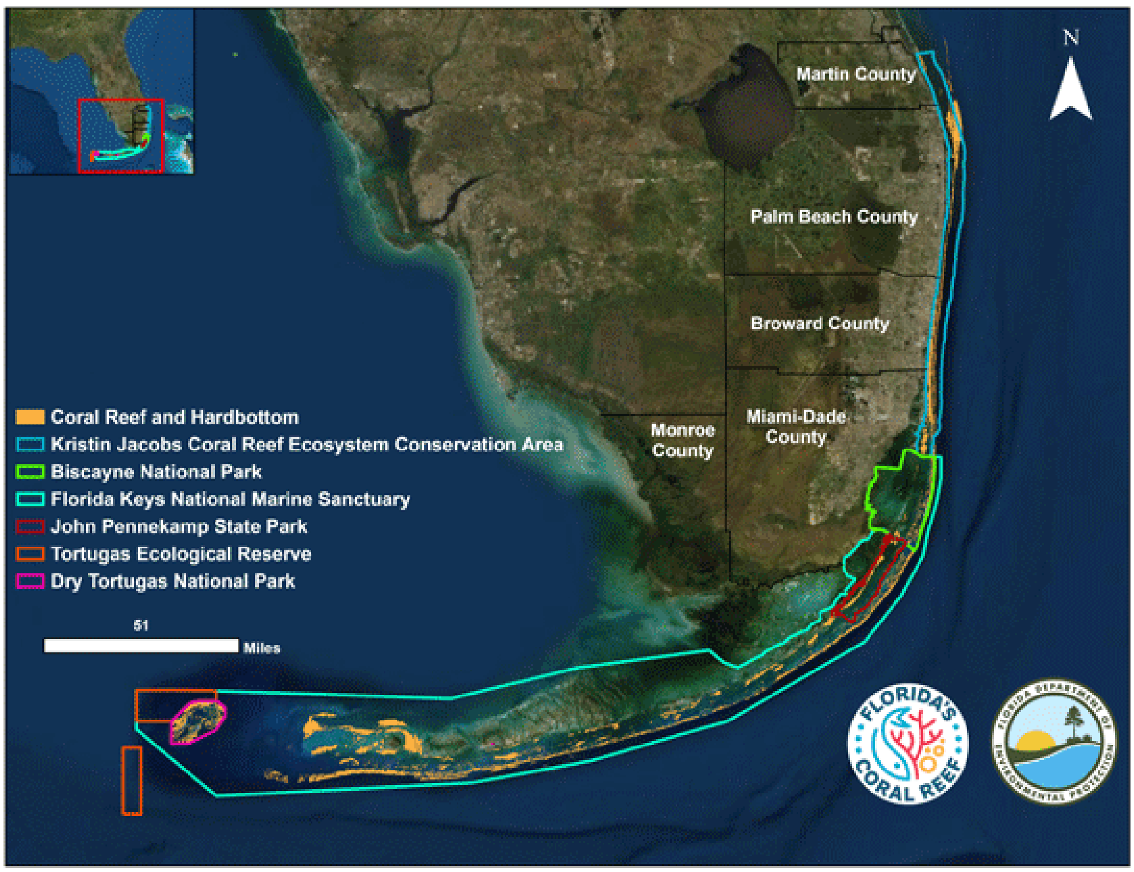

Figure 1. *Map of the Florida Reef Tract's Subdivisions.* The Kristin Jacobs Coral Reef Ecosystem Conservation Area (northern-most, dark blue outline) is the focus of this study.

While numerous scientific studies related to pertinent aspects of these subsystems have been undertaken within the boundaries of the Coral ECA, it was decided that priority would be given to data from contemporary monitoring programs with relatively long-term data series and funding in place to continue their efforts. This latter point is particularly useful for implementing recursive EBM protocols (Levin et al. 2009) that require regular updating based on the status of the system and the resources that comprise it (e.g., the Coral ECA). Another important aspect of the data discovery effort was attempting to incorporate as much work previously performed under DEP and/or SEFCRI leadership as possible. These over-arching constraints were hypothesized to be effective at filtering data collections that were either not focused on the Coral ECA as a holistic unit, or that did not persist long enough to be useful for future goal setting and management scoping efforts.

Finally, as this LAS project seeks to frame its analyses within the scope of specific (and as yet to be determined) resource management priorities, a review by FDOU-51 stakeholders of these data will clarify knowledge gaps within the Coral ECA that align with the stakeholders' priorities that can help guide future research, data collection, and management efforts. The stakeholder pool includes county, state, federal, and academic data providers, statistical experts, and resource managers, and the SEFCRI Project Team. The first phase of FDOU-51 will narrow the scope of work, prioritize the questions resource managers want answered, and lead to a meta-analysis framework to be used in the second phase of this project. The portion of *Phase-I* of FDOU-51 covered in this report is limited to the data discovery aspect of this project.

2. METHODS

2.1. Data Discovery

In order to obtain information about the relevant data streams within the Coral ECA, both direct and indirect contacts were made to numerous individuals and programs throughout the research and monitoring landscape. A fillable .pdf questionnaire was produced (Appendix A) to capture program- and attribute-level information, and which was also converted to an online form to ease respondents' reporting burden (https://survey.alchemer.com/s3/6700708/FDOU-51-Monitoring-Program-Survey-Effort-and-Data-Questionnaire). The data discovery questionnaire was directly emailed to 30 county, state, federal, and academic partners identified by the FDOU-51 team in conjunction with DEP Coordinators and Managers. For cases where monitoring databases were too complex to easily capture in our forms, one-on-one virtual meetings and phone calls were performed to obtain those programs' details. In addition to the direct email contacts and follow-up meetings, indirect efforts were also performed in the form of literature reviews and internet investigations.

2.1.1. Statewide Ecosystem Assessment of Coastal and Aquatic Resources

As previously mentioned, one of the priorities for this effort was to capture previous DEP-supported tools related to the Coral ECA where appropriate. Thus, the Statewide

Ecosystem Assessment of Coastal and Aquatic Resources (SEACAR; DEP 2016; SEACAR 2019) was employed for this project. The SEACAR database comprises 150+ individual programs that operated within the state of Florida and its coastal regions (some dating as far back as the 1940s) and the data discovery interface is searchable by management area, including the Coral ECA. Data collection for SEACAR prioritized five coastal habitats throughout Florida: (*i*) submerged aquatic vegetation (SAV), (*ii*) water column, (*iii*) coral/coral reef, (*iv*) oyster/oyster reef, and (*v*) coastal wetlands (e.g., salt marshes, mangroves). However, given the unique nature of the Coral ECA (i.e., an open-water coastal system within 3 nm of the coast) and the priorities of FDOU-51, much of the SAV, oyster, and wetlands data in SEACAR were not deemed germane to this project. Nevertheless, SEACAR was an excellent primary search tool for data related to this project.

Table 1. *Top-level metadata captured by FDOU-51.*

Attribute	Description
SubSystem	FDOU-51 subsystem assignment (benthic, fish, water quality)
ProgID	Published (or assigned) program/study acronym
Contact	Point(s) of contact
Program/Study	Official long-form name of long-term program or short-term study
Purpose	Stated purpose of data collection/monitoring effort
ProgStart	Start year
ProgEnd	Ending year (or "current" if ongoing)
Design	Description of sampling protocol, experimental design, and frequency of data capture
Extent	Description of spatial extent of the sampling area as related to the Coral ECA's spatial extent
Overlap	Description of overlap with other programs/studies
Format	Data format (e.g., .xlsx, .csv)
Archival	Archival methods and access protocol
Online	Binary value describing whether data are housed online (1) or not (0)
Website	URL(s) for data access and/or program information
Attributes	List of specific attributes measured by the program/study
Potential	Description of potential uses for data as given by point(s) of contact or published information
Notes	FDOU-51 team member notes
Citation	Recommended citation for the data/program/study

2.1.1. Metadata Compilation

All metadata was recorded in two separate Microsoft Excel workbooks (.xlsx format), one each for long- and short-term projects. In both cases, the same top-level data was requested and cataloged (Table 1). Where possible, additional metadata regarding each measured attribute was also collected (Table 2), but in some cases broad or general descriptions of an attribute were best suited for the task. For example, rather than listing each of the individual species being recorded (hundreds of *spp.* in some surveys), general descriptions such as “Nekton species counts” were provided. Furthermore, it was noted whether the particular attribute was finely or coarsely resolved in space (coordinate points vs. averaged over a large area) or time (continuous instantaneous measurements vs. annual observations).

Table 2. *Attribute-level metadata captured by FDOU-51.*

Attribute	Description
SubSystem	FDOU-51 subsystem assignment (benthic, fish, water quality)
ProgID	Published (or assigned) program/study acronym
Indicator	Specific attribute being recorded
iPurpose	Purpose of the indicator
iUM	Units of measure
iResT	Temporal resolution of this indicator's sampling design
iResS	Spatial resolution of this indicator's sampling design
iStart	Start year for data collection
iEnd	End year for data collection ("current" if ongoing)

3. RESULTS

One of piece of work that was uncovered in early literature review that was particularly useful was a National Oceanic and Atmospheric Administration (NOAA) technical memorandum that developed a holistic EBM conceptualization of the entire southeast Florida coastal marine system (Fletcher et al. 2013). While this region is composed of three subregions – (*i*) the Southwest Florida Shelf, (*ii*) the Florida Keys and Dry Tortugas, and (*iii*) the Southeast Florida Coast – the information pertaining to the Southeast Florida Coast was particularly relevant given that the entire Coral ECA is contained within this subregion. Furthermore, this document contained conceptual models specific to the three subsystems identified for this FDOU-51 project, and all three were used as a starting point for data discovery. In all cases, the conceptual models and their reviews were broken down to determine which attributes were measurable within each subsystem and should be targeted for metadata cataloging (Tables 3-5).

The SEACAR data discovery interface returned a total of 30 different programs that operated within the Coral ECA in some capacity (Appendix B). Of those, four were terrestrial-based, seven were sampled mostly outside of the Coral ECA with only a few stations within it, and five had short operational timescales relative to the goals of FDOU-51. The remaining 12 programs that were deemed useful for this effort are detailed below.

Of the 30 data providers contacted with the data discovery questionnaire, 11 replied with information regarding their respective programs. Of those 11 respondents, two described the same sampling cruise (which performed a single transect of water grabs perpendicularly through the major axis of the Coral ECA), and two more explained that they had nothing to contribute. One individual referred us to a different person already on the list, and another described a county level program that has operated for many years, but which did not appear to have a comprehensive sampling plan in place.

3.1. Water Quality Subsystem

The South Florida Water Management District (SFWMD) was founded in 1949 to manage the regional water resources within the state. Their mission addresses a number of water-related concerns and they aim to protect aquatic habitats by "...balancing and improving flood control, water supply, water quality and natural systems" (SFWMD 1949). The effects of land-use, groundwater discharge, wastewater disposal, stormwater runoff, and regional water management are apparent throughout the Coral ECA (Caraco and Drescher 2011; Gregg and Karazsia 2013; Fletcher et al. 2013). Federal, state, county, and other regional partners all put forth extensive effort to survey and monitor their respective water resources, and within the Coral ECA, a watershed-based approach is taken. The land areas of influence, each called an inlet contributing area (ICA), are defined by their proximity to the major points of terrestrial water input to the coastal aquatic ecosystem – the barrier island inlets – and each ICA corresponds with one of the nine inlets located within the Coral ECA (St. Lucie Inlet, Jupiter Inlet, Lake Worth Inlet, Hillsboro Inlet, Boynton Beach Inlet, Boca Raton Inlet, Port Everglades Inlet, Baker's Haulover Inlet, and Government Cut).

These ICAs represent the ecological connection between the land (and the human uses of it) and the adjacent ocean and coral reef ecosystem (Pickering, Baker, and Gregg 2015). Thus, comprehensive monitoring within ICAs is important to aquatic conservation and resilience efforts, and using the watershed approach allows for some level of compartmentalization of the system. Given the population density of the southeast Florida region (Rayer et al. 2021) and the multifaceted coastal system (Fletcher et al. 2013), water monitoring efforts related to the Coral ECA are necessarily complex and involve a number of different chemical and toxicological, physical, and hydrological parameters (Table 3). Within the context of this FDOU-51 project, the relatively long-term data collection and warehousing programs related to water quality can be generally organized into the following categories: offshore *in situ* sampling of the water within the Coral ECA, fluvial inputs and LBSP, data warehousing and aggregation systems, and satellite remote-sensing.

Table 3. *Measurable Attributes for the Water Quality Subsystem.*

Nutrients	Clarity/Light	Suspended Particulate Matter	Phyto-plankton	Food Web Changes	Ocean currents	Pathogens/ Toxins	Zooplankton	Other
Nitrogen	Chromophoric dissolved organic matter (CDOM)	Turbidity	*spp.* and biomass concentration	Isotopic analyses of biological residents	Flow rates and direction	*spp.* and biomass concentration	*spp.* and biomass concentration	Temperature
Phosphorus	KD Light Attenuation	Secchi Disk	Chlorophyll-a as a surrogate	Community compositional shifts	Upwelling	Mercury		KD Light Attenuation
Silicon	Photosynthetically Available Radiation (PAR)					Fecal coliforms		Dissolved O2
Nitrate								Salinity
Nitrite								pH
Nitrate+Nitrite								Freshwater input
Orthophosphate								LBSP
Silicate								

3.1.1. Offshore In Situ Water Quality Sampling

3.1.1.1. Coral Ecosystem Conservation Area Water Quality Assessment (2016-present)

The Southeast Florida Reef Tract Water Quality Assessment was initiated in 2016 under that name, but has changed names and funding sources over the years and is currently known as the Coral Ecosystem Conservation Area Water Quality Assessment (ECA-WQA; Whitall et al. 2019; Whitall and Bicker 2021). This sampling program began by monitoring grab samples related to the ICAs at the northern and southern boundaries of the Coral ECA at St. Lucie Inlet and Government Cut, respectively. In 2017, the seven remaining ICAs were added to the sampling protocol to gain full Coral ECA coverage.

