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National Coral Reef Monitoring Program
Biological Monitoring Summary

Florida: 2022

2023

NOAA | NOS Coral Reef Conservation Program
NOAA | NOS National Centers for Coastal Ocean Science
NOAA | NMFS Southeast Fisheries Science Center

NOAA Technical Memorandum NOS CRCP 48

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Biological Monitoring Summary

Florida: 2022

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Cover photos were taken by Caitlin Langwiser (top, middle) and Jeremiah Blondeau (bottom).

Disclaimer

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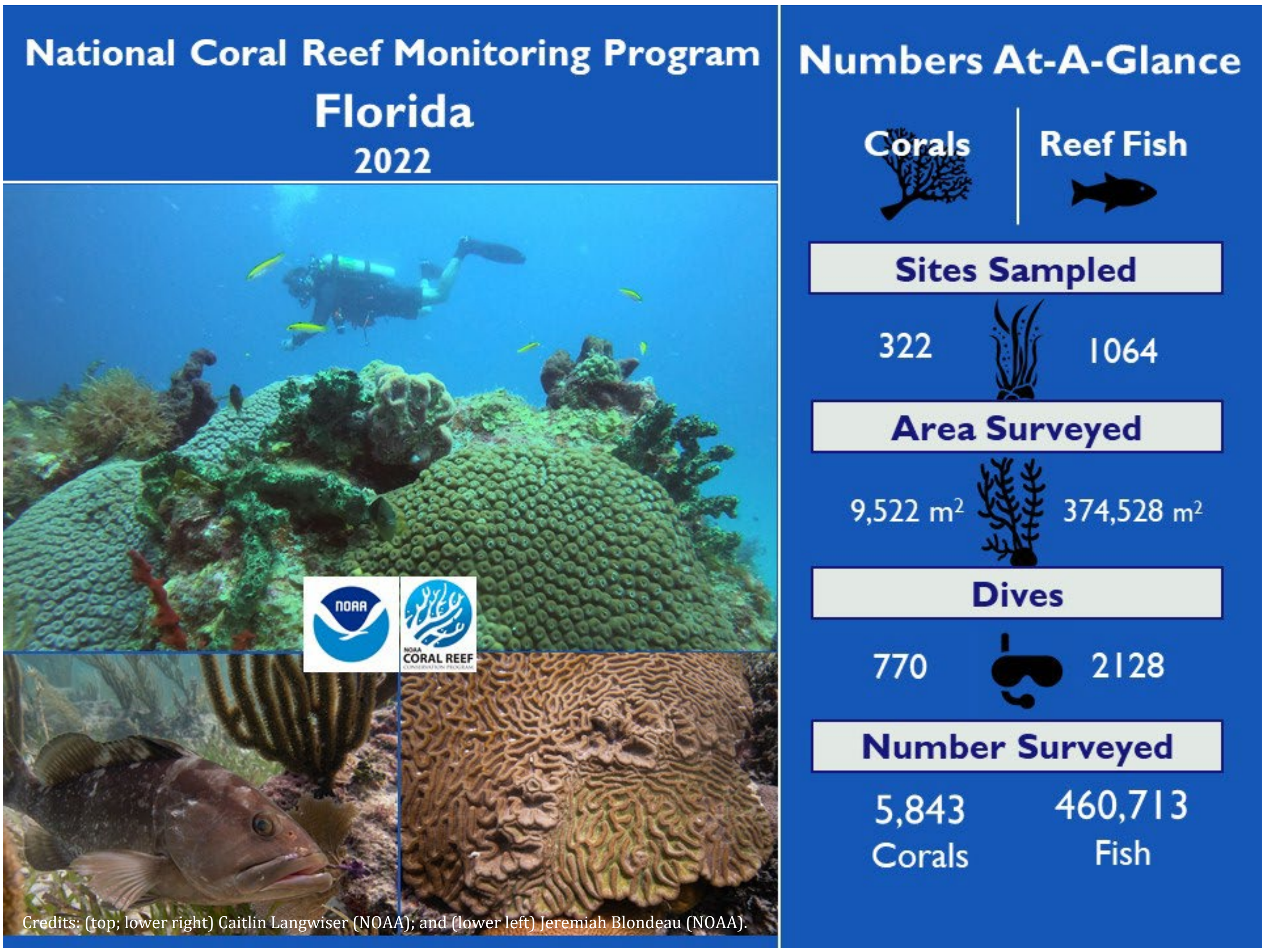
Acronyms

