Identification of Regimes in the Kristin Jacobs Coral Reef Ecosystem Conservation Area using Combined Benthic Composition and Fish Abundance

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

Identification of Regimes in the Kristin Jacobs Coral Reef Ecosystem Conservation Area using Combined Benthic Composition and Fish Abundance

Final Progress Report for FDOU-51, Phase II

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List of Acronyms

CCA	Crustose Coralline Algae
Coral ECA	Kristin Jacobs Coral Reef Ecosystem Conservation Area
CPR	Coral Protection and Restoration Program
CRCP	Coral Reef Conservation Program
DEP	Florida Department of Environmental Protection
DisProf	Dissimilarity Profile
DRM	Disturbance Response Monitoring
FDOU	Fishing, Diving and Other Uses
FDOU-51	FDOU LAS Project #51
FWRI	Florida Fish and Wildlife Research Institute
G1, G2	Reef Fish Trophic Guild Assignment #1 and #2
HB	House Bill
ICA	Inlet Contributing Area
IndVal	Species Indicator Value
LAS	Local Action Strategy
LPI	Line point-intercept
NCRMP	National Coral Reef Monitoring Program
NOAA	National Oceanic and Atmospheric Administration
PCoA	Principal Coordinates Analysis
PI	Principal Investigator
PSU	Primary Sampling Unit
QM1, QM2, QM3	Quarterly Meeting #1, #2, and #3
RVC	Reef-fish Visual Census
SCUBA	Self-Contained Underwater Breathing Apparatus
SEFCRI	Southeast Florida Coral Reef Initiative
UPGMA	Unweighted Pair-Group Method with Arithmetic Mean
USF	University of South Florida

1. INTRODUCTION

1.1. Background

The Southeast Florida Coral Reef Ecosystem Conservation Area was officially established on July 1, 2018 after HB 53 passed the Florida House of Representatives on Jan. 25, 2018 and then subsequently passed the Florida Senate on Feb. 7, 2018 (Florida-Senate, 2018). In honor of the late Broward County state representative, 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. The Coral ECA extends from its northern boundary at St. Lucie Inlet southward, and the northern extent of Biscayne National Park marks the conservation area's southern boundary (Figure 1). Although the Coral ECA 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 region since at least the formation of the Southeast Florida Coral Reef Initiative (SEFCRI) in 2003.

The SEFCRI Team comprises 64 stakeholders and was formed to develop local action strategies (LAS) to protect the ~105 linear miles of coral reef resources spanning Martin through Miami-Dade county waters. These LAS are short-term, locally driven projects, or roadmaps, for cooperative action among federal, state, and non-governmental partners, and which identify, prioritize, and implement actions needed to reduce key threats to coral reef resources in the Coral ECA. The strategies are designed to be implemented over a three- to five-year period, and the Florida Department of Environmental Protection (DEP) Coral Reef Conservation Program (CRCP) was established in 2004 to support and manage the overall progress towards completion of these LAS projects. The SEFCRI Team identified five focus areas for immediate local action, including 'land-based sources of pollution', 'maritime industry and coastal construction impacts', 'fishing, diving, and other uses' (FDOU), 'lack of awareness and appreciation', and 'reef resilience'. Each of these focus areas have LAS projects which are coordinated by the CRCP at DEP.

The project discussed herein is a continuation of the efforts completed in Phase I of FDOU's LAS Project #51 (FDOU-51), which involved several collaborative meetings with input from numerous stakeholders, managers, and technical advisors. FDOU-51, Phase I was directed toward data discovery (Kilborn, 2022a), the scoping of management priorities and research themes for the Coral ECA (Kilborn, 2022c;Kilborn and Lizza, 2022), and the identification of knowledge and data gaps within the system (Kilborn, 2022b). Phase I identified primary sources of data for FDOU-51 and outlined their strengths, weaknesses, and compatibility for the purposes of performing holistic analyses in subsequent phases of FDOU-51 (Kilborn, 2022a). The results of Phase I also included a framework for those holistic analyses, and recommendations for new research priorities and augmented monitoring efforts that would help to better inform the system-wide management of the conservation area (Kilborn, 2022b).

The next FDOU-51 Phases (II-III) will use the framework developed and conduct a set of holistic analyses using existing long-term monitoring data in the Coral ECA to investigate the diversity, abundance, and size composition trends in fish resources and natural habitats within the conservation area. These investigations will examine relationships between these trends and changing water quality and/or benthic habitat, as well as identify fish and coral species/functional groups indicative of different configurations. The Coral ECA is a highly interconnected and spatiotemporally dynamic system. When considered individually, each subsystem is easily as complex as when considered holistically, and therefore the research and monitoring efforts are limited by the scope and resources available to them.

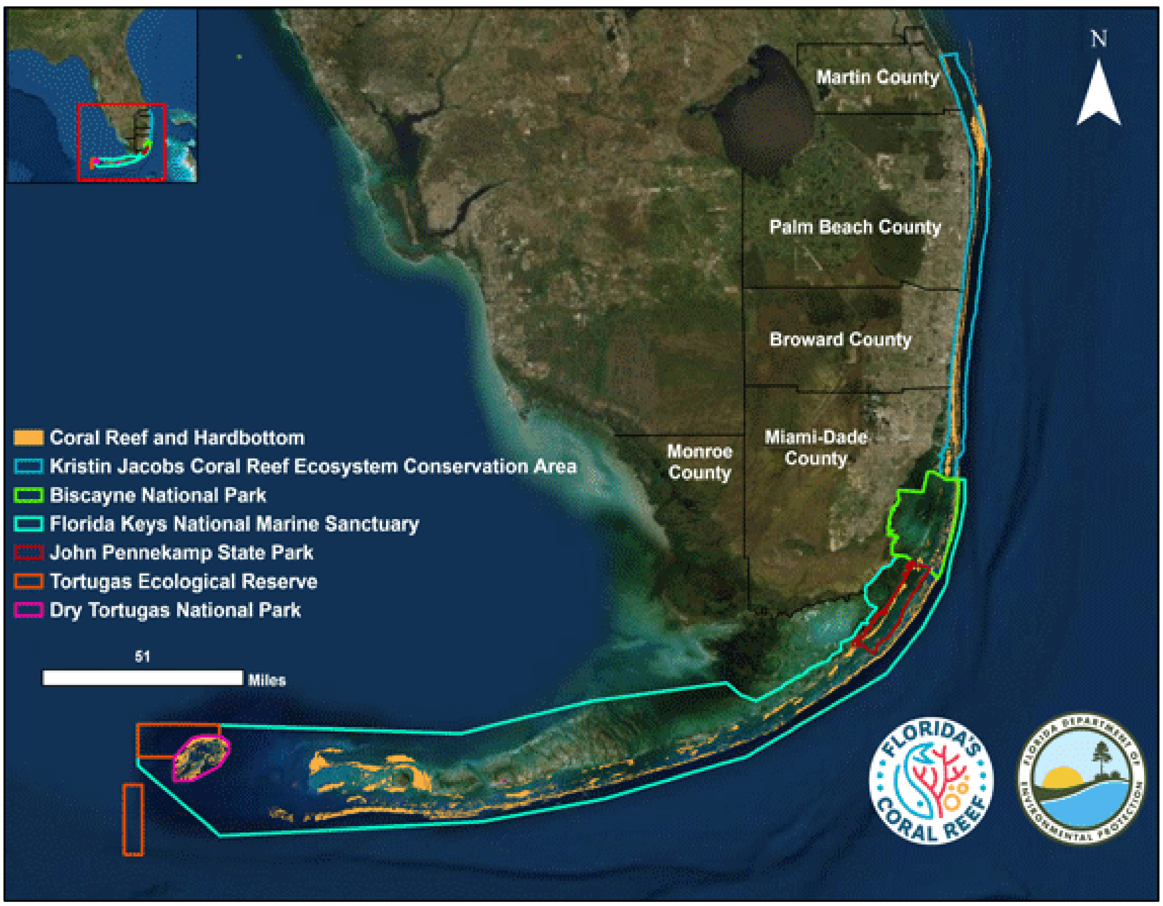

Figure 1. Map of Florida's Coral Reef. The Kristin Jacobs Coral Reef Ecosystem Conservation Area (northern-most, blue outline) encompasses the entire northern portion of Florida's Coral Reef system and spans Martin, Palm Beach, Broward, and north Miami-Dade counties.

1.2. Research Questions

1. Are there unique ecological communities of fishes and live benthos throughout the Coral ECA, and how are they spatially arranged? (FDOU-51, Phase II)
2. How do the reef regimes relate to each inlet contributing area (ICA) and their water qualities? (FDOU-51, Phase III)
3. What are the ecological characteristics of and differences between the unique reef regimes?
    a. Are there differences in the composition, abundance, or indicator species for benthic (Phase III) and fish (Phase II) functional groups?
    b. Are there differences in benthic habitat condition (e.g., disease and bleaching prevalence, bioerosion presence, new recruits)? (Phase III)
    c. Are there differences in stony coral cover and species composition or characteristics? (Phase III)
    d. Are there differences in fish beta-diversity, demographics, or species' characters? (Phase III)

1.3. Project Goals and Objectives

Managers at DEP CRCP have identified several contemporary research priorities for the Coral ECA, including leveraging the long-term monitoring data collected by programs that individually survey the fish, benthic, and water quality subsystems to perform holistic analyses within it. These inquiries focus on understanding the spatial and temporal patterns among the subsystems and resources within the conservation unit, as well as any interconnections that relate their outcomes together. Thus, Phases II-III of FDOU-51 aim to complete these analyses and investigate the ecosystem dynamics and interrelationships among these critical components of the Coral ECA. By utilizing the ICA framework and the existing research previously conducted to understand the differences in water quality within and among these sub-regions (Whitall et al. 2019; Briceno et al., 2023), this project will link differences in abundance and community composition among the fish and benthic subsystems to the water quality subsystem of the conservation area. Coral reef sites within the Coral ECA will be classified into reef regimes using the long-term monitoring data from the fish and benthic subsystems using similar methods to Donovan et al. 2019, and post-hoc analyses to relate them to the ICA framework will be performed. This project aims to describe the composition and condition of the biological, geological, and aquatic resources at each reef site, and to describe each reef regime using existing monitoring parameters. The research questions and project goals described above will be answered and achieved by focusing on the following objectives:

1. Identification of reef regimes **Includes benthic and fish subsystems only.* (Phase II)

2. Examine ecological patterns across reef regimes as defined by the existing parameters and any newly derived ecological indicators. (Phase III)
3. Characterize the physical/chemical conditions within the identified reef regimes. (Phase III)
4. Relate the ICA framework and their water quality signatures to regime states. (Phase III)
5. Identify fish and benthic indicator species within regime states. (Phase II & Phase III)

1.4. Reef Management Application

DEP aims to use the results of this project to improve management efforts, develop a more comprehensive understanding of the subsystems that comprise the Coral ECA, and gain insights into the status of the system as it has changed over time. Coral reef ecosystem status and trends are currently assessed on an individual subsystem level and do not evaluate the ecological interactions and dynamics that exist among them. This project will allow for a better understanding of those ecological interactions through the identification of reef regime states that will be derived from combined descriptors of the reef fish and benthic subsystems, which will then be further related to unique water quality characteristics of the region that are captured by the ICA framework (Whitall et al. 2019 and Briceno et al. 2023). Resource managers will gain knowledge and understanding of fish and benthic indicator species that best characterize regime states as well as a spatiotemporal visualization of the state of the these coupled systems within the Coral ECA. The identification of indicator species may be used as a rapid assessment tool and has potential to improve the efficiency and effectiveness of management actions that address fish, benthic, and water quality conditions. Additionally, this information will be incorporated into the Florida Fish and Wildlife Research Institute (FWRI)'s ongoing development of a decision support tool, overseen by the Coral Protection and Restoration Program (CPR), that is focused on improving the effectiveness of management, future restoration initiatives, and site selections.

2. PROJECT STATUS OF FDOU-51 PHASE II

2.1. Scope of Work for Reporting Period

The reporting period for this report covers the service dates beginning **January 16, 2024**, and continuing through **June 30, 2024**. As per the scope of work, the following tasks were scheduled for completion during this work period.

2.1.1. Task 1: Quarterly Meetings #2 and #3

Quarterly meetings #2 (QM2) and #3 (QM3) comprising the FDOU-51 Project Team, DEP Managers and Coordinators, the FWRI Decision Support Tool Team, and monitoring programs' Data Managers and Program Leads were scheduled for completion during this period. All meetings were planned and facilitated by the project's PI, and brief summaries are included in this report. The QM2 and QM3 agendas, presentations, and verbatim transcripts are included in the deliverable package for this reporting period (see items **'T1.3_QM2.zip'** and **'T1.4_QM3.zip'**).

2.1.1. Task 4: Phase II Final Report

The preliminary portion of Phase II encapsulated the data acquisition and preprocessing activities, and this reporting period involved the identification and description of combined benthic and reef-fish regimes. The latter task included the clustering model development and interpretation, as well as compilation and mapping of the reef regimes across the Coral ECA. The focus of this task and deliverable is the communication of regimes and the methods used to obtain them. The more detailed descriptions of the qualitative differences among them, across both space and time, and incorporating water quality considerations via the ICA framework, are reserved for Phase III of FDOU-51. Therefore, the final report for Phase II, ***this report***, also includes the following technical information:

- Descriptions of final preprocessing and ultimate constitution of the data, parameters, and functional groups used for the analyses.
- All methods employed.
- The results of clustering exercises along with associated figures, tables, ordination diagrams, and selected maps.
- A brief overview of high-level qualitative differences among groups, and any fish indicator species identified.
- A brief description of frequency and spatial distribution of regimes across the Coral ECA and initial indication of any changes over time (where possible).

2.1.2. Task 5: Finalized Data Products

Final maps will be submitted in both .pdf and .svg formats (or others as deemed necessary) along with any ArcGIS datafiles or layers used to create them. All final data products and analytical results will be submitted in either .xlsx or .csv formats (when possible) or as .RData files.

This task entailed the acquisition, preprocessing, and storage of all available data files for the selected monitoring programs used in this analysis. Specifically, the Coral ECA surveillance conducted by the National Coral Reef Monitoring Program (NCRMP), including the line point-intercept (LPI) data for the natural benthic subsystem (Towle et al., 2021) and the reef-fish visual census (RVC) data for the fish subsystem (Kilfoyle et al., 2018;Towle et al., 2021). These two datasets were preprocessed (as described below) and the final deliverables are contained in the archive **'T5.1-4_DataFiles.zip'**, which includes the following files:

- **'bioPSU_2024-03-27.csv'**
    - Contains all raw LPI data, at the primary sampling unit (PSU) level, for the Coral ECA 2014-2022.

- **‘RVC_2014-2055_Abund_Matrix_2024-01-14_forJB.xlsx’**
    - Contains all raw RVC data, at the PSU level, for the Coral ECA 2014-2022.
- **‘bioPSU_2024-03-27_JEB.csv’**
    - Contains combined [LPI + RVC] data for Coral ECA 2014-2022.
    - PSUs were matched across LPI and RVC observations by name and no spatial reconciliation was performed.
- **‘LPI-RVC_2024-05-09_AnalysisReady.csv’**
    - Contains combined [LPI + RVC] data for Coral ECA 2014-2022.
    - PSUs were matched across LPI and RVC observations by name and units whose geographic coordinates were ≤ 1 km apart were retained for analysis

In addition to the raw and preprocessed datafiles, the final “analysis ready” data were also compiled in accordance with the two reef-fish trophic guilds described below and appended to the final grouping solutions obtained for all four of the depth-related models used in sensitivity testing. Thus, the following files are also included in **‘T5.1-4_DataFiles.zip’**:

- **‘NCRMP_G1_2024-05-28_AnalysisReady.csv’**
    - File containing the LPI data matched to the RVC data compiled according to trophic guild assignment #1 (G1, see below).
- **‘NCRMP_G2_2024-05-28_AnalysisReady.csv’**
    - File containing the LPI data matched to the RVC data compiled according to trophic guild assignment #2 (G2, see below).
- **‘NCRMP_G1_ALL_Clusterings_2024-06-10_Scaled_3rdRoot_wSites.csv’**
    - File containing the [LPI + RVC] data compiled according to G1 and including all depth zones’ grouping assignments.
- **‘NCRMP_G2_ALL_Clusterings_2024-06-10_Scaled_3rdRoot_wSites.csv’**
    - File containing the [LPI + RVC] data compiled according to G2 and including all depth zones’ grouping assignments.

