Coral Reef Regime Discovery in the Kristin Jacobs Coral Aquatic Preserve using Combined Benthic Composition and Fish Abundance Data

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

Coral Reef Regime Discovery in the Kristin Jacobs Coral Aquatic Preserve using Combined Benthic Composition and Fish Abundance Data

Final Progress Report for FDOU-51, Phase II-B

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List of Acronyms

BIC	Bayesian Information Criterion
CAP	Canonical Analysis of Principal Coordinates
CCA	Crustose Coralline Algae
Coral AP	Kristin Jacobs Coral Reef Aquatic Preserve
CPR	Coral Protection and Restoration Program
CPUV	Count-Per-Unit-Volume
CRCP	Coral Reef Conservation Program
CRR	Coral Reef Regime
DEP	Florida Department of Environmental Protection
DisProf	Dissimilarity Profile
EM	Expectation Maximization
FDOU	Fishing, Diving and Other Uses
FDOU-51	FDOU LAS Project #51
FWRI	Florida Fish and Wildlife Research Institute
GMM	Gaussian Mixture Model
HB	House Bill
ICA	Inlet Contributing Area
IndVal	Species Indicator Value
LAS	Local Action Strategy
LOO-CV	Leave-One-Out Cross-Validation
LPI	Line Point-Intercept
MBAHC	Model-Based Agglomerative Hierarchical Clustering
NCRMP	National Coral Reef Monitoring Program
nMDS	Non-metric Multidimensional Scaling
NOAA	National Oceanic and Atmospheric Administration
PERMDISP	Permutation-based Multivariate Dispersion
PERMANOVA	Permutation-based Multivariate Analysis of Variance
PI	Principal Investigator
PSU	Primary Sampling Unit
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, the area was renamed the Kristin Jacobs Coral Reef Ecosystem Conservation Area on July 1, 2021. On July 1, 2024, the conservation area was formally recognized as an aquatic preserve and given its current moniker, the Kristin Jacobs Coral Aquatic Preserve (Coral AP). The Coral AP includes the sovereign submerged lands and state waters offshore of Martin, Palm Beach, Broward, and Miami-Dade Counties in southeast Florida, extending from its northern boundary at St. Lucie Inlet southward to the northern extent of Biscayne National Park, which marks the preserve's southern boundary (Figure 1). Although the Coral AP was only established relatively recently, 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 stakeholders to develop local action strategies (LAS) for protecting the ~105 linear miles of coral reef resources spanning Martin through Miami-Dade counties' waters. These LAS are typically short-term, locally driven projects for cooperative action among federal, state, and non-governmental partners. 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 Phases I and II 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 AP (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).

Phase II of FDOU-51 began using the previously developed framework to conduct analyses using existing long-term monitoring data from the National Coral Reef Monitoring Program (NCRMP; Towle et al., 2021) to investigate the diversity, abundance, and composition trends in fish resources and natural habitats of the Coral AP (Kilborn, 2024a;b). These investigations can help inform future efforts to examine relationships between these trends and changing water quality and/or benthic habitat characteristics and will identify fish and habitat functional groups indicative of different configurations.

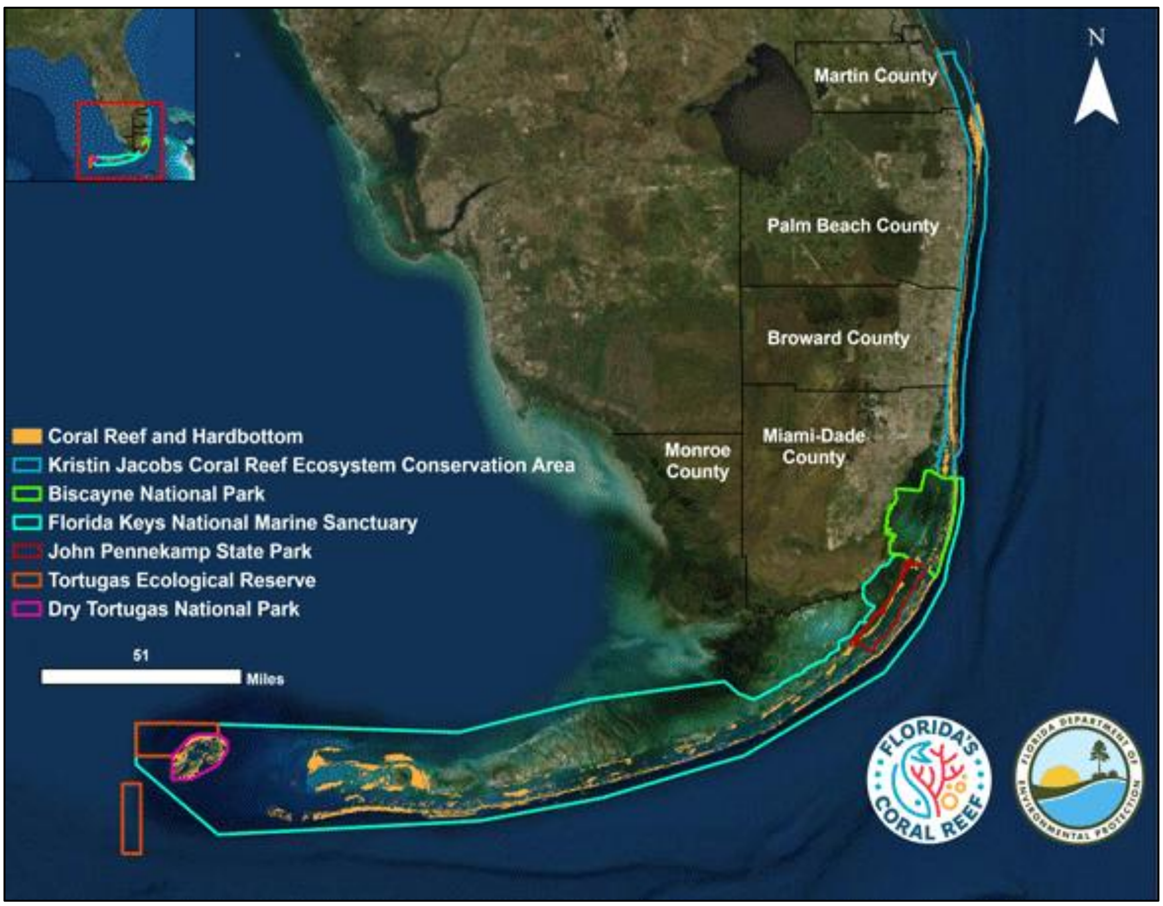

Figure 1. Map of Florida's coral reef. The Kristin Jacobs Coral Aquatic Preserve (northern-most, blue outline) encompasses the entire northern portion of Florida's Coral Reef system and spans Martin, Palm Beach, Broward, and north Miami-Dade counties.

1.2. FDOU-51, Phase II-B Project Objectives

FDOU-51 aims to investigate three major subsystems that comprise the Coral AP: *i*) natural, coral reef and hardbottom benthic habitats, *ii*) reef fishes, and *iii*) physiochemical aquatic conditions. Phase II involved compiling data and pairing together two of these subsystems (live benthos + reef fishes) and analyzing them simultaneously in search of patterns illustrative of the complex relationships between the two subsystem's constituents. There, coral reef and fish monitoring sites within the preserve were classified into coral reef regimes (CRR)s using long-term monitoring data from these subsystems (Kilborn, 2024b) and methods similar to Donovan et al. (2018).

While Phase II was completed successfully, there were a few points in the process where additional work will improve the outcome (Kilborn, 2024b). For example, two trophic guild models were presented to conceptualize the reef fishes' trophic hierarchy and only one model can be used in the final analysis. Additionally, several of the species selected to be "representative" reef fishes drawn from the Coral AP were, ultimately, under sampled within the final observational frame (N = 398 samples). Furthermore, the original clustering solution from Phase II was too fine scaled for effective management application. Therefore, a new classification framework for assigning a CRR to each sample needed to be devised, modeled and condensed, interpreted, and visualized. Importantly, final products need to be concise enough for effective management implementation and community outreach.

1.2.1. Revisit the biological model for Coral AP fishes

The species retained from NCRMP's reef fish monitoring dataset to represent the Coral AP's fish communities were originally selected based on the requirement of appearing in ≥ 0.5% of all observations from the survey's full sampling universe of N_{Survey} = 1,545 stations. After pairing the fish and benthic field observations, the final set of observations retained for these analyses (N = 398) was much smaller and many species were not well represented in the final fish dataset. In Phase II-B, the task of determining which species best comprise the "representative population" of observed reef fishes in the Coral AP is revisited.

In addition to revising the list of representative fishes, one of the two trophic guild assignment frameworks used in Phase II must be selected for final modeling exercises. The Phase II final report (Kilborn, 2024b) presented one scheme designed to capture species' positions within a systematized trophic hierarchy (Parravicini et al., 2020;Kilborn, 2024b) and a second scheme modified to include iconic or endemic Florida reef-fish guilds (e.g., groupers, parrotfishes, snappers). In Phase II-B, the un-modified, generalized trophic framework will be implemented.

1.2.2. Revise and consolidate the CRR solution

After revising the list of representative fish species and guild assignments, they will be included in the paired [benthic + fish] dataset. It should be noted that the benthic data will also be re-examined to determine if any of those descriptors are unnecessary or redundant prior to combination with the fish information. After assembling the data, the clustering algorithm(s) will be rerun, and the new CRR assignments will be extracted. There remains a high likelihood that there may be more groups than can be ecologically interpreted (e.g., ≥ 10) using the resemblance-based methods (Clarke et al., 2008;Kilborn et al., 2017) from Phase II (Kilborn, 2024b), therefore, new clustering approaches and optimal group selection are explored in Phase II-B.

1.2.3. Discriminate among CRRs and enhance visualizations

Upon completion of the clustering and consolidation exercises, updated visualizations and interpretations of the constituent fish and benthic habitat levels within the CRRs can be created. Species indicator values can be assigned to fishes and discriminant analyses among regimes can be deployed at this time. With respect to the final CRR grouping solution defined in Phase II-B, multivariate ordination diagrams will be created, which provide comprehensive visualizations depicting the resemblance structures in the observational data (i.e., sample sites) and accounting for which data streams (i.e., fish guilds, benthic cover categories) best differentiate the CRRs. Likewise, kernel density diagrams will also be used to concisely visualize the underlying fish communities and benthic habitat compositions across regimes. Both sets of diagrams are useful and informative for resource managers and stakeholders, however, the kernel density representations may foster communication more broadly than the relatively technical ordination diagrams. Lastly, in Phase II-B the progression of the CRRs over time will be examined. Specifically, it will be noted if any particular states have become more or less common over the study period.

1.2.4. Update final CRR maps and ArcGIS layer

After all of the CRRs have been fully defined and assigned to all sampling locations, new maps can be created to document where the CRRs are distributed throughout the Coral AP. These maps will include all regimes across all years (as seen in the Phase-II Final Report; Kilborn 2024) along with those for individual sampling years.

1.3. 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 insight 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 CRRs derived from combined descriptors of the reef fish and benthic subsystems, which can 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 benefit from a better understanding of the reef fish and benthic indicators that best characterize regime states as well as from spatiotemporal visualizations of these coupled systems throughout the Coral AP. 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. METHODS

The primary objective of FDOU-51 Phase II-B was to revisit the construction of the multivariate model used to represent the benthic and fish subsystems of the Coral AP and develop an updated definition of the coral reef regime (CRR) states based on their combined [benthic + fish] data. This was done in a stepwise fashion where, first, the two datasets were reconceptualized independently before being recombined. Next, the combined dataset was subjected to both the previously employed frequentist methods for statistical clustering (Clarke et al., 2008;Kilborn et al., 2017;Kilborn, 2024b) as well as alternate approaches that rely on a Bayesian expectation-maximization framework (Fraley and Raftery, 2002;Donovan et al., 2018). After a new clustering solution is realized, discriminant analyses were performed to help capture the underlying trends in the fish and benthic resources that lead to the new CRR definitions, and updated visualization were created to better communicate these findings. Lastly, contemporary and historical maps depicting the spatial distribution of CRRs throughout the Coral AP were created using ArcGIS Pro 3.4.2 (Esri, 2024).

2.1. Data Assembly and Pretreatment

All data for Phase II-B were drawn from two SCUBA diver-based biennial surveys conducted as part of the NCRMP. Specifically, their line point-intercept (LPI) survey (Groves et al., 2025) for estimating proportional cover of benthic habitats, and the reef-fish visual census (RVC) survey (Ganz and Blondeau, 2023) comprising non-cryptic reef fish observations used to estimate species' relative abundances. Daytime survey operations targeted 0.5 to 30 m depths across the Coral AP's natural carbonate reef system (Figure 2). When considered together, these programs observations extend from 2014-2024 and operate every other year, however the 2024 data were not available for these analyses. Thus, there are five discrete sampling seasons (even years through 2022) included in this analysis spanning a total of nine years (2014-2022). Per the NCRMP sampling protocols (Towle et al., 2021), all LPI survey locations (N_{LPI} = 435) are drawn as a

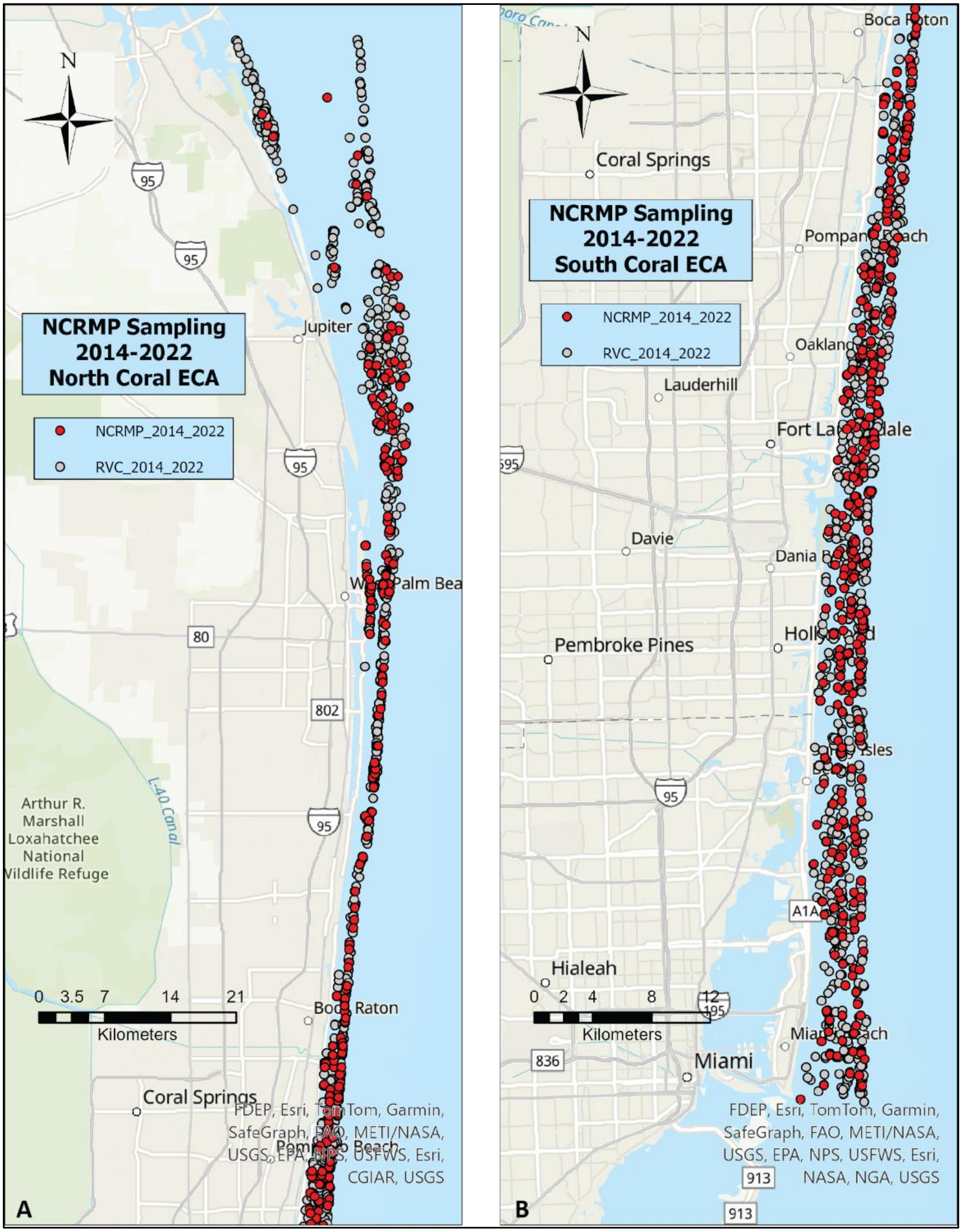

Figure 2. NCRMP survey distributions throughout the Coral AP. Locations for the SCUBA diver surveys conducted for NCRMP and spanning the entire Coral AP from 2014-2022. Survey sites are pictured across the northern (A) and southern (B) portions of the region for both reef-fish visual census (RVC, grey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

subset of the RVC sites (N_{RVC} = 1,545) (Figure 2).

2.1.1. NCRMP survey sample matching

Each of the primary sampling units (PSU)s from the independent NCRMP surveys were married together using a unique identifier combining the sampling year and the NCRMP-assigned PSU value used across both surveys. The geographic distance between the matched PSUs was calculated and only pairs within 1 km of one another were considered the same sampling event. The selected threshold was relatively arbitrary, however, given the scope, scale, and real-world challenges of the programs' field deployments, 1 km was deemed a realistic value. It should also be noted that these events are only married along the spatial dimension and the temporal dimension is reduced to the level of observations being made within the same "sampling season", which is defined as the summer and fall of the sampling year (Towle et al., 2021;Viehman et al., 2023). Of the $N_{[LPI+RVC]}$ = 435 matched [LPI + RVC] samples, N = 398 were retained for these exercises after applying the 1 km threshold. The final distribution of observations across all years and NCRMP 'subregions' is reported in Table 1 and mostly corresponds with the 'red' sampling locations illustrated in Figure 2.

Table 1. Sampling effort acros the Coral AP. 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***

2.1.2. Parameterization of the benthic subsystem

The NCRMP benthic LPI surveys report proportional cover values for 14 discrete benthic habitat categories (Table S1), however, some of these were either condensed into other categories or eliminated, and the final set of parameters used to conceptualize the Coral AP's benthic subsystem utilized eight distinct habitat types (Table 2). Given that '*Peysonnellia*' and '*Ramicrusta spp.*' are themselves considered types of 'Crustose Coralline Algae' (CCA), their observations were added to the CCA observations, which subsequently raised the mean observed abundance of CCA to 1.3% across all samples. This increase, therefore, raised CCA above the 1% threshold used for retention in the final analysis. The categories '*CoralHYDRO*', '*OtherINVERT*', '*Other*', and '*Seagrass*' were all eliminated due to lack of information content (Table 2, Table S1).