AGRRA	Atlantic and Gulf Rapid Reef Assessment
APT	All-Purpose Tool
CRCP	Coral Reef Conservation Program
CV	Coefficient of Variation
DRM	Disturbance Response Monitoring
DRTO	Dry Tortugas National Park
ESA	Endangered Species Act
FKNMS	Florida Keys National Marine Sanctuary
M:IR	Mission: Iconic Reefs
NCCOS	National Centers for Coastal Ocean Science
NCEI	National Centers for Environmental Information
NCRMP	National Coral Reef Monitoring Program
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
SCTLD	Stony Coral Tissue Loss Disease
SPA	Sanctuary Preservation Area

Executive Summary

National Oceanic and Atmospheric Administration (NOAA)'s National Coral Reef Monitoring Program (NCRMP) conducts biological sampling for fish populations and communities, coral populations, and benthic communities every other year. NCRMP normally surveys in Florida in even-numbered years. In 2022, NCRMP surveys of Florida's shallow-water (≤ 30 m) coral reefs occurred throughout summer and fall months. NCRMP data are used to inform coral and fish population management strategies, document the occurrence of endangered species and coral disease, and complement local monitoring efforts. Information about NCRMP's methods, data, and data products are available on the project website: https://www.coris.noaa.gov/monitoring/biological.html.



Credits: (top; lower right) Caitlin Langwiser (NOAA); and (lower left) Jeremiah Blondeau (NOAA).

Report Overview

NCRMP provides large-scale, stratified-random monitoring data to evaluate the status and trends of coral reefs and their communities. The NCRMP biological sampling effort consists of surveys of: 1) fish populations and communities, and 2) coral populations and benthic communities. The goal of this report is to provide a broad overview of NCRMP's accomplishments and sampling results in a summary of the 2022 biological data results collected by NOAA and regional partners in the shallow water coral reef ecosystems in Florida at the sub-jurisdiction or region level (i.e., Dry Tortugas, the Florida Keys, and Southeast Florida).

Sampling Overview

In 2022, Florida NCRMP sampling efforts occurred from June until December at the following locations and dates:

- Southeast Florida:
  - Fish and Benthic Communities: June–October, 2022
- Florida Keys:
  - Fish and Benthic Communities: June–September, 2022
  - Mission: Iconic Reefs (M:IR): August–December, 2022
- Dry Tortugas:
  - Fish: June 1–3 and 21–26, 2022. Both 10-day cruises were shortened due to coronavirus and/or weather. A make-up cruise occurred in July 2023.
  - Benthic Communities: Sept 1–11 (NCRMP cruise) and September 13–18, 2022 (Disturbance Response Monitoring [DRM] cruise with NCRMP Benthic Community surveys added)

Partners involved in NCRMP Florida 2022 efforts included:

- Broward County (BC)
- College of the Florida Keys (CFK)
- Florida Fish and Wildlife Conservation Commission (FWC)
- Florida Keys National Marine Sanctuary (FKNMS)
- Miami-Dade County (MDC)
- National Park Service (NPS)
- Nova Southeastern University (NSU)
- University of Miami (UM)
- University of the Virgin Islands (UVI)
- U.S. Environmental Protection Agency (USEPA)

Key Report Points

Fish Community

- The fishery target species with the highest mean density varied by region from yellowtail snapper (*Ocyurus chrysurus*) in the Dry Tortugas to gray triggerfish (*Balistes capriscus*) in Southeast Florida.

- Mutton snapper (*Lutjanus analis*) densities steadily and significantly increased within marine protected areas in the Dry Tortugas from 2014 to 2022.

- Reefs in all locations are dominated by fishery non-targeted species including masked goby (*Coryphopterus personatus*), bicolor damselfish (*Stegastes partitus*), and bluehead wrasse (*Thalassoma bifasciatum*).

Corals and Benthic Community

❖ NCRMP benthic community data from 2022 showed that coral cover continued to decline in Florida regions, particularly in the Florida Keys.

❖ NCRMP coral demographics data from 2022 showed that the occurrence and density of multiple coral species susceptible to stony coral tissue loss disease (SCTLD) continued to decline.