This task also encompassed the production of sub-regional maps for the Coral ECA capturing the spatiotemporal distributions of the reef regimes detected (e.g., Donovan et al., 2018), and produced using Esri Inc.’s ArcGIS Pro v3.0.3. The files are included in the archive **‘T5.5_Maps.zip’** and include the following files:

- **‘FDOU-51_Phase2.aprx’**
- **‘FDOU-51_Phase2_Maps.mapx’**
- **‘G1_AllGroups.pdf’**
- **‘G2_AllGroups.pdf’**
- **‘G1_BigGroups.pdf’**
- **‘G1_BigGroups.pdf’**

2.2. Work Completed in Reporting Period

2.2.1. Quarterly Meetings

All quarterly meetings have been completed and were convened primarily to update the advisory panel on the current status of FDOU-51 progress and to solicit advice from the panel where appropriate. The final schedule for all Phase II quarterly meetings was as follows:

- QM1: November 29, 2023 (10:00 AM – 12:00 PM EST)
- QM2: March 13, 2024 (11:00 AM – 12:00 PM EDT)
- QM3: June 4*, 2024 (11:00 AM – 12:00 PM EDT)
  - * QM3 rescheduled to June 11 (11:00 AM – 12:00 PM EDT)

The second quarterly meeting of this reporting period (QM2) entailed an update from the PI to the panel regarding the status of the preparation and exploratory analyses of the LPI and RVC datasets. The methods used to delineate reef fish functional guilds were detailed and the species' guild assignments were finalized. These conversations led to the recommendation that two sets of assignments be investigated. One scheme (G1) that assigns all species into one of 10 general trophic guilds ranging from herbivores to piscivores, and a second guild scheme (G2) that includes species of fishes that are not only important recreational and commercial species (i.e., snappers and groupers), but also represent iconic or unique guilds (i.e., parrotfish, groupers) within the Coral ECA.

Additional time was spent on the communication of results from spatial autocorrelation analyses and the implications for the sampling design and inferential frame of the FDOU-51 study. Generally, the agreement was that there is expected to be relatively large amounts of spatial correlation among the samples within the Coral ECA. Further, due the requirement that fish and benthic data be paired together, the paired NCRMP data are significantly reduced (the RVC data in particular), and this reduction exacerbates the autocorrelation issues, as well as reduces the options available to mitigate them (i.e., aggregation of samples at some minimum spatial scale). Extensive follow up discussion ensued with the NCRMP Data Managers and Program Leads, and it was agreed that, while not specifically designed for the purposes outlined in our approach, the manner in which data were compiled and processed would generate defensible results, and hopefully generate novel implications for the Coral ECA.

The third, and final, quarterly meeting of Phase II (QM3) was convened to update the panel on the clustering exercises and to discuss the combined benthic-fish regimes identified for the Coral ECA from 2014-2022. Limited qualitative results, including lists of indicator fishes associated with selected regime states and the states' spatial distributions across the region were also discussed. Ultimately, the group was satisfied with the progress and the discussions were relatively limited throughout QM3. During the presentation of the grouping exercise's sensitivity to the inclusion of relatively shallow (< 5 m) and/or deep (> 25 m) sampling units there was some conversation about the choice of boundaries for the depth zones and what those zones ultimately represented. Furthermore, there was also some commentary about the impact of aggregating both deep and shallow water species into functional guilds and how that might affect the interpretation of results. Unfortunately, the topics of the greatest interest to the group were more related to the discriminant analyses planned for Phase III of FDOU-51.

2.2.2. Data Compilation and Final Constitution

All data for Phase II of FDOU-51 were drawn from the NCRMP surveys for proportional cover of benthic habitat (LPI) and SCUBA diver observations of reef fishes (RVC). Operations were targeted at ~0.5 to 30 m depth across the Coral ECA's natural carbonate reef system (Figure 2). When considered as paired data, these programs extend from 2014-2022 and operate biennially. Thus, there are six discrete sampling seasons (even years) included in this analysis spanning a total of nine years. Per the NCRMP sampling protocols (Towle et al., 2021), the benthic survey locations (N_{LPI} = 435) are drawn as a subset of the reef fish census locations (N_{RVC} = 1,545) (Figure 2).

Data from the full sampling frame were used for exploratory analyses (Kilborn, 2024) and to determine summary statistics for each of the benthic habitat categories (Table S1) and all fish species (Table S2) present. The explicit spatial analyses (Kilborn, 2024) were also performed on the datasets at their full resolution. Based on those test results (Table S3, Table S4) and in the interest of maintaining as many samples as possible from the combined [LPI + RVC] data, none of the independent PSUs were combined into higher order sampling units. Of the $N_{[LPI+RVC]}$ = 435 paired [LPI + RVC] samples, N = 398 were retained for the final clustering exercises. During the pairing process, the geographic distance between the LPI and RVC sampling location was obtained and only pairs whose recorded sampling locations were within 1 km of each other were considered the same event. The selection of 1 km as the threshold value for pairing sites was relatively arbitrary, however, given the scope and scale of the relatively independent programs' field sampling efforts, this distance was considered a realistic threshold. The final distribution of samples across years and NCRMP 'subregions' is reported in Table 1.

Table 1. Sampling effort acros the Coral ECA. Each value represents the distribution of all (N = 398) paired [LPI + RVC] sampling units across years (*italics*) and subregions (**bold**), along with their respective totals.

Year	**Martin**	**North Palm Beach**	**South Palm Beach**	**Deerfield**	**Broward-Miami**	*Total*
2014	0	0	0	0	34	*34*
2016	7	14	11	8	47	*87*
2018	0	20	9	9	29	*67*
2020	0	18	10	14	55	*97*
2022	0	17	12	12	72	*113*
Total	**7**	**69**	**42**	**43**	**237**	***398***

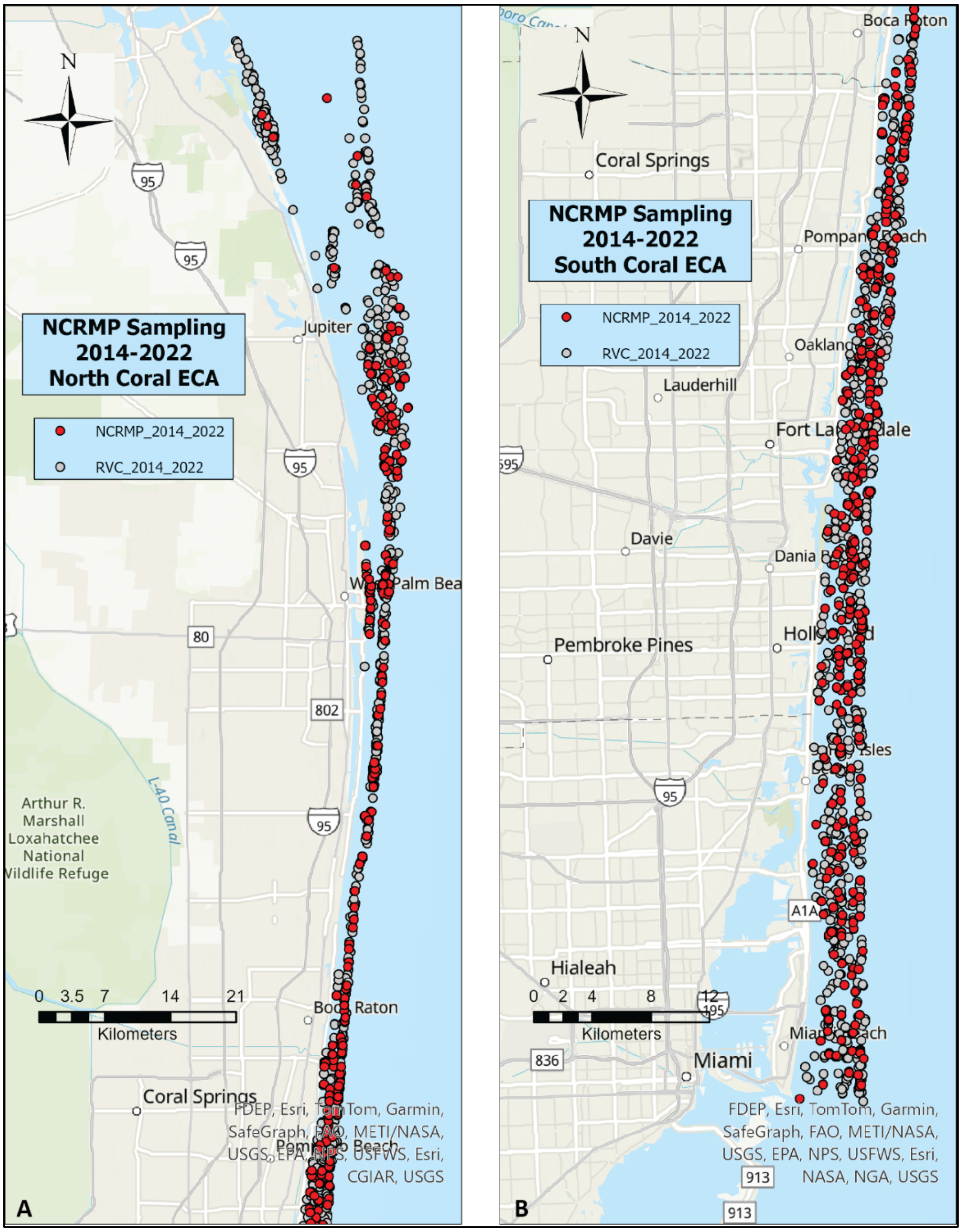

Figure 2. NCRMP reef fish and benthic habitat survey locations across the Coral ECA. Locations for the diver surveys conducted for NCRMP and spanning the entire Coral ECA from 2014-2022. Survey sites are pictured across the northern (A) and southern (B) portions of the region for both reef-fish visual census (RVC, grey circles) and benthic habitat (NCRMP [or LPI], red circles) sampling.

2.2.2.1. Benthic Subsystem Parameterization

The NCRMP benthic LPI surveys report proportional cover data for 14 different discrete benthic habitat types (Table S1), however some of these were condensed and the final set of benthic parameters used here includes 11 different biological habitat types (Table 2). For the purposes of this study, the individual sub-categories '*Peysonnellia*' and '*Ramicrusta spp.*' were added to the 'Crustose Coralline Algae' (CCA) category, and since 'Seagrass' was only present in 2% of all retained samples (9 of 398) it was added to the 'Other' category, which was then given the tag 'NEW' (Table 2). All other benthic cover categories were present in at least 14% (*n* = 57) of all PSUs (Table S1).

Table 2. Summary statistics for final LPI categories. All attributes across all *N* = 398 PSUs in the Coral ECA spanning 2014-2022. Standard deviation ('StedDev') is with respect to the mean value.

LPI - Category	Symbol	Max	Mean	StdDev
Hard Corals	*coralHARD*	17.00	1.18	2.00
Soft Corals	*coralSOFT*	52.00	7.65	8.21
Hydrocorals	*coralHYDRO*	2.50	0.24	0.51
Sponges	*sponges*	43.00	8.11	6.64
Cyanobacterias	*cyanobacteria*	62.00	3.59	7.73
Crustose Coralline Algae	*CCA*	17.82	1.26	2.58
Macroalgae	*algaeMACRO*	94.00	21.95	20.12
Turf Algae	*algaeTURF*	96.00	42.12	23.17
Non-biological Substrate	*substrate*	98.00	12.72	18.16
Other Invertebrates	*otherINV*	17.00	0.63	2.08
Other (incl. Seagrasses)	*otherNEW*	38.00	0.52	2.52

2.2.2.2. Fish Subsystem Parameterization

The NCRMP RVC effort produces mean abundance observations (among diver pairs) for reef fishes and, over the course of this study period, RVC divers produced N = 1,545 fish surveys throughout the Coral ECA. The resultant database contained 474 named fishes identified to the species ($S_{spp.}$ = 421) and genus (S_{genus} = 53) levels. Of those 474 entries, 335 had observations recorded throughout the time series of interest (including those not identified to the species level). Ultimately, a total of S = 190 individual species were identified in at least 0.5% of all surveys (*n* = 8 samples) and retained for analyses (Table 2), and each species was assigned to a functional group depicting their relative trophic position within the food web.

To complete the trophic classifications, the 190 retained species were cross-checked against a database compiled by the PI coding 293 of the known RVC species into one of the trophic guilds used for each of the guild assignment schemes developed here (Table 3). The trophic classification framework employed here is a hybrid approach primarily derived from a globally standardized method for assigning feeding guilds to fishes using gut content data and phylogenetic information (Parravicini et al., 2020). However, since those methods failed to resolve finer detail within the herbivorous trophic guild, likely due to the difficulty in identifying partially digested plant and algal material

(Parravicini et al., 2020), the study authors' single herbivorous level was converted for this project into three separate guilds (browsers, grazers, and scrapers), based upon the model-study by Donovan et al. (2018). The Parravicini et al. (2020) authors' database of ~4,550 individual fishes, classified into eight trophic guilds ('[herbivores + microvores + detritivores]', 'corallivores', 'planktivores', 'sessile invertivores', 'microinvertivores', 'macroinvertivores', 'crustacivores', and 'piscivores'), was used to initialize the classification scheme for the 293 fishes coded for this project. Where the Parravicini et al. (2020) method lacked a classification, or the one provided did not match those suggested by RVC data managers, the entry was flagged. All flagged entries were cross-checked against FishBase (Froese and Pauly, 2023) and in-house expert opinions from the USF College of Marine Science, Fish Ecology Lab and the PI.

Table 3. Reef fish trophic guilds for Coral ECA reef fishes used for analysis. Feeding notes and the number of reef fish species (*S*) included in each guild based on the two classification schemes developed (G1, G2).

Trophic Guild	Feeding and Notes	S_{G1}	S_{G2}
Herbivore – Grazers	Grazes turf algae	8	8
Herbivore – Scrapers	Feed on algal turf, but also remove coral and other hard substrate	10	-
Herbivore – Browsers	Browses on macroalgae and associated epiphytic material	8	5
Parrotfishes	Primarily drawn from 'Scrapers' & 'Browsers'; Iconic Florida species	-	14
Corallivores	Feed on sea anemones, soft corals, and stony corals	6	6
Planktivores	Feed on zooplankton, cyanobacteria, and Harpacticoid copepods	16	16
Sessile Invertivores	Feed on starfishes, sponges, tunicates, sea cucumbers, and Bryozoa	13	13
Microinvertivores	Feed on Arachnida, sea spiders, small crustaceans, and worms	16	15
Macroinvertivores	Feed on mollusks (snails, sea hares, bivalves, squids, and octopuses), urchins, and brittle stars	34	34
Crustacivores	Feed on large crustaceans (crabs, shrimps, lobsters, crayfish, and prawns)	45	37
Snappers	Primarily drawn from 'Crustacivores' & 'Piscivores'; Iconic Florida species	-	9
Groupers	Primarily drawn from 'Crustacivores' & 'Piscivores'; Iconic Florida species	-	5
Lionfish	Invasive species, red lionfish	-	1
Piscivores	Feed primarily on ray finned fishes and cephalopods	34	27

The final guild assignments (Table 3; Table 4) included one framework that strictly follows trophic guilds outlined above (G1), while the second includes recreationally and commercially important sub-groups that also represent iconic (or invasive) Florida species: parrotfishes, snappers, groupers, and lionfish (G2;

Table 4. Final Coral ECA reef fish species' trophic guild assignments. Guild assignments for all reef fishes into the trophic guilds defined in Table 3. For guild assignment #2, species with the tilde (~) denote those reclassified as 'Parrotfish', the exclamation (!) denotes lionfish, single asterisks (*) denote snappers (*Lutjanidae*), and double asterisks (**) denote large carnivorous groupers (*Serranidae*).