2.1.3. Parameterization of the fish subsystem

The NCRMP RVC survey 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 AP. The resultant database contained 474 named fishes identified to the taxonomic levels of species ($S_{spp.}$ = 421) and genus (S_{genus} = 53). 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 = 101 individual species were identified in at least 5% (n = 20) of all N = 398 RVC surveys that were successfully paired with an LPI survey and retained for analyses (Table S2).

Table 2. Final selected benthic categories for the Coral AP. Final subset of LPI benthic cover categories monitored by NCRMP in the Coral AP used for analyses spanning 2014-2022. Percent (%) cover summary statistics for each category are presented and standard deviation ('StndDev') is relative to the observed mean. Data are sorted in descending order by the proportion of the *N* = 398 samples where the category was present.

Cover Category	Proportion of PSUs	Mean Cover Observed (%)	Median	Max	StndDev
AlgaeTURF	0.96	42.1	40.0	96.0	23.2
AlgaeMACRO	0.93	22.0	17.0	94.0	20.1
Sponges	0.91	8.1	7.0	43.0	6.6
Substrate	0.80	12.7	6.0	98.0	18.2
CoralSOFT	0.78	7.7	5.0	52.0	8.2
CoralHARD	0.49	1.2	0.0	17.0	2.0
CCA	0.37	1.3	0.0	17.8	2.6
Cyanobacteria	0.37	3.6	0.0	62.0	7.7

For each fish species, the mean abundance obtained from SCUBA diver pairs was converted to a catch-per-unit-effort value based on the volume of the diver's three-dimensional observational cylinder. The observed volume (m^{-3}) for each PSU was obtained using the depth (m) and visibility (m) recorded by the diver teams in the field, and final fish counts (#) were standardized to count-per-unit-volume (CPUV) form. The CPUV values (# m^{-3}) for each PSU were summed together for all species assigned to each of 10 independent feeding functional guilds (Table 3) representing the Coral AP's complex trophic network of coral reef fishes.

To complete the trophic classifications of fishes, the 101 retained species were cross-checked against a database compiled by the PI coding 293 known RVC fish species into one of the 10 trophic guilds (Table 3). The trophic classification framework employed here is a hybrid approach derived primarily 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 a separate model-study by Donovan et al. (2018). The Parravicini et al. (2020) authors' database of ~4,550 individual fishes, assigned 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 where 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 before a final assignment was made.

Table 3. Trophic guild assignments for Coral AP reef fishes. Feeding notes and the number of fish species included (*S*) in each trophic guild used for analysis of the Coral AP.

Trophic Guild	Feeding and Notes	*S*
Herbivore – Grazers	Grazes turf algae	5
Herbivore – Scrapers	Feed on algal turf, but also remove coral and other hard substrate	6
Herbivore – Browsers	Browses on macroalgae and associated epiphytic material	8
Corallivores	Feed on sea anemones, soft corals, and stony corals	5
Planktivores	Feed on zooplankton, cyanobacteria, and Harpacticoid copepods	12
Sessile Invertivores	Feed on starfishes, sponges, tunicates, sea cucumbers, and Bryozoa	9
Microinvertivores	Feed on Arachnida, sea spiders, small crustaceans, and worms	8
Macroinvertivores	Feed on mollusks (snails, sea hares, bivalves, squids, and octopuses), urchins, and brittle stars	22
Crustacivores	Feed on large crustaceans (crabs, shrimps, lobsters, crayfish, and prawns)	18
Piscivores	Feed primarily on ray finned fishes and cephalopods	8
	Total	**101**

2.1.4. Data standardization and transformation

Final analysis-ready datasets were compiled such that the Coral AP was conceptualized by $N = 398$ PSUs comprising proportional cover data for the eight LPI categories and RVC-derived CPUV data for the 10 fish trophic guilds. All data were standardized to the range [0,1] prior to shadeplot (Clarke et al., 2014) visualization (Figure 3). Shadeplots are used to determine which data transformation appropriately down-weights overly abundant groups and up-weights relatively rare ones. For subsequent analyses, fourth-root transforms of

Table 4. Final Coral AP reef fish species' trophic guild assignments. Guild assignments for all reef fishes across the 10 trophic guilds defined in Table 3.

HERBIVORE - GRAZERS	**Common Name**
Stegastes partitus	bicolor damselfish
Stegastes variabilis	cocoa damselfish
Stegastes adustus	dusky damselfish
Stegastes planifrons	threespot damselfish
Centropyge argi	cherubfish
HERBIVORE - BROWSERS	**Common Name**
Acanthurus bahianus	ocean surgeon
Acanthurus chirurgus	doctorfish
Acanthurus coeruleus	blue tang
Cryptotomus roseus	bluelip parrotfish
Sparisoma radians	bucktooth parrotfish
Kyphosus sectatrix	Bermuda chub
HERBIVORE – SCRAPERS	**Common Name**
Sparisoma aurofrenatum	redband parrotfish
Sparisoma atomarium	greenblotch parrotfish
Scarus iseri	striped parrotfish
Sparisoma viride	stoplight parrotfish
Scarus taeniopterus	princess parrotfish
Sparisoma chrysopterum	redtail parrotfish
Sparisoma rubripinne	yellowtail parrotfish
Scarus vetula	queen parrotfish
CORALLIVORES	**Common Name**
Holacanthus tricolor	rock beauty
Chaetodon ocellatus	spotfin butterflyfish
CORALLIVORES (continued...)	**Common Name**
Chaetodon capistratus	foureye butterflyfish
Aluterus scriptus	scrawled filefish
Chaetodon striatus	banded butterflyfish
PLANKTIVORES	**Common Name**
Chromis cyanea	blue chromis
Chromis insolata	sunshinefish
Xyrichtys splendens	green razorfish
Clepticus parrae	creole wrasse
Abudefduf saxatilis	sergeant major
Opistognathus aurifrons	yellowhead jawfish
Chromis scotti	purple reeffish
Chromis multilineata	brown chromis
Xyrichtys martinicensis	rosy razorfish
Ptereleotris helenae	hovering dartfish
Ptereleotris calliura	blue dartfish
Chromis enchrysura	yellowtail reeffish
SESSILE INVERTIVORES	**Common Name**
Canthigaster rostrata	sharpnose puffer
Pomacanthus arcuatus	gray angelfish
Pomacanthus paru	French angelfish
Holacanthus ciliaris	queen angelfish
Holacanthus bermudensis	blue angelfish
Cantherhines pullus	orangespotted filefish
Acanthostracion polygonia	honeycomb cowfish
Cantherhines macrocerus	whitespotted filefish
Acanthostracion quadricornis	scrawled cowfish

MICROINVERTIVORES	Common Name
Chaetodon sedentarius	reef butterflyfish
Halichoeres maculipinna	clown wrasse
Stegastes leucostictus	beaugregory
Haemulon flavolineatum	French grunt
Lactophrys triqueter	smooth trunkfish
Haemulon aurolineatum	tomtate
Haemulon melanurum	cottonwick
Scarus coeruleus	blue parrotfish

MACROINVERTIVORES	Common Name
Thalassoma bifasciatum	bluehead
Halichoeres garnoti	yellowhead wrasse
Halichoeres bivittatus	slippery dick
Anisotremus virginicus	porkfish
Haemulon plumierii	white grunt
Lachnolaimus maximus	hogfish
Bodianus rufus	Spanish hogfish
Balistes capriscus	gray triggerfish
Calamus calamus	saucereye porgy
Haemulon sciurus	bluestriped grunt
Halichoeres cyanocephalus	yellowcheek wrasse
Diodon holocanthus	balloonfish
Sphoeroides spengleri	bandtail puffer
Halichoeres poeyi	blackear wrasse
Halichoeres radiatus	puddingwife
Anisotremus surinamensis	black margate
Calamus penna	sheepshead porgy
Malacanthus plumieri	sand tilefish
Balistes vetula	queen triggerfish
Calamus bajonado	jolthead porgy
Haemulon carbonarium	caesar grunt

MACROINVERTIVORES (continued…)	Common Name
Haemulon parra	sailors' choice

CRUSTACIVORES	Common Name
Lutjanus analis	mutton snapper
Serranus tigrinus	harlequin bass
Pseudupeneus maculatus	spotted goatfish
Ocyurus chrysurus	yellowtail snapper
Hypoplectrus unicolor	butter hamlet
Serranus tabacarius	tobaccofish
Serranus baldwini	lantern bass
Holocentrus adscensionis	squirrelfish
Pterois volitans	red lionfish
Calamus proridens	littlehead porgy
Serranus tortugarum	chalk bass
Urobatis jamaicensis	yellow stingray
Pareques acuminatus	high-hat
Lutjanus griseus	gray snapper
Lutjanus synagris	lane snapper
Scorpaena plumieri	spotted scorpionfish
Rypticus saponaceus	greater soapfish
Epinephelus guttatus	red hind

PISCIVORES	Common Name
Caranx ruber	bar jack
Cephalopholis cruentata	graysby
Caranx crysos	blue runner
Epinephelus morio	red grouper
Carangoides bartholomaei	yellow jack
Scomberomorus regalis	cero
Aulostomus maculatus	Atlantic trumpetfish
Sphyraena barracuda	great barracuda

the standardized data were used and, where required, Gower's multivariate resemblance (Legendre and Legendre, 2012) was used to calculate dissimilarities among PSUs with different variable types and units of measure (i.e., percent cover [%] and CPUV [# m^{-3}]).

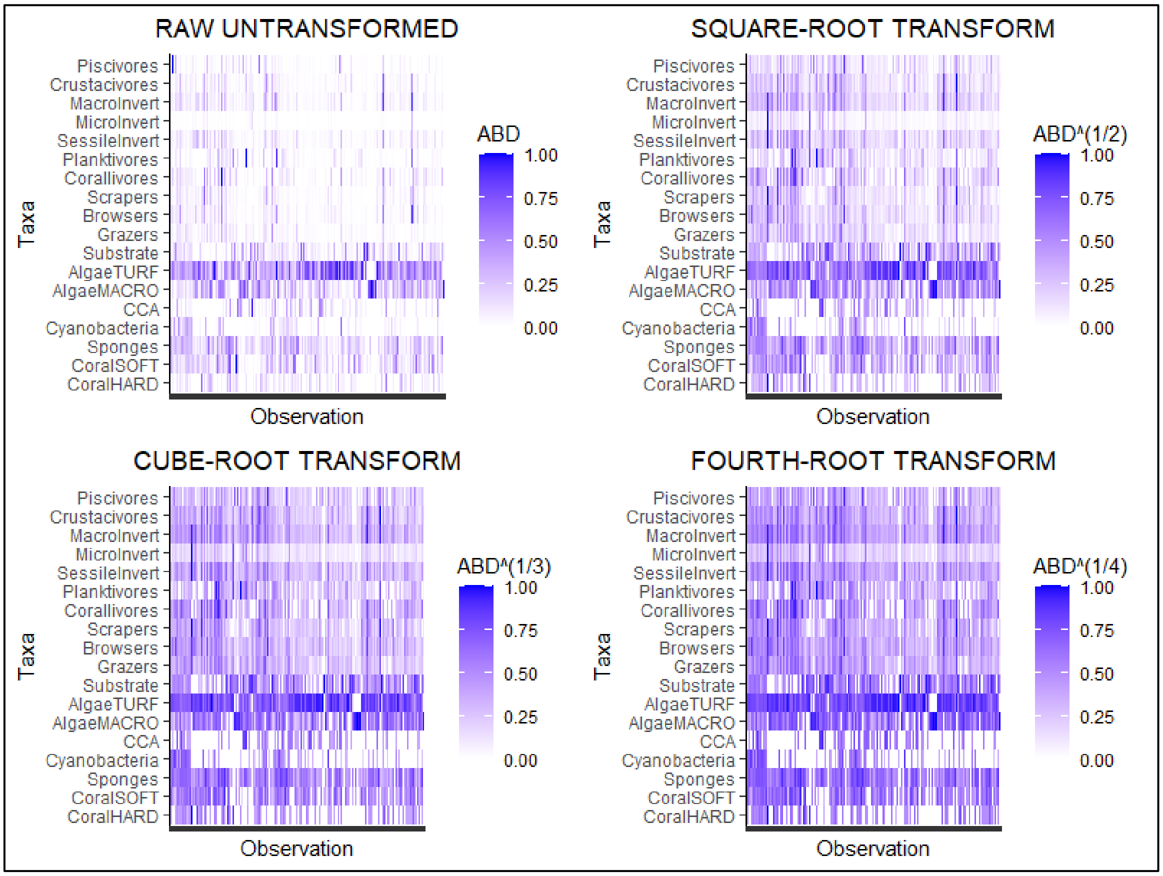

Figure 3. Shadeplot for the combined Coral AP dataset. Visualization depicting the effect of various data transformations on the set of [LPI + RVC] descriptors. "Raw Untransformed" data are the proportional cover and catch-per-unit-volume information from the LPI and RVC surveys standardized to the range [0,1]. Darker colors signify larger values and the color scales are relative to the minimum and maximum values of the transformed data (see legends in each panel).

2.2. Statistical Analyses

Statistical analyses were performed using the R statistical computing language (R Core Team, 2024) within the RStudio development environment (Posit Team, 2025). Where necessary, randomization testing was performed using 10,000 permutations of the raw data, *p*-values generated under multiple-comparison scenarios were adjusted via the Holms progressive correction method (Clarke et al., 2008;Legendre and Legendre, 2012), and significance was determined relative to $\alpha = 0.05$.

2.2.1. Clustering exercises

To maintain continuity with the modeling performed in Phase II (Kilborn, 2024b), clustering solutions were first 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'.

Mean resemblance profiles were constructed using 10,000 permutations of the raw data and all *p*-values were adjusted due to multiple comparisons (Clarke et al., 2008;Legendre and Legendre, 2012). One limitation of Disprof clustering is that it tends to produce very fine-scale solutions often resulting in large numbers of groups that can be difficult to interpret, particularly in biological settings (Clarke et al., 2008;Kilborn et al., 2017). This was the case in Phase II where, depending on the underlying data configuration, clustering solutions produced anywhere from 15 to 24 unique groups (Kilborn, 2024b). Therefore, alternate clustering routines were also explored in Phase II-B.

Model-based clustering (Fraley and Raftery, 2002) is a probabilistic approach to clustering that can use the Bayesian information criterion (BIC) to select an optimal model configuration and number of components (i.e., groups) from the underlying data (Scrucca et al., 2023), and it was implemented via the '*mclust*' package (Scrucca, 2023). The approach is similar to DisProf clustering in that it also begins with a hierarchical partitioning of the multivariate dataset, however in '*mclust*' the method of choice is a model-based agglomerative hierarchical clustering (MBAHC; Banfield and Raferty, 1993) algorithm as opposed to the UPGMA solution employed by DisProf clustering. Another similarity among the DisProf clustering and MBAHC is the exploration of grouping possibilities among the clustering solutions produced, however, the similarities end there, as the model-based routines utilize Gaussian mixture models (GMM), rather than similarity profiles, in an expectation-maximization (EM) optimization framework (Scrucca, 2023;Scrucca et al., 2023).

The incorporation of BIC as a model selection heuristic allows for multiple GMMs to be developed and tested to determine which best captures the ideal number of clusters within the dataset. The GMMs attempt to assign clusters to observations based on GMM models that are constrained by the number of groups to be created, the presumed shape of the groups' associated data clouds (e.g., spherical, diagonal, ellipsoidal, etc.), the volume and homogeneity among those clouds, and data noise levels (Fraley and Raftery, 2002;Scrucca et al., 2023). The process calculates models for over one dozen GMM configurations that incorporate up to as many groups as the user defines. Here, the number of groups obtained by the DisProf clustering process is used as the maximum number of possible groups the '*mclust*' algorithm should attempt to classify. The optimal GMM type, shape, volume, and number of groups are determined by selecting the model that maximizes BIC, and the '*mclust*' solution is obtained and assessed against the DisProf clustering solution.

2.2.2. Discriminant analyses

Once a grouping solution is achieved, the next step is to determine which characteristics (or related trends) are likely to drive any of the patterns detected and might be used to discriminate among groups. To accomplish this, several multivariate approaches were employed. First, using the '*vegan*' package (Oksanen et al., 2024), the multivariate dispersion for each group of PSUs was calculated using the PERMDISP methodology (Anderson 2006), and differences among them were tested using permutation-based multivariate analysis of variance (PERMANOVA; Anderson, 2001;McArdle and Anderson 2001). Pairwise comparisons were also made to determine which, if any, groups' dispersions differed from one another; *p*-values were adjusted for multiple comparisons. Next, canonical analysis of principal coordinates (CAP; Anderson and Willis, 2003) was used to create a classification model of the underlying [LPI + RVC] data that emphasizes explaining the variability defined by the grouping structure resultant from the clustering exercises. The CAP model can also be used to assess group classification success rates via leave-one-out cross-validation (LOO-CV) and its resultant confusion matrix. The '*BiodiversityR*' package (Kindt and Coe, 2005) was used for the implementation of CAP and LOO-CV along with the '*caret*' package (Kuhn, 2008) for confusion matrix production.

Lastly, indicator species value (IndVal) analysis (Dufrene and Legendre, 1997) was implemented via the '*indicspecies*' package (De Cáceres and Legendre, 2009) and performed to determine which reef fish species best characterized the clusters identified across the Coral AP. 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 particular group. In addition to testing just the individual groups presented by the clustering solution, additional tests were also performed to examine all possible combinations of groups (e.g., [group 1 + group 2 + group 5])(De Cáceres and Legendre, 2009).