❖ In 2022, SCTLD and bleaching had high frequency of occurrence on corals in the Dry Tortugas.

❖ *Acropora cervicornis* outplanted colonies were surveyed within M:IR restoration sites in the Florida Keys in 2022. No *A. cervicornis* had been detected in Florida Keys NCRMP surveys since 2016.

Introduction

Coral reefs are valuable ecosystems that provide people with many goods and services including food, coastal protection, and recreational opportunities. Despite their importance, coral reef ecosystems are in decline due to many multiple human-made and natural stressors (Hughes and Tanner, 2000; Knowlton, 2001). In response to these threats, NOAA's Coral Reef Conservation Program (CRCP) established a National Coral Reef Monitoring Program (NCRMP) with partners across the United States (U.S.). This program is a strategic framework for conducting long-term, quantitative surveys of biological, climatic, and socioeconomic indicators in U.S. coral reef states and territories. The resulting data present a picture of the U.S. coral reef ecosystem condition and the communities connected to them.

NCRMP biological monitoring provides an assessment of the coral reef communities over a broad spatial scale in U.S. jurisdictions. The overall goal is to provide robust, quantitative data to document the status and trends of coral reef fishes, corals, and benthic communities in the Atlantic, Caribbean, and Gulf of Mexico basins at a regional (or region) scale (NOAA CRCP, 2021; Towle et al., 2022). NCRMP generates large-scale, regional status and trend information of U.S. shallow water (≤ 30 m) coral reef ecosystems. This context and perspective provide a dataset that can be used for coral reef management. Biological sampling occurs on a two-year cycle within the U.S. Atlantic, Caribbean, and Gulf of Mexico coral reef jurisdictions, including the U.S. Virgin Islands (USVI; including St. Thomas, St. John, and St. Croix), Puerto Rico, Florida, and Flower Garden Banks (Figure 1).

Figure 1. Map of U.S. Atlantic jurisdictions sampled within NCRMP.

This report provides a summary of data collected by the biological sampling of NCRMP shallow water coral reef ecosystems in Florida in 2022. Data summaries for ecologically important metrics are provided for the most recent sampling year, and trends are reported from the onset of NCRMP. The full datasets for 2022 and prior can be obtained from the NCRMP Biological project webpage (https://www.coris.noaa.gov/monitoring/biological.html) and NOAA's National Centers for Environmental Information (NCEI) database (see Appendix for additional reference and archive information).

NCRMP has surveyed in Florida since 2014. This is the second NCRMP Florida report to show trend data for fish and benthic communities between 2014 and the present (Grove et al., 2022). The NCRMP program in Florida builds upon historic monitoring for fish (Reef Visual Census [RVC]: 1999–2013) and coral demographics and benthic communities (Sanctuary Coral Reef Ecosystem Assessment Monitoring [SCREAM]: 1999–2011).

In Florida, NCRMP is part of a mosaic of monitoring efforts for corals and benthic communities that includes both stratified random sampling and fixed-site monitoring. Florida Fish and Wildlife Conservation Commission's Disturbance Response Monitoring (DRM) is an annual stratified random coral demographics survey focused on coral bleaching and disease (2005–present) that is complementary to NCRMP. DRM uses the NCRMP sampling grid to 20-m water depth, while the NCRMP survey domain extends to 30 m. The NCRMP and DRM collaboration continues to grow. In even-numbered years, NCRMP has led the sample allocation and provided sites to DRM to ensure complementarity in geographic coverage. In 2022, NCRMP and DRM collaborated on coral species allocations. Data for coral demographics, coral bleaching, and coral disease prevalence are compatible between both programs; for concomitant NCRMP and DRM sampling years, data from both programs should be used to provide comprehensive coral population estimates. See Stein and Ruzicka (2023) for details of 2022 DRM surveys. For more information on comparisons between NCRMP and other coral monitoring programs, see Viehman and Groves et al. (2023).

In 2022, new NCRMP sampling was added in the Florida Keys to focus on Mission: Iconic Reefs (M:IR) restoration, and additional fish sites were added in Biscayne National Park to support fisheries management. These data are included in the NCRMP Florida Keys.