HERBIVORE - GRAZERS	Common Name
Centropyge argi	cherubfish
Microspathodon chrysurus	yellowtail damselfish
Monacanthus ciliatus	fringed filefish
Stegastes adustus	dusky damselfish
Stegastes diencaeus	longfin damselfish
Stegastes partitus	bicolor damselfish
Stegastes planifrons	threespot damselfish
Stegastes variabilis	cocoa damselfish
HERBIVORE - BROWSERS	**Common Name**
Acanthurus bahianus	ocean surgeon
Acanthurus chirurgus	doctorfish
Acanthurus coeruleus	blue tang
Aluterus schoepfii	orange filefish
~Cryptotomus roseus	~bluelip parrotfish
Kyphosus sectatrix	Bermuda chub
~Nicholsina usta	~emerald parrotfish
~Sparisoma radians	~bucktooth parrotfish
HERBIVORE – SCRAPERS	**Common Name**
~Scarus coelestinus	~midnight parrotfish
~Scarus guacamaia	` rainbow parrotfish
~Scarus iseri	~striped parrotfish
~Scarus taeniopterus	~princess parrotfish
~Scarus vetula	~queen parrotfish
~Sparisoma atomarium	~greenblotch parrotfish

SCRAPERS (continued...)	Common Name
~Sparisoma aurofrenatum	~redband parrotfish
~Sparisoma chrysopterum	~redtail parrotfish
~Sparisoma rubripinne	~yellowtail parrotfish
~Sparisoma viride	~stoplight parrotfish
CORALLIVORES	**Common Name**
Aluterus monoceros	unicorn filefish
Aluterus scriptus	scrawled filefish
Chaetodon capistratus	foureye butterflyfish
Chaetodon ocellatus	spotfin butterflyfish
Chaetodon striatus	banded butterflyfish
Holacanthus tricolor	rock beauty
PLANKTIVORES	**Common Name**
Abudefduf saxatilis	sergeant major
Amblycirrhitus pinos	redspotted hawkfish
Canthidermis sufflamen	ocean triggerfish
Chromis cyanea	blue chromis
Chromis enchrysura	yellowtail reeffish
Chromis insolata	sunshinefish
Chromis multilineata	brown chromis
Chromis scotti	purple reeffish
Clepticus parrae	creole wrasse
Heteroconger longissimus	brown garden eel
Monacanthus tuckeri	slender filefish
Opistognathus aurifrons	yellowhead jawfish
Ptereleotris calliura	blue dartfish
Ptereleotris helenae	hovering dartfish
Xyrichtys martinicensis	rosy razorfish
Xyrichtys splendens	green razorfish
SESSILE INVERTIVORES	**Common Name**
Acanthostracion polygonius	honeycomb cowfish
Acanthostracion quadricornis	scrawled cowfish
Cantherhines macrocerus	whitespotted filefish

SESSILE INV. (continued...)	**Common Name**
Cantherhines pullus	orangespotted filefish
Canthigaster rostrata	sharpnose puffer
Chaetodipterus faber	Atlantic spadefish
Holacanthus bermudensis	blue angelfish
Holacanthus ciliaris	queen angelfish
Holocanthus townsendi	Townsend angelfish
Lactophrys bicaudalis	spotted trunkfish
Pomacanthus arcuatus	gray angelfish
Pomacanthus paru	French angelfish
Stephanolepis hispidus	planehead filefish

MICROINVERTIVORES	**Common Name**
Apogon townsendi	belted cardinalfish
Calamus pennatula	pluma porgy
Chaetodon sedentarius	reef butterflyfish
Chilomycterus atinga	spotted burrfish
Diplodus argenteus	silver porgy
Haemulon album	margate
Haemulon aurolineatum	tomtate
Haemulon flavolineatum	French grunt
Haemulon melanurum	cottonwick
Haemulon striatum	striped grunt
Halichoeres maculipinna	clown wrasse
Halichoeres pictus	rainbow wrasse
Lactophrys triqueter	smooth trunkfish
Lagodon rhomboides	pinfish
~Scarus coeruleus	~blue parrotfish
Stegastes leucostictus	beaugregory

MACROINVERTIVORES	**Common Name**
Anisotremus surinamensis	black margate
Anisotremus virginicus	porkfish
Archosargus probatocephalus	sheepshead
Balistes capriscus	gray triggerfish
Balistes vetula	queen triggerfish

MACROINV. (continued...)	**Common Name**
Bodianus pulchellus	spotfin hogfish
Bodianus rufus	Spanish hogfish
Calamus bajonado	jolthead porgy
Calamus calamus	saucereye porgy
Calamus nodosus	knobbed porgy
Calamus penna	sheepshead porgy
Chilomycterus schoepfii	striped burrfish
Dasyatis americana	southern stingray
Diodon holocanthus	balloonfish
Diodon hystrix	porcupinefish
Gerres cinereus	yellowfin mojarra
Haemulon carbonarium	caesar grunt
Haemulon macrostomum	Spanish grunt
Haemulon parra	sailors choice
Haemulon plumierii	white grunt
Haemulon sciurus	bluestriped grunt
Halichoeres bivittatus	slippery dick
Halichoeres cyanocephalus	yellowcheek wrasse
Halichoeres garnoti	yellowhead wrasse
Halichoeres poeyi	blackear wrasse
Halichoeres radiatus	puddingwife
Lachnolaimus maximus	hogfish
Malacanthus plumieri	sand tilefish
Megalops atlanticus	tarpon
Mulloidichthys martinicus	yellow goatfish
Sphoeroides spengleri	bandtail puffer
Sphoeroides testudineus	checkered puffer
Thalassoma bifasciatum	bluehead
Xyrichtys novacula	pearly razorfish

CRUSTACIVORES	**Common Name**
Apogon binotatus	barred cardinalfish
Apogon maculatus	flamefish
Apogon pseudomaculatus	twospot cardinalfish
Calamus proridens	littlehead porgy

CRUSTACIVORES (continued...)	**Common Name**
Diplectrum formosum	sand perch
Diplodus holbrookii	spottail pinfish
Epinephelus adscensionis	rock hind
Epinephelus guttatus	red hind
Equetus lanceolatus	jackknife-fish
Equetus punctatus	spotted drum
Ginglymostoma cirratum	nurse shark
Gymnothorax miliaris	goldentail moray
Haemulon chrysargyreum	smallmouth grunt
Holocentrus adscensionis	squirrelfish
Holocentrus rufus	longspine squirrelfish
Hypoplectrus gemma	blue hamlet
Hypoplectrus puella	barred hamlet
Hypoplectrus unicolor	butter hamlet
Lactophrys trigonus	trunkfish
**Lutjanus analis*	*mutton snapper
**Lutjanus buccanella*	*blackfin snapper
**Lutjanus griseus*	*gray snapper
**Lutjanus mahogoni*	*mahogany snapper
**Lutjanus synagris*	*lane snapper
Myrichthys breviceps	sharptail eel
Myripristis jacobus	blackbar soldierfish
**Ocyurus chrysurus*	*yellowtail snapper
Odontoscion dentex	reef croaker
Pareques acuminatus	high-hat
Pareques umbrosus	cubbyu
Pseudupeneus maculatus	spotted goatfish
[!]*Pterois volitans*	[!]red lionfish
**Rhomboplites aurorubens*	*vermilion snapper
Rypticus maculatus	whitespotted soapfish
Rypticus saponaceus	greater soapfish
Sargocentron coruscum	reef squirrelfish
Schultzea beta	school bass
Scorpaena plumieri	spotted scorpionfish

CRUSTACIVORES (continued...)	**Common Name**
Serranus annularis	orangeback bass
Serranus baldwini	lantern bass
Serranus subligarius	belted sandfish
Serranus tabacarius	tobaccofish
Serranus tigrinus	harlequin bass
Serranus tortugarum	chalk bass
Urobatis jamaicensis	yellow stingray

PISCIVORES	**Common Name**
Aulostomus maculatus	Atlantic trumpetfish
Carangoides bartholomaei	yellow jack
Caranx crysos	blue runner
Caranx hippos	crevalle jack
Carcharhinus leucas	bar jack
Carcharhinus perezii	bull shark
Caranx ruber	reef shark
Centropristis striata	black sea bass
Cephalopholis cruentata	graysby
Cephalopholis fulva	coney
Elagatis bipinnulata	rainbow runner
***Epinephelus itajara*	**goliath grouper
***Epinephelus morio*	**red grouper
Euthynnus alletteratus	little tunny
Fistularia tabacaria	bluespotted cornetfish
Gymnothorax funebris	green moray
Gymnothorax moringa	spotted moray
Gymnothorax vicinus	purplemouth moray
Heteropriacanthus cruentatus	glasseye snapper
**Lutjanus apodus*	*schoolmaster
**Lutjanus jocu*	*dog snapper
***Mycteroperca bonaci*	**black grouper
***Mycteroperca microlepis*	**gag
***Mycteroperca phenax*	**scamp
Negaprion brevirostris	lemon shark
Priacanthus arenatus	bigeye

PISCIVORES (continued...)	Common Name
Scomberomorus cavalla	king mackerel
Scomberomorus maculatus	Spanish mackerel
Scomberomorus regalis	cero
Seriola dumerili	greater amberjack
Seriola rivoliana	almaco jack
Sphyraena barracuda	great barracuda
Synodus foetens	inshore lizardfish
Synodus intermedius	sand diver

Table 3). However, it is notable that within the primary assignment scheme (G1), all but four parrotfishes were classified as herbivorous scrapers, with bluelip, emerald and bucktooth parrotfishes classified as herbivorous browsers, and blue parrotfish as a macroinvertivore (Table 4). Further, of the relatively large carnivorous snapper species (*Lutjanidae*), all but two (the piscivorous schoolmaster and dog snapper) were originally classified as crustacivores, and all of the large carnivorous groupers (*Serranidae*) were previously in the piscivorous guild (Table 4).

2.2.3. Clustering Analysis Methods

Final, analysis-ready RVC datasets were compiled for the G1 and G2 scenarios containing total abundances for all species within the noted trophic guilds (Table 3), and each was appended with the LPI proportional cover data (Table 2). All data were standardized to the range [0,1] and were subjected to shadeplot (Clarke et al., 2014) visualizations (Figure 3; Figure 4) to determine which data transformation most appropriately down-weights overly abundant groups and up-weights relatively rare ones. For all subsequent clustering analyses, cube-root transforms of the standardized data we used and Gower's multivariate resemblance measure (Legendre and Legendre, 2012) was used since variables were of different types (i.e., percent cover and total abundance).

Clustering solutions were achieved using the agglomerative hierarchical unweighted pair-group method with arithmetic mean (UPGMA) coupled with dissimilarity resemblance profiles (Clarke et al., 2008;Kilborn et al., 2017), and hereafter referred to as 'DisProf clustering'. In DisProf clustering, the π-statistic is calculated as the sum of all deviations between the observed resemblance profile (Clarke et al., 2008) and the average profile computed using 10,000 permutations of the raw data. Both the 95% confidence intervals about the mean profile (determined via bootstrapping), and the Monte Carlo-based p-value used to assess the null hypothesis of "no multivariate structure" at each node of the UPGMA clustering solution, were based on 10,000 iterations of the data. All p-values were corrected using the Holms progressive correction method (Clarke et al., 2008;Legendre and Legendre, 2012).

2.2.1. Clustering Sensitivity Analysis by Depth

Sensitivity analyses were conducted to determine if there was any prominent effect of including relatively shallow or deep sites in the clustered dataset. To that end, the

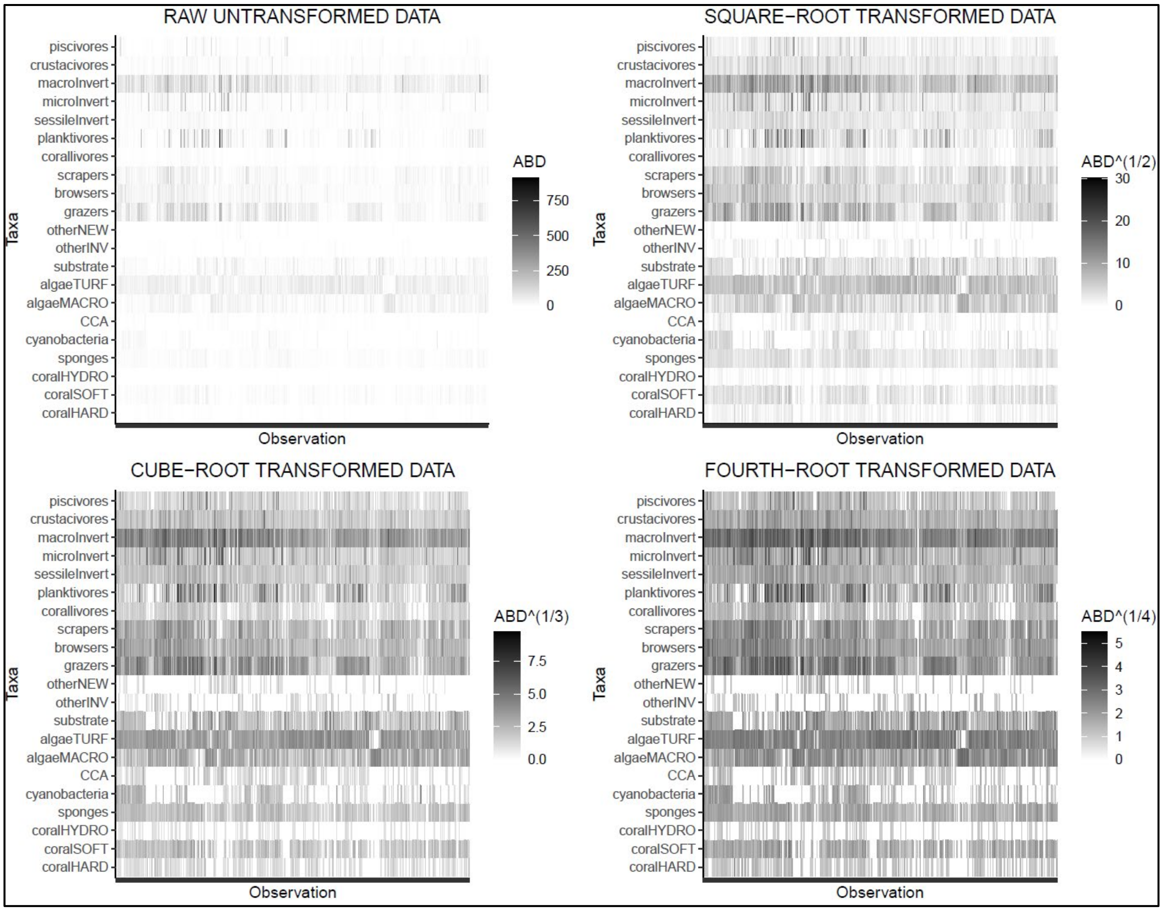

Figure 3. Reef fish trophic guild assignment #1 shadeplot. Visualization depicting the effect of various data transformations on the set of [LPI + RVC] descriptors. Darker colors signify larger values and the color scales are relative to the transformed minimum and maximum values (see legends in each panel).

mean depth for each PSU was determined by averaging the minimum and maximum depths reported for each site by the LPI surveyors along with the single reported RVC location depth for the paired sites. The distribution of site depths (Figure 5) was broken into three additional ranges apart from the full dataset, including, 0-25 m (N = 357), 5-25 m (N = 331), and 5-31 m (N = 372); note, only one retained sample was recorded at > 30 m (31.1m). The rationale for these breaks was that there were relatively few samples in the shallower 0-5 m (n = 26) and the deeper 25-30+ m (n = 41) depths compared to the mid-depths 5-25 m (n = 331), and these shallower and/or deeper sites may be more likely to display characteristics that are less representative of the broader Coral ECA, due to the uniqueness of those particular depths' habitats. A comparison of the number of groups identified by DisProf clustering for all four depth zones (i.e., 'full', 'shallow', 'middle', 'deep') as well as the summary statistics for the LPI and RVC data across those ranges were used to determine the final range of depths used.