2.2.3. Enhanced visualizations for stakeholder engagement

Additional multivariate visualizations to highlight the groups' resemblances with respect to the underlying descriptors were created to enhance the discriminant analyses and to aid stakeholder engagement. While the CAP procedure does technically produce a canonical ordination diagram that highlights the differences among groups, it can generally only be pictured in two or three dimensions. Clustering solutions with more than four groups become difficult to visualize with CAP ordinations, as they require $g - 1$ canonical axes to effectively capture (and draw) 100% of the variability among g groups (Anderson and Willis, 2003;Legendre and Legendre, 2012). Non-metric multidimensional scaling (nMDS; Kruskal, 1964), on the other hand, is designed to visually present multivariate resemblance data in an ordination with as many axes (i.e., dimensions) as the user specifies while maintaining the pairwise resemblance structure among objects (i.e, PSUs). Success is measured via a stress value that captures the n-dimensional ordination's capacity to represent the original data resemblances at their full resolution. Those solutions with a stress value between 0.2 and 0.3 are to be considered "poor" representations, and anything > 0.25 should likely be discarded (Clarke and Gorley, 2015). Therefore, using the '*vegan*' package, both two- and three-dimensional nMDS solutions will be produced to aid in describing the underlying relationships between the groups identified and the data that were used to conceptualize the Coral AP. The two-dimensional ordination will be produced via '*vegan*', and a three-dimensional figure will be created with '*plotly*' (Sievert, 2020). For each group's unique subset of PSUs, kernel density estimations from the '*stats*' package (R Core Team, 2024) will visualize the LPI and the RVC variables' probability density distributions. Finally, all clustering assignments will be mapped across the Coral AP for all years in the study (individually and combined) using ArcGIS Pro v3.4.2 (Esri, 2024).

3. RESULTS

3.1. Clustering Results

For the $N = 398$ [LPI + RVC] samples across all observed depths (0-31 m) throughout the Coral AP, DisProf clustering returned 39 unique clusters of PSUs (Table S3). As expected, the resolution of this grouping solution is far finer than desired and, unfortunately, the newest conceptualization of the Coral AP's LPI and RVC data had even more groups than prior iterations (Kilborn, 2024b). The BIC model selection routine in '*mclust*', when parameterized to allow up to 39 groups, indicated that the optimal Gaussian finite mixture model fitted by the EM algorithm was type "EVI" (i.e., diagonal, equal volume, varying shaped clusters) with eight components (i.e., groups) (Figure 4). The final model-based clustering (log-likelihood = 3526.9, $df = 288$, BIC = 5329.7, ICL = 5305.5) produced eight groups, or CRRs, with $n_{CRR1} = 66$, $n_{CRR2} = 94$, $n_{CRR3} = 23$, $n_{CRR4} = 14$, $n_{CRR5} = 15$, $n_{CRR6} = 86$, $n_{CRR7} = 61$, and $n_{CRR8} = 39$ PSUs (Table 5, Table S4), which varied in size over time (Table 5, Figure 5).

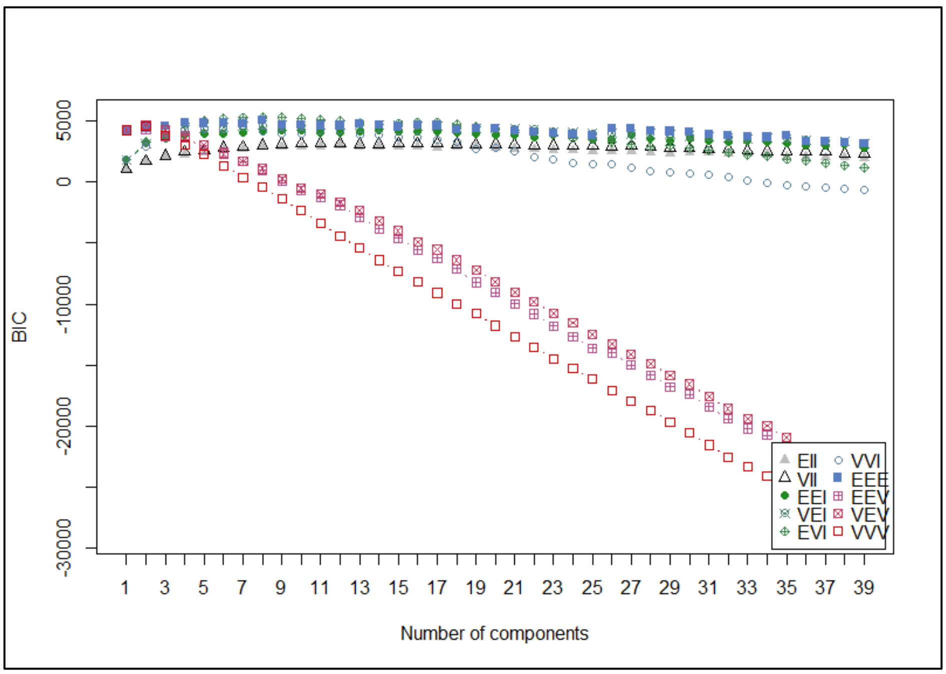

Figure 4. Model selection with BIC. Bayesian information criterion (BIC) values plotted as a function of the number of components (i.e., clusters) and the Gaussian mixture model parameterization (shapes and colors, inset legend). The optimal model configuration and number of clusters is assigned to the one with the largest BIC value.

3.2. Discriminant Analyses Results

3.2.1. Multivariate dispersion

The PERMDISP results (Table S5) showed that the multivariate dispersions among PSUs significantly differed across regimes, and follow-up pairwise tests indicated that 71% of the 28 between-group comparisons were significantly different. Thus, overall, the variability between within-group observations in the underlying Coral AP's LPI and RVC indicators did differ from CRR to CRR, with CRR_4 having the most variable set of observations while CRR_1 and CRR_7 were tied for the least variable PSUs (Table S5).

Table 5. Temporal distribution of Coral AP group assignments. The distribution of Coral AP group assignments throughout the temporal range of the study (2014-2022). Each cell represents the number of PSUs assigned to a particular group in any given year. Totals for each coral reef regime across the entire study period are presented in **bold** and totals by year are *italicized*. Note that the yearly totals match the distribution of effort presented in Table 1.

		CORAL AP GROUPS								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	*Total*
YEAR	*2014*	30	2	2	0	0	0	0	0	*34*
	2016	7	10	9	7	5	37	8	4	*87*
	2018	18	10	9	1	3	8	14	4	*67*
	2020	0	43	3	2	3	11	24	11	*97*
	2022	11	29	0	4	4	30	15	20	*113*
	Total	**66**	**94**	**23**	**14**	**15**	**86**	**61**	**39**	***398***

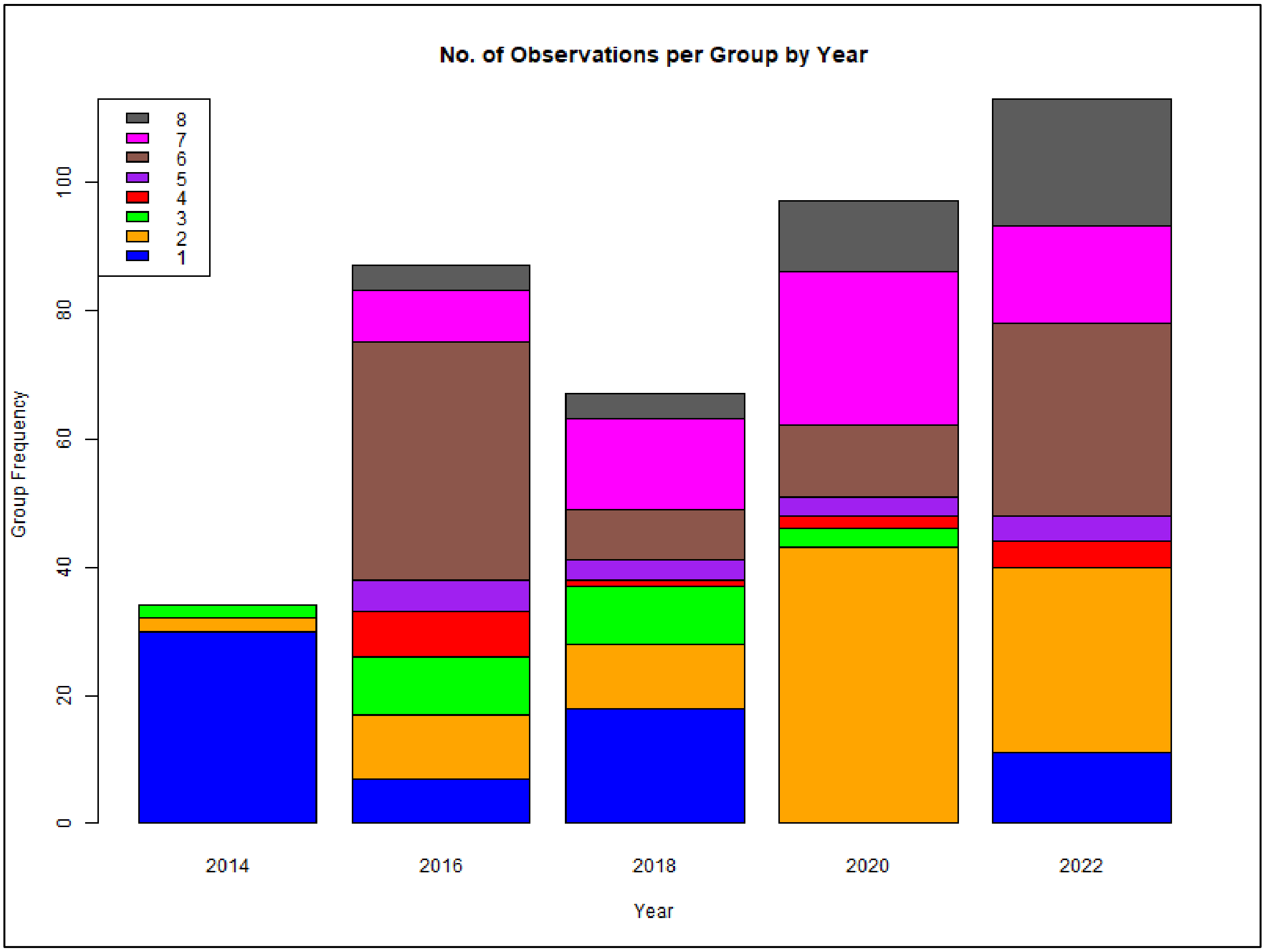

Figure 5. Composition of coral reef regimes by year. Stacked barplot depicting the number and membership of all CRRs assigned in each year of the study. Colors are assigned by regime are recur throughout the visualizations.

3.2.2. CAP and LOO-CV

The CAP classifier obtained an overall classification success rate of 88% (Table S6) with two regimes obtaining rates above 90% (CRR_2 = 97%, CRR_7 = 93%). The two lowest success rates were well below the overall success rate (CRR_5 = 67%, CRR_3 = 78%), whereas the remainder were within the range of 82-86% successful (Table S6). Due to the high overall classification success rate, there were relatively few misclassifications, however, when they occurred samples were typically reclassified into between two and four other CRRs. The highest number of PSU misclassifications from one regime into another was six PSUs from CRR_6 being predicted into CRR_2 (Table S6). The CAP ordination diagram was created (Figure S1), however, the first two visualized axes only accounted for ~53% of the total variability among the eight CRR, and the full solution would require seven canonical axes to capture 100% of the differences among the Coral AP's eight combined benthic and fish regime states.

3.2.3. Species indicator value results

Two sets of species indicator values were created for the Coral AP's fish abundance dataset, one set for only the eight groups identified by '*mclust*' (Table S7) and another set that allowed for those individual groups plus all other possible combinations of groups (Table S8). The eight-group IndVal solution identified 44 of 100 fishes as reliable indicators for five of the regimes with S_{CRR1} = 4, S_{CRR3} = 25, S_{CRR4} = 8, S_{CRR5} = 5, and S_{CRR8} = 2 (Table S7) species selected. Of those species, 38 were shared with the alternate IndVal solution, which produced a total of 55 indicator species across 26 unique combinations of groups. Interestingly, the singleton groups containing only regimes 1, 3, 4, 5, and 8, which had representative species assigned in the first IndVal routine, were also assigned significant indicators in the second exercise. However, the species richness in each group was reduced to S = 1, 1, 2, 1, and 1 species, respectively (Table S8). In fact, of the 25 species originally identified for CRR_3, only cero was assigned when alternate combinations were allowed, and the other 24 species from that regime were spread out across alternate combinations such that, of the 21 non-singleton group combinations tested, CRR_3 was included in 17 of them (Table S8). Lastly, the IndVals identified in the simpler solution were much lower overall than those of the full-combination solution (Table S7, Table S8). In fact, the average IndVal from the latter (~0.6) is nearly identical to the greatest IndVal observed in the former (max = 0.61, Table S7). Further, the relatively large values in the simple result were often due to high levels of within-group fidelity rather than among-group specificity, whereas the combination-based IndVals often exhibited higher levels of both, or the opposite relationship altogether (Table S7, Table S8).

3.3. Enhanced Visualizations

3.3.1. nMDS and kernel density diagrams

Two nMDS ordinations were produced, one with two dimensions and another with three. The stress value (w) for the two-dimensional solution was "poor" (w_{2D} = 0.22), however, increasing to three dimensions produced an acceptable visualization (w_{3D} = 0.16) of the PSUs' multivariate resemblances in reduced space. While three canonical axes were created, only two were used for the nMDS ordination in Figure 6 below, as the static three-dimensional image (Figure S2) did not greatly improve the interpretation of the solution.

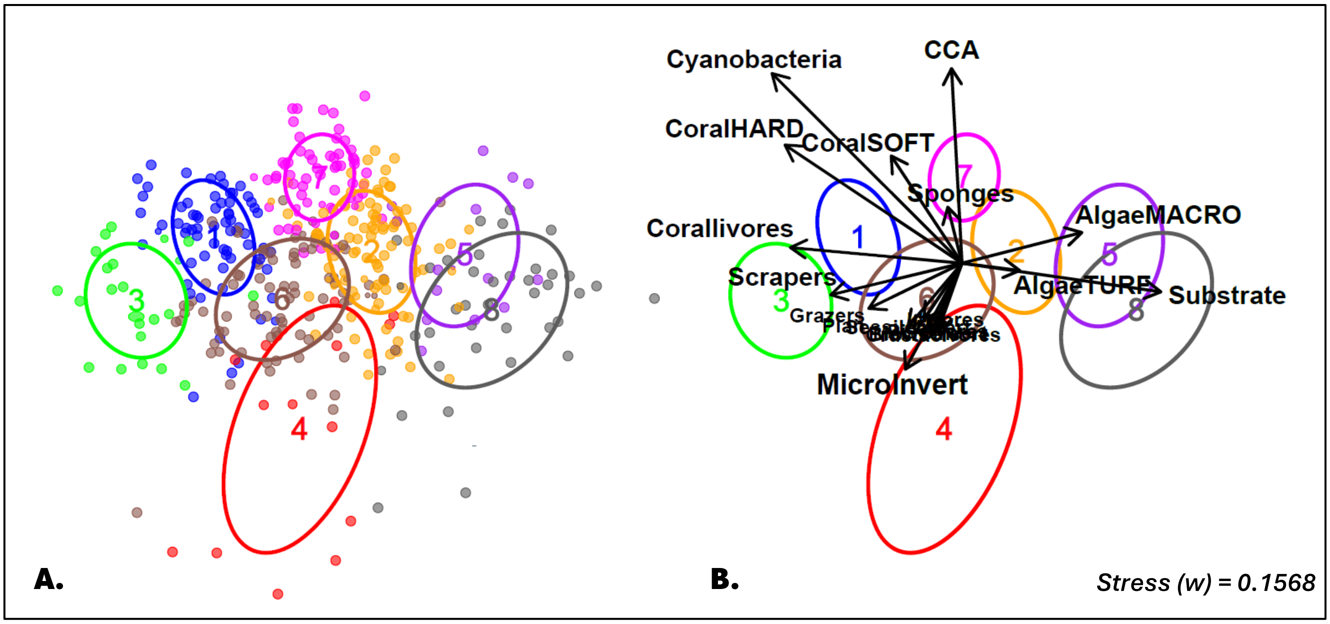

Figure 6. Non-metric multidimensional scaling ordination. The first two dimensions of a three-dimensional nMDS solution (stress: *w* = 0.1568) depicting the underlying data used for these exercises. The ordination of points (**A.**) visualizes the like among PSUs (points) such that those points closer together in multivariate space are mode similar than those placed further apart. Point size corresponds to their uncertainty probability. Correlation biplot vectors (**B.**) depict the correlation between an underlying descriptor and the modeled nMDS axes. Vector direction defines the positive (i.e., "relatively higher") end of a theoretical gradient related to that descriptor, and magnitude implies its relative impact on the placement of points along said gradient. Descriptor labels correspond to those from Table 3, and their sizes are arbitrary. Colors are based on regime assignment (numbers) and correspond to those from Figure 5. Ellipses encompass 50% of each regime's data.

The kernel density diagrams for the Coral AP (Figure 7) highlight the differences among the specific configurations of descriptors from each CRR. These unique and complex combinations of variable configurations can be thought of as the regimes' fingerprints, and each one is captured by the probability densities of the data for those PSUs within to it. Their central tendencies (i.e., means, modes) and spreads (variances) of the [LPI + RVC] can also help compare among them, and these figures can be particularly useful for understanding which descriptors are more impactful than others at describing each fingerprint. When used in conjunction with the nMDS diagrams and other results provided here, a clearer understanding of the Coral AP's dynamics and interrelationships can be presented to stakeholders, managers, and advocates.

3.3.2. Mapping Coral AP regimes in space and time

Six different maps were created to capture the spatial distribution of the eight regimes identified within the Coral AP, one each for the five independent years in the biennial data series (Figures 8-12), and one more visualizing the entire 9-year timespan (Figure 13). The map for 2022 (Figure 8) is the most contemporary model for the distribution of combined benthic and reef fish regimes and should provide the most benefit to stakeholders.

Alternatively, taken in total, the individual years' maps illustrate the changes evident across the entire Coral AP over time.