Methods

Sample Design

NCRMP biological monitoring (i.e., fish, corals, and benthic communities) uses a grid-based stratified random design that is optimized to efficiently sample for ecologically and commercially important species. Details of the sample frame protocol, methods, and definitions of the specific habitat types can be found in the Spatial Framework Protocols (Ault et al., 2021). Each jurisdiction has a unique set of strata specific to the local protected or managed zones and benthic habitat. The survey design ensures that survey sites for fish and corals are allocated by hard bottom habitat type, depth, and management zone, with sites distributed around the sampling region from nearshore to offshore to a maximum depth of 30 m. In 2020, the NCRMP Florida survey grid was updated to a spatial resolution of 50 m x 50 m grid cell from 100 m x 100 m grid cell. Additionally, the Dry Tortugas and Florida Keys jurisdictional strata were updated (Ault et al., 2021). The 2022 NCRMP survey is the second NCRMP year using this updated, higher resolution sampling frame. Domain-level time series analyses are still appropriate despite sample design changes and are included in NCRMP R-package analyses (Ganz and Blondeau, 2015; Groves and Viehman, 2019).

The NCRMP biological monitoring team and partners strive to sample a specific number of sites each year in each jurisdiction. The actual number of sites sampled may vary each year due to numerous factors such as weather conditions and resources. Fish and benthic sites are co-located within the same grid cell but may not be sampled during the same dive or at the exact coordinates. In Florida, the number of fish sites sampled exceeds the number of benthic sites to support fishery stock assessments. As additional data are gathered in future years, the strength of the data and trend analyses will continue to grow.

Florida includes three distinct regions or sampling domains: the Dry Tortugas, the Florida Keys, and Southeast Florida. These three regions vary in their implementation of spatially explicit closure areas (i.e., marine reserves) for recreationally and commercially targeted fish species. The Dry Tortugas has two distinct marine reserves within the NCRMP sampling domain: Tortugas Ecological Reserve – North in the Florida Keys National Marine Sanctuary (FKNMS), and the Research Natural Area within the Dry Tortugas National Park (DRTO). It should be noted that the Tortugas Ecological Reserve – South is not currently included in the NCRMP sampling domain. The Florida Keys has marine reserves known as Sanctuary Preservation Areas (SPAs). The majority of NCRMP sampling occurs outside of the marine reserves; however, the sampling design provides enough power to detect differences in fish densities inside versus outside marine reserves, if relevant. Southeast Florida consists of only open (unprotected) areas; therefore, the entire region was classified as "outside," and no "inside" versus "outside" marine reserve comparisons were made.

Sample Protocols

Field Surveys

The RVC is a stationary-point-count sampling protocol (NOAA CRCP, 2022a) modified from Bohnsack and Bannerot (1986). Field surveys used a one-stage design to sample within a selected subset of 50 m x 50 m grid cells. A two-diver team surveyed all fish within adjacent 15-m diameter cylinders centered on each diver and extending vertically from the substrate to the sea surface. Within each cylinder, fish were identified to the species level and counted, and fork length was estimated to the nearest centimeter (Figure 2). Data collected by the diver survey pair were averaged at the site level.