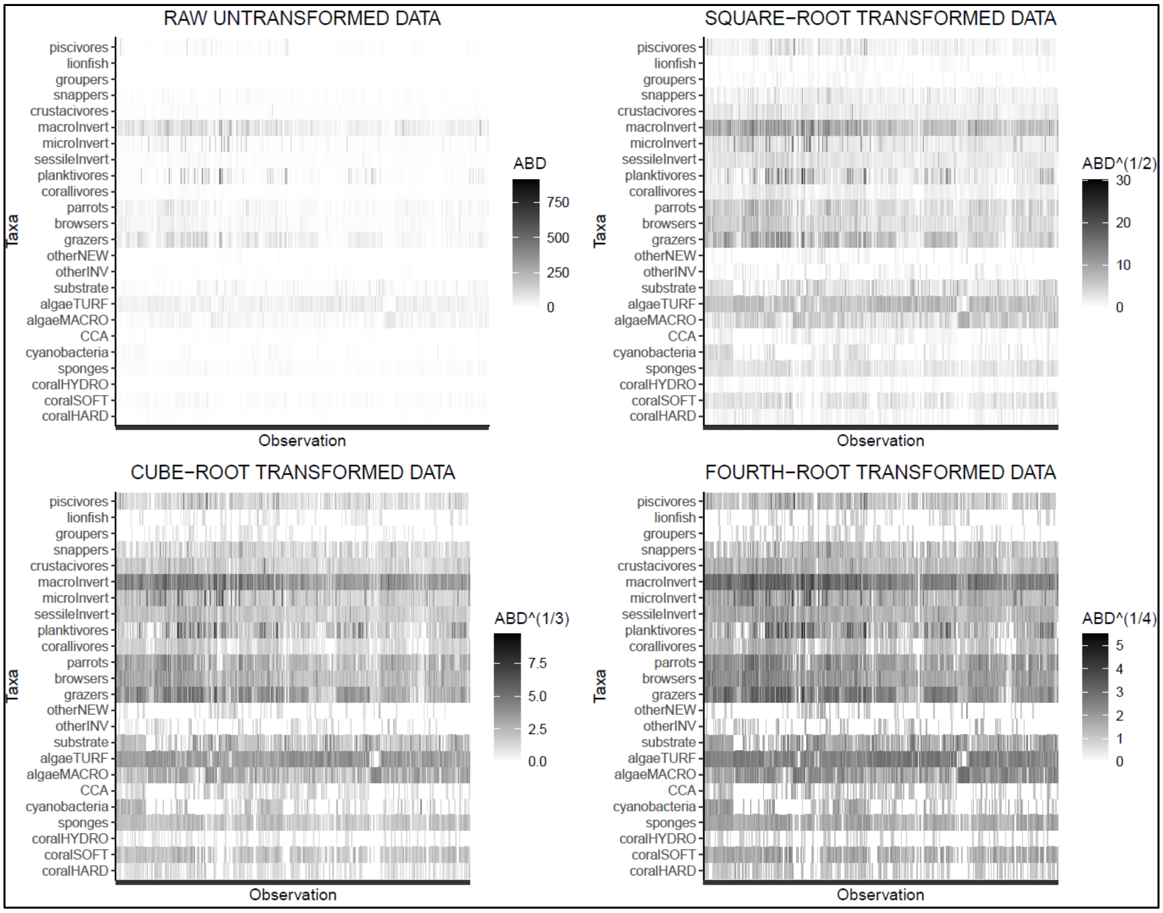

Figure 4. Reef fish trophic guild assignment #2 shadeplot. Visualization depicting the effect of various data transformations on the set of [LPI + RVC] descriptors. Darker colors signify larger values and the color scales are relative to the transformed minimum and maximum values (see legends in each panel).

2.2.2. Indicator Value Analysis and Group Characterization

After obtaining final DisProf clustering solutions for both the G1 and G2 guild assignments, indicator value (IndVal) analysis (Dufrene and Legendre, 1997) was performed to determine which reef fish species best characterized the clusters identified. The IndVal metric combines measures of *specificity* (i.e., the proportion of groups that a species is found in) and *fidelity* (i.e., the proportion of samples within a group that a species is found in) into one IndVal that describes the species' capacity to represent a group. Only those IndVals with a low probability of occurring by chance alone (i.e., p-value < 0.05; 1,000 iterations) after Holms correction were retained to characterize groups. Additional multivariate visualizations, to highlight the PSUs' (and groups') resemblances with respect to the underlying descriptors, were created using principal coordinates analysis (PCoA) (Legendre and Legendre, 2012).

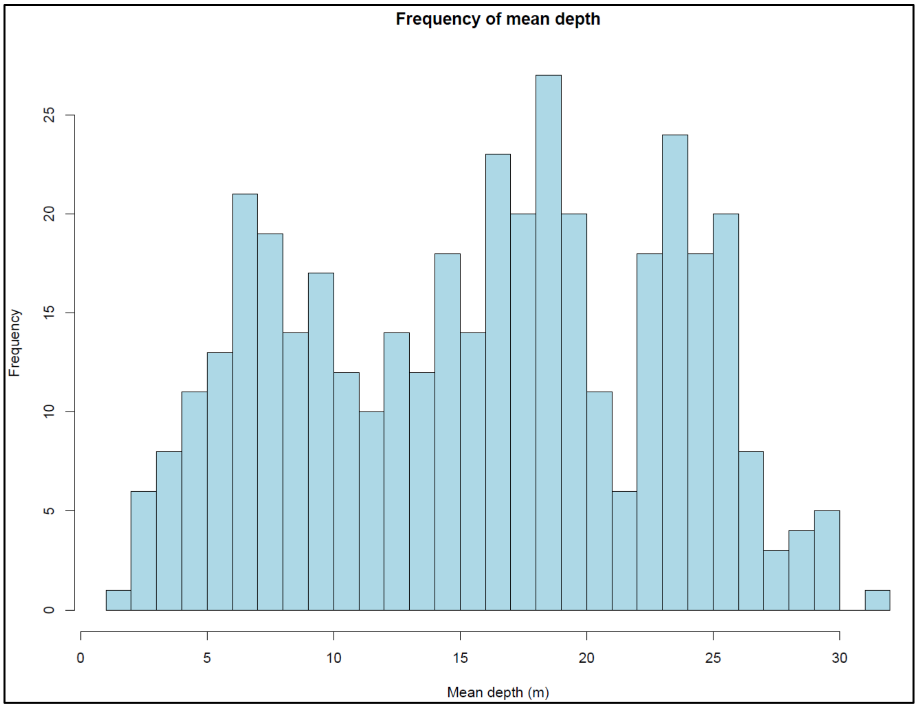

Figure 5. Frequency histogram of mean PSU depths. Distribution of sampling locations' mean depths for all *N* = 398 PSUs analyzed within the Coral ECA.

3. RESULTS

3.1. Clustering Results and Sensitivity to Depth

For the full depth model (0-31 m) of the Coral ECA, the DisProf clustering routines returned a total of 20 unique PSU groups using the G1 trophic guild assignment and 22 groups for G2 (Table 5; Table S5). The depth models all performed relatively similarly across both guild assignments (Table 5), with the exception of the 0-25 m range, where the G1 scheme produced six more unique clusters than the G2 scheme. The 5-25 m range produced the same number of clusters across both schemes, while both the full and 5-31 m models produced two more groups under the G2 scheme than G1.

Table 5. Depth and trophic guild clustering solution counts. Number of unique clusters identified across depth models and fish trophic guild assignments #1 (G1) and #2 (G2).

Depth Model	G1	G2
0 to 25 m (*N* = 357)	24	18
5 to 25 m (*N* = 331)	15	15
5 to 31 m (*N* = 372)	18	20
0 to 31 m (*N* = 398)	20	22

The number of PSUs assigned to the clusters obtained for both the G1 and G2 schemes, and across all depth models (Table 6), is also useful for determining if certain depth (or trophic) models led to instability in the solutions provided (i.e., many groups with low PSU membership, or wildly different results across models). Alternatively, stability can be inferred by concurrence across solutions with respect to all of the group sizes investigated. Here, all but two models produced eight clusters with 10 or more member sites, with the G1, 0-25 m model producing 11 and the G2, 0-31 m model producing seven large clusters (Table 6).

Table 6. Depth and trophic guild clustering solution membership. Number of PSUs assigned to each group defined by DisProf clustering for all four depth models and both trophic guild assignments. The bottom four rows capture the number of groups that contain the number of samples listed on the left. Colors darken as depths for models increase.

	Fish Guild Assignment 1				**Fish Guild Assignment 2**			
Group #	0-5 m	5-25 m	*5-31 m*	*0-31 m*	0-5 m	5-25 m	*5-31 m*	*0-31 m*
1	23	92	20	108	144	142	126	8
2	1	1	2	1	1	1	1	1
3	2	2	1	2	1	1	1	1
4	1	2	41	1	1	2	1	1
5	3	1	1	5	4	4	4	4
6	2	3	4	63	1	1	26	4
7	1	42	36	4	24	19	1	19
8	26	8	1	1	2	17	21	72
9	4	11	2	34	2	2	2	2
10	3	14	3	15	45	14	2	6
11	24	54	18	2	14	38	1	2
12	1	1	9	4	20	2	41	4
13	11	41	53	22	1	21	1	10
14	2	36	7	9	6	55	20	13
15	16	23	32	5	1	12	8	7
16	13	-	35	50	10	-	2	1
17	52	-	99	5	53	-	3	22
18	38	-	8	9	27	-	10	5
19	5	-	-	42	-	-	55	2
20	9	-	-	16	-	-	46	3
21	4	-	-	-	-	-	-	154
22	74	-	-	-	-	-	-	57
23	17	-	-	-	-	-	-	-
24	25	-	-	-	-	-	-	-
TOTAL	**357**	**331**	**372**	**398**	**357**	**331**	**372**	**398**
n ≥ 10	11	8	8	8	8	8	8	7
n ≤ 5	12	6	7	10	9	7	11	12
n ≤ 2	7	5	5	5	8	6	9	7
n = 1	4	3	3	3	6	3	6	4

The number of singleton groups (*n* = 1) was between three or four in all models except for two of the G2 depth models (Table 6). Including groups with *n* ≤ 2 and *n* ≤ 5 shows a bit more variability across models' grouping solutions (Table 6) and highlights the complexity of Coral ECA and the importance of depth (and the trophic guild conceptual models) throughout the region.

Investigating the LPI summary statistics across the new depth models is also informative (Table 7). Doing so reveals that the maximum observed coverage for hard corals (17%) must be at a PSU within the 0-5 m zone, as is the highest observation of turf algae (96%). On the other hand, the maximum value observed for macroalgal cover (94%) was observed in the 25-31 m zone, however, this value is only 1% point higher than other models' maximums for macroalgae (93%). All other maximum values for LPI categories appear to have fallen within the 5-25 m depths (Table 7). Mean values across LPI categories and depth models differed somewhat (Table 7), but the majority of differences were < 1% point (max difference = 3.4% points for turf algae).

Table 7. Summary statistics for LPI categories by depth model. Models' sample sizes (*N*) are listed in the top row, and standard deviation ('StedDev') is with respect to the mean value. See Table 2 for LPI Type symbols and details. Colors darken as depths for models increase.

	All *Z* (*N* = 398)			0 to 25 m (*N* = 357)			5 to 25 m (*N* = 331)			5 to 31 m (*N* = 372)		
LPI Type	**Max**	**Mean**	**StdDev**	**Max**	**Mean**	**StdDev**	**Max**	**Mean**	**StdDev**	**Max**	**Mean**	**StdDev**
coralHARD	17.00	1.18	2.00	17.00	1.28	2.08	11.00	1.26	1.87	11.00	1.16	1.80
coralSOFT	52.00	7.65	8.21	52.00	8.16	8.29	52.00	8.60	8.37	52.00	8.01	8.31
coralHYDRO	2.50	0.24	0.51	2.50	0.26	0.52	2.50	0.28	0.53	2.50	0.26	0.52
sponges	43.00	8.11	6.64	43.00	8.36	6.48	43.00	8.76	6.48	43.00	8.45	6.66
cyanobacteria	62.00	3.59	7.73	62.00	3.88	8.08	62.00	4.17	8.32	62.00	3.84	7.94
CCA	17.82	1.26	2.58	17.82	1.31	2.65	17.82	1.37	2.71	17.82	1.31	2.64
algaeMACRO	94.00	21.95	20.12	93.00	20.24	18.26	93.00	20.21	18.17	94.00	22.05	20.17
algaeTURF	96.00	42.12	23.17	96.00	44.34	22.07	94.00	43.17	21.60	94.00	40.92	22.74
substrate	98.00	12.72	18.16	98.00	10.99	15.96	98.00	11.03	15.81	98.00	12.88	18.18
otherINV	17.00	0.63	2.08	17.00	0.71	2.18	17.00	0.64	2.09	17.00	0.57	1.98
otherNEW	38.00	0.52	2.52	38.00	0.48	2.50	38.00	0.50	2.60	38.00	0.55	2.61

Performing a similar exercise across the RVC trophic guilds is also useful. For example, in both the G1 (Table 8) and G2 (Table 9) trophic schemes, all categories' maximum values were the same across all depth zones (with the exception of macroinvertivores in the 0-25 m and 5-25 m ranges where the maximum abundance observed was 350.50), implying that these maximums were detected in the 5-25 m depth range. The macroinvertivores and herbivorous grazers, respectively, displayed the highest magnitude of differences between mean abundances across any of the zones (macroinvertivores max difference = 5.54, herbivorous grazers max difference = 5.02). Herbivorous scrapers (G1) and parrotfishes (G2) also displayed relatively large maximum differences in their means by depth (scrapers = 2.64, parrotfishes = 2.88). In all of these cases, the highest mean abundances for the guilds were observed in the 5-25 m depth range (Table 8, Table 9).

Table 8. Summary statistics for RVC trophic guild assignment #1 by depth model. Models' sample sizes (*N*) are listed in the top row, and standard deviation ('StedDev') is with respect to the mean value. See Table 4 for trophic RVC guild details. All categories' maximum values were the same across all depth zones with the exception of 'macroInvert' in the 0-25 m and 5-25 m ranges where the maximum abundance observed was 350.50. Colors darken as depths for models increase.

	All *Z* (*N* = 398)				0 to 25 m (*N* = 357)			5 to 25 m (*N* = 331)			5 to 31 m (*N* = 372)		
G1	**Max**	**Mean**	**Median**	**StdDev.**	**Mean**	**Median**	**StdDev.**	**Mean**	**Median**	**StdDev.**	**Mean**	**Median**	**StdDev.**
grazers	310.50	45.27	31.00	48.74	47.61	33.50	49.21	50.29	37.50	49.32	47.49	34.00	48.93
browsers	114.50	20.84	14.50	19.36	21.99	15.00	19.79	22.42	15.50	20.09	21.14	14.50	19.62
scrapers	218.00	19.77	13.25	22.99	21.42	15.50	23.56	22.41	16.50	23.71	20.54	15.00	23.14
corallivores	21.50	2.90	1.50	3.50	2.97	2.00	3.51	3.18	2.00	3.55	3.09	2.00	3.54
planktivores	917.00	25.05	4.50	67.57	24.40	4.50	68.50	25.79	5.00	70.91	26.34	4.50	69.67
sessileInvert	85.50	7.94	5.50	8.53	8.21	6.00	8.68	8.46	6.50	8.79	8.14	6.00	8.63
microInvert	310.75	17.34	5.50	39.85	17.67	6.00	38.52	16.99	6.00	36.45	16.71	5.12	38.17
macroInvert	369.50	65.43	50.00	53.95	68.06	52.00	52.60	70.97	54.00	52.96	67.83	51.50	54.49
crustacivores	123.75	9.01	5.50	11.78	9.10	6.00	11.21	9.40	6.25	11.34	9.27	6.00	11.93
piscivores	158.00	4.89	1.50	13.95	4.82	1.50	13.48	5.01	1.50	13.94	5.07	1.50	14.38

Thus, with respect to the sensitivity to depth of the clustering approach, it appears as though retaining all of the *N* = 398 PSUs for this study captures the full range of responses across all habitat types and trophic guilds. This set of samples also relates to the targeted sampling universe for NCRMP and will best serve to represent the Coral ECAs subsystems.

Table 9. Summary statistics for RVC trophic guild assignment #2 by depth model. Models' sample sizes (*N*) are listed in the top row, and standard deviation ('StedDev') is with respect to the mean value. See Table 4 for RVC guild details. All categories' maximum values were the same across all depth zones with the exception of 'macroInvert' in the 0-25 m and 5-25 m ranges where the maximum abundance observed was 350.50. Colors darken as depths for models increase.