Table 4. *Measurable Attributes for the Fish Subsystem.*

Key *spp.*	Population Statistics	Catch/Yield	Landings	Effort	Other
Greater Amberjack	By target *spp.*	By sector	By sector	By sector	Biodiversity/Richness/Evenness
Black Grouper		By target *spp.*	By target *spp.*	By target *spp.*	Age structure
Blue Angelfish					Catch lengths
French Angelfish					Catch weights
Gray Angelfish					Fecundity
Gray Triggerfish					Condition factor
Great Barracuda					Isotopic constituents (muscle, fins, eye lens)
Hogfish					Gut contents
Mangrove (Gray) Snapper					
Mutton Snapper					
Parrotfish					
Queen Angelfish					
Red Grouper					
Rock Beauty					
Tomtate					
White Grunt					
Yellowtail Snapper					
Bonefish					
Atlantic Tarpon					
Lionfish					

Table 5. *Measurable Attributes for the Benthic Subsystem.*

Reef Structure	Diversity	Species Abundance	Species Distribution	Colony Sizes	% Cover	Other
Relief	Growth (*spp.*/group)	Growth (*spp.*/group)	Growth (*spp.*/group)	Growth (*spp.*/group)	Stony coral	Dredging
Rugosity	Mortality (spp./group)	Mortality (spp./group)	Mortality (spp./group)	Mortality (spp./group)	Soft coral	Boat damages
Geomorphology	Reproduction (spp./group)	Reproduction (spp./group)	Reproduction (spp./group)	Reproduction (spp./group)	Macroalgae	Storm damages
	Recruitment (spp./group)	Recruitment (spp./group)	Recruitment (spp./group)	Recruitment (spp./group)	Sponges	Disease outbreak
					Sand	Bleaching
					Rock/Rubble	

Water samples are taken monthly at the central, north, south, and eastern points each the ICA's inlet mouth. Additional sampling is also undertaken at reef sites offshore each ICA, and which are meant to overlap with the Southeast Florida Coral Reef Evaluation and Monitoring Project (SECREMP; see below for details). Furthermore, sewage outfall sites are also sampled at Boca, Hillsboro, Port Everglades and Baker's Haulover Inlets, and at Government Cut. Lastly, water samples are taken at each sampling station at the surface and at maximum depth (where field equipment allows). See Appendix C for maps of recent sampling locations.

Of the 16 attributes that measured by the ECA-WCA (Table 6), chlorophyll-a was only initiated in 2019, urea was discontinued in 2018, and total organic carbon was only measured in 2020. The remaining attributes were all continuously recorded throughout the full term of the monitoring effort. The 2016-2018 data analyzed by Texas A&M is archived in the NOAA National Centers for Environmental Information (NCEI), and the remainder is housed at the Water Information Network (WIN; see below for details) with the exception of the analyte nitrite due to the fact that this is a calculated value and not directly measured. The data are also directly available from DEP Office of Resilience and Coastal Protection upon request.

Table 6. *Coral Reef Ecosystem Conservation Area Water Quality Assessment (ECA-WQA) Analytes by Year.* *Denotes those analytes and years where the lab analyses were conducted at Texas A&M University Geochemical & Environmental Research Group. All other years' lab analyses were performed by the Broward County Office of Environmental Services.

Attributes	2016-2018*	2017	2018	2019	2020	2021
Ammonia (NH_3)	NH_3	NH_3	NH_3	NH_3	NH_3	NH_3
Chlorophyll-a corrected (Chl-a)	-	-	-	Chl-a	Chl-a	Chl-a
Depth, Secchi	Secchi	Secchi	Secchi	Secchi	Secchi	Secchi
Depth, Site	Depth	Depth	Depth	Depth	Depth	Depth
Nitrate (NO_3)	NO_3	NO_3	NO_3	NO_3	NO_3	NO_3
Nitrate-Nitrite (N+N)	N+N	N+N	N+N	N+N	N+N	N+N
Nitrite (NO_2)	NO_2	NO_2	NO_2	NO_2	NO_2	NO_2
Nitrogen, Total (TN)	TN	-	-	-	-	-
Nitrogen, Total Kjeldahl (TNK)	-	TNK	TNK	TNK	TNK	TNK
Orthophosphate (OPO_4)	OPO_4	OPO_4	OPO_4	OPO_4	OPO_4	OPO_4
Phosphorus, Total (TPO_4)	TPO_4	TPO_4	TPO_4	TPO_4	TPO_4	TPO_4
Residues, Nonfilterable (TSS)	TSS	TSS	TSS	TSS	TSS	TSS
Salinity	Salinity	Salinity	Salinity	Salinity	Salinity	Salinity
Silicate (SiO)	SiO	SiO	SiO	SiO	SiO	SiO
Total Organic Carbon (TOC)	-	-	-	-	TOC	-
Turbidity	-	Turbidity	Turbidity	Turbidity	Turbidity	Turbidity
Urea	Urea	-	-	-	-	-

3.1.1.2. National Coral Reef Monitoring Program – Climate and Carbonate Chemistry (2018-present)

Since 2018, in addition to the fish and benthic data that are collected by the National Coral Reef Monitoring Program (NCRMP; Towle et al. 2021), a suite of climate-related environmental attributes is measured at a subset of the randomized fish/benthic sites (see below for experimental design details) on the same bi-annual schedule ($n_{2018} = 48$, $n_{2020} = 50$). The purpose of this portion of the NCRMP sampling effort is to capture the effects of planetary changes in ocean temperatures and acidification on the vital processes and rates that govern coral reef structure and function (Towle et al. 2021). Thus, measurements of standard water quality parameters such as temperature, salinity, and sample depth are captured along with a number of carbonate chemistry characteristics. Water grab samples are taken at the surface and analyzed in the lab for the following characteristics: total alkalinity, aragonite saturation state value, dissolved inorganic carbon content, partial pressure of CO_2, and pH (Table 7).

3.1.2. Water Quality Data Warehousing Programs

There are several online data warehousing services tailored to water-quality data. Many of the short-term or discontinued programs house their data in these locations, as do many of the ongoing or long-term programs (e.g., ECA-WQA). The U.S. Environmental Protection Agency (EPA) maintained their STOrage and RETrieval Data Warehouse (STORET) until 2018, after which it was replaced with new submission and retrieval mechanisms called the Water Quality Exchange (WQX) and Water Quality Portal (WQP), respectively (EPA 2018). According to the SEACAR database, >25 different federal, state, county and private programs contribute data to STORET that are related to the Coral ECA. The locations, dates/times, methods, and experimental designs for the various sampling efforts all vary, as do the water characteristics that are measured. Available attributes include: alkalinity, ammonia-nitrogen, calcium, chloride, depth, dissolved oxygen, fluoride, hardness, iron, magnesium, nitrate, organic nitrogen, orthophosphate (as P and PO_4), phosphate-phosphorous (as P and PO_4), potassium, sodium, specific conductance, sulfate (as SO_4), tannin and lignin, temperature, total solids, and turbidity (Table 7).

Likewise, a Florida-specific version of STORET was initiated, but is now referred to as the Water Information Network (WIN; DEP 2018) and it houses data by DEP and any other program using DEP-approved methods and laboratories. Some of the data in WIN may also be housed by STORET, and both systems provide access to many comparable water quality attributes (Table 7). While the totality of the data collection efforts warehoused within WIN are comprehensive and cover the full spatial extent of the Coral ECA (Appendix C), just as with those data within STORET, many of the same data issues with respect to timing, coverage, and experimental design are all present in WIN. Nevertheless, a large number of water quality-related parameters within the Coral ECA are available from WIN including: alkalinity, ammonia, chlorophyll-a (corrected/uncorrected for pheophytin), depth (site and Secchi disk), dissolved oxygen, enterococcus group bacteria, fecal coliforms, fluoride, nitrate-nitrite, total nitrogen (Kjeldahl), orthophosphate, pH, pheophytin-a, phosphorus, phosphate-phosphorus, potassium, residues and total suspended solids, salinity, specific conductance, total organic carbon, and turbidity.

3.1.1. Monitoring of Fluvial Inputs and Land-Based Sources of Pollution

Several programs focus their attention on the riverine and various other groundwater and land-based contributions to the nearby oceanic system by overserving various flux-points. Extensive work has gone into cataloging the variety of pollutants, sources, and effects on the Coral ECA, and for full details see one of the reviews listed here (Caraco and Drescher 2011; Gregg and Karazsia 2013; Pickering, Baker, and Gregg 2015). Generally, these efforts involve surveying physical parameters related to flow rates, water levels, and other

Table 7. *Comparison of Collected Water Quality Attributes Across Programs.*

	STORET	WIN	ECA-WQA	NCRMP
Alkalinity	x			x
Alkalinity ($CaCO_3$)		x		
Ammonia (NH_3)			x	
Ammonia (N)		x		
Ammonia-Nitrogen	x			
Aragonite Saturation State				x
Calcium	x			
Chloride	x			
Chlorophyll-a, corrected for Pheophytin		x	x	
Chlorophyll-a, free of Pheophytin		x		
Chlorophyll-a, uncorrected for Pheophytin		x		
Chlorophyll-a/Pheophytin Ratio		x		
Depth, Secchi		x	x	
Depth, Site	x	x	x	x
Dissolved Inorganic Carbon (DIC)				x
Dissolved Oxygen	x	x		
Dissolved Oxygen Saturation		x		
Enterococcus Group Bacteria		x		
Fecal Coliforms		x		
Fluoride	x	x		
Hardness	x			
Iron	x			
Magnesium	x			
Nitrate (NO_3)	x		x	
Nitrate-Nitrite (N+N)		x	x	
Nitrite (NO_2)			x	
Nitrogen, Total (TN)			x	
Nitrogen, Total Kjeldahl (TNK)		x	x	
Organic Nitrogen	x			
Orthophosphate (as P and PO_4)	x	x	x	
Partial Pressure of CO_2 (pCO_2)				x
pH		x		x
Pheophytin-a		x		
Phosphate-Phosphorous (as P and PO_4)	x	x		
Phosphorus (as P)		x		
Phosphorus, Total (TPO_4)			x	
Potassium	x			

Table 7 (cont.). *Comparison of Collected Water Quality Attributes Across Programs.*

	STORET	WIN	ECA-WQA	NCRMP
Residues, Nonfilterable (TSS)	x	x	x	
Salinity, Bottle				x
Salinity, CTD		x	x	x
Silicate (SiO)			x	
Sodium	x			
Specific Conductance	x	x		
Sulfate (as SO4)	x			
Tannin and Lignin	x			
Temperature	x			x
Total Organic Carbon (TOC)		x	x	
Turbidity	x	x	x	
Urea			x	

hydrologic conditions, as well as those related to the constituents of the water being released into the oceanic system. These constituents can range from the relatively simple (e.g., salinity, turbidity) to the very complex (e.g., eDNA, DNA, microbial communities). As with many other high-complexity systems, full-scale monitoring efforts are hard to come by, and spatiotemporal sampling designs vary extensively across different parameters observed throughout the Coral ECA.

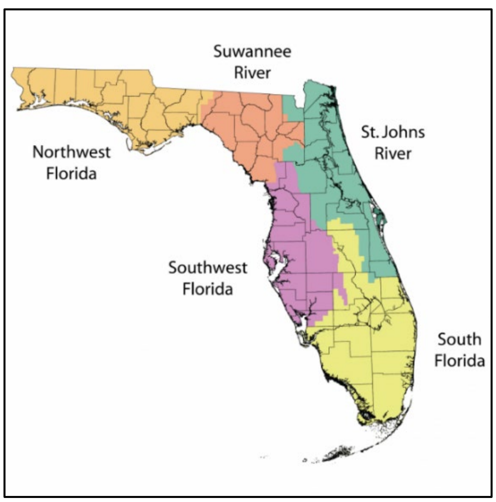

Figure 2. *Map of the Five Florida Water Management Districts.* The South Florida Water Management District is noted in yellow.

The National Water Information System (NWIS) program is operated by the U.S. Geological Survey (USGS) to monitor streams, lakes, and wells for flow rates, water levels and quality. The NWIS data collections have been ongoing since 2000, are measured continuously by various automatic stations as well as intermittently via manual measurements (USGS 2020), and cover approximately 27 unique attributes (Table 8).

The SFWMD also maintains a database of environmental observations related to hydrogeologic, hydrologic, meteorologic, and water quality parameters called DBHYDRO (SFWMD 2020b, 2020a). This effort is a large-scale undertaking that encompasses data from the entire SFWMD (Figure 2). Querying DBHYDRO returns a total of 1,121 unique attributes that are recorded across four data classes: flow, stage, weather, and water quality.

Table 8. *National Water Information System (NWIS) Parameters.*

NWIS Parameter	Units of Measure
Chlorophyll, total, water, fluorometric, 650-700 nanometers, in situ sensor	Micrograms per Liter
Discharge	Cubic Feet per Second
Discharge, tidally filtered	Cubic Feet per Second
Dissolved organic matter fluorescence (fDOM), water, in situ	Micrograms per Liter as Quinine Sulfate Equivalents (Qse)
Dissolved oxygen, water, unfiltered	Milligrams per Liter
Dissolved solids, water, filtered, estimated by regression equation	Milligrams per Liter
Elevation above NGVD 1929	Feet
Evapotranspiration	Millimeters per Day
Gage height	Feet
Groundwater level above NAVD 1988	Feet
Groundwater level above NGVD 1929	Feet
Latent-heat flux	Watts per Square Meter
Net radiation (net solar + net long wave radiation)	Watts per Square Meter
Nitrate plus nitrite, water, in situ	Milligrams per Liter as Nitrogen
pH, water, unfiltered, field	Standard Units
Precipitation, total	Inches
Relative humidity	Percent
Salinity, water, unfiltered	Parts per Thousand
Sensible-heat flux	Watts per Square Meter
Specific conductance, water, unfiltered	Microsiemens per Centimeter at 25 Degrees Celsius
Stream water level elevation above NAVD 1988	In Feet
Stream water level elevation above NGVD 1929	In Feet
Temperature, air	Degrees Celsius
Temperature, water	Degrees Celsius
Total solar radiation (direct + diffuse radiation on a horizontal surface)	Watts per Square Meter
Wind speed	Meters per Second

3.1.2. Satellite Remote Sensing of Water Quality

The University of South Florida's Optical Oceanography Laboratory accumulates a number of relevant satellite remote-sensed products that are observed within the Coral ECA and stores them online (https://optics.marine.usf.edu/). However, due to the nature of satellite measurements (i.e., explicit orbital paths, cloud cover, coastal and atmospheric interference) these data are often restricted both spatially ($\geq$ 250 m^2 resolution) and temporally (weekly, monthly, seasonal, annual means). Another limitation of these data is the fact that they are all derived quantities and do not represent *in situ* observations, and in most cases the data are compiled from visible light measurements at various wavelengths, and incorporate the inherent absorptive and reflective properties of light.

Nine separate satellite products are available within the boundaries of the Coral ECA during daytime passes. Chlorophyll-a is used as a proxy for primary productivity, as are the two fluorescence line height products (processed in different ways), and the color index product. Normal and "enhanced" red-green-blue images can be used to determine relative water clarity and to potentially classify majority constituents (e.g., CDOM heavy, clear), and relative turbidity can also be used to estimate broad scale water clarity trends (however, this is an experimental product). The floating algae index, and its nearly identical "enhanced" counterpart can be used to estimate surface coverage of green macroalgae, cyanobacteria, and *Sargassum*. During nighttime passes, two additional products are produced that capture sea surface temperature.