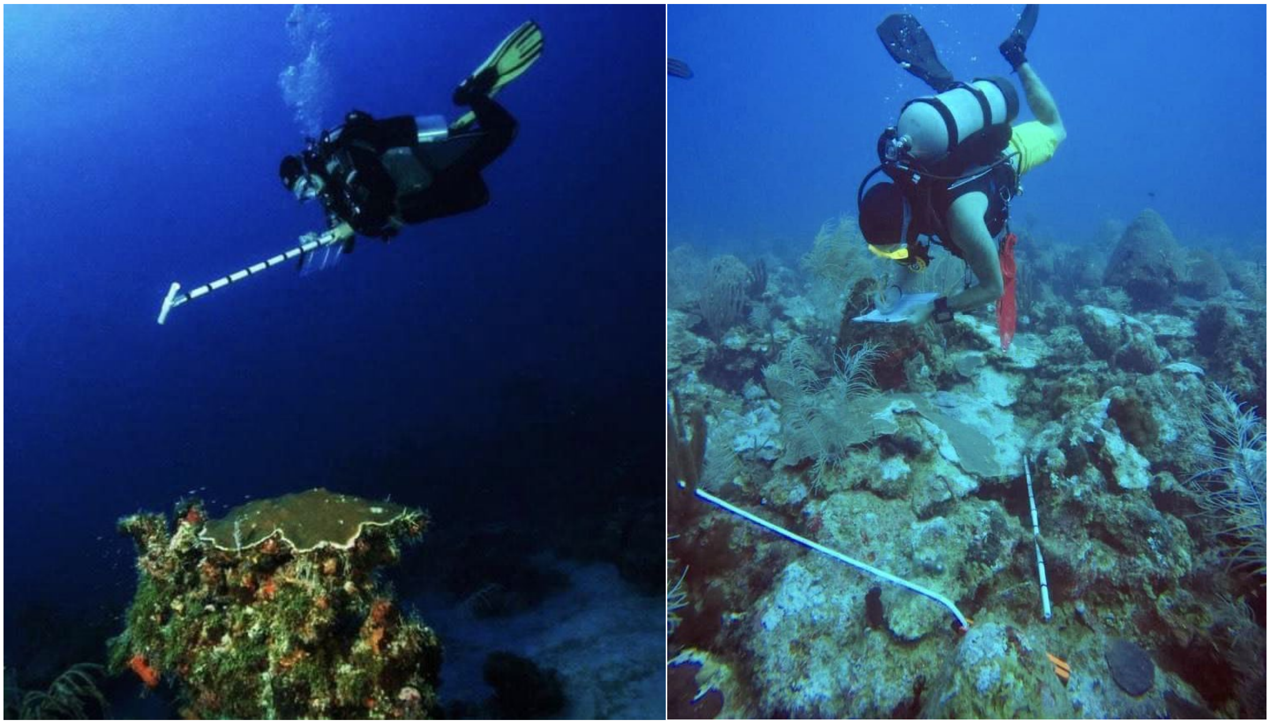


Figure 2. Examples of (left) a diver collecting Reef Visual Census fish survey data in the Dry Tortugas and (right) a diver collecting benthic community data in the Dry Tortugas. Photo credits: (left) Rob Waara, National Park Service; (right) Caitlin Langwiser, NOAA.

Corals and benthic communities were monitored using a Benthic Community Assessment survey and a Coral Demographics survey (NOAA CRCP, 2022b, 2022c). The Benthic Community Assessment survey includes: 1) benthic cover (%) estimates along a 15-m transect with a line point intercept method, 2) presence/absence of Endangered Species Act (ESA)-listed coral species (NOAA National Marine Fisheries Service, 2014), 3) abundance of key macroinvertebrates, and 4) reef rugosity measurements within a 15 m x 2 m belt-transect area (NOAA CRCP, 2022b; Figure 2 [right]). At the same site, coral demographics were surveyed within a 10 m x 1 m belt-transect area (NOAA CRCP, 2022c). In Coral Demographics surveys, all live coral colonies ≧ 4 cm were counted, identified to species, and measured to the nearest centimeter (length, width, height), and estimates were made of the proportion per colony of any present mortality (recent or old), disease (present, slow, fast), and/or bleaching (total, partial, paling). Only live coral colonies were included in the survey; dead colonies with 100% mortality were not surveyed (e.g., colonies killed by coral disease). Juvenile corals (< 4 cm) were reported for species richness only and were not included in counts, size measurements, or estimates of condition.

NCRMP Coral Demographics surveys provide information on disease occurrence on individual coral colonies without identification of specific diseases. Disease progression rate estimates (i.e., slow or fast rates) were added at the request of partners as a rapid, general approach to identify potential stony coral tissue loss disease (SCTLD). However, further information has shown that rate is not a reliable indicator of SCTLD; therefore, NCRMP will revisit the inclusion of this classification approach in subsequent survey years. Additional information on how NCRMP can inform SCTLD is provided in Towle et al. (2021).

Coral bleaching (total, partial, paling, none) is consistently surveyed during NCRMP sampling; however, field sampling dates do not always coincide with bleaching events. Therefore, peak bleaching events may not be represented comprehensively in NCRMP data.

In 2022, NCRMP added new data collection fields onto data sheets for *Diadema* disease observed at a site (NOAA CRCP, 2022b, 2022c). At the time of planning for the 2022 field season, scientific concern was being expressed about *Diadema* disease and the potential for a widespread *Diadema* die-off around the Caribbean. NCRMP provides extensive eyes in the water; therefore, to support these observation efforts, NCRMP divers noted whether *Diadema* disease was observed at a site. No *Diadema* disease was observed, and results were shared with the Atlantic and Gulf Rapid Reef Assessment (AGRRA). Unless *Diadema* disease continues to be an emerging threat in 2024, *Diadema* disease observations will not be continued on the NCRMP data sheet in 2024.