	All *Z* (*N* = 398)				0 to 25 m (*N* = 357)			5 to 25 m (*N* = 331)			5 to 31 m (*N* = 372)		
G2	**Max**	**Mean**	**Median**	**StdDev.**	**Mean**	**Median**	**StdDev.**	**Mean**	**Median**	**StdDev.**	**Mean**	**Median**	**StdDev.**
grazers	310.50	45.27	31.00	48.74	47.61	33.50	49.21	50.29	37.50	49.32	47.49	34.00	48.93
browsers	105.00	18.94	13.00	17.93	19.90	14.00	18.35	20.25	14.00	18.61	19.19	13.00	18.15
parrots	233.00	21.74	15.50	24.16	23.56	17.50	24.70	24.62	18.50	24.84	22.56	17.00	24.32
corallivores	21.50	2.90	1.50	3.50	2.97	2.00	3.51	3.18	2.00	3.55	3.09	2.00	3.54
planktivores	917.00	25.05	4.50	67.57	24.40	4.50	68.50	25.79	5.00	70.91	26.34	4.50	69.67
sessileInvert	85.50	7.94	5.50	8.53	8.21	6.00	8.68	8.46	6.50	8.79	8.14	6.00	8.63
microInvert	310.75	17.27	5.38	39.82	17.62	6.00	38.53	16.94	6.00	36.46	16.64	5.00	38.13
macroInvert	369.50	65.43	50.00	53.95	68.06	52.00	52.60	70.97	54.00	52.96	67.83	51.50	54.49
crustacivores	102.50	5.07	3.50	7.25	5.07	3.50	5.52	5.29	3.50	5.61	5.26	3.50	7.42
snappers	109.25	3.85	1.50	8.40	3.95	1.50	8.81	4.02	1.50	8.93	3.90	1.50	8.49
groupers	4.75	0.16	0.00	0.45	0.17	0.00	0.47	0.18	0.00	0.48	0.17	0.00	0.46
lionfish	7.50	0.18	0.00	0.60	0.17	0.00	0.61	0.19	0.00	0.63	0.19	0.00	0.62
piscivores	158.00	4.65	1.50	13.89	4.56	1.50	13.40	4.74	1.50	13.86	4.81	1.50	14.32

3.2. Species Indicator Value Results and Group Characterizations

For the full depth models, reef fish indicators were identified for 7 of 20 groups (35%) for G1, and 9 of 22 groups (41%) for G2. These clusters accounted for a total of *n* = 53 (13%) and 58 (15%) PSUs, respectively, out of all *N* = 398 PSUs clustered. Notably, while group-3 of the G1 solution contained two PSUs, groups 2, 3, and 4 in both schemes apparently identify the same sites and all but G1's group-3 contained one PSU. Furthermore, in all three cases the fish species most indicative of those groups were charismatic megafauna that were likely only seen rarely throughout the RVC sampling, particularly after reducing the samples from 1,500+ to *N* = 398. The top IndVal species for groups 2, 3, and 4 were goliath grouper, reef shark, and king mackerel, respectively (Table 10, Table 11). Redband parrotfish characterized the most PSUs in the

G1 scheme (*n* = 34) and second most in G2 (*n* = 19) where the clown wrasse (*n* = 22) slightly edged it out with three more PSUs. In all of these cases the IndVals were relatively low, implying a tradeoff between specificity and fidelity at play (Table 10, Table 11). Unfortunately, the ultimate constitution of the lists of indicator species are relatively poor for the purposes of this study, because they do not capture large numbers of PSUs or the major groups identified via DisProf clustering. They performed exceptionally well at identifying robust and unique communities of fishes for singleton (or double) PSU groups, but this is not conducive to management decision making or characterizing the Coral ECA in general. Thus, as part of Phase III of FDOU-51, it would be prudent to revisit these indicator lists and try to home in on better examples of representative species (or life stages) across the remaining clusters.

Table 10. Reef fish indicator values for the G1 full depth (0-31 m) model. Only groups where fishes presented significant ($p > 0.05$) indicator values (IndVal)s are reported. IndVals range from 0 to 1 and are interpreted as a proportional value with 1 being assigned to a species that is a "perfect" indicator for the group it is associated with.

Scientific Name	Common Name	Group	IndVal	*p*-value
Epinephelus itajara	goliath grouper	2 (*n* = 1)	0.9844	0.005
Holocanthus townsendi	townsend angelfish	2	0.7831	0.009
Haemulon parra	sailors choice	2	0.6017	0.040
Epinephelus morio	red grouper	2	0.3622	0.045
Holocentrus adscensionis	squirrelfish	2	0.3040	0.043
Anisotremus virginicus	porkfish	2	0.2051	0.012
Holacanthus ciliaris	queen angelfish	2	0.1990	0.046
Haemulon plumierii	white grunt	2	0.1868	0.025
Sparisoma atomarium	greenblotch parrotfish	2	0.1466	0.019
Carcharhinus perezii	reef shark	3 (*n* = 2)	0.4846	0.017
Clepticus parrae	creole wrasse	3	0.4233	0.004
Chromis insolata	sunshinefish	3	0.3154	0.019
Chromis cyanea	blue chromis	3	0.2766	0.004
Scarus taeniopterus	princess parrotfish	3	0.2333	0.010
Holacanthus tricolor	rock beauty	3	0.1537	0.014
Stegastes partitus	bicolor damselfish	3	0.1123	0.004
Thalassoma bifasciatum	bluehead	3	0.1006	0.024
Scomberomorus cavalla	king mackerel	4 (*n* = 1)	0.9818	0.008
Elagatis bipinnulata	rainbow runner	4	0.9194	0.006
Cantherhines macrocerus	whitespotted filefish	4	0.5750	0.019
Urobatis jamaicensis	yellow stingray	4	0.4239	0.013
Odontoscion dentex	reef croaker	5 (*n* = 5)	0.4000	0.032
Equetus lanceolatus	jackknife-fish	8 (*n* = 1)	0.9267	0.002
Sparisoma aurofrenatum	redband parrotfish	9 (*n* = 34)	0.1054	0.047
Halichoeres garnoti	yellowhead wrasse	14 (*n* = 9)	0.1158	0.004

Table 11. Reef fish indicator values for the G2 full depth (0-31 m) model. Only groups where fishes presented significant ($p > 0.05$) indicator values (IndVal)s are reported. IndVals range from 0 to 1 and are interpreted as a proportional value with 1 being assigned to a species that is a "perfect" indicator for the group it is associated with.

Scientific Name	Common Name	Group	IndVal	*p*-value
Epinephelus itajara	goliath grouper	2 (*n* = 1)	0.9863	0.018
Holocanthus townsendi	townsend angelfish	2	0.8153	0.010
Haemulon plumierii	white grunt	2	0.1732	0.022
Anisotremus virginicus	porkfish	2	0.1606	0.043
Sparisoma atomarium	greenblotch parrotfish	2	0.1324	0.036
Carcharhinus perezii	reef shark	3 (*n* = 1)	0.9863	0.009
Myripristis jacobus	blackbar soldierfish	3	0.7987	0.029
Canthidermis sufflamen	ocean triggerfish	3	0.6752	0.044
Chromis insolata	sunshinefish	3	0.2931	0.018
Ocyurus chrysurus	yellowtail snapper	3	0.2676	0.003
Chromis cyanea	blue chromis	3	0.2397	0.006
Thalassoma bifasciatum	bluehead	3	0.1108	0.001
Stegastes partitus	bicolor damselfish	3	0.1089	0.002
Scomberomorus cavalla	king mackerel	4 (*n* = 1)	0.9679	0.016
Elagatis bipinnulata	rainbow runner	4	0.9072	0.009
Urobatis jamaicensis	yellow stingray	4	0.4604	0.003
Sparisoma aurofrenatum	redband parrotfish	7 (*n* = 19)	0.1173	0.001
Odontoscion dentex	reef croaker	9 (*n* = 2)	1.0000	0.001
Serranus subligarius	belted sandfish	9	0.4882	0.041
Stegastes adustus	dusky damselfish	9	0.4861	0.013
Calamus penna	sheepshead porgy	12 (*n* = 4)	0.4812	0.042
Halichoeres garnoti	yellowhead wrasse	15 (*n* = 7)	0.0981	0.029
Gerres cinereus	yellowfin mojarra	16 (*n* = 1)	0.7899	0.028
Haemulon striatum	striped grunt	16	0.6365	0.042
Halichoeres bivittatus	slippery dick	16	0.1222	0.042
Halichoeres maculipinna	clown wrasse	17 (*n* = 22)	0.1462	0.018

The PCoA visualization for G1 (Figure 6) displayed a very strong effect of herbivorous grazers and scrapers, along with macroinvertivores, planktivores, and corallivores, in contributing to the ecological resemblance among samples. The G2 PCoA (Figure 7) showed similar trends in trophic guilds' influences, however, once the parrotfishes replaced the scrapers in this scheme the role of herbivorous browsers became more important. The influence of LPI habitats appears more prominent in the G1 solution than G2 (Figure 6, Figure 7), but both are primarily driven by the soft coral, sponge, substrate, cyanobacteria, and CCA coverages. The G2 diagram does show more clumping with respect to the biplot vector placements than in G1, where the influence of all of the descriptor biplots appears more evenly spread throughout the system.

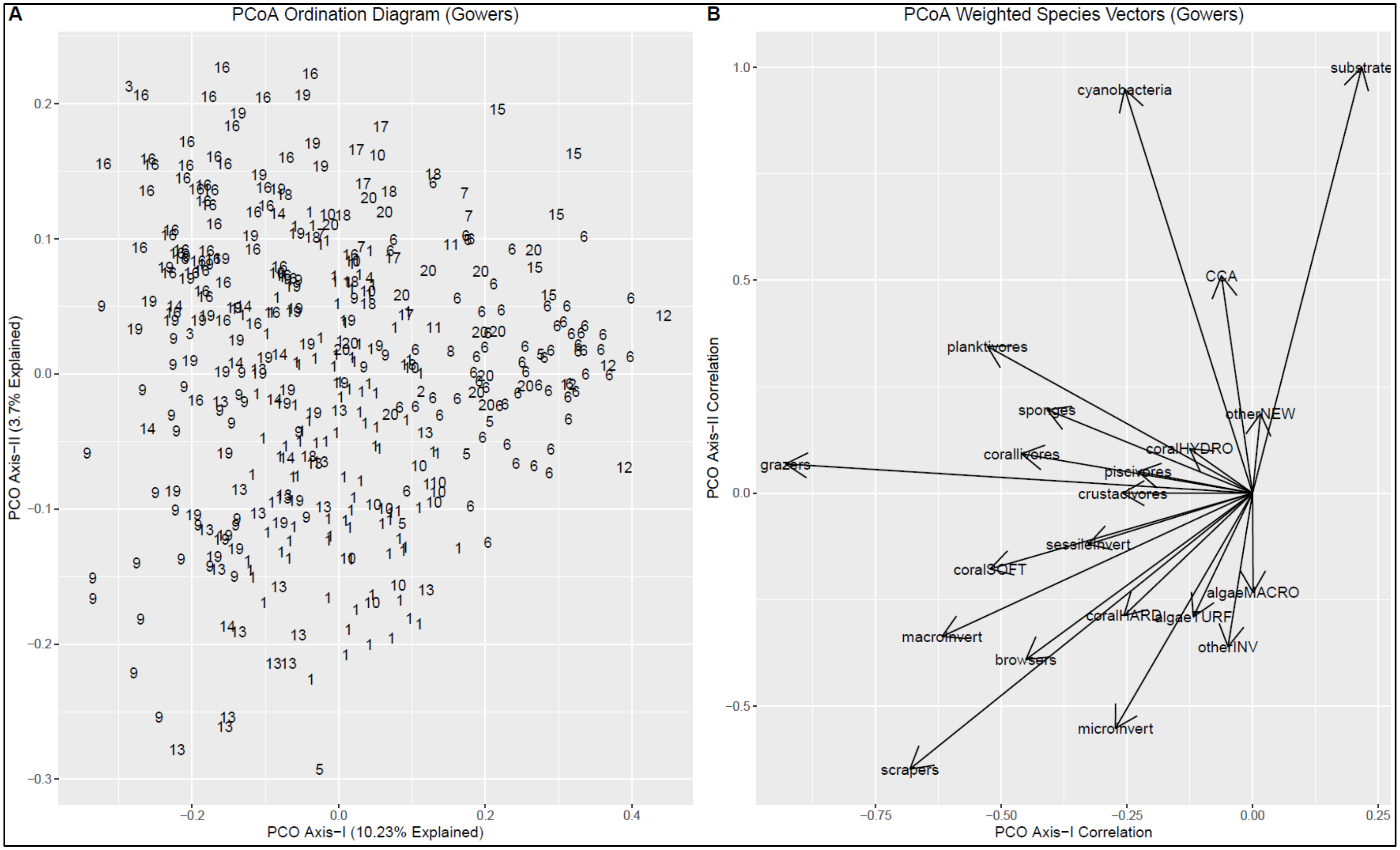

Figure 6. Principal coordinates analysis for the G1 full depth (0-31 m) model. Principal coordinates analysis (PCoA) ordination (panel A) of all *N* = 398 PSUs (site labels represent grouping assignments) in the Coral ECA with respect to the underlying composition and abundance of LPI habitat and RVC G1 guild assignment. Correlation biplot vectors' (panel B) endpoint coordinates were defined by the raw data descriptors' correlations with the first (horizontal) and second (vertical) canonical axes' sites scores that are depicted in the ordination panel. The proportion of the total variability in the dataset accounted for by each axis visualized is listed in the ordination axes labels.

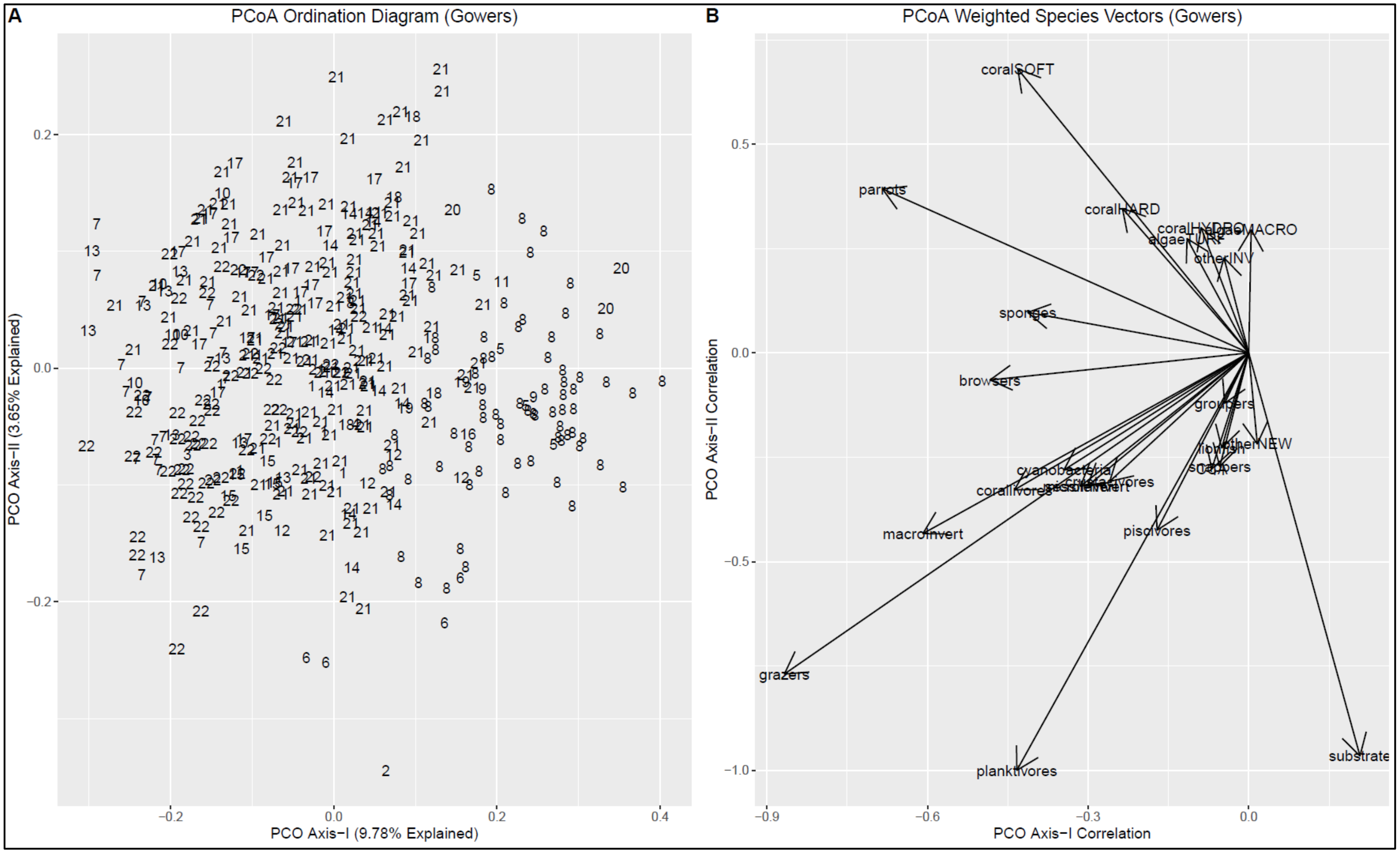

Figure 7. Principal coordinates analysis for the G2 full depth (0-31 m) model. Principal coordinates analysis (PCoA) ordination (panel A) of all *N* = 398 PSUs (site labels represent grouping assignments) in the Coral ECA with respect to the underlying composition and abundance of LPI habitat and RVC G2 guild assignment. Correlation biplot vectors' (panel B) endpoint coordinates were defined by the raw data descriptors' correlations with the first (horizontal) and second (vertical) canonical axes' sites scores that are depicted in the ordination panel. The proportion of the total variability in the dataset accounted for by each axis visualized is listed in the ordination axes labels.

Both PCoA ordinations capture ~14% of the total variability among all PSUs on the first two canonical axes (Figure 6, Figure 7), and which is another point emphasizing the complexity of the Coral ECA and the aquatic resources that it comprises.