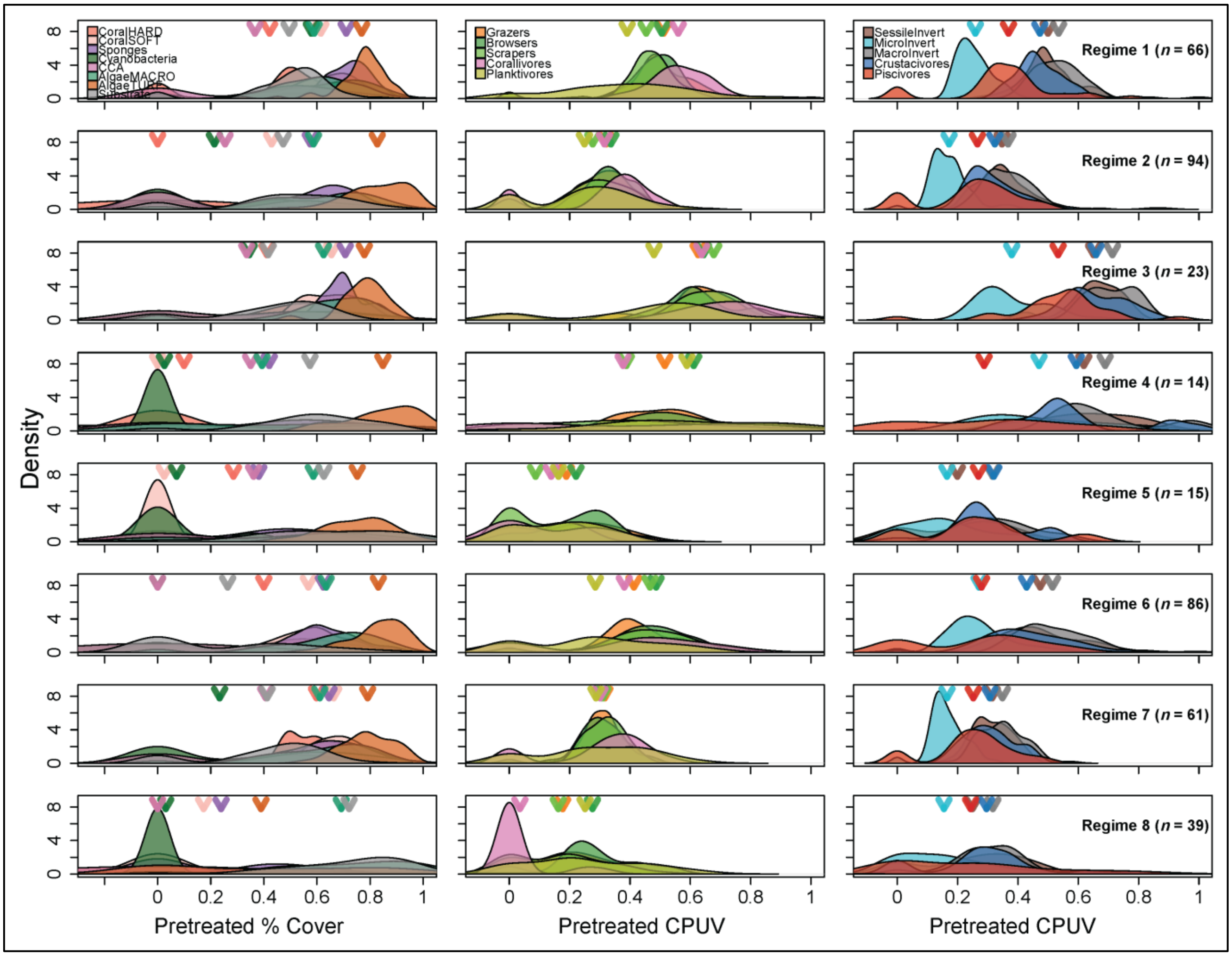

Figure 7. Kernel density estimates for all data by CRR. The kernel density of benthic habitats (left panels), herbivores, corallivores, and planktivores (center panels), and invertivores, crustacivores, and piscivores (right panels) by regime (rows, labeled in right-most panels). The x-axis corresponds to the scaled and transformed data used in clustering exercises, and the arrows correspond to that variable's mean value in that regime. See inset legends for color scheme assignments.

4. DISCUSSION

4.1. Spatiotemporal Considerations for Reef Regimes across the Coral AP

4.1.1. Widely distributed CRRs throughout the Coral AP

Of the eight CRRs obtained by the clustering exercises, four of them were highly abundant throughout the sampling universe (n_{CRR2} = 94, n_{CRR6} = 86, n_{CRR1} = 66, n_{CRR7} = 61; Table 5). In all cases, these regimes could be found in relatively high numbers throughout all subregions in the study (Figure 13). Thes four regimes should likely be considered the dominant reef types likely to be encountered in the Coral AP at any given place or time, albeit with some temporal caveats (Figure 5; see *§4.1.3* for details). As such, they capture broad-scale changes throughout the system and can provide insight at the level of the Coral AP and the entire combined [benthos + fish] subsystem.

4.1.2. Spatially limited CRRs throughout the Coral AP

Sampling effort in 2014 was both low (n_{2014} = 34) and spatially restricted to the Broward-Miami subregion (Table 1), resulting in only three of eight CRRs being observed that year, and the majority of which were assigned to CRR_1 (Figure 12). Additionally, all of Martin county's seven observations occurred in 2016 (Table 1), and a total of three regimes (n_{CRR2} = 1, n_{CRR4} = 3, n_{CRR5} = 3) were detected there as well. CRR_4 and CRR_5 had the #1 and #2 lowest occurrences out of all regimes, respectively, and these three positive identifications in 2016 for Martin county account for ~20% of those two regimes' total assignments across the Coral AP. Additionally, CRR_5 only appears in relatively deep sites north of the South Lake Worth Inlet (Figure 13) and, while CRR_4 is spread more evenly throughout the Coral AP (Figure 13), it is only ever observed a few times per year (Figures 8-12) across the entire spatial domain. Other spatially limited CRRs include CRR_3 (n_{CRR3} = 23), which was only observed north of the Hillsboro Inlet once (Figure 11), and CRR_8 (n_{CRR8} = 39). CRR_8 is most highly concentrated in relatively deep waters, first, in the N. Palm Beach subregion, followed by S. Palm Beach, but can also be found sporadically in relatively shallow waters in the subregions to the south (Figure 13).

Like the more frequently encountered CRRs, the spatially constrained CRRs also carry interpretive weight and management potential for the Coral AP, however their applications are either more specific to a portion of the preserve (i.e., northern or southern sites), or reef type (e.g., deep, shallow). From north to south, CRR_5 represents deep northern sites, CRR_4 is an example of a mostly northern site that is rarely encountered in the south, CRR_8 is mostly concentrated in deep water off of Palm Beach while occasionally observed in shallow southern waters, and CRR_3 is exclusively found in southern regions.

4.1.3. Temporal trends of CRRs throughout the Coral AP

Of the most abundant regimes, CRR_2 and CRR_7 were more prevalent in the later portion of the time series, CRR_6 was better represented in the 2016 and 2022 surveys than in the interim years, and CRR_1 was most abundant in 2014 but did persist through later years at lower levels (Table 5). CRR_1's high frequency in the early portion of the time series might be attributed to the uneven sampling effort applied to the Broward-Miami in 2014 (the year CRR_1 was most detected) and potentially due to a local effect, however, the effort in that region has only grown greater over time (Table 1) and the presence of CRR_1 has not persisted in that area, or anywhere else in the Coral AP (Table 5). While CRR_2 has been observed in all years, like CRR_7, stark increases in observations were noted after 2020 (Table 5). Overall, the general trend in the composition of CRRs in the Coral AP (Figure 5) is driven by the decrease in prevalence of CRR_1, increases in CRR_2 and CRR_7, and periodic fluctuations in CRR_6.

Even though CRR_8 appears mostly in the Palm Beach regions, the spatial distribution of PSUs is still relatively broad (Figure 13), and the regime encompasses a large number of deep sites in the Coral AP. Thus, the apparently increasing trajectory of this CRR appears to directly relate to these deep-water habitats and may be of concern to managers and stakeholders. Alternatively, CRR_3 was mostly prevalent in 2016 and 2018, and has not been observed since three PSUs were identified in 2020 (Table 5, Figure 5), whereas CRR_4 and CRR_5 have been consistently rare throughout the Coral AP over time (Figure 5).

4.2. Ecological Characteristics for CRRs in the Coral AP

The nMDS figure presents gradients of conditions underlying the various reef regimes (Figure 6). For example, sites (and regimes) on the right side of the ordination have relatively higher cover with respect to substrate, turf algae, and macroalgae and relatively low counts of corallivores, scrapers, and grazers (Figure 6, Table 6). The opposite is true for those sites placed on the left side of the diagram. For more detailed views of the same groups' characteristics, the kernel density figures show the distributions of values for each reef-fish functional guild and associated habitat types (Figure 7), and Table 6 includes the mean and standard deviations for the raw proportional cover and abundance data by CRR. Taken in total, general descriptions for each coral reef regime can be obtained.

Table 6. Summary statistics for all data by CRR. Mean (standard deviation) for all variables used to define the coral reef regime states (CRR_i) in the Coral AP. The dashed line indicates the separation between benthic habitat descriptors (top) and reef fish trophic guilds (bottom).

Descriptor	CRR_1	CRR_2	CRR_3	CRR_4	CRR_5	CRR_6	CRR_7	CRR_8
CoralHard	1.4 (1.4)	0.0 (0.0)	1.3 (1.2)	0.9 (3.0)	0.8 (0.9)	2.0 (2.9)	2.6 (1.8)	0.0 (0.0)
CoralSoft	10.1 (7.8)	6.6 (8.2)	10.8 (6.2)	0.0 (0.0)	0.1 (0.3)	8.2 (8.6)	12.1 (8.1)	1.6 (3.4)
Sponges	11.9 (5.3)	7.5 (5.8)	11.6 (5.6)	4.9 (6.1)	3.1 (4.0)	8.3 (6.6)	9.5 (7.7)	1.6 (2.7)
Cyanobacteria	12.5 (10.2)	2.5 (5.6)	6.6 (9.7)	0.1 (0.3)	0.2 (0.4)	0.0 (0.0)	3.4 (8.7)	0.1 (0.6)
CCA	1.7 (2.9)	1.2 (2.2)	1.8 (2.9)	3.9 (5.8)	2.2 (2.6)	0.0 (0.0)	2.3 (2.9)	0.0 (0.0)
AlgaeMacro	15.7 (13)	19.4 (17.7)	21.8 (15.0)	13.6 (17.9)	29.1 (28.1)	23.6 (18.4)	20.1 (15.8)	38.4 (32.9)
AlgaeTurf	36.3 (14.1)	49.9 (23.6)	37.6 (14.4)	55.9 (28.1)	35.4 (21.3)	49.7 (21.0)	41 (19)	18.4 (27.8)
Substrate	9.2 (8.1)	12.0 (14.5)	6.6 (5.7)	18.7 (18.7)	28.3 (28.0)	6.6 (14.4)	6.8 (7.7)	38.7 (29.1)
Grazers	75.1 (57)	34.5 (28.5)	84.5 (58.7)	30.2 (32.5)	15.1 (18.7)	46.1 (52.3)	49.2 (48.1)	5.9 (13.0)
Browsers	29 (19.6)	15.5 (13.2)	38.6 (26.6)	17.5 (17.8)	12.0 (14.0)	26.5 (20.6)	18.2 (17.7)	5.2 (6.8)
Scrapers	24.6 (17.4)	12.5 (13.1)	47.8 (30.2)	6.0 (9.0)	1.7 (2.6)	29.2 (32.2)	19.4 (13.4)	3.9 (10.4)
Corallivores	4.1 (2.9)	2.5 (2.8)	4.9 (4.4)	2.2 (4.2)	1.2 (2.4)	3.1 (4.3)	3.1 (3.0)	0.1 (0.3)
Planktivores	38.3 (123.6)	16.4 (32)	30.5 (59.5)	25.9 (36.8)	9.0 (14.8)	18.1 (50.7)	45.9 (73.8)	6.5 (11.7)
SessileInvert	9.6 (6.1)	5.9 (4.5)	12.8 (8.2)	10.4 (12.1)	4.1 (7.1)	8.8 (8.8)	6.2 (4.7)	2.2 (2.5)
MicroInvert	13.1 (21.2)	7.7 (15.8)	30.6 (45.8)	77.1 (109.9)	20.8 (35.3)	21.8 (44.8)	9.8 (20.7)	12.5 (33.5)
MacroInvert	86.8 (56.2)	49.1 (33.0)	122.8 (62.9)	67.3 (39.9)	41.8 (37.7)	75.2 (58.4)	62.2 (47.3)	24.4 (45.4)
Crustacivores	10.6 (15.1)	5.9 (6.4)	17 (11.5)	8.0 (7.5)	5.6 (2.9)	8.5 (9.9)	6.4 (6.1)	4.9 (12.5)
Piscivores	5.2 (13.6)	2.8 (5.6)	4.8 (5.5)	1.1 (1.8)	3.0 (3.5)	3.6 (10.3)	4.5 (10.5)	5.1 (18.5)

4.2.1. Overall composition of benthos and reef fishes across CRRs

CRR_1 is characterized by a sponge and cyanobacteria dominated reef, with moderate coral cover, and supporting all fish trophic guilds except for microinvertivores. CRR_2 is best described as a turf algal dominated habitat with some soft coral and sponges, depleted fish abundances (including the lowest mean microinvertivore counts of all regimes), and no hard coral coverage. This CRR represents a highly degraded habitat with low trophic functioning. CRR_3 displays a complex and abundant benthic community dominated by corals and sponges and supporting the healthiest fish community of all regimes. This regime had the highest observed mean abundances of all herbivores, corallivores, and sessile invertivores, along with the second highest abundance of microinvertivores (Table 6). CRR_4's benthic habitat is dominated by CCA and turf algae, displaying the highest observed means for these two substrate types, and no soft coral cover. This regime also has, by far, the highest abundance of microinvertivores and elevated levels of all other invertivores and crustacivores, suggesting an invertebrate dominated benthic community and potentially a disturbed or successional reef state. CRR_5, like CRR_2, is a turf- and macroalgal dominated system, with minimal coral cover, and a depauperate fish community apart from some invertivores, once again suggesting a highly degraded and potentially transitional regime.

CRR_6 contains a relatively healthy mosaic of hard corals (second highest mean cover observed) and turf algae, a very active herbivorous fish community, and it also supports the mid-to-upper trophic levels (e.g., macroinvertivores). CRR_7 showcases the healthiest coral reef communities of all the regimes with the highest hard and soft coral covers, very high sponge cover, the highest planktivore abundance, very high piscivorous activity, and healthy assemblages of herbivores, corallivores, and macroinvertivores (Figure 7, Table 6). Thus, CRR_7, along with $CRR_{3,}$ represents one of the more productive and biodiverse systems observed in the Coral AP. CRR_8, on the other hand, represents exactly the opposite, as it is a macroalgal and substrate dominated system with only piscivores present. In fact, both of these benthic categories had their highest observed coverages and the piscivores displayed the second highest levels observed (Figure 7). All other categories, aside from microinvertivores, displayed the lowest, or near-lowest, levels of all regimes, suggesting that this is a completely collapsed regime state acting as a predator refugia.

4.2.2. Reef fish indicator species

Given that CRR_3 has the healthiest reef fish community observed, it's not surprising that, under the non-combination scenario, this group produced the largest set of indicator species (S_{CRR3} = 25) comprising all 10 of the trophic guilds. When combinations were unrestricted, CRR_3 appeared in a majority of the resultant species indicator groups, and again all trophic guilds were well represented. As discussed above, the no-combination IndVals were generally too low to be useful (with the exception of just a few in CRR_3 and CRR_4) and those that were useful largely remained so due to elevated fidelity rather than specificity values. This implies that these species are more or less ubiquitous throughout the Coral AP, as the only mathematical way for a species in that scenario to obtain a greater specificity is to preferentially present in only one regime's samples and not others'. This phenomenon also plays out in the combination-based results where several species were assigned to combinations of CRRs that encompassed nearly all PSUs (e.g., group [1 + 2 + 3 + 4 + 5 + 6 +7]. Furthermore, only about a dozen of the species indicators selected in that exercise were due to both IndVal components being elevated and the majority of those were in combinations of five or more groups. The remaining indicator species mostly had very high specificity values with lower fidelity, and, in this case, this is likely the result of many groups being combined and, therefore, capturing many observations in a single large group prior to comparison for the purposes of defining group specificity. This enhances any natural discrepancies among these groups and nullifies the effect of the specificity parameter on the IndVal calculation. Therefore, given the selected indicator species and their assigned trophic guilds, both IndVal processes tended to corroborate the general characterizations of the CRRs described above, however, their species-specific utility is likely limited to special cases.

4.3. Conclusions

The investigation performed for FDOU-51, Phase II-B yielded eight distinct coral reef regime states throughout the Coral AP exhibiting from 2014-2022. Generally, these CRRs were not stable over space or time and exhibited a broad range of conditions. For example, three regimes can be described as positive states (CRR_3, CRR_6, CRR_7), two are disturbed (CRR_1, CRR_4), two are degraded (CRR_2, CRR_5), and one is collapsed (CRR_8). Of the eight, only four are widespread throughout the data series and of those four, three are increasing in frequency while the fourth (CRR_1) declined over time. CRR_1 was a sponge- and cyanobacteria-dominated transitional community that is no longer present in the Coral AP as of 2022. Whether or not this disappearance was due to the regime's PSUs fully transitioning into another regime state is unclear, nor is any other explanation obvious. The increasing frequency trend for CRR_2 is not particularly fortuitous, as this degraded regime is a turf-algae dominated system with severely depleted fish communities. Further, this regime is already the most prevalent in the Coral AP and increases to its frequency imply continuing system-wide degradation across the preserve. Likewise, CRR_8 is indicative of a fully collapsed coral reef system and, while this CRR has been mostly contained in relatively deeper waters off of West Palm Beach, it has been observed in other places as well as in shallower water. Thus, this may be an indication that the degradation captured by the steady rise in regimes such as CRR_2 not slowing its course, and the number of collapsed reefs is growing. In may also imply that the CRR_8 conditions are spreading from Palm Beach's deeper waters into other areas.

Alternatively, the other two largest regimes (CRR_6, CRR_7) are both increasing in frequency over time and are characterized by robust coral reefs with resilient and biodiverse fish communities. This may imply recovery underway throughout the preserve and can be taken as a positive sign. There are implications of both stress and resilience within the Coral AP's natural benthic habitats and coral reef fishes. This study will allow managers and stakeholders to better monitor and prepare for the complex changes as they present across the preserve and through time.