3.2. Fish Subsystem

Generally, fish monitoring is broken into two types, fisheries dependent monitoring (FDM) and fisheries independent monitoring (FIM). Fisheries dependent programs rely on commercial fishing and harvesting activities to perform surveys, and FIM programs are not subject to the market pressures associated with FDM, and can therefore employ randomized statistical survey designs. As such, FIM data are generally more desirable and considered a better representation of true fish population and community structures within any management area, however they are limited by funding availability and often under-sample populations either spatially or temporally (Grüss et al. 2018). On the other hand, FDM data are also highly valuable, particularly for fisheries management, as they also provide detailed information about the vital statistics of targeted and managed species, and fishing effort and removals estimations (Grüss et al. 2018).

Spatially, FDM and FIM data are often very different. Because FIM surveys are specifically planned to produce a representative sampling of the area of interest or employ repeated sampling at fixed stations, they tend to also have geographic coordinates for the points where fishing gear, SCUBA divers, cameras, or other observational equipment are deployed. Commercial and recreational fishing data compiled from FDM surveys are often not nearly as explicit, both for privacy reasons and because, in many cases, the data are not recovered until the fishing vessel has returned to port. Thus, in many cases FDM data can be aggregated to known public fishing access points, ports, counties, or regions.

Within the boundaries of the Coral ECA, only one FIM program was discovered with comprehensive coverage. Other FIM programs are operated by the Florida Fish and Wildlife Conservation Commission (FWC) in the region, however they target the estuaries and inshore habitats, and are technically outside the Coral ECA bounds. On the other hand, there are six relevant FDM programs. In addition to the FIM/FDM dichotomy, within the FDM cluster of monitoring efforts there are two more relevant subdivisions. First is the fleet type, either recreational or commercial; the second is based on the type of fishing being employed by those anglers being surveyed, and is called the fishing mode. Fishing modes are assigned across both recreational and commercial fleets, and consist of the following levels: (*i*) commercial, (*ii*) charter, (*iii*) headboat, (*iv*) private boat, (*v*) shore, or (*vi*) tournament.

3.2.1. Fishery Independent Monitoring in the Coral ECA

3.2.1.1. National Coral Reef Monitoring Program – Reef Fish Census (2012-present)

Early reviews of available FIM data within the Coral ECA determined that there was essentially none that would be able to capture the entire spatial universe, nor did any persist for very long (Ault and Franklin 2011; Ault, Browder, and Nuttle 2013). This assessment gap ultimately resulted in the establishment of the Southeast Coral Reef Fishery-Independent Baseline Assessment from 2012-2016 (Kilfoyle et al. 2018), and which was eventually enveloped into NCRMP in 2018 (Towle et al. 2021). There is a data gap in 2017 (and every odd-year thereafter) since the original annual sampling protocol was altered to become bi-annual after the incorporation into NCRMP. Nevertheless, these reef fish surveys represent the only comprehensive FIM program operating continuously throughout the entire Coral ECA at this time.

The FIM aspect of the NCRMP program within the Coral ECA was designed to fit seamlessly with the existing Reef Visual Census (RVC) program that already sampled from Biscayne Bay National Park through the Florida Keys, and uses a stratified random sampling design (Smith et al. 2011) that was adapted based on local knowledge (Kilfoyle et al. 2018). Natural hardbottom habitat in < 30 m water depth is targeted, and sampling locations were randomly drawn from a stratified 100 x 100 m grid system at the program's inception, but changed to a 50 x 50 m grid starting in 2020. The random stratification design incorporates five subregions (Broward-Miami, Deerfield, S. Palm Beach, N. Palm Beach, and Martin), three slope relief types (high, low, and n/d), and 17 different benthic habitat classifications that account for reef type (ridge, linear, patch, colonized pavement, spur and groove), depth (deep, shallow), position (inner, middle, outer), or other habitat class (seagrass, unconsolidated sediment, scattered coral/rock, other). Data collections are made from May through October every other year.

At each sampling site, two RVC stationary point-count surveys (Bohnsack and Bannerot 1986) are conducted by SCUBA divers who establish in the centers of theoretical cylinders with a diameter of 15 m and which encapsulate all of the water column from the seafloor to the surface. During these surveys, the first five minutes are spent recording the names of all species that are present within each cylinder (except for highly migratory species, which are fully enumerated immediately), and the second five minutes are spent recording the numbers of individuals of each species and their size ranges (based on fork length), along with any new species that are encountered. In addition to the RVC of fishes, additional habitat features are also recorded including: GPS coordinates, slope, maximum vertical relief (hard and soft), surface relief coverage proportion (hard and soft), abiotic footprint, major biotic cover, habitat type, underwater visibility (and resultant cylinder radii), water temperature, and current strength. For select species, limited life history data can be obtained such as median length at maturity, minimum length at capture, and both linear and exponential coefficients of the allometric grown equation. (Kilfoyle et al. 2018)

3.2.2. Fishery Dependent Monitoring – Commercial Fishing Fleet Programs

3.2.2.1. Accumulative Landings System (1926-present)

The Accumulative Landings System (ALS; NOAA 1926) collects and warehouses data regarding the commercialization of fishing harvests throughout the United States. As it relates to the Coral ECA, the ALS program compiles data from two relevant programs, FWC's State Trip Ticket Program (DEP 2018) and a cooperative effort between FWC and NOAA that is the Trip Interview Program (TIP; FWC 1980; NOAA 1980).

The Florida State Trip Ticket Program (1984-present) is legally mandated throughout the state and requires that any seafood products extracted from State waters (Figure 3) and then purchased must be documented and subsequently reported to the program via the Marine Fisheries Trip Ticket. The trip ticket (Appendix D) includes: vessel ID, number of crew members, purchase dealer ID, trip starting and unloading dates, actual time, area, depth, and gear fished, state and county where harvest was landed, number of fishing gear sets used, quantity of gear (used to estimate catch per unit effort, or CPUE), whether it was a headboat/guide/charter, aquaculture lease if a cultured product, species code, size, and condition, and amount of each species caught, purchase price, dollar value, continuation, and disposition. Trip ticket data are reported at the county level.

The FDM effort TIP (1980s-present) involves FWC/NOAA field biologists conducting dock-side and fish house interviews with commercial fishers to collect information about catch, effort, and biostatistical data. Biostatistical data include otoliths (for aging), spines, tissue samples, and fish meristic measurements such as length and weight. Lab testing of body parts creates data related to chemical concentrations of various notable compounds (e.g., mercury) and DNA sequences. Furthermore, the angler interviews allow for the collection of detailed first-hand information about the fishing effort and on-water events, and can be used to validate the trip ticket data. These data are reported at the county level.

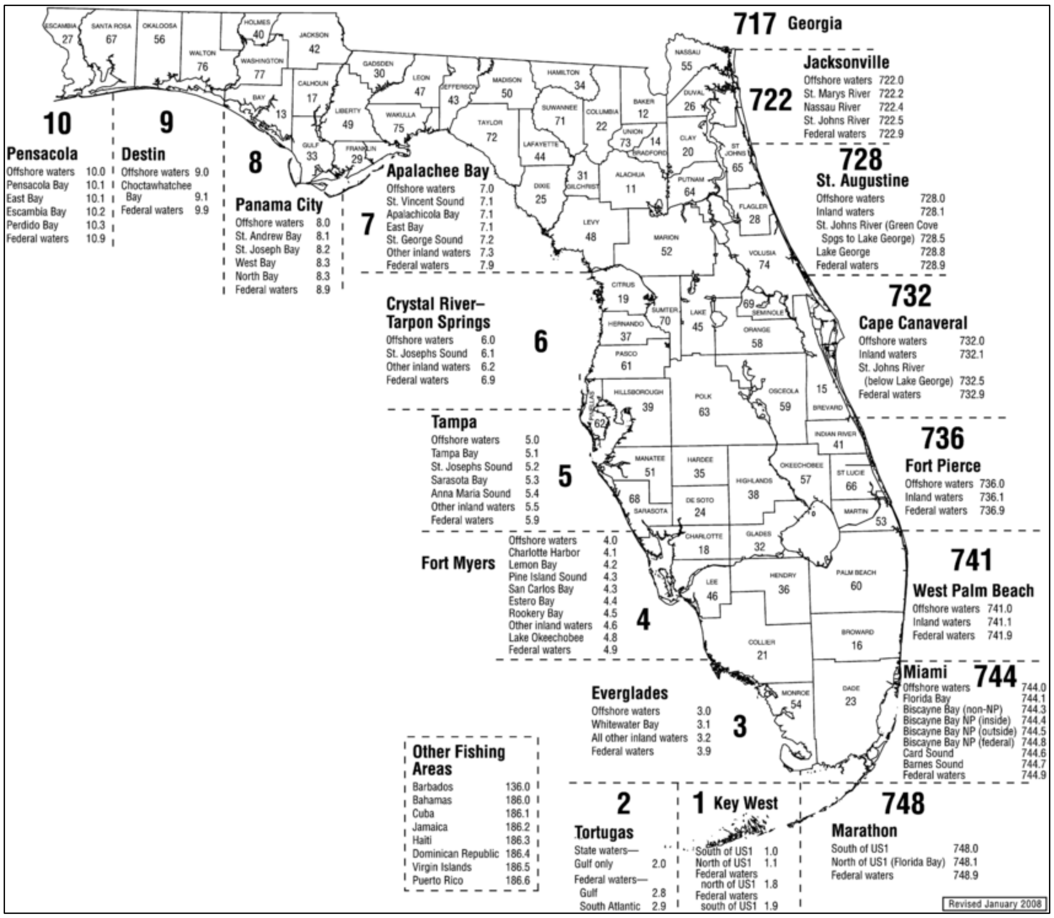

Figure 3. *FWC Marine Fisheries Trip Ticket Area Code Map.*

3.2.3. Fishery Dependent Monitoring – Recreational Fishing Fleet Programs

3.2.3.1. Southeast Region Headboat Survey (1972-present)

The Southeast Region Headboat Survey (SRHS; NOAA 1972) began in North and South Carolina in 1972 and expanded down through the Florida Keys in 1978 (Figure 4). Since then the methodology has been relatively unchanged aside from both spatial and fleet expansions. The fleet began with 30 vessels and now includes 96 in the southeastern U.S., and 94 in the Gulf of Mexico, however the fleet's vessels and their associated ports have entered and exited the sampling universe over time. Biological survey methods were designed to inform fisheries management and provide indices of abundance for decision making. Critical population-level life history parameters (e.g., growth, maturity, age/sex distributions) are derived from estimates of annual catches, CPUE, length frequencies, and mean weights for various target species. Unfortunately, target species are based upon management priorities, and are not static, but dockside surveyors are trained to identify approximately 60 of the most common species in their area. Biological sampling obtains the species caught, lengths, weight, and various other fish parts such as otoliths, stomachs, and gonads, and is typically performed dockside or at fish houses. Guidelines stipulate that each vessel should be visited within 10 to 14 days one or more times, but that excessive repetitive sampling should be avoided.

In addition to biological sampling, trip information is also collected via logbooks and interviews through the SRHS. This includes the date and location of landing, vessel ID, a single fishing location for the entire trip (regardless of how many were fished, and assigned to a 10’ x 10’ rectangle of latitude and longitude), type/duration of trip, and number of anglers (for CPUE estimation). However, since all trip information is derived from self-reported records submitted by captains, and due to high non-compliance rates (~50%) from 1980-2008 in the southeast Florida area, these data are not reliable until the recent period where compliance rates have reached ~95% (Fitzpatrick et al. 2017).

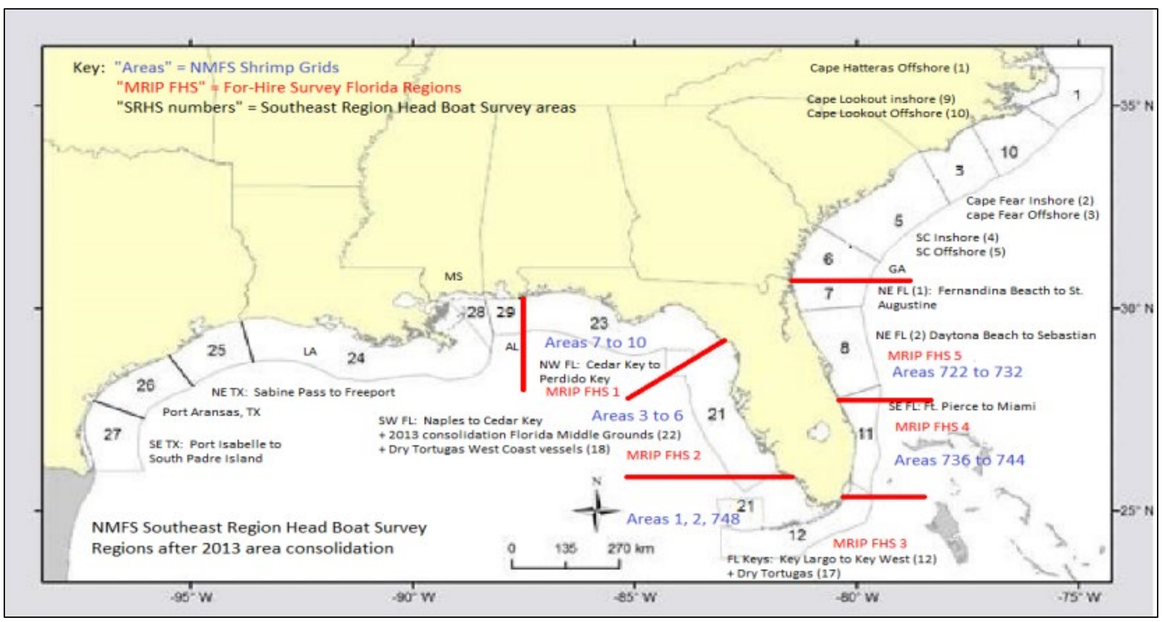

***Figure 4**. National Marine Fisheries Service (NMFS) maps for the Southeast Region Headboat Survey (SRHS) and the Marine Recreational Information Program (MRIP).*

3.2.3.2. Marine Recreational Information Program (1979-present)

The Marine Recreational Information Program (MRIP; NAS 2017) has operated since 1979 under the former name Marine Recreational Fisheries Statistics Survey (MRFSS) and captures information about shore, private boat, and charter fishing modes. The renaming in 2009 to MRIP coincided with programmatic changes that were meant to reduce bias and improve the survey's overall quality and performance in providing estimates of total recreational catch. Within Florida and the Coral ECA, the For-Hire Survey (FHS) and the Access Point Angler Intercept Survey (APAIS) comprise MRIP, are administered from January through February each year, and conform to the regions seen in the map in Figure 4. The FHS program operates a telephone survey among a sub-sample of federally permitted for-hire vessels, and the interviewer gathers information from each operator for a specified one-week reference period (typically the week prior to the phone call). Vessel operators are asked to recount the details of each trip during that period, including the number of anglers that fished from the boat, the amount of time fished and where, the method of fishing, and the target species. These data can be aggregated to the county level.