4. SUMMARY

The FDOU-51 local action strategy is primarily interested in the investigation of the three subsystems that comprise the Coral ECA: the living benthic habitat, the reef fish communities, and the water quality conditions. The major tasks of Phase II were to compile a dataset pairing together the two *biological* subsystems (benthic habitat + reef fishes) in the Coral ECA, and to analyze them simultaneously in search of patterns in the composition and abundance of the benthic and fish categories. Within that context, Phase II has been completed, and patterns were discovered within the natural reefs of the conservation area. However, the number of unique clusters were very high in the two trophic guild models (G1 and G2, 0-31 m) developed, with 20 and 22 individual [benthos + fish] signatures defined, respectively.

The elevated number of groups makes it particularly difficult to discern the qualities that differentiate groups from one another, as they may be subtle. Discriminant analyses will be heavily employed in Phase III of FDOU-51 and will help to clarify if any of the clusters might actually be considered “outliers”, rare events, or simply not representative of the broader Coral ECA. Those clusters with relatively low PSU membership (e.g., singletons, $n \leq 5$) are excellent starting points for that discussion, and those singletons observed here with charismatic megafauna acting as indicator species (Table 10, Table 11) may be examples of such outlier events. Furthermore, the final classification solution developed should be simple enough for management implementation, as anything with too many classes will be unwieldy (and costly) for decision makers and field staff to effectively operationalize and maintain.

In addition to the complexity related to the description and interpretation of the individual clusters of PSUs, the grouping solutions were variably distributed throughout the Coral ECA (Figure 8, Figure 9). The largest clusters tended to be spread across the entire ECA, and in both the G1 and G2 solutions presented here, the group with the largest PSU membership displayed greater site density in the southern portion of the ECA that reduced moving northward. On the other hand, the second-most prominent group in both solutions, as well as the category comprising all other groups with $n < 10$ PSUs, showed the reversed north-to-south trend for site density decreases (Figure 10, Figure 11). Other groups where $n \geq 10$ PSUs showed variations of these trends at scales related to the membership size and ranging from relatively local to multi-subregional scales (Figure 10, Figure 11). Thus, further discrimination of the groups’ constituent sites’ habitat and fish compositions will likely clarify some of these broad-scale trends evident throughout the Coral ECA.

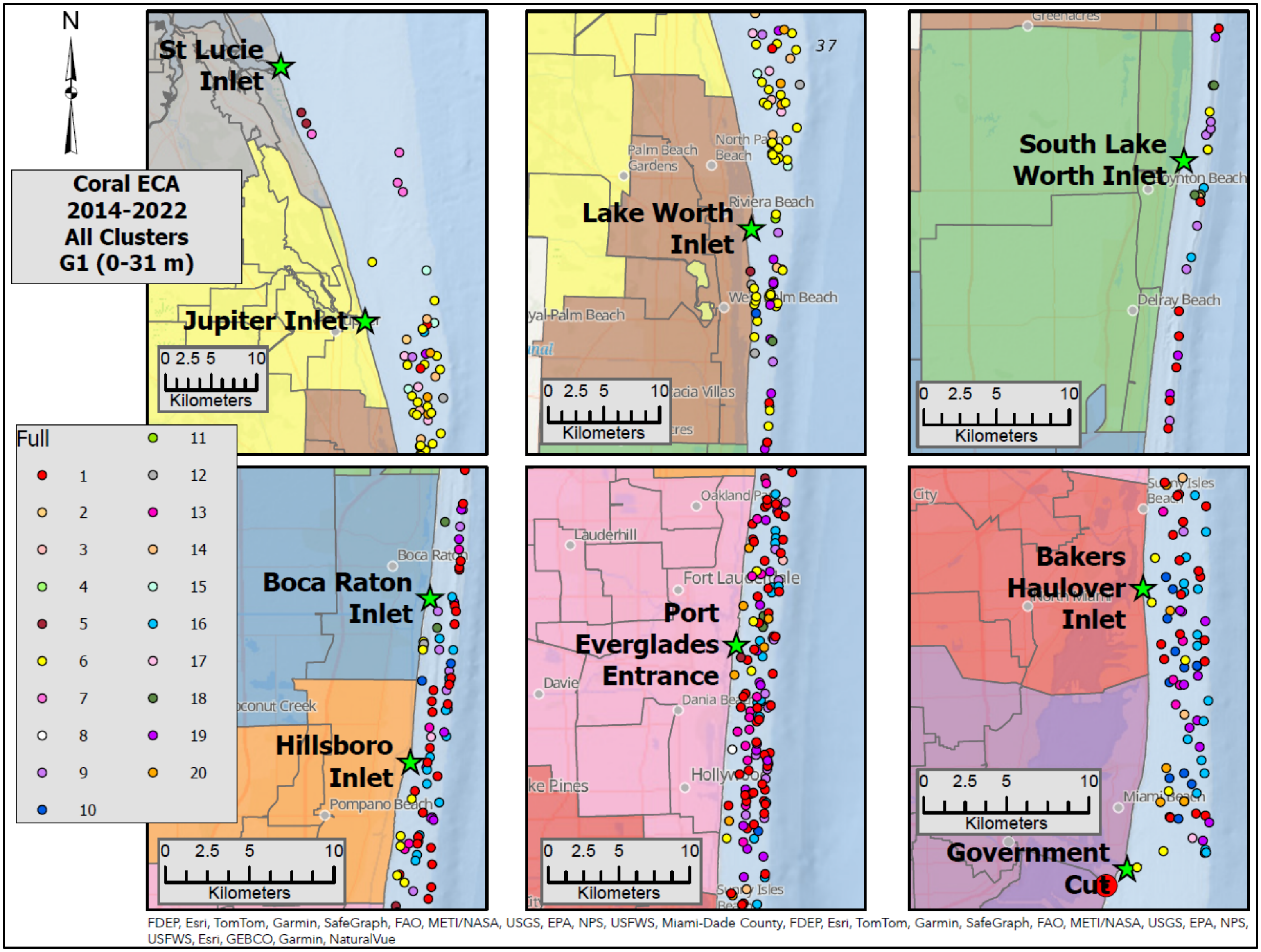

Figure 8. Spatial distribution of all PSU clusters for the G1 full depth (0-31 m) model. Mapping of all 20 unique PSU groups identified via DisProf clustering of all *N* = 398 sites in the Coral ECA and using fish trophic guild assignment #1.

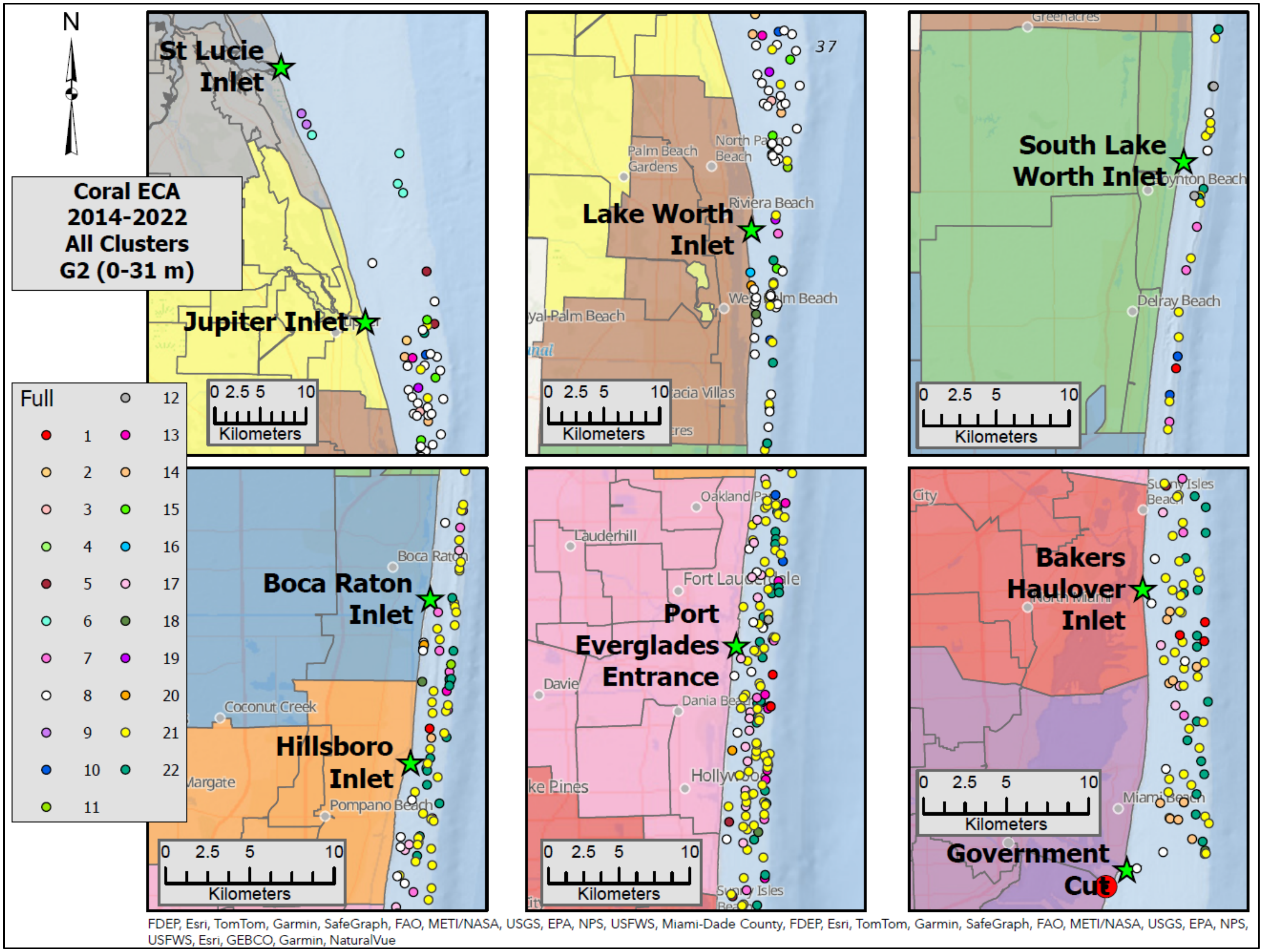

Figure 9. Spatial distribution of all PSU clusters for the G2 full depth (0-31 m) model. Mapping of all 20 unique PSU groups identified via DisProf clustering of all *N* = 398 sites in the Coral ECA and using fish trophic guild assignment #2.

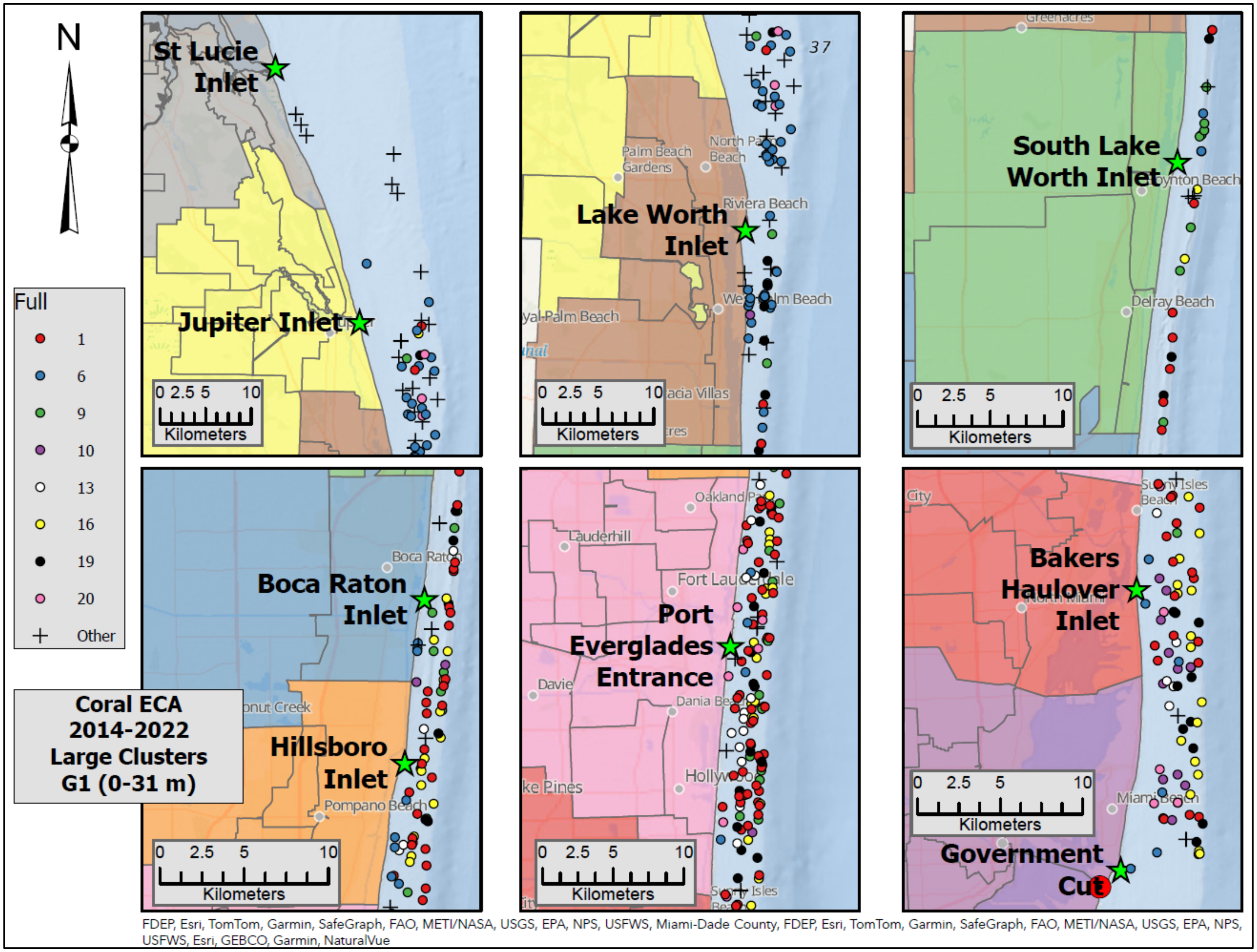

Figure 10. Spatial distribution of select PSU clusters for the G1 full depth (0-31 m) model. Mapping of eight large PSU groups ($n \geq 10$) identified via DisProf clustering of all N = 398 sites in the Coral ECA and using fish trophic guild assignment #1. Groups with $n < 10$ PSUs are all marked with the plus sign (+).

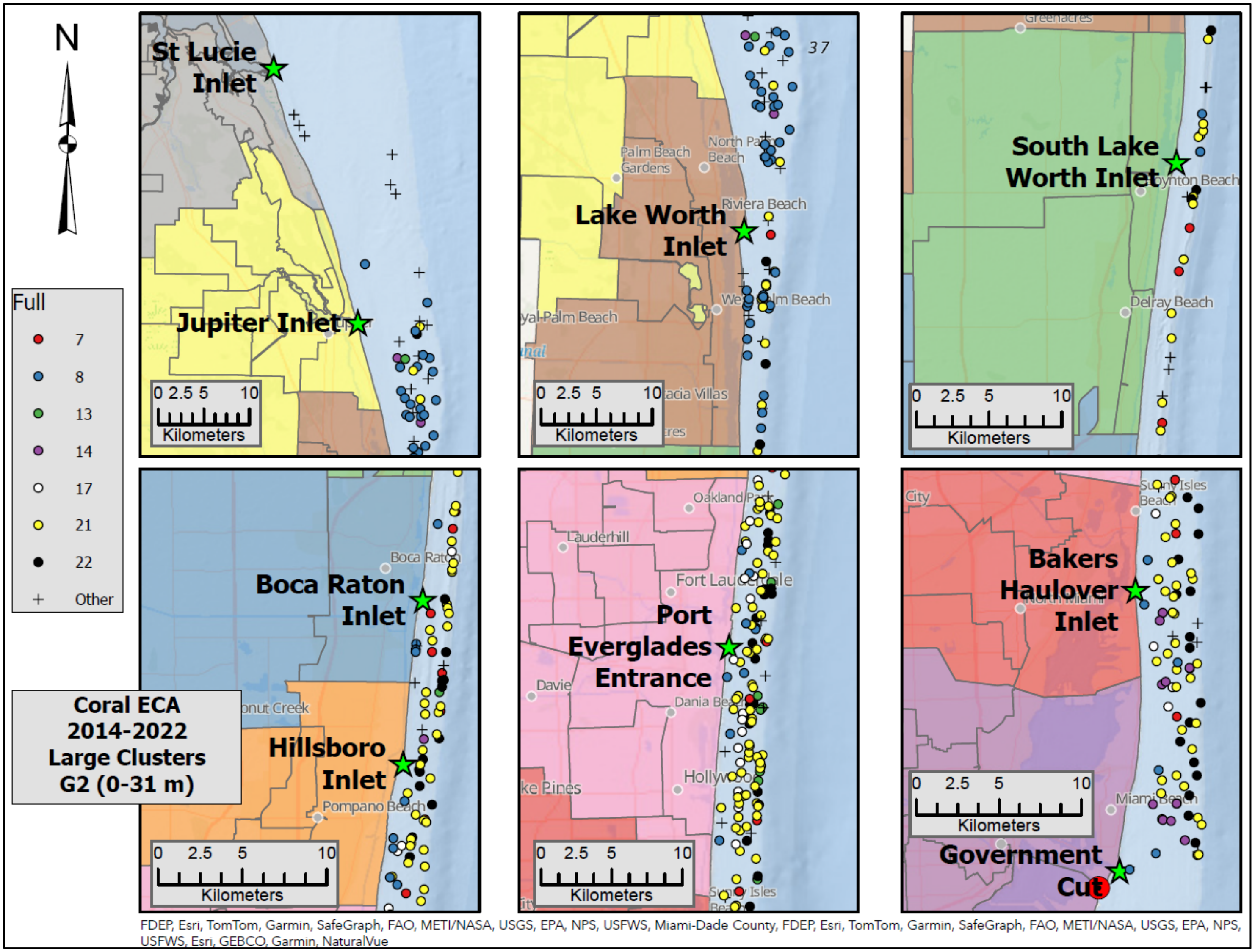

Figure 11. Spatial distribution of select PSU clusters for the G2 full depth (0-31 m) model. Mapping of seven large PSU groups (*n* ≥ 10) identified via DisProf clustering of all *N* = 398 sites in the Coral ECA and using fish trophic guild assignment #2. Groups with *n* < 10 PSUs are all marked with the plus sign (+).