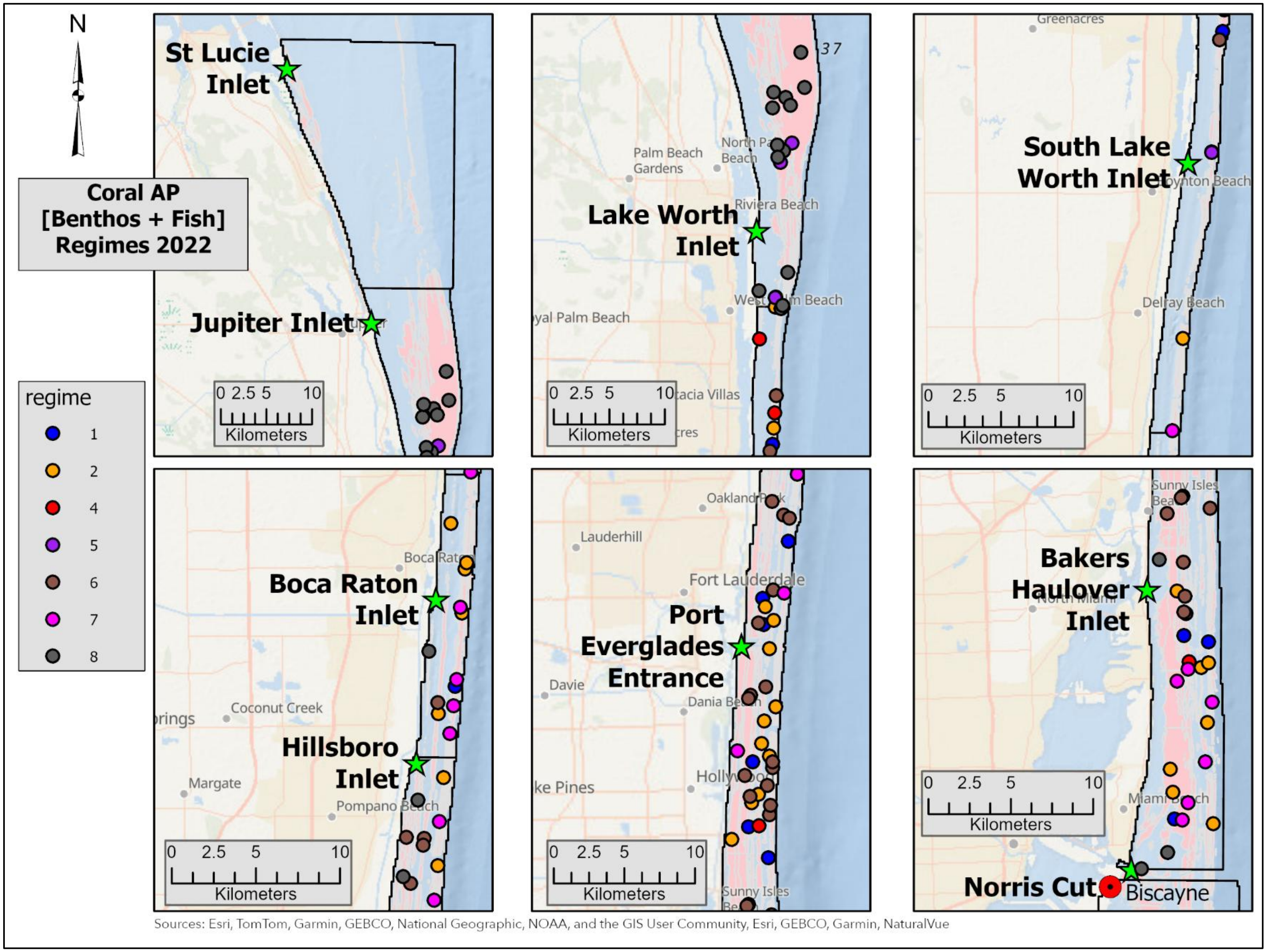

Figure 8. Distribution of CRRs in the Coral AP in 2022. Mapping of all eight coral reef regimes identified across the Coral AP using NCRMP data. 2022 is visualized. Panels are oriented north to south as you read left-to-right, top-to-bottom. PSUs may be duplicated across panels.

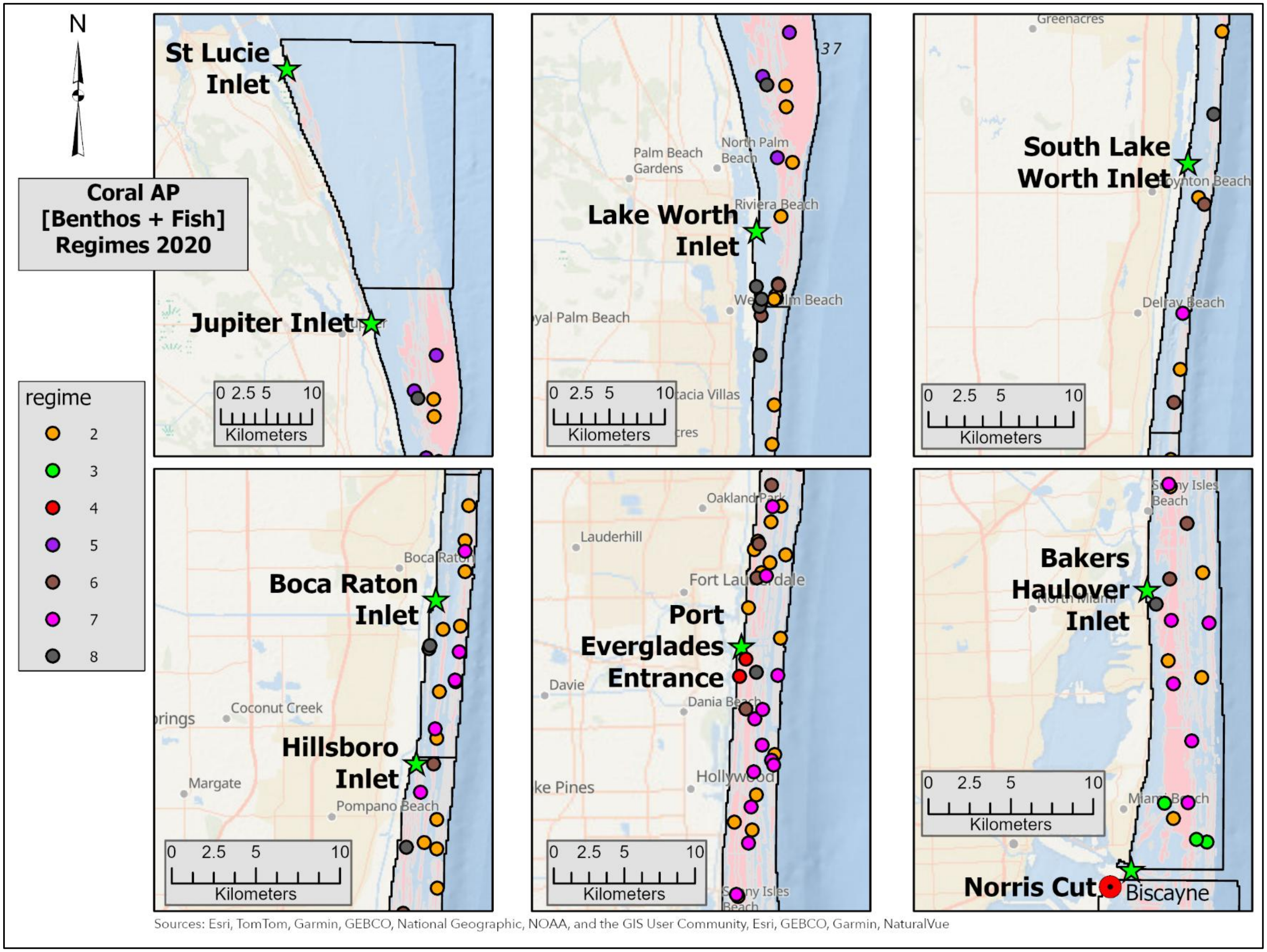

Figure 9. Distribution of CRRs in the Coral AP in 2020. Mapping of all eight coral reef regimes identified across the Coral AP using NCRMP data. 2020 is visualized. Panels are oriented north to south as you read left-to-right, top-to-bottom. PSUs may be duplicated across panels.

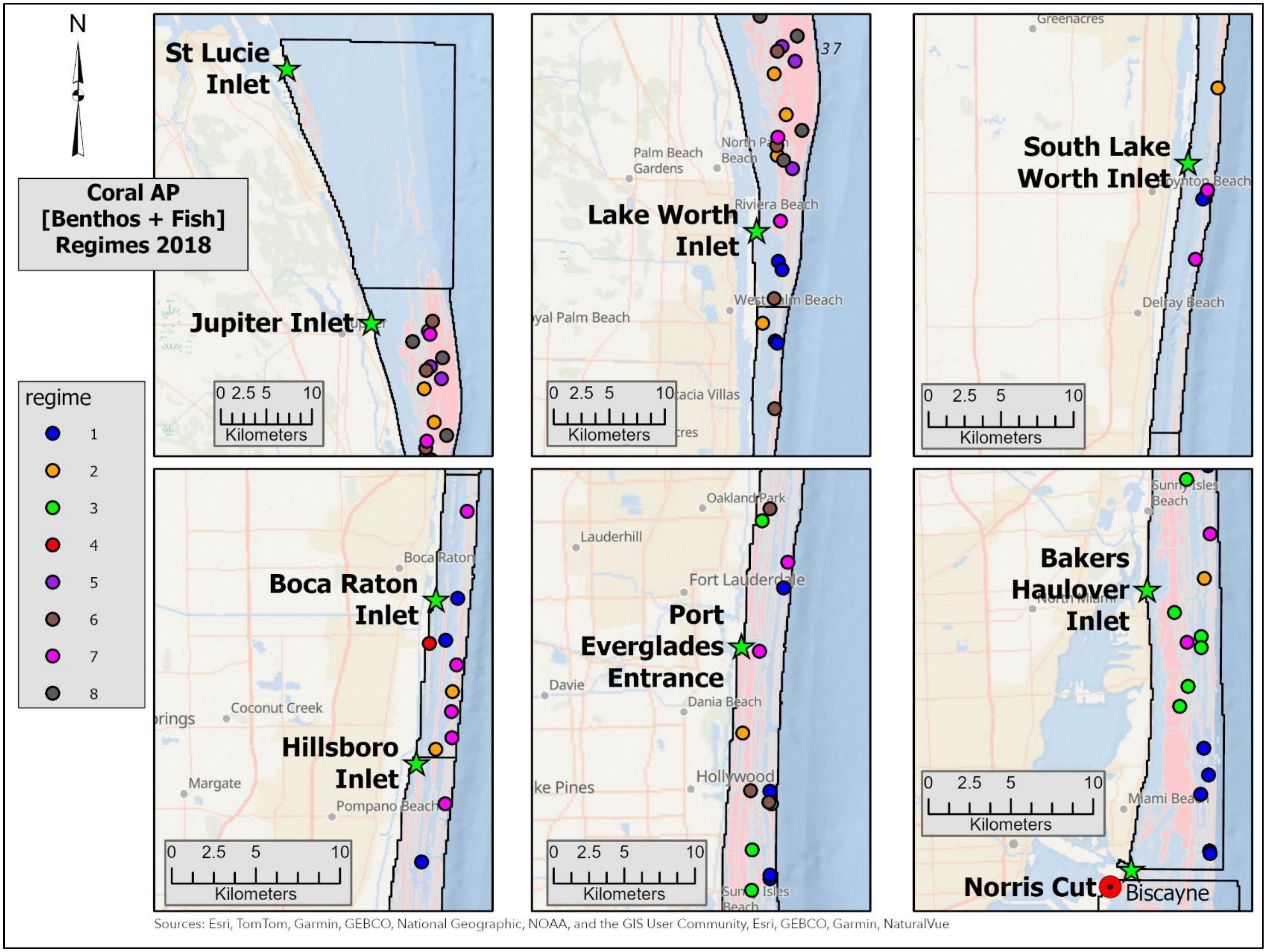

Figure 10. Distribution of CRRs in the Coral AP in 2018. Mapping of all eight coral reef regimes identified across the Coral AP using NCRMP data. 2018 is visualized. Panels are oriented north to south as you read left-to-right, top-to-bottom. PSUs may be duplicated across panels.

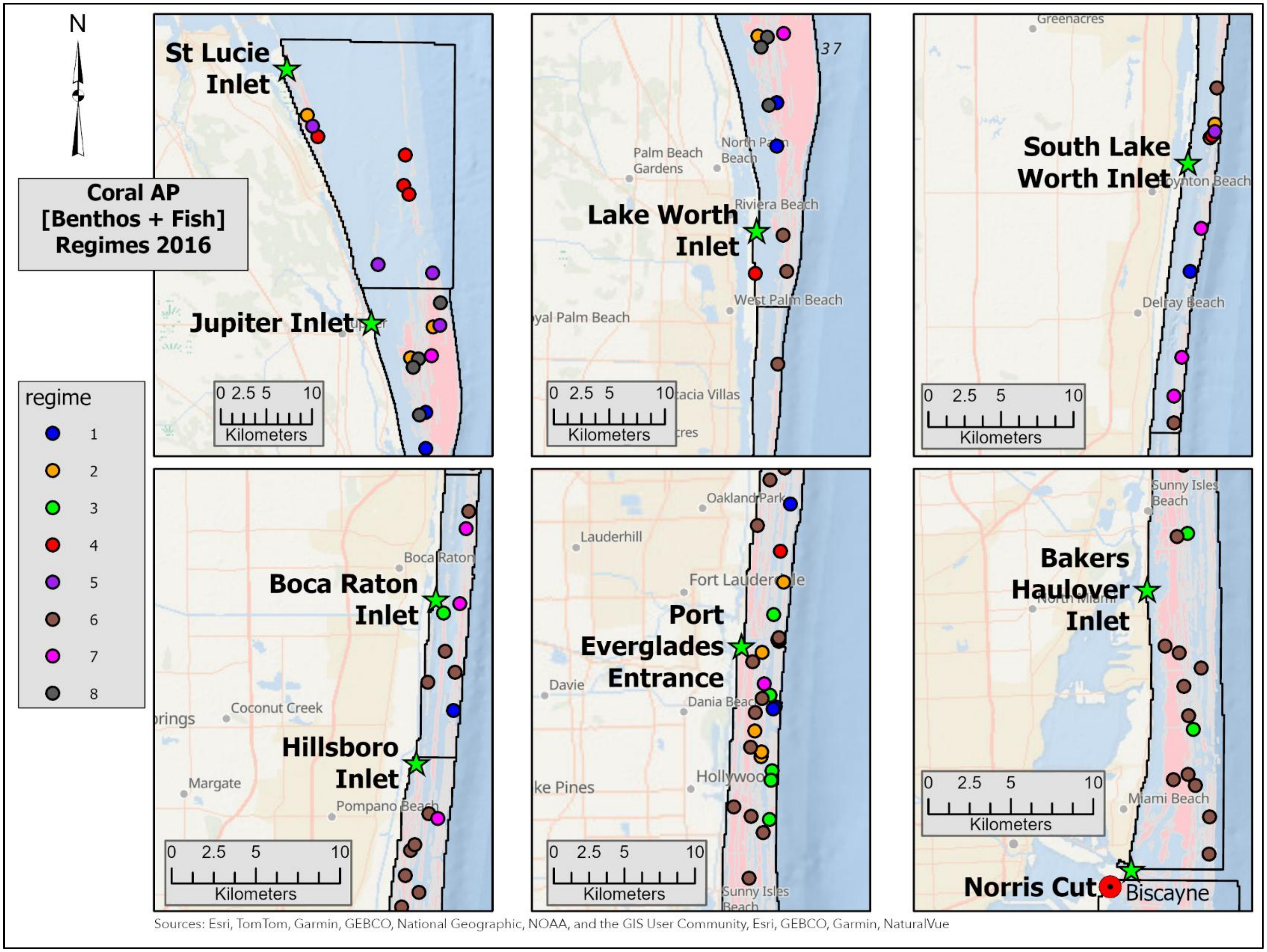

Figure 11. Distribution of CRRs in the Coral AP in 2016. Mapping of all eight coral reef regimes identified across the Coral AP using NCRMP data. 2016 is visualized. Panels are oriented north to south as you read left-to-right, top-to-bottom. PSUs may be duplicated across panels.

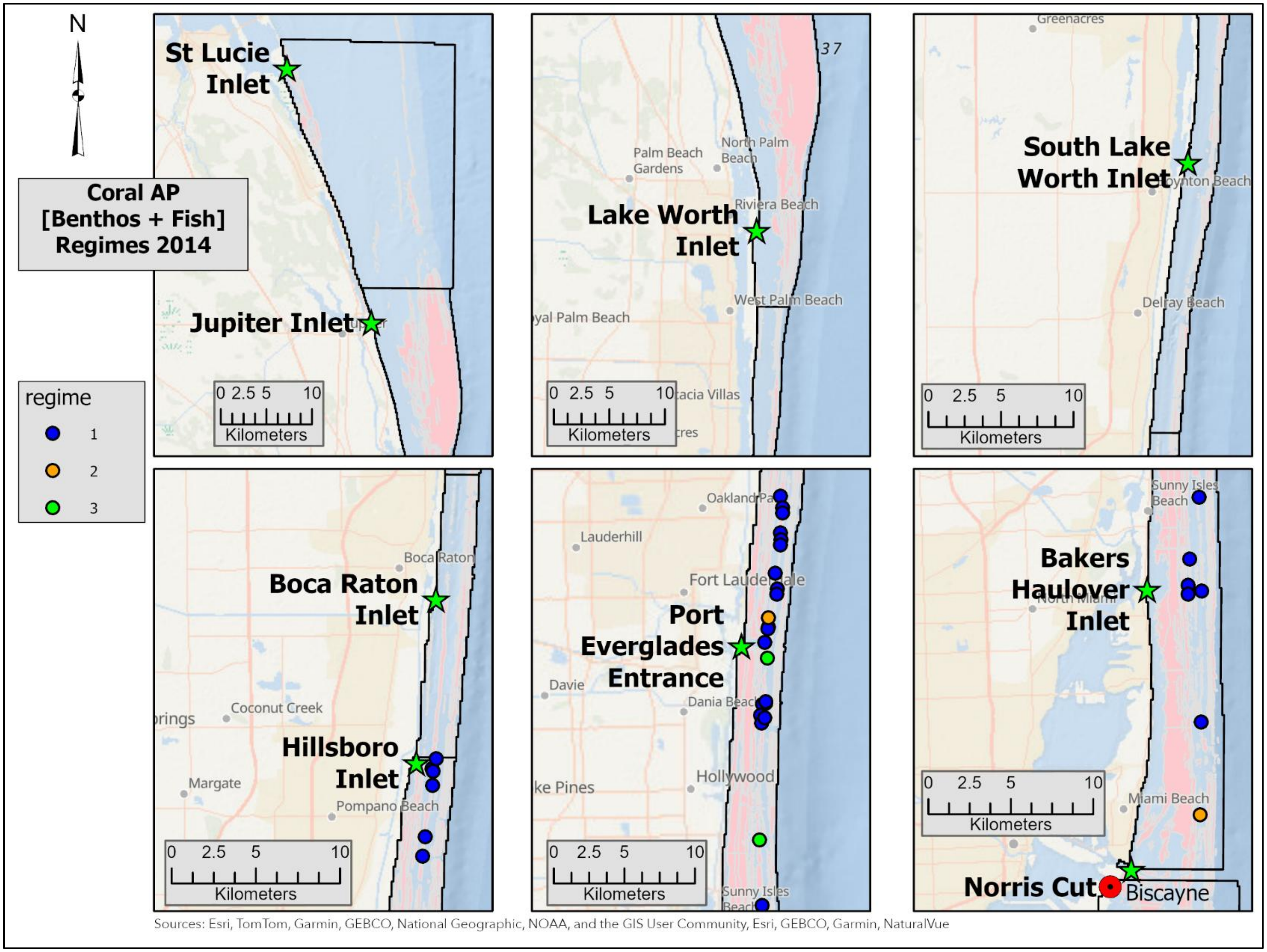

Figure 12. Distribution of CRRs in the Coral AP in 2014. Mapping of all eight coral reef regimes identified across the Coral AP using NCRMP data. 2014 is visualized. Panels are oriented north to south as you read left-to-right, top-to-bottom. PSUs may be duplicated across panels.