The APAIS portion of MRIP is the dockside component of this recreational survey, and it also conforms to the map noted above (Figure 4). The main priorities of the APAIS sampling are to gather counts of completed fishing trips, and to conduct angler interviews (NAS 2017). These interviews are conducted only at public access points, and obtain information about a trip's location and length, the species caught and counts (including releases), and the gear used. Observations of length and weight are also made, as well as visual confirmations of reported species. Finally, the number of anglers is noted, regardless of whether they were interviewed, and some demographic information for fishers is retained.

3.2.3.3. FWC At-Sea Observer Program (2005-present)

The At-Sea Observer Program (ASOP) for headboat and charter fishing modes is the most spatially resolved FDM data, as it provides GPS coordinates for each fishing station within a trip (or it reports the commercial statistical area otherwise). For each fish caught, ASOP observers will record the species, size (fork length), condition, and disposition. Additionally, a subset of anglers from a vessel are tracked for the duration of a trip, and for each fish that they capture, the hook type, size, and position are noted. Limited information regarding depredation events is also captured. Data are housed at FWC and are available upon request.

3.2.3.4. Newly Initiated Fishery Dependent Monitoring Programs

Two additional programs were just implemented within Florida over the last two years, and which will ultimately be useful for providing recreational fishing data in the future.

The FWC Biological Catch Survey was implemented in 2021 to supplement other catch surveys that capture biological data and to support the stock assessment process. This survey records lengths, weights, and ages for all recreational fishing modes (shore, private boat, and charter). These data are aggregated to the county level, and are available upon request from FWC. Finally, the State Reef Fish Survey (FWC 2020b) was implemented in 2020 to expand and replace the Gulf Reef Fish Survey. This survey has two components, mail surveys and dockside interviews. The mail survey collects information about fishing trips from the previous month, and seeks to quantify the number of trips and the targeted reef fish species. Dockside interviews detail the numbers and types of fish caught (and released) over the course of the day's trip, and if permitted record their size, weight, and age.

3.3. Benthic and Hardbottom Habitat Subsystem

Coral reef ecosystems, and the resources that comprise them, are known to be highly complex and dynamic systems affected by a variety of natural and anthropogenic factors. In the case of the FRT, the vast majority of the system is adjacent to large population centers (Rayer et al. 2021) and high-traffic tourism destinations (Fletcher et al. 2013; Gilliam et al. 2021). As such, the FRT is considered a highly prized natural resource to the many stakeholders that utilize it within Florida's waters, as well as for those adjacent to it in coastal communities (Johns, Milon, and Sayers 2004; Johns et al. 2001; Storlazzi et al. 2019).

The northern portion of the FRT encompassed within the Coral ECA consists of a series of three shoreline-parallel terraces that become progressively deeper as distance from shore increases, and which are termed the "inner", "middle", and "outer" reefs. These reef terraces, along with a nearshore "ridge complex" habitat, are interspersed with sand flats, and the occasional non-contiguous "intermediate ridge" (Moyer et al. 2003; Banks et al. 2007; Finkl and Andrews 2008; Fletcher et al. 2013; Riegl, Gilliam, and Lirman 2013). These reefs contain numerous geomorphological forms such as patch, spur and groove, and worm reefs, and they support a diverse range of octocoral, stony coral, macroalgal, and sponge communities (Finkl and Andrews 2008; Moyer et al. 2003; Gilliam et al. 2021).

3.3.1. In Situ Coral Reef Monitoring

3.3.1.1. Southeast Florida Coral Reef Evaluation and Monitoring Project (2003-present)

Prior to the installation of SEFCRI in 2003, most coral and hardbottom habitat monitoring in the northern section of the FRT was deployed in response to disturbances such as vessel groundings, disease outbreaks, or bleaching events (Gilliam et al. 2021; FWC 2020a; Waddell 2017). In the mid-1990s the Coral Reef Evaluation and Monitoring Project

(CREMP) was initiated within the FL Keys National Marine Sanctuary, and was eventually expanded into the southeast Florida reefs located within the Coral ECA (Gilliam et al. 2021). Thus, in 2003 the Southeast Florida Coral Reef Evaluation and Monitoring Project (SECREMP) was established and began surveying 10 fixed sites in Palm Beach (n = 3), Miami-Dade (n = 3), and Broward (n = 4) Counties, and in 2006 Martin (n = 2) County was added. In 2010, four more sites were added to Palm Beach and Miami-Dade Counties (n = 2 each), and then in 2013 six more were added to Broward and Miami-Dade Counties (n = 3 each) to bring the total to n = 22 sites (Table 9) across the four reef zones mentioned above (Gilliam et al. 2021). Sites are monitored by the National Coral Reef Institute at Nova Southeastern University Oceanographic Center annually between May and August.

Table 9. *Southeast Coral Reef Evaluation and Monitoring Project (SECREMP) Monitoring Sites.* The sampling sites for SECREMP throughout Miami-Dade (DC), Broward (BC), Palm Beach (PB), and Martin (MC) Counties, and across the inner, middle, and outer reefs, as well as the nearshore ridge complex (NRC). Depth values are converted to meters (m) and locations' GPS coordinates are provided in degree and decimal-minutes format. Modified from Table 1 of Gilliam et al. (2021).

Site Code	Reef Type	Depth (m)	Latitude (N)	Longitude (W)
DC1	Inner	7.6	25° 50.530'	80° 06.242'
DC2	Middle	13.7	25° 50.520'	80° 05.704'
DC3	Outer	16.8	25° 50.526'	80° 05.286'
DC4	Outer	12.5	25° 40.357'	80° 05.301'
DC5	Inner	7.3	25° 39.112'	80° 05.676'
DC6	NRC	4.6	25° 57.099'	80° 06.534'
DC7	Middle	16.8	25° 57.530'	80° 05.639'
DC8	NRC	4.6	25° 40.707'	80° 07.111'
BCA	NRC	7.6	26° 08.985'	80° 05.810'
BC1	NRC	7.6	26° 08.872'	80° 05.758'
BC2	Middle	12.2	26° 09.597'	80° 04.950'
BC3	Outer	16.8	26° 09.518'	80° 04.641'
BC4	Inner	9.1	26° 08.963'	80° 05.364'
BC5	Middle	13.7	26° 18.100'	80° 04.095'
BC6	Outer	16.8	26° 18.067'	80° 03.634'
PB1	NRC	7.6	26° 42.583'	80° 01.714'
PB2	Outer	16.8	26° 40.710'	80° 01.095'
PB3	Outer	16.8	26° 42.626'	80° 00.949'
PB4	Outer	16.8	26° 29.268'	80° 02.345'
PB5	Outer	16.8	26° 26.504'	80° 02.854'
MC1	NRC	4.6	27° 07.900'	80° 08.042'
MC2	NRC	4.6	27° 06.722'	80° 07.525'

The SECREMP sampling design includes four monitoring stations within each site that are permanently marked and sampled annually. Each station consists of a north-south oriented 22 m linear transect which is relatively parallel to the underlying reef terrace complex. Since 2003, image transects are performed on the east side of the transect and capture a ~40 cm wide swath ~40 cm above the substrate. Point-count analyses are performed at 15 randomly placed points within each image (n = ~60 images per transect), and beneath each point the following information is collected for various benthic attributes: species, genus, higher taxonomic levels (e.g., encrusting or branching octocoral, crustose coralline algae, zoanthid, sponge, and macroalgae), and substrate type (sand, consolidated pavement, or rubble). (Gilliam et al. 2021)

In addition to the image transects, starting in 2013 three additional surveys were added to the program, and all are conducted along the same transects, albeit with modified spatial coverages. Both a stony coral demographic survey and a barrel sponge (*Xestospongia muta*) population survey utilize a 1 x 22 m belt transect, and an octocoral demographic survey uses a reduced area captured using a 1 x 10 m belt transect at the northern end of each permanent site. Stony coral surveys identify every coral species present within the belt area with a diameter ≥ 4 cm (from 2013-2017, reduced to ≥ 2 cm in 2018), each colony also has the maximum diameter and maximum height recorded. Visual assessments are performed for the presence of diseases, bleaching, predation, or other disturbances, and the estimated proportions and recency of any resultant partial mortality are also captured. Starting in 2018, all coral colonies ≤ 2 cm are identified to the lowest taxonomic unit possible, and enumerated. Lastly, all *Diadema antillarum* present are also tallied. (Gilliam et al. 2021)

Barrel sponges (*Xestospongia muta*) are surveyed by counting all sponges present in the belt area, and are measured for the maximum diameter, maximum base diameter, and maximum height. Visual assessment of disease, bleaching, predation, and other conditions are conducted analogously to the stony coral demographic survey. Octocoral demographic surveys are performed in the reduced belt area such that on the first pass all octocorals are counted regardless of their species, and on a second pass three target species (*Antillogorgia americana*, *Eunicea flexuosa*, and *Gorgonio ventalina*) are sampled in more detail. Each targeted octocoral is measured for maximum height and assessed for disease, bleaching, predation, and other conditions. (Gilliam et al. 2021)

Lastly, since 2007, water temperature is measured by a data logger at 2-hour intervals. Two data loggers are deployed at the northern end of stations one and two for each site ~ 10 cm above the substrate, and are replaced annually. See Table 10 for comparisons across benthic monitoring programs. All data for SECREMP are housed by FWC's Fish and Wildlife Research Institute (FWRI) and are available upon request.

3.3.1.2. Florida Reef Resilience Program's Disturbance Response Monitoring (2005-present)

The Florida Reef Resilience Program's Disturbance Response Monitoring (DRM; FWC 2020a) been ongoing since 2005 and samples annually. The DRM program began as a Nature Conservancy initiative to monitor shallow water reefs from Martin County to the Dry Tortugas in order to gather information about the effects of temperature increases (FWC 2020a). While the primary focus of the program is temperature-related, since the discovery in Florida of Stony Coral Tissue Loss Disease (SCTLD) in 2014 (Muller et al. 2020), the DRM protocol has been altered to collect detailed data on diseased coral colonies as well. Within the Coral ECA, sampling is undertaken in all four counties, employs a probabilistic experimental design for site selection using a 100 x 100 m sampling grid, and samples in water up to 20 m in depth.

From 2005-2019 two 1 x 10 m belt transects were performed at each monitoring site, and starting in 2020 that was increased to four. In all cases, the first two transects enumerate all corals ≥ 4 cm and juveniles of select subfamilies, and transects three and four target 10 species known to be susceptible to SCTLD (*Colpopyllia natans, Dichocoenia stokesii, Diploria labyrinthformis, Meandrina meandrites, Mussa angulosa, Mycetophyllia aliciae, M. ferox, M. lamarckiana, Pseudodiploria clivosa, and P. strigosa)*. For each transect the following information is recorded: GPS coordinates (decimal degrees, based on site), transect depth, subregion (generally based on county-level designations), zone (based on distance from shore and depth), and habitat (one of 31 different substrate classifications from unknown, sand, rubble, and seagrass, to high/low relief, deep/shallow reef, and more). Within each transect, coral species is recorded, and for each colony the maximum diameter and maximum height is measured, along with bleaching stress, mortality recency, tissue loss, tissue loss rate, disease identification (unknown, SCTLD, White Plague, White Band Disease, White Pox, Rapid Tissue Loss, Dark Spot Disease, Black/Red Band Disease, and discoloration), and other conditions (e.g., predation, abrasion, overgrowth, sedimentation, Clinoid infestation, and mucus sheathing). Rugosity is also measured for the first two transects since 2018, and several species are marked present/absent in the visible area outside the belt transect, including *Diadema antillarum*, *Acropora cervicornis*, *A. palmata*, and *Dendrogyra cylindrus*. See Table 10 for comparisons across benthic data collection surveys. All data are available upon request. (FWC 2020a)

3.3.1.3. National Coral Reef Monitoring Program (2014-present)

As a compliment to the DRM program, and in addition to RVC fish and *in situ* water quality monitoring described above, NCRMP also conducts benthic surveys related to coral and other reef-related substrate types at depths up to 30 m. While NCRMP and DRM use the same sampling grid, the NCRMP design was updated after 2018 to a 50 x 50 m grid cell resolution, and together these two programs provide complete coverage throughout the Coral ECA (Figure 5). The stratified random experimental design employed for fish monitoring is also implemented for benthic monitoring and, in fact, benthic sampling is performed at a subset of the fish survey sites at the same time (Towle et al. 2021; Roberson, Viehman, and Clark 2014). Marrying these programs' data together increases the interpretability between the two monitoring efforts, and allows managers and stakeholders to begin to answer questions about the relationships among the two programs' measured attributes (Towle et al. 2021).

The NCRMP benthic surveys are focused on capturing information regarding the diversity, abundance, size structure, and condition of corals, and perform two main protocols for monitoring – line point-intercepts and belt transects (Towle et al. 2021). The specifics of the surveys are similar to those developed for SECREMP. The line point-intercept (LPI) uses a 15 m transect line; macroinvertebrates and Endangered Species Act (ESA) listed species are observed along a 15 x 2 m belt transect; and the coral demographic survey uses a 10 x 1 m belt transect (Roberson, Viehman, and Clark 2014; Towle et al. 2021).

As RVC fish surveys are conducted concurrently, the benthic surveyors (i.e., SCUBA divers) begin their monitoring transects close to the fish surveyors' observation cylinders and assess the benthos along linear transects oriented in a haphazardly selected (but constant) heading from the area where the RVC cylinders are closest. The LPI surveys enumerate all substrate types and biotic inhabitants beneath each point at 20 cm intervals along the 15 m transect (n = 75 observations), including: hardbottom, rubble, sand, corals to species, turf-, macro-, and coralline encrusting-algae, gorgonians, sponges, seagrass, and other. Macroinvertebrate counts (*Diadema antillarum*, *Panulirus argus*, *P. guttatus*, and *Strombus gigas*) and the presence/absence of ESA listed coral species (*Acropora cervicornis*, *A. palmata*, *Dendrogyra cylindrus*, *Mycetophyllia ferox*, *Orbicella annularis*, *O. faveolata*, and *O. franksi*) are collected in 1 m swaths on either side of the 15 m linear transect. Additionally, the LPI and macroinvertebrate/ESA surveys both record rugosity classifications. (Roberson, Viehman, and Clark 2014; Towle et al. 2021)

The coral demography is recorded along a truncated 10 x 1 m belt transect along the "left" side (starting at the 0 cm mark) of the larger 15 m transect described above, and divers identify and enumerate all corals of any size. For those colonies ≥ 4 cm, additional detail is recorded including: maximum diameter, diameter perpendicular to max. diameter, maximum height, percentages of old and recent mortality, bleaching status (total, paling, partial, none), disease presence (type not identified), and other disturbances. (Roberson, Viehman, and Clark 2014; Towle et al. 2021) See Table 10 for comparisons across benthic monitoring programs.