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6. SUPPLEMENTAL TABLES

Table S12. NCRMP benthic cover categories for the Coral ECA. All benthic cover categories monitored along with the percent (%) cover summary statistics for each. Standard deviation ('StndDev.') is relative to the mean, and data are sorted in descending order by the percent of *N* = 398 samples where the category was present.

Substrate Category	% of *N* where Present (*n*)	Maximum	Mean	Stnd Dev.
Turf Algae	96.0 (*n* = 382)	96.00	41.66	22.78
Macroalgae	93.0 (*n* = 370)	94.00	21.87	19.99
Sponges	90.7 (*n* = 361)	43.00	8.40	6.75
Substrate	79.6 (*n* = 317)	98.00	12.65	17.79
Soft Corals	78.1 (*n* = 311)	52.00	7.71	8.12
Hard Corals	49.2 (*n* = 196)	17.00	1.19	1.95
Cyanobacteria	36.7 (*n* = 146)	62.00	3.85	7.79
Crustose Coralline Algae (CCA)	30.9 (*n* = 123)	17.82	0.89	2.08
Hydrocorals	21.4 (*n* = 85)	2.50	0.23	0.50
Other Invertebrates	17.3 (*n* = 69)	17.00	0.68	2.14
Other	14.3 (*n* = 57)	11.00	0.29	1.04
Peysonnellia spp.	11.6 (*n* = 46)	10.00	0.29	1.09
Ramicrusta spp.	3.8 (*n* = 15)	4.00	0.07	0.39
Seagrasses	2.3 (*n* = 9)	38.00	0.21	2.18

Table S13. List of reef fishes retained for analysis. All non-cryptic species of reef fishes retained for analysis. Species are sorted according to the proportion of all *N* = 1,545 sites where they were observed [Presence (%)]. Scientific and common names are given.

Scientific Name	Common Name	Presence (%)
Canthigaster rostrata	sharpnose puffer	87.6%
Thalassoma bifasciatum	bluehead	87.4%
Stegastes partitus	bicolor damselfish	86.2%
Acanthurus bahianus	ocean surgeon	83.2%
Acanthurus chirurgus	doctorfish	78.6%
Halichoeres garnoti	yellowhead wrasse	74.2%
Sparisoma aurofrenatum	redband parrotfish	73.7%
Halichoeres bivittatus	slippery dick	69.8%
Acanthurus coeruleus	blue tang	64.0%
Chaetodon sedentarius	reef butterflyfish	63.4%
Anisotremus virginicus	porkfish	61.9%
Pomacanthus arcuatus	gray angelfish	57.5%
Haemulon plumierii	white grunt	55.7%
Halichoeres maculipinna	clown wrasse	55.5%
Sparisoma atomarium	greenblotch parrotfish	52.2%
Lutjanus analis	mutton snapper	52.1%
Holacanthus tricolor	rock beauty	48.6%
Caranx ruber	bar jack	46.4%
Scarus iseri	striped parrotfish	46.3%
Serranus tigrinus	harlequin bass	46.0%
Stegastes variabilis	cocoa damselfish	45.5%
Pseudupeneus maculatus	spotted goatfish	45.2%
Sparisoma viride	stoplight parrotfish	44.4%
Bodianus rufus	Spanish hogfish	43.4%
Lachnolaimus maximus	hogfish	41.1%
Balistes capriscus	gray triggerfish	40.6%
Chaetodon ocellatus	spotfin butterflyfish	40.3%
Pomacanthus paru	French angelfish	38.6%
Scarus taeniopterus	princess parrotfish	38.1%
Ocyurus chrysurus	yellowtail snapper	37.6%
Holacanthus ciliaris	queen angelfish	37.0%
Cephalopholis cruentata	graysby	36.3%
Chromis cyanea	blue chromis	35.3%
Cryptotomus roseus	bluelip parrotfish	32.4%
Holacanthus bermudensis	blue angelfish	31.3%
Calamus calamus	saucereye porgy	30.9%
Stegastes leucostictus	beaugregory	30.6%
Chromis insolata	sunshinefish	29.1%
Chaetodon capistratus	foureye butterflyfish	25.9%
Haemulon sciurus	bluestriped grunt	25.9%
Hypoplectrus unicolor	butter hamlet	25.8%
Haemulon flavolineatum	French grunt	22.9%
Xyrichtys splendens	green razorfish	22.8%
Aluterus scriptus	scrawled filefish	22.1%
Haemulon aurolineatum	tomtate	22.1%
Serranus baldwini	lantern bass	21.9%
Serranus tabacarius	tobaccofish	21.9%
Abudefduf saxatilis	sergeant major	20.8%
Sparisoma chrysopterum	redtail parrotfish	20.7%
Caranx crysos	blue runner	20.6%
Sphoeroides spengleri	bandtail puffer	20.5%
Holocentrus adscensionis	squirrelfish	20.4%
Clepticus parrae	creole wrasse	19.6%
Sparisoma radians	bucktooth parrotfish	19.4%
Pterois volitans	red lionfish	19.2%
Halichoeres poeyi	blackear wrasse	18.8%
Halichoeres cyanocephalus	yellowcheek wrasse	18.1%
Cantherhines pullus	orangespotted filefish	17.6%
Anisotremus surinamensis	black margate	16.2%
Halichoeres radiatus	puddingwife	16.1%
Sparisoma rubripinne	yellowtail parrotfish	16.1%
Opistognathus aurifrons	yellowhead jawfish	15.9%
Chromis scotti	purple reeffish	15.5%
Lutjanus griseus	gray snapper	15.3%
Diodon holocanthus	balloonfish	15.1%
Stegastes adustus	dusky damselfish	14.5%
Epinephelus morio	red grouper	14.4%
Pareques acuminatus	high-hat	14.3%
Lactophrys triqueter	smooth trunkfish	14.2%

Chromis multilineata	brown chromis	13.8%	*Microspathodon chrysurus*	yellowtail damselfish	4.6%
Lutjanus synagris	lane snapper	13.7%	*Monacanthus tuckeri*	slender filefish	4.6%
Urobatis jamaicensis	yellow stingray	12.9%	*Holocanthus townsendi*	Townsend angelfish	4.6%
Calamus proridens	littlehead porgy	12.8%	*Rypticus saponaceus*	greater soapfish	4.5%
Calamus penna	sheepshead porgy	12.4%	*Stephanolepis hispidus*	planehead filefish	4.5%
Calamus pennatula	pluma porgy	12.4%	*Diplodus holbrookii*	spottail pinfish	4.4%
Serranus tortugarum	chalk bass	12.3%	*Haemulon macrostomum*	Spanish grunt	4.2%
Carangoides bartholomaei	yellow jack	12.1%	*Diplectrum formosum*	sand perch	4.1%
Acanthostracion polygonius	honeycomb cowfish	11.1%	*Lutjanus apodus*	schoolmaster	3.9%
Kyphosus sectatrix	Bermuda chub	10.4%	*Epinephelus guttatus*	red hind	3.5%
Chromis enchrysura	yellowtail reeffish	10.4%	*Pareques umbrosus*	cubbyu	3.4%
Acanthostracion quadricornis	scrawled cowfish	9.8%	*Archosargus probatocephalus*	sheepshead	3.3%
Aulostomus maculatus	Atlantic trumpetfish	9.7%	*Priacanthus arenatus*	bigeye	3.2%
Haemulon carbonarium	caesar grunt	8.9%	*Haemulon chrysargyreum*	smallmouth grunt	3.1%
Ptereleotris calliura	blue dartfish	8.6%	*Scarus guacamaia*	rainbow parrotfish	3.0%
Scomberomorus regalis	cero	8.5%	*Canthidermis sufflamen*	ocean triggerfish	3.0%
Stegastes planifrons	threespot damselfish	8.0%	*Lactophrys bicaudalis*	spotted trunkfish	3.0%
Malacanthus plumieri	sand tilefish	7.8%	*Ginglymostoma cirratum*	nurse shark	2.9%
Scorpaena plumieri	spotted scorpionfish	7.4%	*Hypoplectrus puella*	barred hamlet	2.9%
Haemulon melanurum	cottonwick	7.1%	*Stegastes diencaeus*	longfin damselfish	2.9%
Haemulon parra	sailors choice	7.1%	*Calamus nodosus*	knobbed porgy	2.9%
Chaetodon striatus	banded butterflyfish	6.6%	*Heteropriacanthus cruentatus*	glasseye snapper	2.9%
Chaetodipterus faber	Atlantic spadefish	6.5%	*Aluterus schoepfii*	orange filefish	2.8%
Balistes vetula	queen triggerfish	6.1%	*Epinephelus adscensionis*	rock hind	2.8%
Ptereleotris helenae	hovering dartfish	6.0%	*Aluterus monoceros*	unicorn filefish	2.5%
Xyrichtys martinicensis	rosy razorfish	5.9%	*Apogon pseudomaculatus*	twospot cardinalfish	2.5%
Cantherhines macrocerus	whitespotted filefish	5.9%	*Gymnothorax miliaris*	goldentail moray	2.5%
Sphyraena barracuda	great barracuda	5.7%	*Serranus subligarius*	belted sandfish	2.5%
Centropyge argi	cherubfish	5.6%	*Mycteroperca bonaci*	black grouper	2.5%
Gymnothorax moringa	spotted moray	5.6%	*Fistularia tabacaria*	bluespotted cornetfish	2.4%
Bodianus pulchellus	spotfin hogfish	5.6%	*Elagatis bipinnulata*	rainbow runner	2.3%
Seriola rivoliana	almaco jack	5.5%	*Synodus intermedius*	sand diver	2.2%
Scarus coeruleus	blue parrotfish	5.4%	*Hypoplectrus gemma*	blue hamlet	2.1%
Holocentrus rufus	longspine squirrelfish	5.1%	*Haemulon striatum*	striped grunt	2.1%
Scarus vetula	queen parrotfish	5.0%	*Gymnothorax funebris*	green moray	2.1%
Calamus bajonado	jolthead porgy	4.9%	*Equetus punctatus*	spotted drum	2.0%
Cephalopholis fulva	coney	4.8%	*Myripristis jacobus*	blackbar soldierfish	2.0%
Rypticus maculatus	whitespotted soapfish	4.7%	*Rhomboplites aurorubens*	vermilion snapper	1.8%

Xyrichtys novacula	pearly razorfish	1.8%
Diplodus argenteus	silver porgy	1.8%
Apogon maculatus	flamefish	1.7%
Epinephelus itajara	goliath grouper	1.7%
Synodus foetens	inshore lizardfish	1.7%
Equetus lanceolatus	jackknife-fish	1.6%
Lutjanus mahogoni	mahogany snapper	1.6%
Scarus coelestinus	midnight parrotfish	1.6%
Diodon hystrix	porcupinefish	1.6%
Gerres cinereus	yellowfin mojarra	1.6%
Centropristis striata	black sea bass	1.6%
Seriola dumerili	greater amberjack	1.6%
Apogon binotatus	barred cardinalfish	1.4%
Haemulon album	margate	1.4%
Halichoeres pictus	rainbow wrasse	1.4%
Mycteroperca phenax	scamp	1.3%
Heteroconger longissimus	brown garden eel	1.3%
Odontoscion dentex	reef croaker	1.1%
Dasyatis americana	southern stingray	1.1%
Lutjanus buccanella	blackfin snapper	1.0%
Schultzea beta	school bass	1.0%
Apogon townsendi	belted cardinalfish	1.0%
Myrichthys breviceps	sharptail eel	0.9%
Serranus annularis	orangeback bass	0.8%
Mulloidichthys martinicus	yellow goatfish	0.8%
Euthynnus alletteratus	little tunny	0.8%
Scomberomorus maculatus	Spanish mackerel	0.8%
Monacanthus ciliatus	fringed filefish	0.8%
Gymnothorax vicinus	purplemouth moray	0.8%
Lutjanus jocu	dog snapper	0.8%
Amblycirrhitus pinos	redspotted hawkfish	0.8%
Sargocentron coruscum	reef squirrelfish	0.7%
Caranx hippos	crevalle jack	0.7%
Negaprion brevirostris	lemon shark	0.7%
Scomberomorus cavalla	king mackerel	0.7%
Carcharhinus leucas	bull shark	0.6%
Carcharhinus perezii	reef shark	0.6%
Sphoeroides testudineus	checkered puffer	0.6%
Lagodon rhomboides	pinfish	0.6%
Lactophrys trigonus	trunkfish	0.5%
Nicholsina usta	emerald parrotfish	0.5%
Chilomycterus schoepfii	striped burrfish	0.5%
Megalops atlanticus	tarpon	0.5%
Chilomycterus atinga	spotted burrfish	0.5%
Mycteroperca microlepis	gag	0.5%

Table S3. NCRMP – LPI benthic habitat Mantel correlogram analysis results. Table of results from the Mantel correlogram testing of the benthic habitat to determine the level of spatial autocorrelation present among the *N* = 435 observations of benthos. The minimum and maximum distances (km) for each distance class are noted along with the number of distances pairs ("No. Dists.") within each class, their Mantel autocorrelation statistic (*r*), and the associated raw and Holm's adjusted *p*-values. Significance (*) was based on 10,000 permutations of the raw data and α = 0.05. All distance classes exceeding one-half the maximum distance are not interpreted.

Class	Min Dist.	Max Dist.	No. Dists.	Mantel (*r*)	*p*-value	*p* Adjusted
1	0.0	8.5	26782	0.1012	0.0001	*0.0001**
2	8.5	17.0	24962	0.0729	0.0001	*0.0002**
3	17.0	25.5	22022	0.0532	0.0001	*0.0003**
4	25.5	34.0	17820	0.0123	0.0339	*0.0339**
5	34.0	42.5	14482	-0.0068	0.2101	0.2101
6	42.5	51.0	12018	-0.0370	0.0003	*0.0009**
7	51.0	59.6	10578	-0.0540	0.0001	*0.0007**
8	59.6	68.1	9816	-0.0558	0.0001	*0.0008**
9	68.1	76.6	9882	-0.0532	0.0001	*0.0009**
10	76.6	85.1	9826	-0.0432	0.0001	*0.0010**
11	85.1	93.6	8818			
12	93.6	102.1	7528			
13	102.1	110.6	5954			
14	110.6	119.1	4138			
15	119.1	127.6	2514			
16	127.6	136.1	962			
17	136.1	144.6	466			
18	144.6	153.1	222			

Table S4. NCRMP – RVC community Mantel Correlogram analysis results. Table of results from the Mantel correlogram testing of the reef fish visual census data to determine the level of spatial autocorrelation present among the *N* = 1,535 observations of fish communities. The minimum and maximum distances (km) for each distance class are noted along with the number of distances pairs ("No. Dists.") within each class, their Mantel autocorrelation statistic (*r*), and the associated raw and Holm's adjusted *p*-values. Significance (*) was based on 10,000 permutations of the raw data and α = 0.05. All distance classes exceeding one-half the maximum distance are not interpreted.