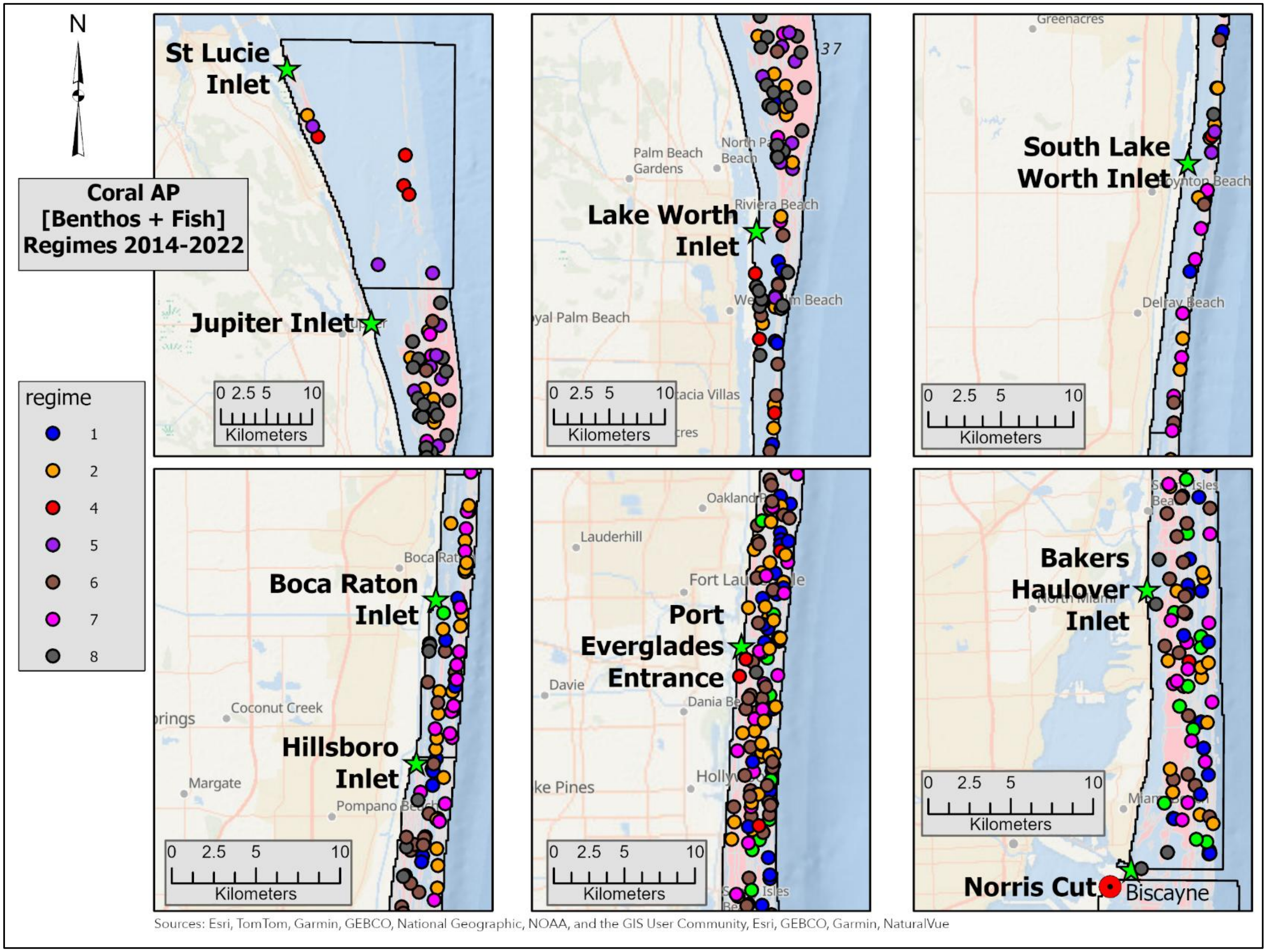

Figure 13. Distribution of CRRs in the Coral AP, 2014-2022. Mapping of all eight coral reef regimes identified across the Coral AP using NCRMP data. All years included in the study are visualized. Panels are oriented north to south as you read left-to-right, top-to-bottom. PSUs may be duplicated across panels.

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6. SUPPLEMENTAL TABLES

Table S1. NCRMP benthic cover categories for the Coral AP. Original LPI benthic cover categories monitored by NCRMP in the Coral AP along with the percent (%) cover summary statistics observed for each. Standard deviation ('Std.Dev.') is relative to the mean, and data are sorted in descending order by the proportion of the *N* = 398 samples where the category was present.

Cover Category	Proportion of PSUs	Mean Cover Observed (%)	Median	Max.	St.Dev.
AlgaeTURF	0.96	42.1	40.0	96.0	23.2
AlgaeMACRO	0.93	22.0	17.0	94.0	20.1
Sponges	0.91	8.1	7.0	43.0	6.6
Substrate	0.80	12.7	6.0	98.0	18.2
CoralSOFT	0.78	7.7	5.0	52.0	8.2
CoralHARD	0.49	1.2	0.0	17.0	2.0
Cyanobacteria	0.37	3.6	0.0	62.0	7.7
CCA	0.31	0.9	0.0	17.8	2.1
CoralHYDRO	0.21	0.2	0.0	2.5	0.5
OtherIVERT	0.17	0.6	0.0	17.0	2.1
Other	0.14	0.3	0.0	11.0	1.1
Peysonnellia	0.12	0.3	0.0	10.0	1.1
Ramicrusta spp.	0.04	0.1	0.0	4.0	0.4
Seagrasses	0.02	0.2	0.0	38.0	2.3

Table S2. 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* = 398 sites where they were observed [Presence (%)] and only species that were present in at least 5% of observations (*n* = 20 PSUs). Scientific and common names are given.

Scientific Name	Common Name	Presence (%)
Canthigaster rostrata	sharpnose puffer	92.5%
Thalassoma bifasciatum	bluehead	91.7%
Stegastes partitus	bicolor damselfish	91.0%
Acanthurus bahianus	ocean surgeon	88.7%
Sparisoma aurofrenatum	redband parrotfish	81.7%
Halichoeres garnoti	yellowhead wrasse	79.6%
Acanthurus chirurgus	doctorfish	75.6%
Acanthurus coeruleus	blue tang	70.4%
Chaetodon sedentarius	reef butterflyfish	68.8%
Halichoeres bivittatus	slippery dick	68.1%
Pomacanthus arcuatus	gray angelfish	62.3%
Anisotremus virginicus	porkfish	60.8%
Halichoeres maculipinna	clown wrasse	60.8%
Sparisoma atomarium	greenblotch parrotfish	59.0%
Haemulon plumierii	white grunt	57.8%
Holacanthus tricolor	rock beauty	55.3%
Lutjanus analis	mutton snapper	55.3%
Serranus tigrinus	harlequin bass	52.0%
Scarus iseri	striped parrotfish	51.5%
Sparisoma viride	stoplight parrotfish	51.5%
Pseudupeneus maculatus	spotted goatfish	51.3%
Caranx ruber	bar jack	47.2%
Lachnolaimus maximus	hogfish	44.7%
Bodianus rufus	Spanish hogfish	44.2%
Scarus taeniopterus	princess parrotfish	43.7%
Chromis cyanea	blue chromis	41.7%
Pomacanthus paru	French angelfish	41.7%
Cephalopholis cruentata	graysby	40.7%
Chaetodon ocellatus	spotfin butterflyfish	39.9%
Balistes capriscus	gray triggerfish	37.9%
Cryptotomus roseus	bluelip parrotfish	37.9%
Stegastes variabilis	cocoa damselfish	37.9%
Ocyurus chrysurus	yellowtail snapper	37.2%
Holacanthus ciliaris	queen angelfish	36.2%
Chromis insolata	sunshinefish	32.7%
Calamus calamus	saucereye porgy	30.7%
Hypoplectrus unicolor	butter hamlet	29.1%
Haemulon sciurus	bluestriped grunt	28.1%
Holacanthus bermudensis	blue angelfish	28.1%
Chaetodon capistratus	foureye butterflyfish	27.6%
Serranus tabacarius	tobaccofish	27.4%
Aluterus scriptus	scrawled filefish	24.6%
Sparisoma chrysopterum	redtail parrotfish	23.6%
Halichoeres cyanocephalus	yellowcheek wrasse	23.4%
Stegastes leucostictus	beaugregory	23.4%
Xyrichtys splendens	green razorfish	23.1%
Clepticus parrae	creole wrasse	22.9%
Sparisoma radians	bucktooth parrotfish	22.1%
Haemulon flavolineatum	French grunt	21.9%
Abudefduf saxatilis	sergeant major	21.6%
Serranus baldwini	lantern bass	20.4%
Holocentrus adscensionis	squirrelfish	19.6%
Diodon holocanthus	balloonfish	19.1%
Sphoeroides spengleri	bandtail puffer	18.8%
Opistognathus aurifrons	yellowhead jawfish	17.8%

Halichoeres poeyi	blackear wrasse	17.6%
Pterois volitans	red lionfish	17.1%
Lactophrys triqueter	smooth trunkfish	16.6%
Calamus proridens	littlehead porgy	16.3%
Halichoeres radiatus	puddingwife	15.8%
Sparisoma rubripinne	yellowtail parrotfish	15.6%
Chromis scotti	purple reeffish	15.3%
Anisotremus surinamensis	black margate	15.1%
Caranx crysos	blue runner	15.1%
Cantherhines pullus	orangespotted filefish	14.8%
Epinephelus morio	red grouper	14.6%
Chromis multilineata	brown chromis	14.3%
Serranus tortugarum	chalk bass	13.6%
Urobatis jamaicensis	yellow stingray	13.3%
Pareques acuminatus	high-hat	12.6%
Acanthostracion polygonia	honeycomb cowfish	12.3%
Stegastes adustus	dusky damselfish	12.3%
Haemulon aurolineatum	tomtate	12.1%
Calamus penna	sheepshead porgy	10.8%
Carangoides bartholomaei	yellow jack	10.6%
Stegastes planifrons	threespot damselfish	10.1%
Kyphosus sectatrix	Bermuda chub	9.5%
Lutjanus griseus	gray snapper	9.3%
Scomberomorus regalis	cero	9.0%
Aulostomus maculatus	Atlantic trumpetfish	8.3%
Lutjanus synagris	lane snapper	8.3%
Xyrichtys martinicensis	rosy razorfish	7.5%
Cantherhines macrocerus	whitespotted filefish	7.3%
Malacanthus plumieri	sand tilefish	7.3%
Ptereleotris helenae	hovering dartfish	7.3%
Scarus vetula	queen parrotfish	7.3%
Sphyraena barracuda	great barracuda	7.3%
Scorpaena plumieri	spotted scorpionfish	6.8%
Balistes vetula	queen triggerfish	6.5%
Ptereleotris calliura	blue dartfish	6.5%
Acanthostracion quadricornis	scrawled cowfish	6.3%
Haemulon melanurum	cottonwick	6.3%
Centropyge argi	cherubfish	6.0%
Calamus bajonado	jolthead porgy	5.5%
Haemulon carbonarium	caesar grunt	5.5%
Rypticus saponaceus	greater soapfish	5.5%
Chromis enchrysura	yellowtail reeffish	5.3%
Haemulon parra	sailors choice	5.3%
Scarus coeruleus	blue parrotfish	5.3%
Chaetodon striatus	banded butterflyfish	5.0%
Epinephelus guttatus	red hind	5.0%

Table S3. Dissimilarity profile clustering results. Results of the DisProf clustering tests at each node of the UPGMA connection tree until a stopping point was achieved (e.g., no more clusters). All *p*-values are adjusted using the Holms correction and are used to assess the significance of the *π*-statistic.

No. Groups	π	P	No. Groups	π	p	No. Groups	π	p
2	1564.5	0.0000	19	0.8	1.0000	35	0.4	1.0000
3	0.4	0.3480	19	76.0	0.0030	35	0.1	1.0000
3	1460.8	0.0000	20	33.5	0.0030	35	4.9	0.0280
4	37.9	0.0000	21	0.1	1.0000	36	0.2	1.0000
5	712.7	0.0000	21	24.6	0.0030	36	0.5	1.0000
6	25.4	0.0010	22	0.0	1.0000	36	0.3	1.0000
7	710.7	0.0010	22	24.6	0.0030	36	4.4	0.0120
8	535.3	0.0010	23	20.3	0.0030	37	7.6	0.0060
9	185.2	0.0010	24	24.7	0.0040	38	1.5	0.3420
10	13.8	0.0010	25	2.2	0.7270	38	0.5	1.0000
11	1.2	0.2390	25	13.9	0.0040	38	1.5	0.0060
11	1.1	0.0660	26	3.0	0.0040	39	6.2	0.0060
11	47.2	0.0010	27	15.6	0.0040	40	0.8	1.0000
12	0.1	1.0000	28	0.4	1.0000	40	2.7	0.4620
12	19.4	0.0020	28	16.9	0.0040	40	0.1	1.0000
13	44.6	0.0020	29	16.0	0.0040	40	1.6	1.0000
14	38.6	0.0020	30	10.2	0.0040	40	2.0	0.2690
15	32.8	0.0020	31	0.1	1.0000	40	1.1	1.0000
16	0.2	1.0000	31	2.6	0.0450	40	0.5	1.0000
16	3.6	1.0000	32	13.3	0.0050	40	0.4	1.0000
16	0.1	1.0000	33	11.7	0.0050	40	0.2	1.0000
16	7.4	0.0020	34	0.1	1.0000	40	0.2	1.0000
17	171.2	0.0020	34	0.3	1.0000	40	0.1	1.0000
18	1.9	0.0580	34	1.8	0.6800	40	0.1	1.0000
18	0.0	1.0000	34	14.8	0.0050			
18	20.7	0.0030	35	0.4	1.0000			

Table S4. '*mclust*' results. Clustering assigments for each PSU in the Coral AP according to the '*mclust*' routine.

uID	Year	Subregion	Regime
2014-3125	2014	Broward-Miami	1
2014-3126	2014	Broward-Miami	1
2014-3127	2014	Broward-Miami	1
2014-3128	2014	Broward-Miami	1
2014-3129	2014	Broward-Miami	1
2014-3130	2014	Broward-Miami	1
2014-3131	2014	Broward-Miami	1
2014-3133	2014	Broward-Miami	1
2014-3134	2014	Broward-Miami	1
2014-3135	2014	Broward-Miami	1
2014-3137	2014	Broward-Miami	1
2014-3138	2014	Broward-Miami	1
2014-3139	2014	Broward-Miami	1
2014-3140	2014	Broward-Miami	1
2014-3144	2014	Broward-Miami	1
2014-3145	2014	Broward-Miami	1
2014-3146	2014	Broward-Miami	1
2014-3147	2014	Broward-Miami	1
2014-3148	2014	Broward-Miami	1
2014-3155	2014	Broward-Miami	1
2014-3156	2014	Broward-Miami	1
2014-3157	2014	Broward-Miami	1
2014-3158	2014	Broward-Miami	1
2014-3159	2014	Broward-Miami	1
2014-3160	2014	Broward-Miami	1
2014-3163	2014	Broward-Miami	1
2014-3164	2014	Broward-Miami	1
2014-3165	2014	Broward-Miami	1
2014-3166	2014	Broward-Miami	1

uID	Year	Subregion	Regime
2014-3167	2014	Broward-Miami	1
2016-3119	2016	Broward-Miami	1
2016-3143	2016	Broward-Miami	1
2016-3144	2016	Broward-Miami	1
2016-3178	2016	Deerfield	1
2016-3194	2016	South Palm Beach	1
2016-3257	2016	North Palm Beach	1
2016-3259	2016	North Palm Beach	1
2018-3048	2018	North Palm Beach	1
2018-3096	2018	Broward-Miami	1
2018-3097	2018	Broward-Miami	1
2018-3103	2018	Deerfield	1
2018-3117	2018	Broward-Miami	1
2018-3202	2018	Broward-Miami	1
2018-3219	2018	South Palm Beach	1
2018-3222	2018	South Palm Beach	1
2018-3230	2018	Broward-Miami	1
2018-3242	2018	Broward-Miami	1
2018-3243	2018	Broward-Miami	1
2018-3246	2018	Deerfield	1
2018-3252	2018	South Palm Beach	1
2018-3254	2018	South Palm Beach	1
2018-3263	2018	Broward-Miami	1
2018-3272	2018	Broward-Miami	1
2018-3278	2018	Broward-Miami	1
2018-3545	2018	North Palm Beach	1
2022-3050	2022	Broward-Miami	1
2022-3063	2022	Broward-Miami	1
2022-3064	2022	Broward-Miami	1