In 2022, NCRMP added new data-sheet fields for coral restoration (NOAA CRCP, 2022a, 2022b, 2022c). Due to the increase in coral restoration efforts within the NCRMP sampling geography in general, and specifically within M:IR sites, NCRMP data sheets added new fields to all data sheets regarding whether coral restoration was observed at an NCRMP site (No/Yes/Unknown), and to Coral Demographics data sheet as to whether surveyed corals were restored (No/Yes/Unknown). In 2022, restored corals were observed only at M:IR sites, and these results will be included in a M:IR-specific report (in prep). Given the expansion of coral restoration in Florida, Puerto Rico, and the U.S. Virgin Islands, it is expected that NCRMP will continue data collection related to coral restoration in continuing years.

Data Quality Assurance

NCRMP data quality standards were met using five primary approaches:

1) NCRMP surveyors demonstrated expertise in field identification prior to field surveys. Surveyors were trained in NCRMP methods through a) detailed training for new surveyors and b) annual refresher training for repeat surveyors;
2) NCRMP fish surveyors initially calibrated their fork length measurements using an All-Purpose Tool (APT) during training dives and, to ensure consistency, continued to use an APT during field surveys;
3) Reciprocal data checks followed data collection at each site. Upon surveyors' return to the survey vessel after each dive, surveyors traded data sheets with their dive buddy and reviewed to ensure all data were collected consistently and completely;
4) Divers entered their data into the database and then compared their original data sheets with the database entries; and
5) Quality checks were applied to data after export from the database. Basic statistical analyses were conducted and included in quality checks (e.g., by species, by diver). After the data were fully vetted through these quality checks, data were archived at NCEI and released publicly (Appendix).

Analytical Methods

Fish Communities

NCRMP fish sampling targets a coefficient of variation (CV) of 20% or less for the regionally specific sampling design species. A 20% CV can be translated to the ability to statistically detect a 40% change in density; a lower CV increases the ability to detect changes over time. In Florida, the sample allocation selects for fishery-targeted species. In all sampling domains, the allocation species are red grouper (*Epinephelus morio*), hogfish (*Lachnolaimus maximus*), mutton snapper (*Lutjanus analis*), and yellowtail snapper (*Ocyurus chrysurus*). The final allocation species varies by region based on species occurrence. Black grouper (*Mycteroperca bonaci*) is used in the Dry Tortugas and Florida Keys, while gray triggerfish (*Balistes capriscus*) is selected in Southeast Florida. Other common reef fish species or fishes that share similar characteristics to the allocation species are similarly well sampled.

Standard fish metrics, including density, occurrence, and relative length composition, are reported herein. Computational formulas of standard metrics for a single-stage stratified random sampling design are modified from Smith et al. (2011) and provided in detail in Grove et al. (2021) and Bryan et al. (2016). Additionally, a two-tailed t-test (Ault et al., 2013) was performed to evaluate density between years inside versus outside of spatial protection (i.e., marine reserves) where appropriate (see Results section).

Fish analysis scripts are open source and available at NCRMP **Fish R package** (Ganz and Blondeau, 2015).

Corals and Benthic Communities

Coral demographic sampling within NCRMP similarly targets a minimum CV of 20% for the regionally specific sampling design. The sample allocation is optimized for species that are identified as major reef-building species or those of interest to management. In Florida, the sample allocation species in 2022 for NCRMP and DRM were: (Southeast Florida) *Meandrina meandrites*, *Montastraea cavernosa*, *Orbicella faveolata*, *Porites astreoides*, *Pseudodiploria strigosa*, *Siderastrea siderea;* (Florida Keys) *Colpophyllia natans*, *M. cavernosa*, *Orbicella annularis*, *O. faveolata*, *Pseudodiploria clivosa*, *P. strigosa*, *S. siderea*, *Solenastrea bournoni;* (Dry Tortugas) *C. natans*, *M. meandrites*, *M. cavernosa*, *O. annularis*, *O. faveolata*, *Orbicella franksi*, *P. strigosa*, and *S. siderea.*