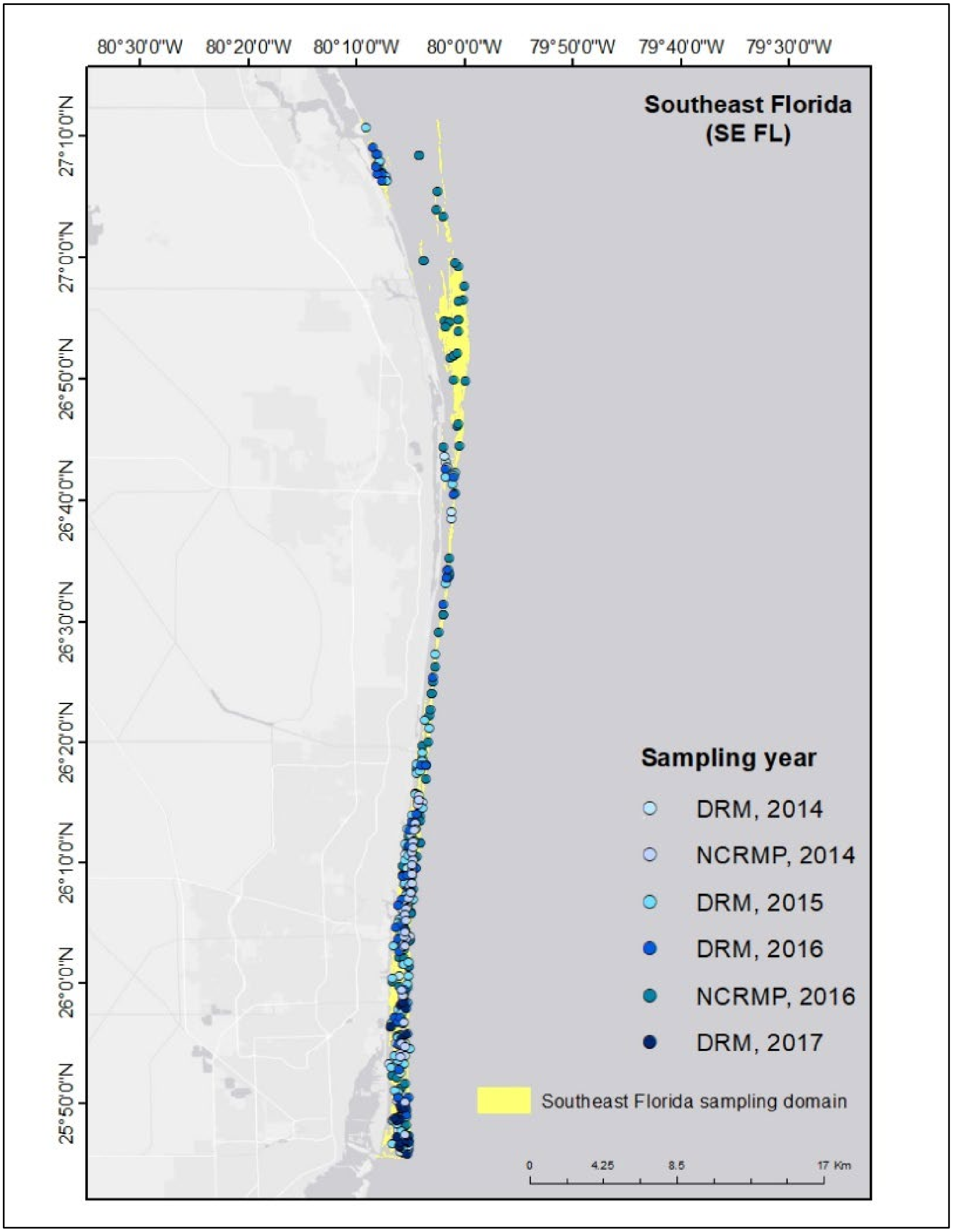

Figure 5. *Sampling Locations for the Disturbance Response Monitoring (DRM) and National Coral Reef Monitoring Program (NCRMP) Surveys in the Coral ECA 2014-2017.*

Table 10. *Comparison of Measurable Attributes Across Three Major Benthic Monitoring Programs in the Coral ECA.*

	SECRMP	DRM	NCRMP	
Coral Demographics				**DRM SCTLD Targets**
Census All Species ≥ 4 cm	2013	2005	2014	*Colpophyllia natans*
Census All Species ≥ 2 cm	2018	-	-	*Dichocoenia stokesii*
Bleaching	x	x	x	*Diploria labyrinthformis*
Disease Presence	x	x*	x	*Meandrina meandrites*
Disease Type		x		*Mussa angulosa*
Juvenile Colony Pres/Abs.	x		x	*Mycetophyllia aliciae*
Max. Diameter	x	x	x	*Mycetophyllia ferox*
Max. Height	x	x	x	*Mycetophyllia lamarckiana*
Morality Recency	x	x	x	*Pseudodiploria clivosa*
Mortality/Tissue Loss (%)	x	x	x	*Pseudodiploria strigosa*
Other Disturbances	x	x	x	***DRM Diseases/Other Disturb.**
Predation	x	x*	x	Stony Coral Tissue Loss Disease
SCTLD Target *spp.*		x		White Plague
****Macro-Inverts & ESA Corals**				White Band Disease
Acropora cervicornis		x	x	White Pox
Acropora palmata		x	x	Rapid Tissue Loss
Dendrogyra cylindrus		x	x	Dark Spot Disease
*Diadema antillarum***		x	x	Black Band Disease
Mycetophyllia ferox			x	Red Band Disease
Orbicella annularis			x	Discoloration
Orbicella faveolata			x	Abrasion
Orbicella franksi			x	Overgrowth
*Panulirus argus***			x	Sedimentation
*Panulirus guttatus***				Clinoid Infestation
*Strombus gigas***			x	Mucus Sheathing
Line Point-Intercept Surveys				
Algae, Coralline Encrusting	x		x	
Algae, Macro	x		x	
Algae, Turf	x		x	
Octocoral/Gorgonian	x		x	
Pavement/Hardbottom	x		x	
Rubble	x		x	
Rugosity	x		x	
Sand	x		x	
Sponge	x		x	
Stony Coral	x		x	
Zoanthid	x		x	

3.4. Short-Term/Small-Scale and Other Projects

Many scientific studies and LAS projects encountered during the data discovery for FDOU-51 did not fully satisfy the requirements that they both cover the full spatial extent of the Coral ECA, and persist for a relatively long-term with plans to continue into the foreseeable future. Below is a non-exhaustive selection of programs relevant to the Coral ECA, but not at the spatiotemporal scales required for FDOU-51. Nevertheless, these efforts result in data products that may be useful to researchers investigating fundamental problems related to the coral reef ecosystem in southeast Florida waters.

3.4.1. Additional Reef Fish Studies in the Coral ECA

Given the nature of fish ecology, it is relatively unreasonable to assume that demographic data that are far-removed (e.g., 10-20 years) from the last observation date are representative of the contemporary system. Nevertheless, some information may still be gleaned from work that was undertaken by various groups. Studies exist within the Coral ECA to describe fish assemblage variation across natural and artificial reefs (Arena, Jordan, and Spieler 2007; Baron, Jordan, and Spieler 2004; Thanner, McIntosh, and Blair 2006; Phipps et al. 2018), and with respect to the topographic complexity of the reef habitat (Walker, Jordan, and Spieler 2009). Still other work has focused on fish species that aggregate to spawn and on identifying those spawning locations of interest with the Coral ECA (Binder et al. 2021).

3.4.2. Additional Water Quality Studies in the Coral ECA

A number of other short-term and small-scale studies have been undertaken within the Coral ECA to investigate the effects of pollutants related to sewage outfalls in the vicinity (Koopman et al. 2006) and estimating the distance outfall water traveled (Wanninkhof et al. 2005) and its effects, along with those of other LBSP, on essential fish habitats (Gregg and Karazsia 2013). Other studies have investigated the ICAs in regional contexts with respect to their chemical output (Stamates, Carsey, and Brown 2015; Carsey et al. 2015; Carsey et al. 2011), or their flow rates, outflow prism dynamics, and other hydrographic properties (Stamates 2013; Stamates et al. 2013).

3.4.2.1. Harmful Algal Bloom Monitoring (2000-present)

Starting in 1954, the Harmful Algal Bloom Monitoring (HABMON; FWC 1954) program is one of the longest time series collected throughout Florida. The data have been gathered by the FWC and comprise 190+ contributing partners over the time series. The collections were historically responses to large harmful algal blooms (HABs) and did not contain substantial sampling until the 1990s. However, the majority of routine monitoring undertaken by HABMON is within the Gulf of Mexico waters adjacent to Florida. In 2000

FWRI established a volunteer monitoring program (FWRI 2000) for red tide (*Karenia brevis*) which includes more regular reporting on the Coral ECA, however, they are not particularly regular in space or time. The volunteer monitoring programs contribution to HABMON could be used for determining local impacts of red tides in the conservation area where they are available.

3.4.2.1. NOAA National Status and Trends Database (1986-present)

The NOAA National Status and Trends (NS&T) data is a combination of three programs, Benthic Surveillance, Mussel Watch, and Bioeffects, and began in 1986 (NOAA 1986). Unfortunately, the Bioeffects program was discontinued in 1993 and the other two programs only produce data adjacent to the Coral ECA in the St. Lucie Estuary and at stations in Maule Lake just north of Biscayne Bay. The data collected comprise information about the status, changes, and quality of waters through monitoring of chemical contaminants in sediments and bivalve tissues. Over 150 different attributes are measured, including (but not limited to) PAHs, PCBs, chlorinated pesticides, along with both major and trace elements and metals (NOAA 1986).

3.4.3. Additional Coral and Benthic Habitat Studies in the Coral ECA

Research across the Coral ECA related to the benthos are varied. A relatively large amount of attention has been paid to the effects of stressors on coral community constituents including temperature and disease (Jones et al. 2021; Manzello, Berkelmans, and Hendee 2007). Disease research has become more important since the recent outbreak of SCTLD along the FRT in 2014 (Muller et al. 2020), and recent work has investigated changes before vs. after disease outbreaks (Hayes 2019; Peters and Fogarty 2016) as well as how to treat disease symptoms *in situ* (Brunelle 2020). Similar to this undertaking for the Coral ECA, a data discovery effort related to the 2014/2015 disease outbreak, at the FRT-scale, and utilizing the Southeast Florida Action Network (Peters and Fogarty 2016), produced over 120 different data sources that were relevant to the topic and which had data both before and after the event.

In addition to monitoring stressors to corals, a number of large coral colonies (> 2 m in diameter) along the coast have been identified and are actively being monitored, however, only in the southern portion of the Coral ECA. A program operated by the Nova Southeastern University Oceanographic Center identified and inventoried 115 large corals whose community composition was dominated by *Orbicella faveolata*, followed by *Montastrea cavernosa, Siderastrea siderea, Colpophyllia natans, Orbicella annularis,* and *Pseudodiploria strigosa* (Walker and Klug 2014, 2015). Other studies focused on *Acropora cervicornis* and characterized its spatial distribution and abundance (D'Antonio, Gilliam, and Walker 2016) in the region, as well as details of large thickets of the coral off of Fort Lauderdale, FL (Vargas-Ángel, Thomas, and Hoke 2003).

Work to describe the underlying geomorphology of the FRT has been ongoing since at least the 1990s (Lidz and Shinn 1991; Finkl, Benedet, and Andrews 2005), and expanded northward through the Coral ECA into the 2000s (Finkl and Andrews 2008; Banks et al. 2007; Walker et al. 2012). Similarly, much work has gone into characterizing the community compositional patterns (Moyer et al. 2003; Walker and Klug 2014) and biogeographic boundaries (Walker 2012) and patterns (Walker and Gilliam 2013) throughout the Coral ECA.

Notwithstanding catastrophic impacts like disease (Muller et al. 2020) or trophic shifts like the *Diadema antillarum* die-off (Hughes, Reed, and Boyle 1987; Lessios 2016), coral reef habitats are somewhat resistant to short-term changes given their relatively low population growth and reproduction rates. Thus, there is value in the many different mapping products that have been produced to catalog and describe these resources. In particular, the *Our Florida Reefs* (OFR) Marine Planner is an online planning tool (SEFCRI 2016) that compiles 110+ different data layers (Walker and Costaregni 2016) regarding Fish (10), Coral (12), Habitat (22), Management (46), People (17), and Water (10) indices. Another mapping product, and one which is also available through the OFR Marine Planner, is the Unified Florida Coral Reef Tract Map (FWRI 2016a). These Unified Reef Maps were designed to provide a consistent framework to classify and map the geomorphology of the FRT from Martin County to the Dry Tortugas (FWRI 2016b). Lastly, the SFWMD also provides extensive mapping products and geospatial/geographic information systems (GIS) that cover all manner of aspects that affect the aquatic resources within south Florida (SFWMD 2022) including a comprehensive accounting of all land use and land cover classifications for the terrestrial areas directly adjacent to the Coral ECA.

4. DISCUSSION & RECOMMENDATIONS

4.1. Subdividing the Coral ECA

Dividing the Kristin Jacobs Coral Reef Ecosystem Conservation Area into water quality, fish, and benthic subsystems allowed for a comprehensive review of the contemporary monitoring programs, survey efforts, and data collections operating within it. Recall that the ultimate focus of FDOU-51 is to identify and describe trends and changes in the structure and function of the Coral ECA and its related resources (along with any dynamic interactions among them). Therefore, the primary data of interest were those produced by existing, fully-funded programs, spanning the full spatial extent of the Coral ECA.

Each subsystem has at least one monitoring program that employs randomized sampling designs that were developed to answer questions at the scale of the Coral ECA, and

NCRMP was the only program that is currently implemented across all three. Given the nature of marine ecosystems, it is obvious that the water quality subsystem has profound effects on the fish and benthic systems, but it is also true that what happens on land has an equally profound effect on the water quality. Thus, the ICA framework advocated by Pickering, Baker, and Gregg (2015) is a compelling approach to data management and hypothesis generation for this management area.

Data from the ECA-WQA and NCRMP paired with data from the water quality data warehouses (STORET, WIN, and DBHYDRO) combine to form a comprehensive assessment of hydrographic, chemical, toxicological, and physical water characteristics that span the Coral ECA. Some specific attributes may be temporally (or spatially) limited, given the variations in the sampling designs for all data within the warehouses, and so any future efforts that employ these data will need to be carefully organized.

Like the water quality data, the benthic habitat data are very comprehensive and scientifically robust with respect to their experimental designs. Furthermore, the protocols and site selection for SECREMP, DRM, and NCRMP are tailored to complement one another. However, while the benthic system in the Coral ECA is very well surveyed at this time, it could benefit from more frequent sampling. Furthermore, regularly updated GIS and other mapping products provide useful information for stakeholders and managers seeking to target particular habitats or substrate types for various activities (e.g., coral restoration, sand dredging) or research.