uID	Year	Subregion	Regime
2022-3071	2022	Broward-Miami	1
2022-3131	2022	Broward-Miami	1
2022-3193	2022	Broward-Miami	1
2022-3229	2022	Broward-Miami	1
2022-3234	2022	Broward-Miami	1
2022-3280	2022	Deerfield	1
2022-3281	2022	South Palm Beach	1
2022-3290	2022	Broward-Miami	1
2014-3132	2014	Broward-Miami	2
2014-3149	2014	Broward-Miami	2
2016-3057	2016	Broward-Miami	2
2016-3071	2016	Broward-Miami	2
2016-3097	2016	Broward-Miami	2
2016-3117	2016	Broward-Miami	2
2016-3138	2016	Broward-Miami	2
2016-3186	2016	South Palm Beach	2
2016-3207	2016	South Palm Beach	2
2016-3226	2016	North Palm Beach	2
2016-3229	2016	North Palm Beach	2
2016-3265	2016	Martin	2
2018-3008	2018	North Palm Beach	2
2018-3039	2018	North Palm Beach	2
2018-3042	2018	North Palm Beach	2
2018-3085	2018	Broward-Miami	2
2018-3122	2018	Deerfield	2
2018-3162	2018	South Palm Beach	2
2018-3179	2018	Broward-Miami	2
2018-3247	2018	Deerfield	2
2018-3248	2018	South Palm Beach	2
2018-3262	2018	North Palm Beach	2

uID	Year	Subregion	Regime
2020-3005	2020	North Palm Beach	2
2020-3067	2020	North Palm Beach	2
2020-3073	2020	North Palm Beach	2
2020-3085	2020	Broward-Miami	2
2020-3090	2020	Broward-Miami	2
2020-3103	2020	Broward-Miami	2
2020-3116	2020	Broward-Miami	2
2020-3121	2020	Broward-Miami	2
2020-3123	2020	Deerfield	2
2020-3124	2020	Deerfield	2
2020-3125	2020	Broward-Miami	2
2020-3126	2020	Broward-Miami	2
2020-3131	2020	Deerfield	2
2020-3137	2020	Broward-Miami	2
2020-3143	2020	Broward-Miami	2
2020-3150	2020	Broward-Miami	2
2020-3153	2020	Broward-Miami	2
2020-3166	2020	Broward-Miami	2
2020-3169	2020	Broward-Miami	2
2020-3172	2020	Broward-Miami	2
2020-3180	2020	Broward-Miami	2
2020-3207	2020	North Palm Beach	2
2020-3231	2020	Broward-Miami	2
2020-3237	2020	Deerfield	2
2020-3253	2020	North Palm Beach	2
2020-3258	2020	Broward-Miami	2
2020-3259	2020	Broward-Miami	2
2020-3280	2020	Broward-Miami	2
2020-3282	2020	Deerfield	2
2020-3288	2020	Deerfield	2

uID	Year	Subregion	Regime
2020-3297	2020	South Palm Beach	2
2020-3303	2020	North Palm Beach	2
2020-3305	2020	Broward-Miami	2
2020-3309	2020	South Palm Beach	2
2020-3311	2020	North Palm Beach	2
2020-3312	2020	North Palm Beach	2
2020-3315	2020	Broward-Miami	2
2020-3317	2020	Deerfield	2
2020-3320	2020	South Palm Beach	2
2020-3324	2020	Broward-Miami	2
2020-3328	2020	South Palm Beach	2
2020-3329	2020	North Palm Beach	2
2020-3330	2020	North Palm Beach	2
2022-3053	2022	Broward-Miami	2
2022-3058	2022	Broward-Miami	2
2022-3094	2022	Broward-Miami	2
2022-3097	2022	Broward-Miami	2
2022-3105	2022	Deerfield	2
2022-3108	2022	Broward-Miami	2
2022-3110	2022	Broward-Miami	2
2022-3111	2022	Broward-Miami	2
2022-3118	2022	Broward-Miami	2
2022-3123	2022	Deerfield	2
2022-3130	2022	Broward-Miami	2
2022-3138	2022	Broward-Miami	2
2022-3148	2022	Broward-Miami	2
2022-3149	2022	Broward-Miami	2
2022-3188	2022	Broward-Miami	2
2022-3190	2022	Broward-Miami	2
2022-3191	2022	Broward-Miami	2

uID	Year	Subregion	Regime
2022-3200	2022	Broward-Miami	2
2022-3203	2022	Deerfield	2
2022-3211	2022	South Palm Beach	2
2022-3215	2022	South Palm Beach	2
2022-3249	2022	South Palm Beach	2
2022-3252	2022	South Palm Beach	2
2022-3258	2022	Broward-Miami	2
2022-3264	2022	North Palm Beach	2
2022-3269	2022	Broward-Miami	2
2022-3273	2022	Broward-Miami	2
2022-3277	2022	Deerfield	2
2022-3279	2022	Deerfield	2
2014-3136	2014	Broward-Miami	3
2014-3141	2014	Broward-Miami	3
2016-3067	2016	Broward-Miami	3
2016-3078	2016	Broward-Miami	3
2016-3094	2016	Broward-Miami	3
2016-3124	2016	Broward-Miami	3
2016-3125	2016	Broward-Miami	3
2016-3127	2016	Broward-Miami	3
2016-3140	2016	Broward-Miami	3
2016-3142	2016	Broward-Miami	3
2016-3162	2016	Deerfield	3
2018-3053	2018	Broward-Miami	3
2018-3059	2018	Broward-Miami	3
2018-3062	2018	Broward-Miami	3
2018-3063	2018	Broward-Miami	3
2018-3109	2018	Broward-Miami	3
2018-3110	2018	Broward-Miami	3
2018-3136	2018	Broward-Miami	3

uID	Year	Subregion	Regime
2018-3155	2018	Broward-Miami	3
2018-3240	2018	Broward-Miami	3
2020-3152	2020	Broward-Miami	3
2020-3213	2020	Broward-Miami	3
2020-3325	2020	Broward-Miami	3
2016-3110	2016	Broward-Miami	4
2016-3185	2016	South Palm Beach	4
2016-3212	2016	North Palm Beach	4
2016-3270	2016	Martin	4
2016-3286	2016	Martin	4
2016-3288	2016	Martin	4
2016-3289	2016	Martin	4
2018-3161	2018	Deerfield	4
2020-3135	2020	Broward-Miami	4
2020-3177	2020	Broward-Miami	4
2022-3065	2022	Broward-Miami	4
2022-3119	2022	Broward-Miami	4
2022-3157	2022	South Palm Beach	4
2022-3262	2022	South Palm Beach	4
2016-3202	2016	South Palm Beach	5
2016-3217	2016	North Palm Beach	5
2016-3225	2016	North Palm Beach	5
2016-3266	2016	Martin	5
2016-3285	2016	Martin	5
2018-3001	2018	North Palm Beach	5
2018-3018	2018	North Palm Beach	5
2018-3050	2018	North Palm Beach	5
2020-3011	2020	North Palm Beach	5
2020-3016	2020	North Palm Beach	5
2020-3321	2020	North Palm Beach	5

uID	Year	Subregion	Regime
2022-3008	2022	North Palm Beach	5
2022-3028	2022	North Palm Beach	5
2022-3214	2022	South Palm Beach	5
2022-3263	2022	North Palm Beach	5
2016-3001	2016	Broward-Miami	6
2016-3002	2016	Broward-Miami	6
2016-3004	2016	Broward-Miami	6
2016-3009	2016	Broward-Miami	6
2016-3016	2016	Broward-Miami	6
2016-3021	2016	Broward-Miami	6
2016-3030	2016	Broward-Miami	6
2016-3036	2016	Broward-Miami	6
2016-3037	2016	Broward-Miami	6
2016-3040	2016	Broward-Miami	6
2016-3045	2016	Broward-Miami	6
2016-3058	2016	Broward-Miami	6
2016-3059	2016	Broward-Miami	6
2016-3061	2016	Broward-Miami	6
2016-3064	2016	Broward-Miami	6
2016-3066	2016	Broward-Miami	6
2016-3069	2016	Broward-Miami	6
2016-3072	2016	Broward-Miami	6
2016-3083	2016	Broward-Miami	6
2016-3089	2016	Broward-Miami	6
2016-3091	2016	Broward-Miami	6
2016-3095	2016	Broward-Miami	6
2016-3099	2016	Broward-Miami	6
2016-3105	2016	Broward-Miami	6
2016-3108	2016	Broward-Miami	6
2016-3120	2016	Broward-Miami	6

uID	Year	Subregion	Regime
2016-3139	2016	Broward-Miami	6
2016-3150	2016	Broward-Miami	6
2016-3160	2016	Deerfield	6
2016-3165	2016	Deerfield	6
2016-3174	2016	Deerfield	6
2016-3175	2016	Deerfield	6
2016-3189	2016	South Palm Beach	6
2016-3199	2016	South Palm Beach	6
2016-3206	2016	South Palm Beach	6
2016-3250	2016	North Palm Beach	6
2016-3261	2016	North Palm Beach	6
2018-3002	2018	North Palm Beach	6
2018-3043	2018	North Palm Beach	6
2018-3049	2018	North Palm Beach	6
2018-3066	2018	Broward-Miami	6
2018-3180	2018	Broward-Miami	6
2018-3210	2018	Broward-Miami	6
2018-3269	2018	South Palm Beach	6
2018-3285	2018	North Palm Beach	6
2020-3101	2020	Broward-Miami	6
2020-3130	2020	Broward-Miami	6
2020-3155	2020	Broward-Miami	6
2020-3159	2020	Broward-Miami	6
2020-3164	2020	Broward-Miami	6
2020-3191	2020	South Palm Beach	6
2020-3203	2020	Broward-Miami	6
2020-3204	2020	Broward-Miami	6
2020-3252	2020	South Palm Beach	6
2020-3299	2020	South Palm Beach	6
2020-3304	2020	North Palm Beach	6

uID	Year	Subregion	Regime
2022-3039	2022	Broward-Miami	6
2022-3047	2022	Broward-Miami	6
2022-3060	2022	Broward-Miami	6
2022-3066	2022	Broward-Miami	6
2022-3074	2022	Broward-Miami	6
2022-3076	2022	Broward-Miami	6
2022-3078	2022	Broward-Miami	6
2022-3085	2022	Broward-Miami	6
2022-3088	2022	Broward-Miami	6
2022-3101	2022	Broward-Miami	6
2022-3102	2022	Deerfield	6
2022-3109	2022	Broward-Miami	6
2022-3114	2022	Broward-Miami	6
2022-3127	2022	Broward-Miami	6
2022-3136	2022	Broward-Miami	6
2022-3139	2022	Broward-Miami	6
2022-3141	2022	Broward-Miami	6
2022-3144	2022	Broward-Miami	6
2022-3147	2022	Broward-Miami	6
2022-3150	2022	Broward-Miami	6
2022-3175	2022	Broward-Miami	6
2022-3189	2022	Broward-Miami	6
2022-3197	2022	Broward-Miami	6
2022-3201	2022	Broward-Miami	6
2022-3219	2022	Broward-Miami	6
2022-3224	2022	Broward-Miami	6
2022-3225	2022	Broward-Miami	6
2022-3243	2022	South Palm Beach	6
2022-3257	2022	Broward-Miami	6
2022-3261	2022	South Palm Beach	6

uID	Year	Subregion	Regime
2016-3085	2016	Broward-Miami	7
2016-3115	2016	Broward-Miami	7
2016-3167	2016	Deerfield	7
2016-3172	2016	Deerfield	7
2016-3195	2016	South Palm Beach	7
2016-3203	2016	South Palm Beach	7
2016-3210	2016	South Palm Beach	7
2016-3254	2016	North Palm Beach	7
2018-3006	2018	North Palm Beach	7
2018-3046	2018	North Palm Beach	7
2018-3047	2018	North Palm Beach	7
2018-3077	2018	Broward-Miami	7
2018-3079	2018	Broward-Miami	7
2018-3213	2018	Deerfield	7
2018-3231	2018	Broward-Miami	7
2018-3241	2018	Broward-Miami	7
2018-3245	2018	Deerfield	7
2018-3250	2018	South Palm Beach	7
2018-3253	2018	South Palm Beach	7
2018-3258	2018	Deerfield	7
2018-3266	2018	Broward-Miami	7
2018-3268	2018	Deerfield	7
2020-3093	2020	Broward-Miami	7
2020-3095	2020	Broward-Miami	7
2020-3099	2020	Broward-Miami	7
2020-3104	2020	Broward-Miami	7
2020-3105	2020	Broward-Miami	7
2020-3110	2020	Broward-Miami	7
2020-3112	2020	Broward-Miami	7
2020-3114	2020	Broward-Miami	7

uID	Year	Subregion	Regime
2020-3128	2020	Broward-Miami	7
2020-3132	2020	Deerfield	7
2020-3133	2020	Broward-Miami	7
2020-3138	2020	Broward-Miami	7
2020-3148	2020	Broward-Miami	7
2020-3157	2020	Broward-Miami	7
2020-3174	2020	Broward-Miami	7
2020-3235	2020	Deerfield	7
2020-3248	2020	South Palm Beach	7
2020-3268	2020	Broward-Miami	7
2020-3270	2020	Broward-Miami	7
2020-3306	2020	Broward-Miami	7
2020-3307	2020	Deerfield	7
2020-3308	2020	Deerfield	7
2020-3316	2020	Broward-Miami	7
2020-3318	2020	Deerfield	7
2022-3057	2022	Broward-Miami	7
2022-3075	2022	Broward-Miami	7
2022-3134	2022	Broward-Miami	7
2022-3140	2022	Broward-Miami	7
2022-3145	2022	Broward-Miami	7
2022-3192	2022	Broward-Miami	7
2022-3220	2022	Broward-Miami	7
2022-3223	2022	Broward-Miami	7
2022-3237	2022	Deerfield	7
2022-3239	2022	Deerfield	7
2022-3259	2022	Deerfield	7
2022-3260	2022	Deerfield	7
2022-3271	2022	Broward-Miami	7
2022-3275	2022	Broward-Miami	7

uID	Year	Subregion	Regime
2022-3282	2022	South Palm Beach	7
2016-3222	2016	North Palm Beach	8
2016-3230	2016	North Palm Beach	8
2016-3231	2016	North Palm Beach	8
2016-3240	2016	North Palm Beach	8
2018-3009	2018	North Palm Beach	8
2018-3024	2018	North Palm Beach	8
2018-3025	2018	North Palm Beach	8
2018-3033	2018	North Palm Beach	8
2020-3038	2020	North Palm Beach	8
2020-3084	2020	Broward-Miami	8
2020-3178	2020	Broward-Miami	8
2020-3184	2020	Broward-Miami	8
2020-3189	2020	Deerfield	8
2020-3190	2020	Deerfield	8
2020-3192	2020	South Palm Beach	8
2020-3193	2020	North Palm Beach	8
2020-3206	2020	North Palm Beach	8
2020-3208	2020	North Palm Beach	8
2020-3327	2020	South Palm Beach	8

uID	Year	Subregion	Regime
2022-3002	2022	South Palm Beach	8
2022-3005	2022	North Palm Beach	8
2022-3006	2022	North Palm Beach	8
2022-3007	2022	North Palm Beach	8
2022-3010	2022	North Palm Beach	8
2022-3012	2022	North Palm Beach	8
2022-3013	2022	North Palm Beach	8
2022-3016	2022	North Palm Beach	8
2022-3019	2022	North Palm Beach	8
2022-3023	2022	North Palm Beach	8
2022-3025	2022	North Palm Beach	8
2022-3026	2022	North Palm Beach	8
2022-3129	2022	Broward-Miami	8
2022-3137	2022	Broward-Miami	8
2022-3143	2022	Broward-Miami	8
2022-3146	2022	Broward-Miami	8
2022-3154	2022	Deerfield	8
2022-3159	2022	North Palm Beach	8
2022-3285	2022	North Palm Beach	8
2022-3288	2022	Broward-Miami	8

Table S5. PERMDISP results. Multivariate dispersions (mean distance to centroid) by coral reef regime. Source of variation, degrees of freedom (*df*), sums-of- and mean squares (Sum Sq, Mean Sq.), the *F*-statistic (*F*), and *p*-value (*p*), related to the PERMANOVA test for among-group dispersion differences, and the matrix reports the *p*-values for pairwise testing. *P*-values above the diagonal have been adjusted for multiple comparisons.

	CORAL AP REGIME							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Mean distance to centroid	0.11	0.12	0.13	0.17	0.14	0.12	0.11	0.13

Source	***df***	**Sum Sq.**	**Mean Sq.**	***F***	***p***
Coral AP Regimes	7	0.07141	0.0102017	9.2295	0.0001
Residuals	390	0.43108	0.0011053		

CAR	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	-	0.0363	0.0065	0.0001	0.0023	0.0037	0.9688	0.0032
2	0.0354	-	0.0633	0.0001	0.0114	0.1842	0.0160	0.0685
3	0.0059	0.0671	-	0.0012	0.3540	0.4745	0.0007	0.9389
4	0.0000	0.0000	0.0013	-	0.0278	0.0003	0.0001	0.0029
5	0.0018	0.0097	0.3466	0.0270	-	0.1468	0.0003	0.4054
6	0.0040	0.1878	0.4802	0.0000	0.1457	-	0.0012	0.5031
7	0.9694	0.0154	0.0004	0.0000	0.0001	0.0015	-	0.0005
8	0.0040	0.0670	0.9327	0.0022	0.4038	0.4948	0.0009	-

Table S6. Leave-one-out cross-validation confusion matrix. Groups assignment (PREDICTION) for each known PSU (REFERENCE) after leave-one-out cross-validation of the CAP model. *n* is the number of PSUs in each group, and the success rate describes the percentage of each group's *n* samples where the reference observation was reclassified into the group it was originally drawn from. Overall rate refers to the succes rate of all samples across all groups.

		REFERENCE							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
PREDICTION	**1**	57	1	4	0	0	0	2	0
	2	2	91	0	0	3	6	0	4
	3	1	0	18	0	0	1	0	0
	4	0	0	0	12	0	0	0	2
	5	0	1	0	1	10	1	0	1
	6	4	0	1	1	0	73	2	0
	7	2	0	0	0	0	5	57	0
	8	0	1	0	0	2	0	0	32
	n	**66**	**94**	**23**	**14**	**15**	**86**	**61**	**39**
	Success Rate	*86%*	*97%*	*78%*	*86%*	*67%*	*85%*	*93%*	*82%*
	Overall Rate	*88%*							

Table S7. Species indicator values with no group combinations. Table of reef fish species selected as significant indicators for the coral reef regimes indicated (Group). Significance is determined via adjusted *p*-values (*p*) for the square-root of the indicator value ($IndVal^{1/2}$) which is the product of the species' among group specificities (Specificity) and within group fidelities (Fidelity). Each species' assigned trophic guild is also presented. Only groups with only one regime were permitted for this exercise. The red-to-blue and yellow-to-purple color scales encode for the range [0,1], respectively. Darker colors represent more extreme values.