Standard metrics, including benthic cover (% cover of corals and macroalgae), coral species occurrence, coral density, and relative size composition, are reported herein. Coral population metrics include M:IR data and demographics data collected by DRM in years where both were sampled. To ensure compatibility in survey area for combined NCRMP and DRM coral demographics data (DRM data and 2014 NCRMP data have a larger survey area [20 m] than subsequent NCRMP years [10 m]), only 10 m are included from NCRMP 2014 and DRM data. Computational formulas of standard metrics for single-stage stratified random sampling design are provided in detail in Smith et al. (2011), Groves and Viehman (2023), and Viehman, Groves et al. (2023). Length frequency distributions were generated from colony size measurements (maximum diameter) of colonies greater ≥ 4 cm, which included areas of partial mortality (Bak and Meesters, 1999; Meesters et al., 2001). Frequency within each length class was composed of colonies that had least some amount of live tissue. For temporal comparisons, a pairwise two-tailed t-test was performed to evaluate differences between years where appropriate (see Results section). Site-level coral bleaching and disease prevalence were calculated as the percentage of colonies with any bleaching or disease divided by the total number of corals by species at each site. Domain-level coral bleaching and disease prevalence by species were calculated as the mean percentage of colonies with any bleaching/disease divided by the total number of corals for each species across all sites and strata; these were then weighted by the proportion of the strata within the entire sampling domain (Smith et al., 2011).

NCRMP analyses scripts for corals and benthic communities are open source and available at NCRMP **Benthic R package** (Groves and Viehman, 2023).

Results

In 2022, NCRMP surveyed 1,083 total sites along Florida's Coral Reef (Table 1; Figure 3). This included 306 fish sites and 115 benthic sites in Southeast Florida, 648 fish sites and 186 benthic sites in the Florida Keys, and 118 fish sites and 96 benthic sites in the Dry Tortugas (Table 1). The number of fish and benthic sites in the Florida Keys included additional sampling efforts within M:IR restoration areas (78 fish sites and 90 benthic sites) by the FKNMS (Figures 4 and 5) and in Biscayne National Park by the National Park Service (176 fish sites; Figure 4). Due to Covid-19 and weather complications, fish sampling in the Dry Tortugas was limited in 2022 (Figure 5), and a make-up cruise occurred in July 2023 (2023 data are not included in this report). Fluctuations in the number of sites surveyed for 2020–2021 and 2022 were largely driven by Covid-19 limitations (Table 1).

Table 1. NCRMP fish and benthic surveys completed by region and year along Florida's Coral Reef.

Year	Southeast Florida		Florida Keys		Dry Tortugas	
	Fish	*Benthic*	*Fish*	*Benthic*	*Fish*	*Benthic*
2022	306	115	648	186	118	96
2020–2021	305	98	218	12	229	129
2018	298	77	434	90	337	139
2016	-	98	405	93	286	98
2014	-	49	432	349	358	106