Of the three subsystems investigated, the fish subsystem suffered from an undersupply of unbiased data collection efforts, as it only has one FIM program operating within the Coral ECA (i.e., NCRMP). Furthermore, NCRMP currently only samples bi-annually, and this is a very long span between sampling events in terms of fish populations' capacities to change and be affected by external drivers and pressures. On the other hand, the fish subsystem has a relatively large number of FDM survey efforts underway that accumulate data from the Coral ECA (Trip Ticket, TIP, SRHS, MRIP, FHS, APAIS, and ASOP) that are highly valuable for fisheries management. Unfortunately, given the limits on the spatial resolution of the data reporting, these data will be difficult to adapt to questions relevant to the coral reef resources associated with the ECA.

4.2. Data Compatibility

One of the most difficult challenges facing any analytical effort that aims to use the data described here, particularly in constrained analysis frameworks, will be the aggregation and pretreatment of the data such that any two (or more) datasets can be investigated together. Most of the monitoring and research efforts cataloged above were designed and implemented to prioritize their particular research topic and maximize the return from available funds. This extends to almost all aspects of every program given the “problem of pattern and scale” (Levin 1992). Course-resolution spatial designs may gain the capability to implement superior large-scale spatial or temporal coverage (i.e., the entire Coral ECA, annual monitoring), but they lack the capacity to capture information about small-scale processes. On the other hand, where finely resolved designs regain that capacity, they often become too logistically complex or expensive to maintain for long periods of time, or to cover great spatial extents. Funding also ultimately determines the longevity of many programs, and uncertainty surrounding future funds may limit present monitoring efforts in order to “stretch” available dollars for as long as possible. Funding gaps often lead to data gaps, and data gaps across multiple datasets may preclude them from being analyzed concurrently, thus, altering the landscape of available investigations that may be pursued.

Program priorities are also a major factor affecting the compatibility of datasets. This issue is immediately apparent when comparing the various long-term efforts against other short-term “snapshot” efforts. On the surface, the complications related to differing priorities seems intuitive because the focus of any investigation determines which specific attributes or characteristics of a system (i.e., variables) are observed. Thus, where a long-term study may prioritize the collection of growth rate data for coral reefs, a short-term study may only collect data on event-related coral mortality. While one might conceive a study that investigates whether contemporary growth rates relate to greater mortality during disturbance events, determining whether the data obtained by these two hypothetical programs can be aggregated in some way to address that problem defensibly is the challenge. Problems like this are central in data science, as they increase the data-handling time considerably and are exacerbated in high-complexity systems like the Coral ECA.

4.3. Conclusion and Recommendations

The data described in this report represent the contemporary monitoring landscape for the Coral ECA with respect to the water quality, fish, and benthic subsystems that comprise it. All subsystems have a variety of sources to draw from that researchers can use to compile datasets representative of a number of coral reef ecosystem components and focus areas. As with many investigations, after developing a detailed definition of the problem, data requirements become clearer, and this document will allow researchers and managers to determine if their particular priority is feasible given the current data collection programs within the Coral ECA. Once monitoring programs are selected, a full determination must be made of whether the available data products are appropriate for the statistical or analytical methods required, and/or how they might be pretreated in order to become appropriate. Once again, the hope is that the experimental design details and monitoring priorities described herein will be useful in that regard as well. Finally, once the problem definition, data identification/collection, and methods selections have been made, holistic analyses to uncover patterns and trends may begin in earnest.

5. LITERATURE CITED

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6. APPENDICES

6.1. Appendix A – Monitoring Program, Survey Effort, and Data Questionnaire

Monitoring Program, Survey Effort, and Data Questionnaire for the Florida Department of Environmental Protection's FDOU-51 Project

A data compilation effort – under the Southeast Florida Coral Reef Initiative (SEFCRI)'s, Fishing, Diving, and Other Uses local action strategy #51 (FDOU-51)[1] – will seek to identify and describe the various scientific survey and monitoring efforts compiling data pertinent to the Kristin Jacobs Coral Reef Ecosystem Conservation Area (Coral ECA). The FDOU 51 project will emphasize State waters (i.e., within three nautical miles of the coastline) off of southeast Florida, and will prioritize data streams that are relatively long-term and with contemporary updates, however, historical and short-term data will also be cataloged.

At this time only metadata regarding the monitoring program, survey/sampling efforts, and data details will be compiled. If warranted, data acquisition will take place at a later date.

Presently, we hope to capture and summarize the following information for each participating program:

For each monitoring program and survey/sampling effort:

Contact = the personnel point of contact for the monitoring program or scientific study

Program = the name of the monitoring program or scientific study that collected the dataset

Purpose = the original purpose or primary focus/goal of the program or data collection effort

ProgStart = the start date of the program or monitoring effort

ProgEnd = the end date of the program or monitoring effort (leave blank if ongoing)

Design = was any specific experimental design used, and if so, what was it? Describe in detail

Extent = the spatial extent of the sampling effort (i.e., boundary coordinates)

Overlap = known overlap with other data collection efforts

Format = storage format for data collected

[1] https://southeastfloridareefs.net/las-project-status/#tab-279532

Archival = archival methods for data collected

Online = are the data available online

Website = link to the online location for the data

Attributes = a complete list of all measured variables that the monitoring program/survey effort collected

Potential = a complete list of *other* measured variables that could be collected if requested/funded

For each measured variable (i.e., "indicator"):

Indicator = the name/ID for the measured variable

iPurpose = the purpose of the indicator

iUM = units of measure for the indicator

iResT = the *temporal* resolution of the indicator's sampling effort (e.g., hourly, daily, monthly, etc.)

iResS = the *spatial* resolution of the indicator's sampling effort (e.g., point, area/volume obs., etc.)

iStart = indicator sampling date beginning

iEnd = indicator sampling date ending (leave blank if ongoing)

iExtent = spatial sampling extent for the indicator (i.e., boundary coordinates)

iLimits = any known limitations/gaps/issues for indicator

iMethod = description of the sampling methodology for the indicator

6.2. Appendix B – Program Matrix Returned from SEACAR for the Coral ECA

A list of monitoring programs returned by the Statewide Ecosystem Assessment of Coastal (SEACAR) and Aquatic Resources data discovery interface. The SEACAR program matrix was filtered by "Managed Area" to include only those that operated within the Kristin Jacobs Coral Reef Ecosystem Conservation Area.

No.	Program Name	Start Year	End Year	Frequency	Habitats	Indicators
1	Atlantic Oceanographic and Meteorological Laboratory (AOML) South Florida Program Synoptic Shipboard Surveys	1995	Current	Variable	Water Column	WaterCol - Nutrients, WaterCol - Water Quality, WaterCol - Water Clarity
2	National Data Buoy Center	1967	Current	Continuous	Water Column	WaterCol - Water Quality
3	National Water Information System	Varies	Current	Continuous	Water Column	WaterCol - Nutrients, WaterCol - Water Quality, WaterCol - Water Clarity
4	Southeast Area Monitoring and Assessment Program (SEAMAP) - Gulf of Mexico Fall & Summer Shrimp/Groundfish Survey	1981	Current	Annual	Water Column	WaterCol - Water Quality, WaterCol - Water Clarity, WaterCol - Nekton, WaterCol - Additional Indicators
5	Fisheries-Independent Monitoring (FIM) Program	1989	Current	Monthly	Water Column	WaterCol - Water Quality, WaterCol - Water Clarity, WaterCol - Nekton, WaterCol - Additional Indicators
6	Harmful Algal Bloom Marine Observation Network	2000	Current	Variable	Water Column	WaterCol - Water Quality, WaterCol - Water Clarity, WaterCol - Additional Indicators
7	National Status and Trends Mussel Watch	1986	Current	Annual	Water Column, Oyster/Oyster Reef	WaterCol - Water Quality, Oysters - Size Class

No.	Program Name	Start Year	End Year	Frequency	Habitats	Indicators
8	EPA STOrage and RETrieval Data Warehouse (STORET)	early 1960's	Current	Variable	Water Column	WaterCol - Nutrients, WaterCol - Water Quality, WaterCol - Water Clarity, WaterCol - Additional Indicators
9	National Aquatic Resource Surveys, National Coastal Condition Assessment	1999	Current	Periodic	Water Column	WaterCol - Nutrients, WaterCol - Water Quality, WaterCol - Water Clarity, WaterCol - Additional Indicators
10	National Status and Trends Bioeffects program	1986	Current	One-time	Water Column	WaterCol - Water Quality
11	Florida Keys and Southeast Florida Coral Reef Evaluation and Monitoring Project (CREMP/SECREMP)	1996	Current	Annual	Coral/Coral Reef	Coral - Community Composition, Coral - Grazers and Reef Dependent Species, Coral - Percent Cover, Coral - Additional Indicators
12	NPS South Florida/Caribbean Inventory and Monitoring Network: Coral Reef Monitoring	2004	Current	Annual	Coral/Coral Reef	Coral - Community Composition, Coral - Grazers and Reef Dependent Species, Coral - Percent Cover
13	Florida Reef Resilience Program	2005	Current	Annual	Coral/Coral Reef	Coral - Community Composition, Coral - Additional Indicators
14	Lagoon Watch (Formerly Marine Discovery Center)	2013	Current	Weekly	Water Column	WaterCol - Water Quality, WaterCol - Water Clarity

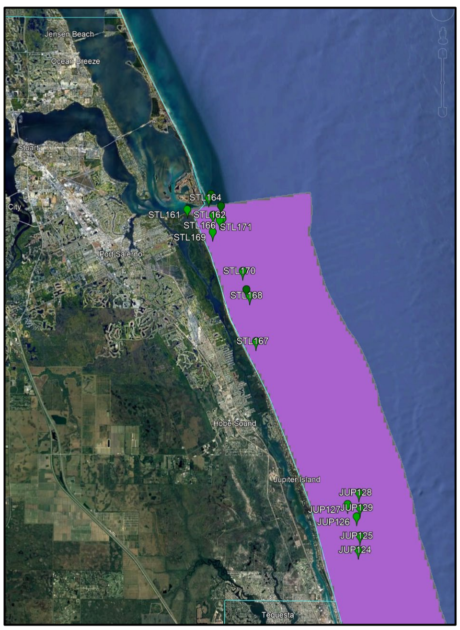
No.	Program Name	Start Year	End Year	Frequency	Habitats	Indicators
15	National Coral Reef Monitoring Program (NCRMP)	2014	Current	Biennial	Coral/Coral Reef	Coral - Community Composition, Coral - Grazers and Reef Dependent Species, Coral - Percent Cover
16	Palm Beach County Artificial and Natural Reef Monitoring Program	2017	2018	TBD	Coral/Coral Reef	Coral - Community Composition, Coral - Grazers and Reef Dependent Species, Coral - Percent Cover
17	Florida Cooperative Land Cover (CLC) map	2014	Current	Periodic	Coastal Wetlands	Wetlands - Acreage (by habitat)
18	National Gap Analysis Program (GAP)	2010	2011	One-time	Coastal Wetlands	Wetlands - Acreage (by habitat)
19	Southeast Gap Analysis Project	1999	2001	One-time	Coastal Wetlands	Wetlands - Acreage (by habitat)
20	2003 Florida Vegetation and Land Cover	2003	2003	One-time	Coastal Wetlands	Wetlands - Acreage (by habitat)
21	Benthic information	2012	2012	One-time	Submerged Aquatic Vegetation, Coral/Coral Reef	SAV - Acreage, Coral - Acreage
22	Unified Reef Maps	2013	Current	Periodic	Submerged Aquatic Vegetation, Coastal Wetlands, Coral/Coral Reef	SAV - Acreage, Wetlands - Acreage (by habitat), Coral - Acreage
23	Florida STORET / WIN	Varies	Current	Variable	Water Column	WaterCol - Nutrients, WaterCol - Water Quality, WaterCol - Water Clarity

No.	Program Name	Start Year	End Year	Frequency	Habitats	Indicators
24	Southeast Florida Water Quality Assessment Survey	2016	Current	Monthly	Water Column	WaterCol - Water Quality, WaterCol - Water Clarity, WaterCol - Additional Indicators
25	Reef Visual Census (RVC) 5-year Assessment of benthic habitat and fish populations	2012	2016	Annual	Coral/Coral Reef	Coral - Grazers and Reef Dependent Species, Coral - Additional Indicators
26	SE FL ECA Large Coral Inventory	2017	Current	Monthly	Coral/Coral Reef	Coral - Percent Cover, Coral - Additional Indicators
27	Characterization of Acropora cervicornis Patches	2015	2015	One-time	Coral/Coral Reef	Coral - Grazers and Reef Dependent Species
28	Southeast Florida Coral Reef Initiative (SEFCRI) Water Quality Monitoring Report	2009	2011	Quarterly	Water Column	WaterCol - Nutrients, WaterCol - Water Quality, WaterCol - Water Clarity
29	FWC-FWRI GIS Data Layers	1986	Current	Variable	Submerged Aquatic Vegetation, Oyster/Oyster Reef, Coral/Coral Reef	SAV - Acreage, Oysters - Acreage, Coral - Acreage
30	South Florida Water Management District (SFWMD) Land Use Land Cover (LULC)	1995	Current	Periodic	Coastal Wetlands	Wetlands - Acreage (by habitat)

6.3. Appendix C – Water Quality Monitoring Stations for Select Programs

Sampling station locations for the Coral Ecosystem Conservation Area Water Quality Assessment (ECA-WQA) and for those locations available in the Water Information Network (WIN) database. Both sets of locations represent the complete spatial sampling universe available for both programs at the time of this report's publication. All maps are presented for ECA-WQA locations in the left-hand panels A, C, E, G, and I (green markers), and for WIN in the right-hand panels B, D, F, H, and J (blue markers). Maps are also presented from North to South for Martin County (A, B), Palm Beach County (C, D), Broward County (E, F), and Miami-Dade County (G, H). The final two panels represent the full sampling extent for the Coral ECA covered by the ECA-WQA (I) and WIN (J) data collection efforts.

A.