Class	Min Dist.	Max Dist.	No. Dists.	Mantel (*r*)	*p*-value	*p* Adjusted
1	0.0	8.4	272930	0.0969	0.0001	*0.0001* *
2	8.4	16.8	260040	0.0488	0.0001	*0.0002* *
3	16.8	25.2	231370	0.0310	0.0001	*0.0003* *
4	25.2	33.6	200060	0.0199	0.0001	*0.0004* *
5	33.6	42.0	167560	0.0121	0.0011	*0.0011* *
6	42.0	50.4	144430	-0.0090	0.0356	*0.0356* *
7	50.4	58.8	121460	-0.0184	0.0002	*0.0007* *
8	58.8	67.3	111120	-0.0236	0.0001	*0.0008* *
9	67.3	75.7	110190	-0.0351	0.0001	*0.0009* *
10	75.7	84.1	116860	-0.0364	0.0001	*0.0010* *
11	84.1	92.5	119320	-0.0336	0.0001	*0.0011* *
12	92.5	100.9	119060			
13	100.9	109.3	109030			
14	109.3	117.7	95112			
15	117.7	126.1	80704			
16	126.1	134.5	55946			
17	134.5	142.9	40566			
18	142.9	151.3	23736			
19	151.3	159.7	5592			
20	159.7	168.1	112			
21	168.1	176.5	152			
22	176.5	184.9	138			

Table S5. DisProf clustering solutions. Grouping solutions for all *N* = 398 PSUs examined in the Coral ECA across both fish guild assignments (G1 & G2). Each PSU's unique site identification contains the sampling year in the first four digits and the site in the last four.

Group ID	Fish Guild Assignment #1 (G1) - All Depths (*N* = 398)	Fish Guild Assignment #2 (G2) - All Depths (*N* = 398)
Group 1	2014-3140, 2014-3149; 2016-3001, 2016-3004, 2016-3009, 2016-3016, 2016-3021, 2016-3030, 2016-3089, 2016-3094, 2016-3105, 2016-3108, 2016-3139, 2016-3150, 2016-3226, 2016-3250; 2018-3043, 2018-3079, 2018-3085, 2018-3122, 2018-3180, 2018-3202, 2018-3210, 2018-3263; 2020-3085, 2020-3090, 2020-3095, 2020-3101, 2020-3105, 2020-3114, 2020-3116, 2020-3121, 2020-3124, 2020-3126, 2020-3130, 2020-3138, 2020-3153, 2020-3157, 2020-3164, 2020-3166, 2020-3180, 2020-3204, 2020-3231, 2020-3237, 2020-3248, 2020-3252, 2020-3258, 2020-3259, 2020-3268, 2020-3282, 2020-3297, 2020-3299, 2020-3305, 2020-3306, 2020-3315, 2020-3316, 2020-3317, 2020-3320, 2020-3324; 2022-3039, 2022-3047, 2022-3050, 2022-3058, 2022-3060, 2022-3064, 2022-3074, 2022-3078, 2022-3085, 2022-3088, 2022-3094, 2022-3101, 2022-3102, 2022-3108, 2022-3109, 2022-3111, 2022-3119, 2022-3123, 2022-3127, 2022-3131, 2022-3136, 2022-3139, 2022-3150, 2022-3189, 2022-3190, 2022-3191, 2022-3197, 2022-3200, 2022-3201, 2022-3203, 2022-3219, 2022-3223, 2022-3225, 2022-3229, 2022-3234, 2022-3237, 2022-3249, 2022-3257, 2022-3258, 2022-3259, 2022-3260, 2022-3273, 2022-3275, 2022-3277, 2022-3279, 2022-3280, 2022-3281, 2022-3282, 2022-3290	2014-3134, 2014-3140, 2014-3149; 2016-3001, 2016-3004, 2016-3009, 2016-3016, 2016-3021, 2016-3030, 2016-3058, 2016-3066, 2016-3089, 2016-3094, 2016-3108, 2016-3110, 2016-3139, 2016-3150, 2016-3185 2016-3186 2016-3202 2016-3207, 2016-3226, 2016-3250; 2018-3018, 2018-3039, 2018-3043, 2018-3053, 2018-3077, 2018-3079, 2018-3085, 2018-3096, 2018-3136, 2018-3162, 2018-3179, 2018-3180, 2018-3210, 2018-3222, 2018-3252; 2020-3005, 2020-3011, 2020-3067, 2020-3073, 2020-3085, 2020-3090, 2020-3093, 2020-3095, 2020-3101, 2020-3104, 2020-3114, 2020-3116, 2020-3121, 2020-3123, 2020-3124, 2020-3126, 2020-3130, 2020-3133, 2020-3135, 2020-3137, 2020-3138, 2020-3143, 2020-3148, 2020-3152, 2020-3153, 2020-3157, 2020-3164, 2020-3166, 2020-3169, 2020-3172, 2020-3174, 2020-3180, 2020-3203, 2020-3204, 2020-3231, 2020-3237, 2020-3248, 2020-3252, 2020-3258, 2020-3259, 2020-3268, 2020-3270, 2020-3282, 2020-3297, 2020-3299, 2020-3303, 2020-3304, 2020-3305, 2020-3306, 2020-3312, 2020-3315, 2020-3316, 2020-3317, 2020-3318, 2020-3320, 2020-3324, 2020-3330; 2022-3008, 2022-3028, 2022-3039, 2022-3047, 2022-3050, 2022-3058, 2022-3060, 2022-3063, 2022-3074, 2022-3078, 2022-3085, 2022-3088, 2022-3094, 2022-3097, 2022-3101, 2022-3102, 2022-3108, 2022-3109, 2022-3111, 2022-3119, 2022-3123, 2022-3127, 2022-3130, 2022-3131, 2022-3134, 2022-3136, 2022-3138, 2022-3139, 2022-3150, 2022-3157, 2022-3175, 2022-3189, 2022-3190, 2022-3191, 2022-3197, 2022-3200, 2022-3201, 2022-3203, 2022-3211, 2022-3219, 2022-3223, 2022-3225, 2022-3229, 2022-3234, 2022-3237, 2022-3249, 2022-3258, 2022-3259, 2022-3263, 2022-3264, 2022-3273, 2022-3275, 2022-3277, 2022-3279, 2022-3282, 2022-3290

Group ID	Fish Guild Assignment #1 (G1) - All Depths (*N* = 398)	Fish Guild Assignment #2 (G2) - All Depths (*N* = 398)
Group 2	2018-3033	2018-3033
Group 3	2016-3257; 2081-3266	2016-3257
Group 4	2018-3269	2018-3269
Group 5	2016-3002, 2016-3212, 2016-3265, 2016-3266; 2020-3177	2016-3270, 2016-3286, 2016-3288, 2016-3289
Group 6	2016-3222, 2016-3231, 2016-3240, 2016-3285; 2018-3009, 2018-3018, 2018-3024, 2018-3025, 2018-3039, 2018-3161, 2018-3162, 2018-3262; 2020-3038, 2020-3073, 2020-3084, 2020-3150, 2020-3178, 2020-3184, 2020-3189, 2020-3206, 2020-3207, 2020-3208, 2020-3253, 2020-3309, 2020-3311, 2020-3312, 2020-3327, 2020-3329, 2020-3330; 2022-3002, 2022-3005, 2022-3006, 2022-3007, 2022-3008, 2022-3012, 2022-3013, 2022-3016, 2022-3019, 2022-3023, 2022-3025, 2022-3026, 2022-3028, 2022-3065, 2022-3129, 2022-3130, 2022-3137, 2022-3141, 2022-3143, 2022-3144, 2022-3146, 2022-3147, 2022-3148, 2022-3154, 2022-3157, 2022-3159, 2022-3211, 2022-3214, 2022-3252, 2022-3262, 2022-3263, 2022-3264, 2022-3285, 2022-3288	2020-3328

Group ID	Fish Guild Assignment #1 (G1) - All Depths (*N* = 398)	Fish Guild Assignment #2 (G2) - All Depths (*N* = 398)
Group 7	2016-3270, 2016-3286, 2016-3288, 2016-3289	2016-3078, 2016-3085, 2016-3091, 2016-3095, 2016-3120, 2016-3124, 2016-3125, 2016-3127, 2016-3138, 2016-3140, 2016-3142, 2016-3143, 2016-3144, 2016-3162, 2016-3167, 2016-3175, 2016-3178, 2016-3194, 2016-3199, 2016-3203, 2016-3206, 2016-3210, 2016-3261; 2018-3059, 2018-3242, 2018-3247, 2018-3254, 2018-3266
Group 8	2022-3145	2016-3222, 2016-3231; 2018-3009, 2018-3024, 2018-3025; 2020-3150; 2022-3005, 2022-3007, 2022-3010, 2022-3012, 2022-3013, 2022-3016, 2022-3019, 2022-3023, 2022-3025, 2022-3026, 2022-3129, 2022-3137, 2022-3141, 2022-3143, 2022-3144, 2022-3146, 2022-3147, 2022-3148, 2022-3285, 2022-3288
Group 9	2016-3072, 2016-3078, 2016-3085, 2016-3091, 2016-3097, 2016-3110, 2016-3119, 2016-3120, 2016-3124, 2016-3125, 2016-3127, 2016-3138, 2016-3140, 2016-3142, 2016-3143, 2016-3144, 2016-3162, 2016-3165, 2016-3167, 2016-3174, 2016-3175, 2016-3178, 2016-3185, 2016-3186, 2016-3189, 2016-3194, 2016-3199, 2016-3202, 2016-3203, 2016-3206, 2016-3207, 2016-3230, 2016-3261; 2018-3247	2016-3265, 2016-3266

Group ID	Fish Guild Assignment #1 (G1) - All Depths (*N* = 398)	Fish Guild Assignment #2 (G2) - All Depths (*N* = 398)
Group 10	2016-3036, 2016-3037, 2016-3040, 2016-3064, 2016-3099, 2016-3160; 2018-3258; 2020-3133, 2020-3148, 2020-3159, 2020-3191; 2022-3057, 2022-3118, 2022-3140, 2022-3149	2016-3002; 2020-3099, 2020-3110, 2020-3155; 2020-3177, 2022-3075
Group 11	2018-3046, 2018-3285	2016-3036, 2016-3037, 2016-3040, 2016-3064, 2016-3099, 2016-3160;2018-3050, 2018-3258;2020-3159;2022-3118, 2022-3145, 2022-3149
Group 12	2020-3190, 2020-3192, 2020-3193; 2022-3010	2016-3212
Group 13	2016-3045, 2016-3058, 2016-3059, 2016-3066, 2016-3069, 2016-3071, 2016-3095; 2018-3053, 2018-3077, 2018-3155, 2018-3179; 2020-3093, 2020-3099, 2020-3104, 2020-3110, 2020-3132, 2020-3155, 2020-3203, 2020-3235; 2022-3063, 2022-3075, 2022-3175	2016-3045, 2016-3059, 2016-3069, 2016-3071, 2016-3083, 2016-3105, 2016-3119, 2016-3165, 2016-3174, 2016-3230, 2016-3259; 2018-3002, 2018-3122, 2018-3155, 2018-3230; 2022-3064

Group ID	Fish Guild Assignment #1 (G1) - All Depths (*N* = 398)	Fish Guild Assignment #2 (G2) - All Depths (*N* = 398)
Group 14	2016-3083, 2016-3259; 2018-3001, 2018-3002, 2018-3047, 2018-3049, 2018-3059, 2018-3254, 2018-3545	2014-3126, 2014-3127, 2014-3128, 2014-3130, 2014-3136, 2014-3137, 2014-3138, 2014-3139, 2014-3141, 2014-3144, 2014-3146, 2014-3147, 2014-3148, 2014-3155, 2014-3156, 2014-3157, 2014-3159, 2014-3160, 2014-3163, 2014-3164, 2014-3165, 2014-3166, 2014-3167; 2016-3189; 2018-3109, 2018-3110, 2018-3117, 2018-3202, 2018-3231, 2018-3240, 2018-3241, 2018-3243, 2018-3246, 2018-3250, 2018-3263, 2018-3268, 2018-3278; 2020-3112, 2020-3132, 2020-3235, 2020-3307, 2020-3308; 2022-3188, 2022-3257, 2022-3260, 2022-3271, 2022-3280, 2022-3281
Group 15	2016-3217, 2016-3225; 2018-3050; 2020-3016, 2020-3321	2018-3248, 2018-3262, 2022-3110

Group ID	Fish Guild Assignment #1 (G1) - All Depths (*N* = 398)	Fish Guild Assignment #2 (G2) - All Depths (*N* = 398)
Group 16	2014-3126, 2014-3127, 2014-3128, 2014-3130, 2014-3135, 2014-3136, 2014-3137, 2014-3138, 2014-3139, 2014-3141, 2014-3144, 2014-3145, 2014-3146, 2014-3147, 2014-3155, 2014-3156, 2014-3157, 2014-3159, 2014-3160, 2014-3163, 2014-3164, 2014-3165, 2014-3166, 2014-3167; 2018-3006, 2018-3096, 2018-3103, 2018-3109, 2018-3110, 2018-3117, 2018-3230, 2018-3231, 2018-3240, 2018-3241, 2018-3242, 2018-3243, 2018-3245, 2018-3246, 2018-3250, 2018-3253, 2018-3268, 2018-3272, 2018-3278; 2020-3112, 2020-3307, 2020-3308, 2020-3318; 2022-3188, 2022-3192, 2022-3271	2016-3217, 2016-3225
Group 17	2016-3229; 2018-3008, 2018-3042; 2020-3131, 2020-3325	2016-3229; 2018-3001, 2018-3008, 2018-3047, 2018-3049, 2018-3545; 2020-3131, 2020-3325

Group ID	Fish Guild Assignment #1 (G1) - All Depths (*N* = 398)	Fish Guild Assignment #2 (G2) - All Depths (*N* = 398)
Group 18	2014-3132, 2014-3133, 2014-3134; 2018-3222, 2018-3248, 2018-3252; 2020-3123m 20203328; 2022-3105	2014-3125, 2014-3129, 2014-3131, 2014-3132, 2014-3133, 2014-3135, 2014-3145, 2014-3158; 2016-3057, 2016-3061, 2016-3067, 2016-3072, 2016-3097, 2016-3115, 2016-3117, 2016-3172, 2016-3195, 2016-3254; 2018-3006, 2018-3048, 2018-306,2 2018-3063, 2018-3066, 2018-3097, 2018-3103, 2018-3213, 2018-3219, 2018-3245, 2018-3253; 2020-3103, 2020-3125, 2020-3128, 2020-3213, 2020-3280, 2020-3288; 2022-3053, 2022-3057, 2022-3066, 2022-3071, 2022-3076, 2022-3114, 2022-3140, 2022-3192, 2022-3193, 2022-3215, 2022-3220, 2022-3224, 2022-3239, 2022-3243, 2022-3261, 2022-3269
Group 19	2014-3125, 2014-3129, 2014-3131, 2014-3148, 2014-3158; 2016-3057, 2016-3061, 2016-3067, 2016-3115, 2016-3117, 2016-3172, 2016-3195, 2016-3210, 2016-3254; 2018-3048, 2018-3062, 2018-3063, 2018-3066, 2018-3097, 2018-3213, 2018-3219; 2020-3103, 2020-3125, 2020-3128, 2020-3213, 2020-3270, 2020-3280, 2020-3288, 2020-3304; 2022-3053, 2022-3066, 2022-3071, 2022-3076, 2022-3114, 2022-3193, 2022-3215, 2022-3220, 2022-3224, 2022-3239, 2022-3243, 2022-3261, 2022-3269	2018-3042, 2018-3046, 2018-3272, 2018-3285; 2020-3105, 2020-3191

Group ID	Fish Guild Assignment #1 (G1) - All Depths (*N* = 398)	Fish Guild Assignment #2 (G2) - All Depths (*N* = 398)
Group 20	2018-3136; 2020-3005, 2020-3011, 2020-3067, 2020-3135, 2020-3137,020-3143, 2020-3152, 2020-3169, 2020-3172, 2020-3174, 2020-3303; 2022-3097, 2022-3110, 2022-3134, 2022-3138	2020-3178
Group 21	-	2020-3190, 2020-3192, 2020-3193; 2022-3002
Group 22	-	2016-3240, 2016-3285; 2018-3161; 2020-3016, 2020-3038, 2020-3084, 2020-3184, 2020-3189, 2020-3206, 2020-3207, 2020-3208, 2020-3253, 2020-3309, 2020-3311, 2020-3321, 2020-3327, 2020-3329; 2022-3006, 2022-3065, 2022-3105, 2022-3154, 2022-3159, 2022-3214, 2022-3252, 2022-3262