Common Name	Trophic Guild	Group	Specificity	Fidelity	$IndVal^{1/2}$	*p*
yellowhead wrasse	MacroInvert	1	0.2205	0.9848	0.4660	0.0023
reef butterflyfish	MicroInvert	1	0.1949	0.9091	0.4210	0.0382
rock beauty	Corallivores	1	0.2019	0.8182	0.4060	0.0429
caesar grunt	MacroInvert	1	0.7718	0.1667	0.3590	0.0151
striped parrotfish	Scrapers	3	0.4472	0.8261	0.6080	0.0001
redband parrotfish	Scrapers	3	0.3241	1.0000	0.5690	0.0001
bluehead	MacroInvert	3	0.2772	1.0000	0.5270	0.0002
yellowtail snapper	Crustacivores	3	0.3980	0.6957	0.5260	0.0010
white grunt	MacroInvert	3	0.3152	0.8696	0.5240	0.0030
stoplight parrotfish	Scrapers	3	0.3486	0.7391	0.5080	0.0030
butter hamlet	Crustacivores	3	0.3929	0.6522	0.5060	0.0004
bicolor damselfish	Grazers	3	0.2507	1.0000	0.5010	0.0003
bluelip parrotfish	Browsers	3	0.3418	0.6957	0.4880	0.0011
harlequin bass	Crustacivores	3	0.3140	0.7391	0.4820	0.0019
princess parrotfish	Scrapers	3	0.2967	0.7391	0.4680	0.0116
blue tang	Browsers	3	0.2421	0.8696	0.4590	0.0117
clown wrasse	MicroInvert	3	0.2544	0.8261	0.4580	0.0130
sharpnose puffer	SessileInvert	3	0.2088	1.0000	0.4570	0.0245
doctorfish	Browsers	3	0.2479	0.8261	0.4530	0.0361
hogfish	MacroInvert	3	0.3608	0.5652	0.4520	0.0177
gray angelfish	SessileInvert	3	0.2244	0.8696	0.4420	0.0069
spotfin butterflyfish	Corallivores	3	0.2628	0.7391	0.4410	0.0045
ocean surgeon	Browsers	3	0.2118	0.9130	0.4400	0.0369
spotted goatfish	Crustacivores	3	0.2408	0.7826	0.4340	0.0264
foureye butterflyfish	Corallivores	3	0.3725	0.4783	0.4220	0.0068
French angelfish	SessileInvert	3	0.2810	0.6087	0.4140	0.0174
cero	Piscivores	3	0.6508	0.2609	0.4120	0.0031
French grunt	MicroInvert	3	0.3536	0.4783	0.4110	0.0154
tobaccofish	Crustacivores	3	0.3439	0.4348	0.3870	0.0238
slippery dick	MacroInvert	4	0.3187	0.8571	0.5230	0.0017
beaugregory	MicroInvert	4	0.5356	0.5000	0.5170	0.0009
tomtate	MicroInvert	4	0.5813	0.4286	0.4990	0.0003
cocoa damselfish	Grazers	4	0.3103	0.6429	0.4470	0.0083
sergeant major	Planktivores	4	0.3602	0.5000	0.4240	0.0138

yellowtail reeffish	Planktivores	4	0.8303	0.2143	0.4220	0.0042
lane snapper	Crustacivores	4	0.4140	0.4286	0.4210	0.0036
puddingwife	MacroInvert	4	0.3551	0.3571	0.3560	0.0236
mutton snapper	Crustacivores	5	0.2485	0.8000	0.4460	0.0136
gray triggerfish	MacroInvert	5	0.2602	0.6667	0.4170	0.0376
black margate	MacroInvert	5	0.2956	0.4667	0.3710	0.0480
cherubfish	Grazers	5	0.5039	0.2667	0.3670	0.0074
littlehead porgy	Crustacivores	5	0.3136	0.4000	0.3540	0.0403
green razorfish	Planktivores	8	0.3751	0.6579	0.4970	0.0012
rosy razorfish	Planktivores	8	0.6259	0.2632	0.4060	0.0069

Table S8. Species indicator values with with group combinations. Table of reef fish species selected as significant indicators for the coral reef regimes indicated (Group). Significance is determined via adjusted *p*-values (*p*) for the square-root of the indicator value ($IndVal^{1/2}$) which is the product of the species' among group specificities (Specificity) and within group fidelities (Fidelity). Each species' assigned trophic guild is also presented. All group combinations were permitted for this exercise. The red-to-blue and yellow-to-purple color scales encode for the range [0,1], respectively. Darker colors represent more extreme values.

Common Name	Trophic Guild	Group	Specificity	Fidelity	$IndVal^{1/2}$	*p*
caesar grunt	MacroInvert	1	0.7718	0.1667	0.3590	0.0190
cero	Piscivores	3	0.6508	0.2609	0.4120	0.0043
tomtate	MicroInvert	4	0.5813	0.4286	0.4990	0.0005
yellowtail reeffish	Planktivores	4	0.8303	0.2143	0.4220	0.0046
cherubfish	Grazers	5	0.5039	0.2667	0.3670	0.0101
rosy razorfish	Planktivores	8	0.6259	0.2632	0.4060	0.0085
lane snapper	Crustacivores	4 + 5	0.5879	0.3103	0.4270	0.0036
tobaccofish	Crustacivores	1 + 3 + 4	0.6614	0.4757	0.5610	0.0006
yellowhead jawfish	Planktivores	1 + 3 + 4	0.6695	0.2913	0.4420	0.0432
chalk bass	Crustacivores	1 + 3 + 4	0.7705	0.2524	0.4410	0.0078
creole wrasse	Planktivores	1 + 3 + 7	0.7845	0.3800	0.5460	0.0008
Atlantic trumpetfish	Piscivores	1 + 3 + 7	0.7977	0.1467	0.3420	0.0455
purple reeffish	Planktivores	1+4+7	0.8177	0.2340	0.4370	0.0339
dusky damselfish	Grazers	3+4+5	0.6525	0.2500	0.4040	0.0126
sergeant major	Planktivores	3+4+6	0.6829	0.3415	0.4830	0.0385
green razorfish	Planktivores	4+5+8	0.8227	0.5672	0.6830	0.0001
littlehead porgy	Crustacivores	4+5+8	0.6986	0.2687	0.4330	0.0303
butter hamlet	Crustacivores	1+3+4+7	0.8166	0.4451	0.6030	0.0001
yellowtail parrotfish	Scrapers	1+3+4+7	0.8267	0.2622	0.4660	0.0024
foureye butterflyfish	Corallivores	1+3+6+7	0.8975	0.3644	0.5720	0.0001
French grunt	SessileInvert	3+4+5+6	0.8297	0.3768	0.5590	0.0003
beaugregory	MicroInvert	3+4+5+6	0.8775	0.3406	0.5470	0.0008
striped parrotfish	Scrapers	1+2+3+6+7	0.9580	0.6030	0.7600	0.0001
cocoa damselfish	Grazers	1+3+4+5+6	0.8347	0.4706	0.6270	0.0072

red lionfish	Crustacivores	1+3+4+5+7	0.8259	0.2346	0.4400	0.0205
stoplight parrotfish	Scrapers	1+3+4+6+7	0.8914	0.6360	0.7530	0.0001
yellowtail snapper	Crustacivores	1+3+4+6+7	0.8868	0.4440	0.6270	0.0011
redtail parrotfish	Scrapers	1+3+4+6+7	0.9070	0.3080	0.5290	0.0005
orangespotted filefish	SessileInvert	1+3+4+6+7	0.9058	0.1920	0.4170	0.0131
blue chromis	Planktivores	1+2+3+4+5+7	0.9426	0.5018	0.6880	0.0001
redband parrotfish	Scrapers	1+2+3+4+6+7	0.9775	0.8808	0.9280	0.0001
harlequin bass	Crustacivores	1+2+3+4+6+7	0.9937	0.5959	0.7700	0.0001
princess parrotfish	Scrapers	1+2+3+4+6+7	0.9975	0.5029	0.7080	0.0001
spotfin butterflyfish	Corallivores	1+2+3+5+6+7	0.9657	0.4493	0.6590	0.0001
threespot damselfish	Grazers	3+4+5+6+7+8	0.9414	0.1435	0.3670	0.0327
bluehead	MacroInvert	1+2+3+4+5+6+7	0.9834	0.9554	0.9690	0.0001
bicolor damselfish	Grazers	1+2+3+4+5+6+7	0.9837	0.9415	0.9620	0.0001
yellowhead wrasse	MacroInvert	1+2+3+4+5+6+7	0.9721	0.8384	0.9030	0.0001
blue tang	Browsers	1+2+3+4+5+6+7	0.9921	0.7604	0.8690	0.0001
reef butterflyfish	MicroInvert	1+2+3+4+5+6+7	0.9797	0.7409	0.8520	0.0001
rock beauty	Corallivores	1+2+3+4+5+6+7	0.9986	0.6100	0.7800	0.0001
spotted goatfish	Crustacivores	1+2+3+4+5+6+7	0.9659	0.5460	0.7260	0.0007
Spanish hogfish	MacroInvert	1+2+3+4+5+6+7	0.9807	0.4819	0.6870	0.0001
hogfish	MacroInvert	1+2+3+4+5+6+7	0.9711	0.4791	0.6820	0.0008
graysby	Piscivores	1+2+3+4+5+6+7	0.9928	0.4485	0.6670	0.0001
French angelfish	SessileInvert	1+2+3+4+5+6+7	0.9622	0.4513	0.6590	0.0007
bluelip parrotfish	Browsers	1+2+3+4+5+6+7	0.9687	0.3983	0.6210	0.0288
queen angelfish	Scrapers	1+2+3+4+5+6+7	0.9487	0.3872	0.6060	0.0318
sunshinefish	Planktivores	1+2+3+4+5+6+7	0.9893	0.3565	0.5940	0.0034
scrawled filefish	Corallivores	1+2+3+4+5+6+7	0.9959	0.2702	0.5190	0.0075
slippery dick	MacroInvert	1+2+3+4+5+6+8	0.9619	0.7232	0.8340	0.0002
gray triggerfish	MacroInvert	1+2+3+4+5+6+8	0.9771	0.4137	0.6360	0.0012
bluestriped grunt	MacroInvert	1+3+4+5+6+7+8	0.9654	0.3069	0.5440	0.0303

7. SUPPLEMENTAL FIGURES

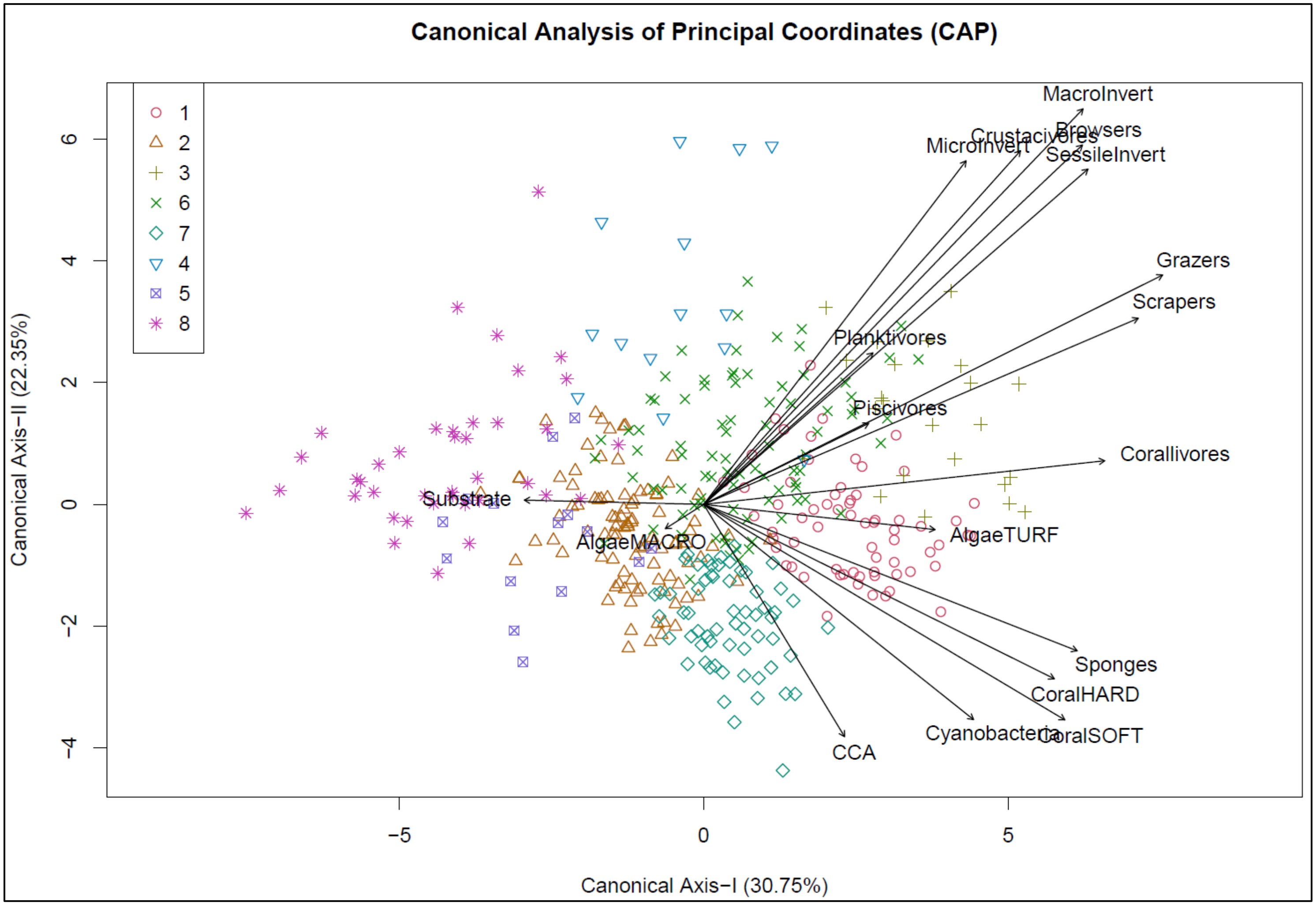

Figure S1. Canonical analysis of principal coordinates ordination. An ordination drawing the first two axes of the 7-dimensional solution that maximizes the depiction of among-group separation for PSUs representing the NCRMP data throughout the Coral AP. The horizontal axis accounts for ~31% of the group variability and the vertical axis captures ~22%. The biplot vectors show the descriptors correlation with the underlying canonical axes and can be interpreted similarly to those described in Figure 6. Group symbols and colors are in the legend.

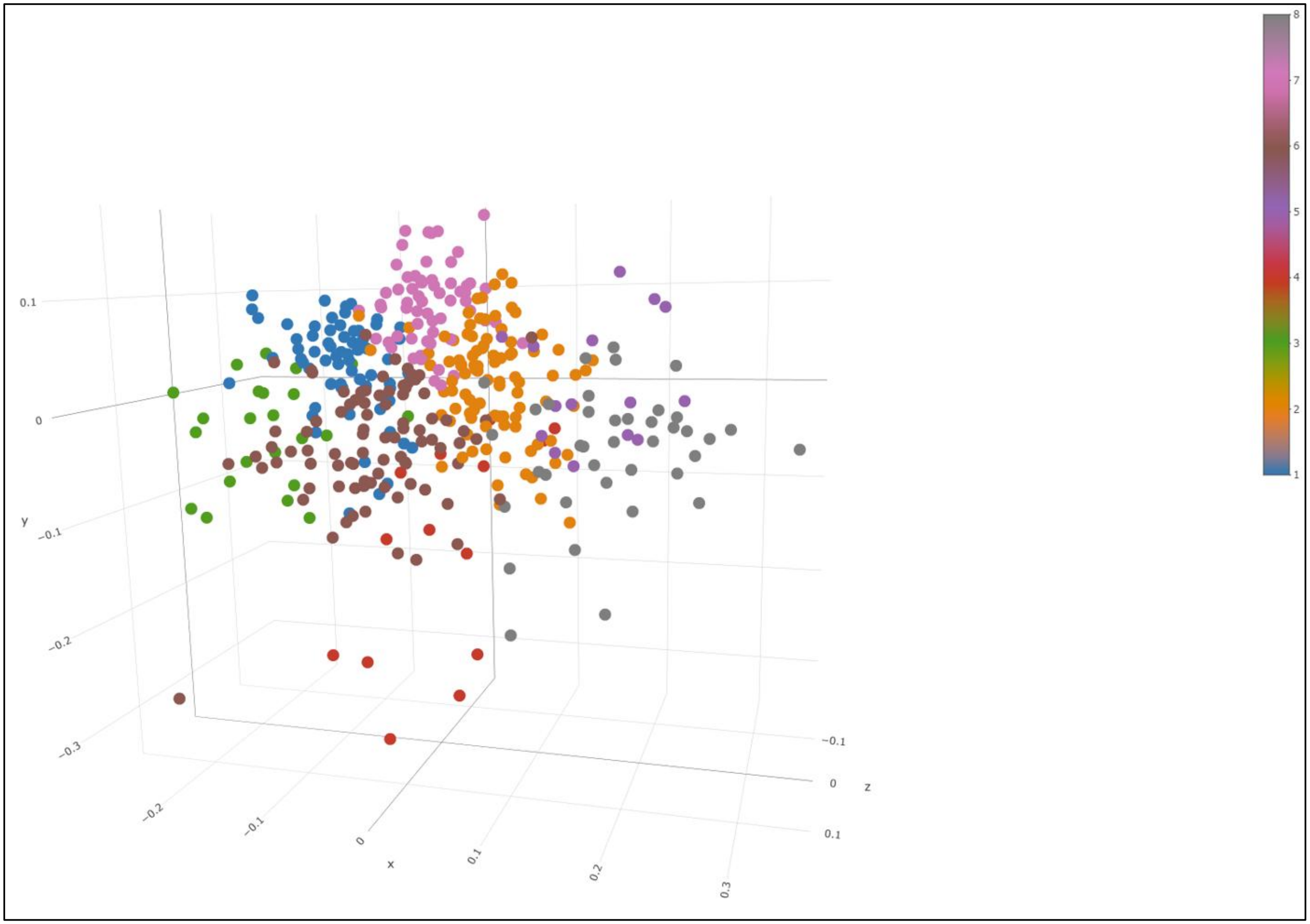

Figure S2. 3-Dimensional non-metric multidimensional scaling ordination. This figure depicts the full 3-D nMDS solution (stress: *w* = 0.1568). Colors correspond to those in the legend and loosely match those used in Figure 6. Data points' proximities depict multivariate resemblance, and point sizes are uniform. Orientation is similar to Figure 6 but has been rotated slightly to highlight the *z*-axis.