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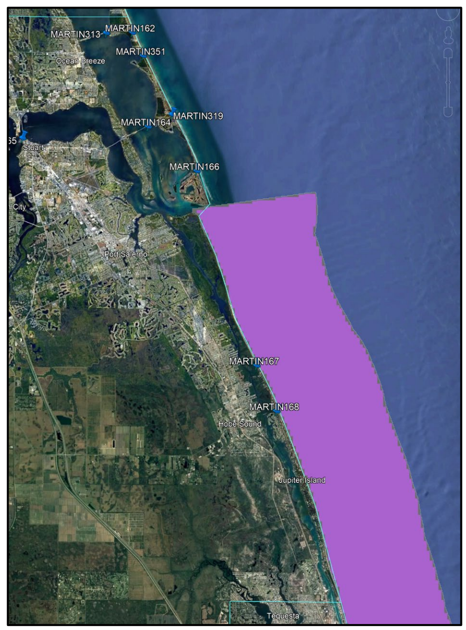

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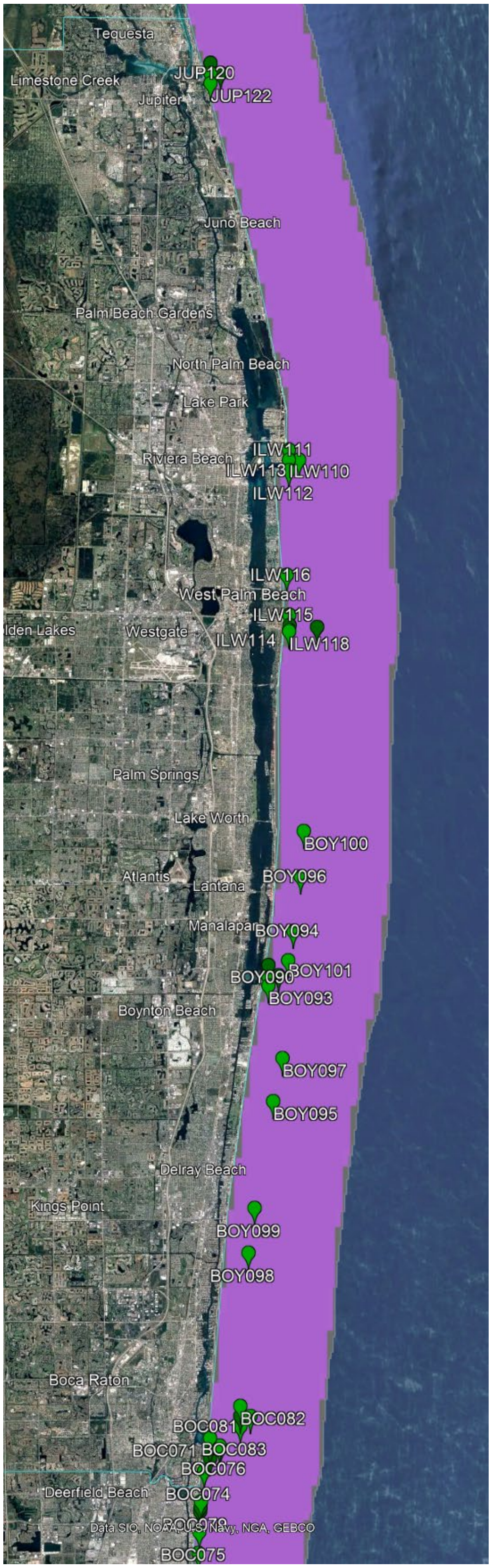
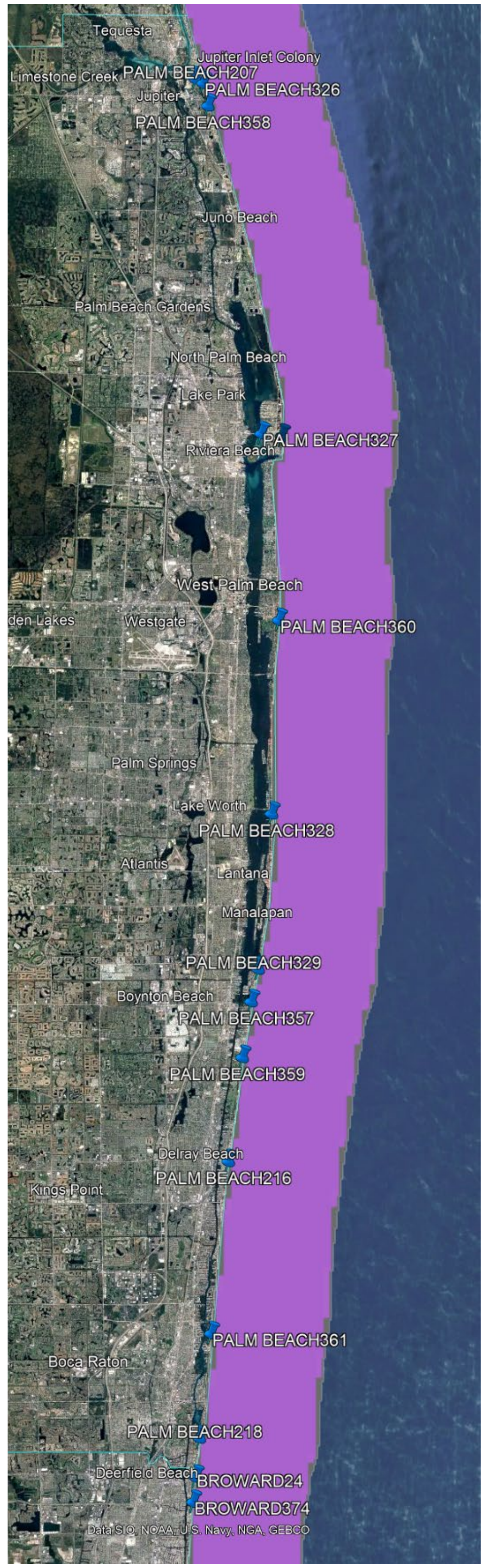

Tequesta
Limestone Creek
Jupiter
JUP120
JUP122
Juno Beach
Palm Beach Gardens
North Palm Beach
Lake Park
Riviera Beach
ILW111
ILW113
ILW110
ILW112
ILW116
West Palm Beach
ILW115
Westgate
ILW114
ILW118
Palm Springs
Lake Worth
BOY100
Atlantis
Lantana
BOY096
Manalapan
BOY094
BOY090
BOY101
BOY093
Boynton Beach
BOY097
BOY095
Delray Beach
Kings Point
BOY099
BOY098
Boca Raton
BOC081
BOC082
BOC071
BOC083
BOC076
Deerfield Beach
BOC074
BOC075
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

D.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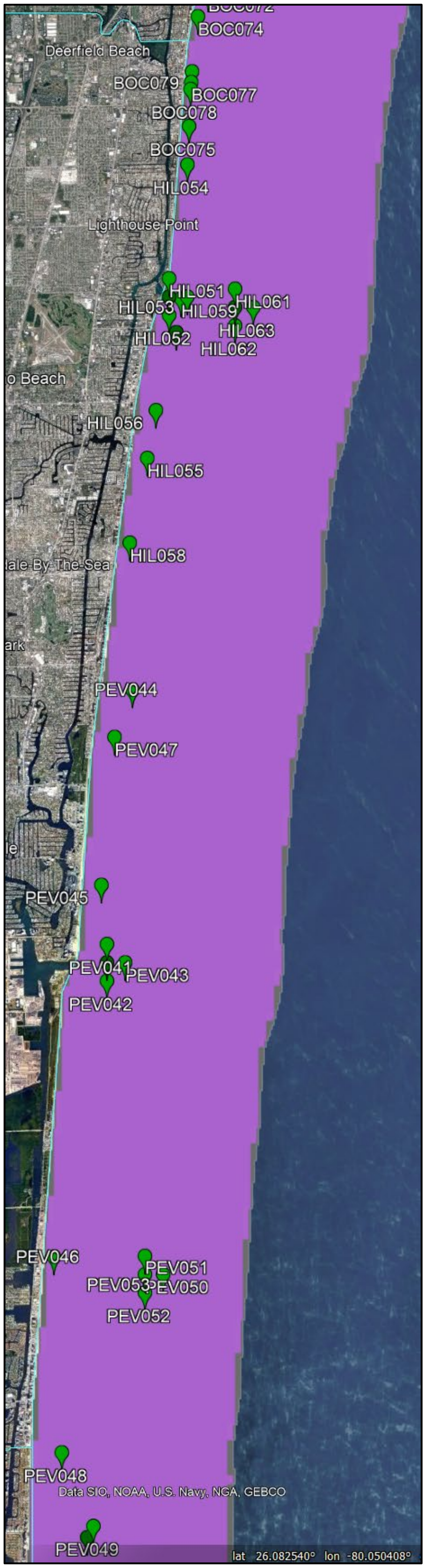
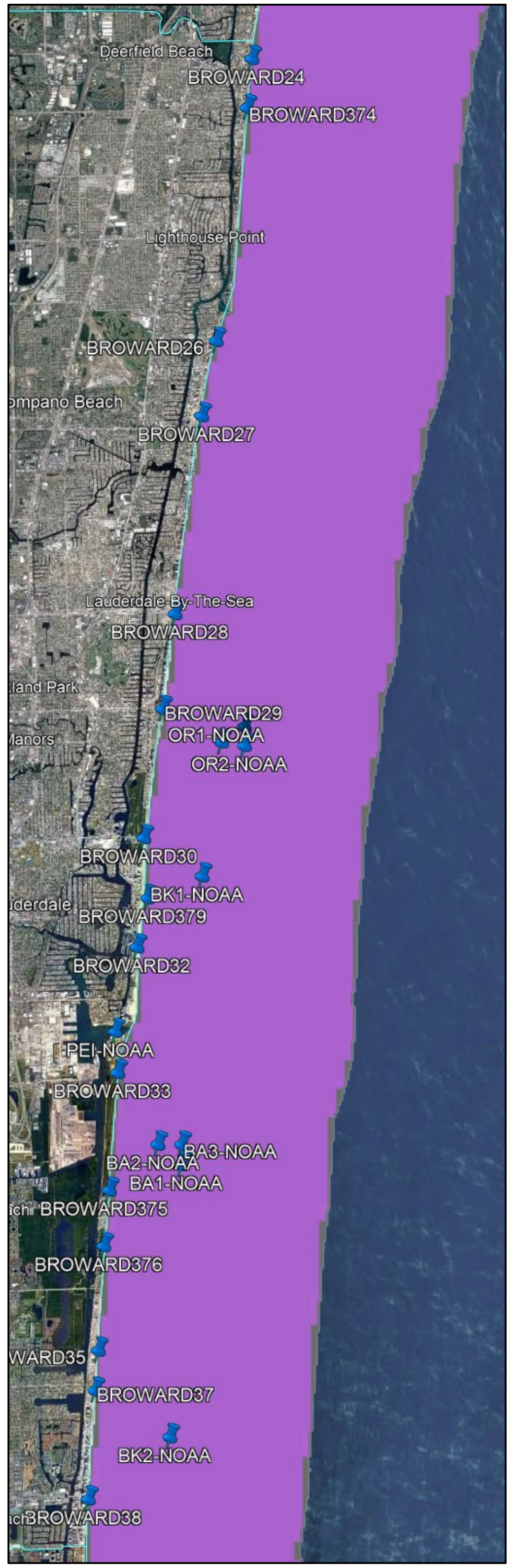
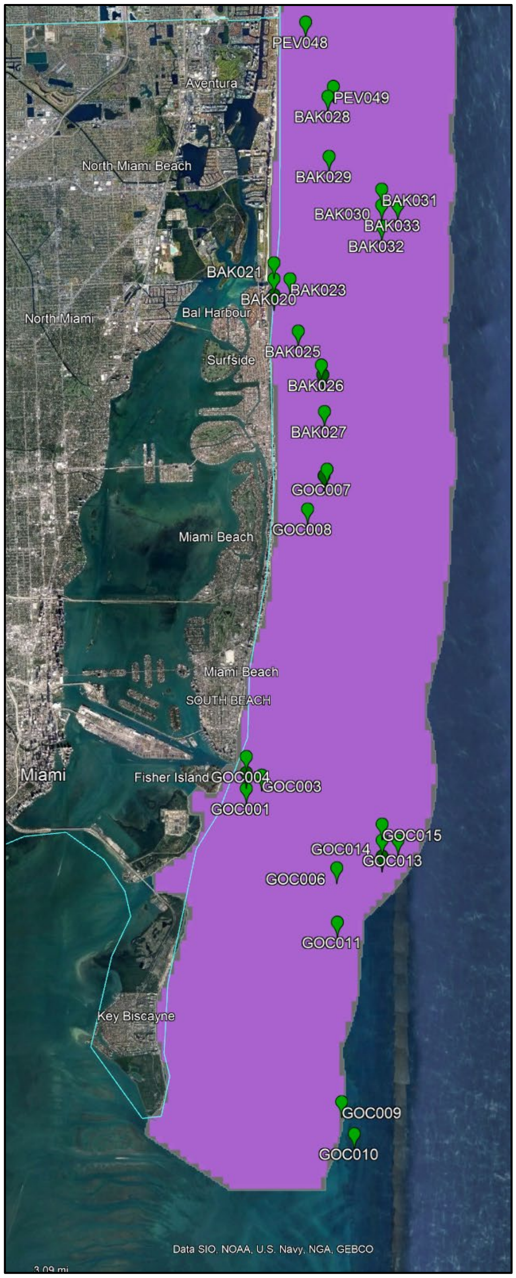
Jupiter Inlet Colony
Limestone Creek
PALM BEACH207
Jupiter
PALM BEACH326
PALM BEACH358
Juno Beach
Palm Beach Gardens
North Palm Beach
Lake Park
Riviera Beach
PALM BEACH327
West Palm Beach
Westgate
PALM BEACH360
Palm Springs
Lake Worth
PALM BEACH328
Atlantis
Lantana
Manalapan
PALM BEACH329
Boynton Beach
PALM BEACH357
PALM BEACH359
Delray Beach
Kings Point
PALM BEACH216
PALM BEACH361
Boca Raton
PALM BEACH218
Deerfield Beach
BROWARD24
BROWARD374
Data SIO, NOAA, U.S. Navy, NGA, GEBCO


BOC072
BOC074
Deerfield Beach
BOC079
BOC077
BOC078
BOC075
HIL054
Lighthouse Point
HIL051
HIL061
HIL053
HIL059
HIL063
HIL052
HIL062
o Beach
HIL056
HIL055
ale-By-The-Sea
HIL058
ark
PEV044
PEV047
le
PEV045
PEV041
PEV043
PEV042
PEV046
PEV051
PEV053
PEV050
PEV052
PEV048
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
PEV049
lat 26.082540° lon -80.050408°

E.

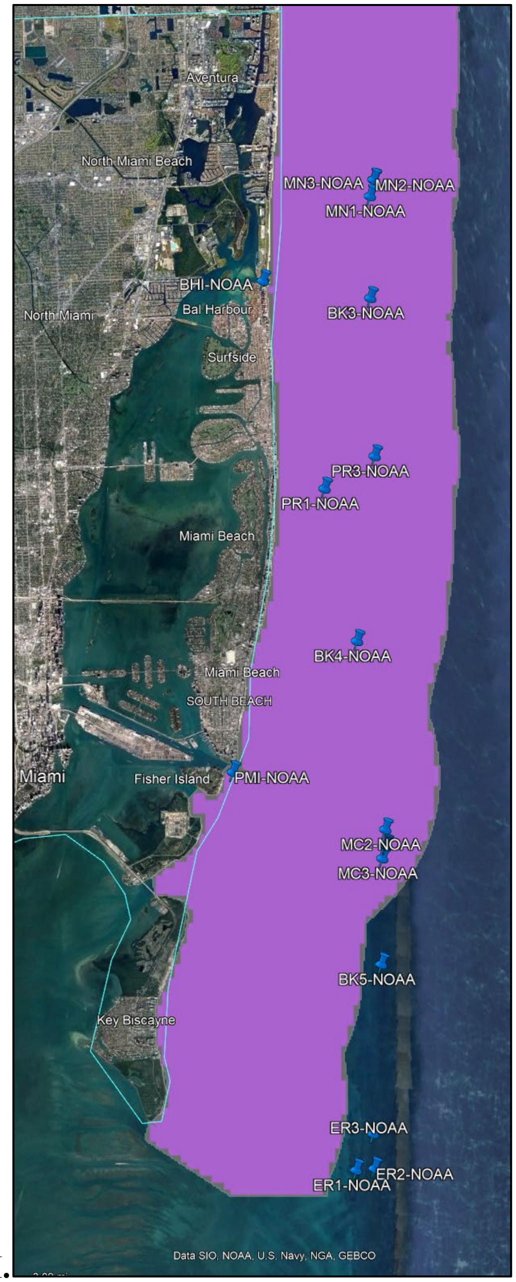

Deerfield Beach
BROWARD24
BROWARD374
Lighthouse Point
BROWARD26
mpano Beach
BROWARD27
Lauderdale-By-The-Sea
BROWARD28
land Park
BROWARD29
OR1-NOAA
Manors
OR2-NOAA
BROWARD30
BK1-NOAA
derdale
BROWARD379
BROWARD32
PEI-NOAA
BROWARD33
BA3-NOAA
BA2-NOAA
BA1-NOAA
BROWARD375
BROWARD376
WARD35
BROWARD37
BK2-NOAA
BROWARD38

F.



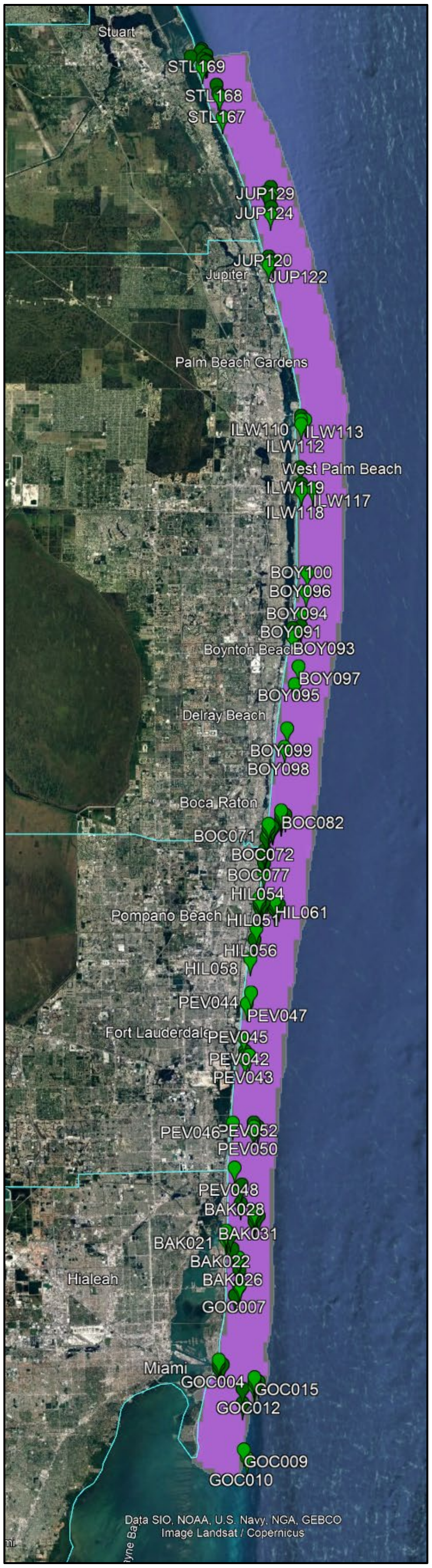
PEV048
Aventura
PEV049
BAK028
North Miami Beach
BAK029
BAK031
BAK030
BAK033
BAK032
BAK021
BAK023
BAK020
North Miami
Bal Harbour
BAK025
Surfside
BAK026
BAK027
GOC007
GOC008
Miami Beach
Miami Beach
SOUTH BEACH
Miami
Fisher Island
GOC004
GOC003
GOC001
GOC015
GOC014
GOC013
GOC006
GOC011
Key Biscayne
GOC009
GOC010
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

G.

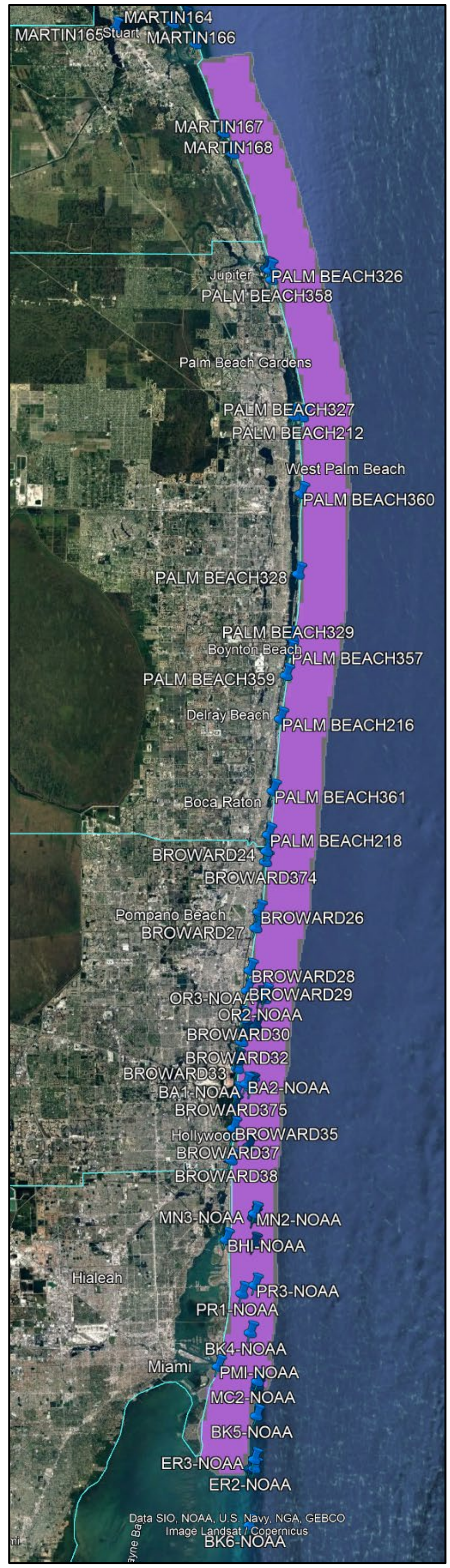


Aventura
North Miami Beach
MN3-NOAA
MN2-NOAA
MN1-NOAA
BHI-NOAA
North Miami
Bal Harbour
BK3-NOAA
Surfside
PR3-NOAA
PR1-NOAA
Miami Beach
BK4-NOAA
Miami Beach
SOUTH BEACH
Miami
Fisher Island
PMI-NOAA
MC2-NOAA
MC3-NOAA
BK5-NOAA
Key Biscayne
ER3-NOAA
ER2-NOAA
ER1-NOAA
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

H.


Stuart
STL169
STL168
STL167
JUP129
JUP124
JUP120
Jupiter
JUP122
Palm Beach Gardens
ILW110
ILW113
ILW112
West Palm Beach
ILW119
ILW117
ILW118
BOY100
BOY096
BOY094
BOY091
Boynton Beach
BOY093
BOY097
BOY095
Delray Beach
BOY099
BOY098
Boca Raton
BOC082
BOC071
BOC072
BOC077
HIL054
Pompano Beach
HIL051
HIL061
HIL056
HIL058
PEV044
PEV047
Fort Lauderdale
PEV045
PEV042
PEV043
PEV046
PEV052
PEV050
PEV048
BAK028
BAK031
BAK021
BAK022
Hialeah
BAK026
GOC007
Miami
GOC004
GOC015
GOC012
GOC009
GOC010
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus

I.


MARTIN164
MARTIN165
Stuart
MARTIN166
MARTIN167
MARTIN168
Jupiter
PALM BEACH326
PALM BEACH358
Palm Beach Gardens
PALM BEACH327
PALM BEACH212
West Palm Beach
PALM BEACH360
PALM BEACH328
PALM BEACH329
Boynton Beach
PALM BEACH357
PALM BEACH359
Delray Beach
PALM BEACH216
Boca Raton
PALM BEACH361
PALM BEACH218
BROWARD24
BROWARD374
Pompano Beach
BROWARD26
BROWARD27
BROWARD28
OR3-NOAA
BROWARD29
OR2-NOAA
BROWARD30
BROWARD32
BROWARD33
BA1-NOAA
BA2-NOAA
BROWARD375
Hollywood
BROWARD35
BROWARD37
BROWARD38
MN3-NOAA
MN2-NOAA
BHI-NOAA
Hialeah
PR3-NOAA
PR1-NOAA
BK4-NOAA
Miami
PMI-NOAA
MC2-NOAA
BK5-NOAA
ER3-NOAA
ER2-NOAA
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
BK6-NOAA

J.

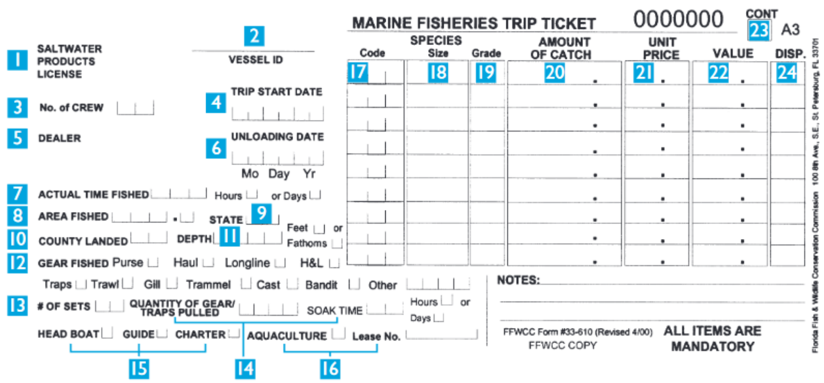
6.4. Appendix D – Example of a Florida State Marine Fisheries Trip Ticket

The Marine Fisheries Trip Ticket

Chapter 68E-5 (F.A.C.) requires that all Florida wholesale dealers maintain records of each purchase of saltwater products. Retailers who produce their own product must also maintain records of the saltwater products that they produce for sale through their retail license. The marine fisheries trip ticket, shown below, is used to record the required information for each trip. The boxes describe each item on the ticket and explain how to fill it out. **All appropriate data items are mandatory.**

All correspondence related to Florida's marine fisheries trip ticket data collection system should be addressed as follows:

Florida Fish and Wildlife Conservation Commission
Fish and Wildlife Research Institute
Trip Ticket Office
100 Eighth Avenue SE
St. Petersburg, FL 33701-5020



1 Saltwater Products License
The seller's Saltwater Products License number or Aquaculture Permit number.

2 Vessel ID
The vessel registration number (Coast Guard or FL vessel number).

3 Number of Crew
The number of individuals, including the Captain, working aboard a vessel during a trip.

4 Trip Start Date
Date the vessel left port to begin the fishing trip.

5 Dealer
The wholesale (WD) or retail central (RC) dealer number. Retailers can produce only their own product, not buy from other fishermen.

6 Unloading Date
Date the fish were offloaded from the vessel. If a portion of the catch from the same trip is sold to another dealer, then a separate trip ticket should be filled out for each dealer. The invoice numbers should be the same with the CONT field indicating the first dealer with a '1' and the second dealer with a '2'. This is similar to splitting the catch between two or more fishermen. The second dealer would need to know the trip ticket number used by the original dealer. This should be available from the fisherman.

7 Actual Time Fished
The duration of the fishing trip (time away from the dock). Indicate whether time fished is in hours or days by checking the appropriate box.

8 Area Fished
The area where saltwater products were caught. Use the area codes provided on the Fishing Area Codes poster.* If products were caught over more than one area, you may use the Continuation field, as described in Box 23.

9 State
Postal abbreviation for state where fish were landed.

10 County Landed
The county code in which the saltwater products were landed (brought ashore).

11 Depth
The approximate (average) depth where the saltwater products were caught. Depth may be recorded in feet or fathoms by checking the appropriate box.

12 Gear Fished
Check the appropriate gear box for only those gears used on the trip. Or you may be more specific and write the gear code, from the gear list* in the space for "other" gear. Example: 4760 for stab gill net. If products were caught with more than one gear, you may use the Continuation field as described in Box 23.

13 Number of Sets
Use only when saltwater products are caught with trawls, longlines, gill nets, purse seines, or other type nets or seines. Record the number of times that the fishing gear was set during the trip.

14 Quantity of Gear/Traps Pulled, Soak Time
Record the quantity of gear (number of hooks/nets per set, number of traps pulled) on each trip. For trap fisheries, record the number of days or hours that the traps were being fished.

15 Head Boat/Guide/Charter
Check the appropriate box if the trip was from a head boat, guide boat, or charter boat.

16 Aquaculture/Lease Number
Check the box for aquaculture if catch is cultured product and record the lease site number.

17 Species Code
Record the species code of each saltwater product landed. A list of species names is on the back of each ticket. A poster with a complete list of species codes is available.*

18 Species Size
If the product is sized, record the letter S for small, M for medium, L for large, etc.; otherwise leave blank. Shrimp counts can be recorded here.

19 Species Grade
Physical condition of the fish. For example, the quality of the fish (#1, #2, A, B, etc.), or whether headed and/or gutted, etc. A short list of grade codes will be provided.

20 Amount of Catch
The quantity of each species caught. Several species use measurements other than pounds, such as gallons (oysters) or numbers of individuals (bait shrimp). Additional species codes* have been provided for these situations.

21 Unit Price
The price-per-pound, or other measure, paid for each species purchased.

22 Dollar Value (Optional)
The value of each species purchased.

23 Cont (Continuation)
The Continuation box allows two or more fishermen to divide their catch from the same fishing trip and sell it to you under their respective Saltwater Products Licenses. It also allows a fisherman to split his catch among two or more fishing areas, gears, or depths. Place a number here to indicate the first (1) fisherman, area, or gear, etc. The invoice number should be the same. Please keep the invoices in numerical order. Call for more details or if you have questions.

24 Disp (Disposition)
This refers to discarded, released, and unsold catch with regard to regulations or market conditions. A short list of disposition codes will be provided.

NOTE: Posters for area and species codes may be obtained from the Trip Ticket Office. Lists of county, gear, and disposition codes are also available. The address and phone number of the Trip Ticket office are on this brochure.