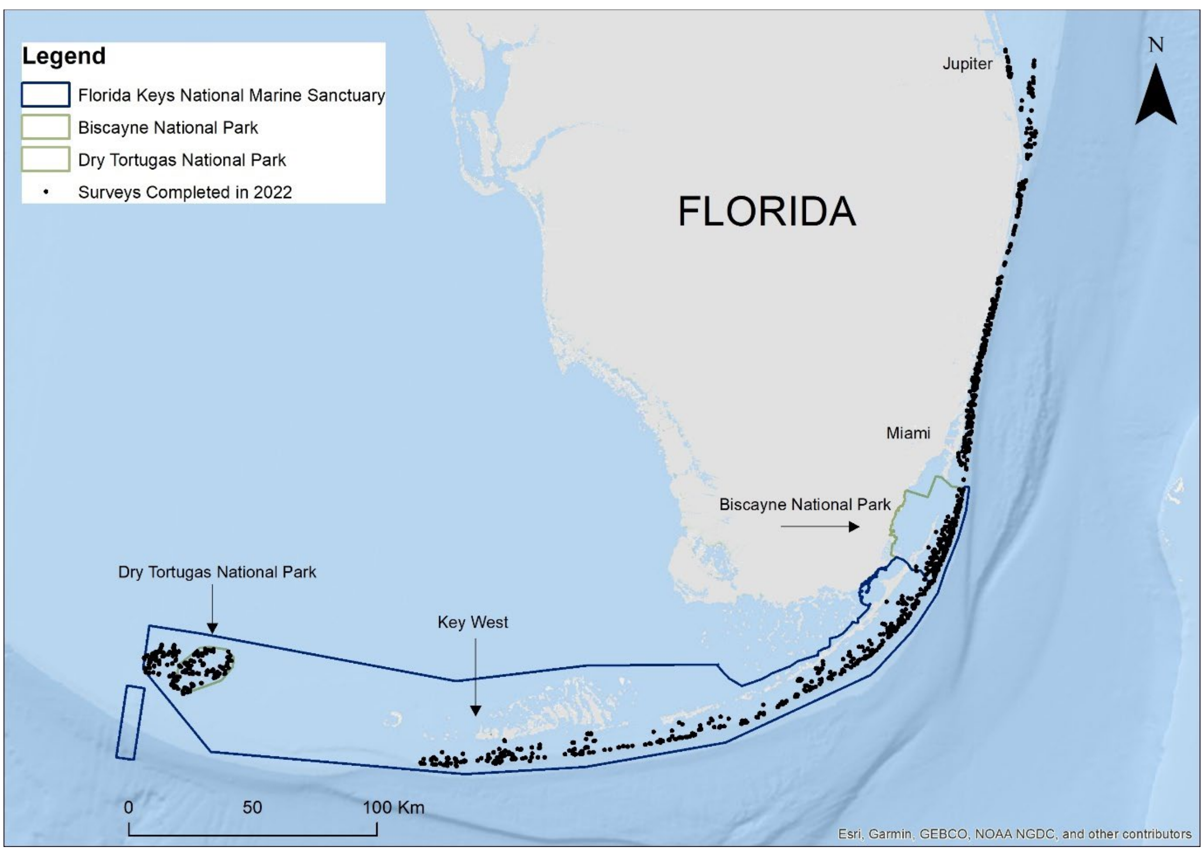
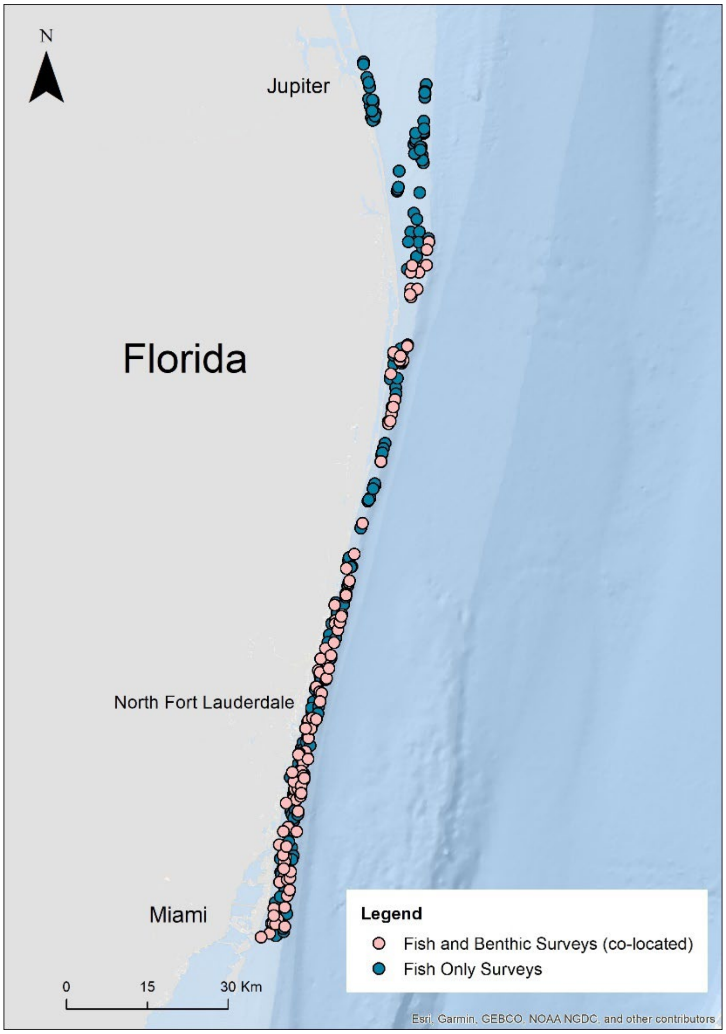
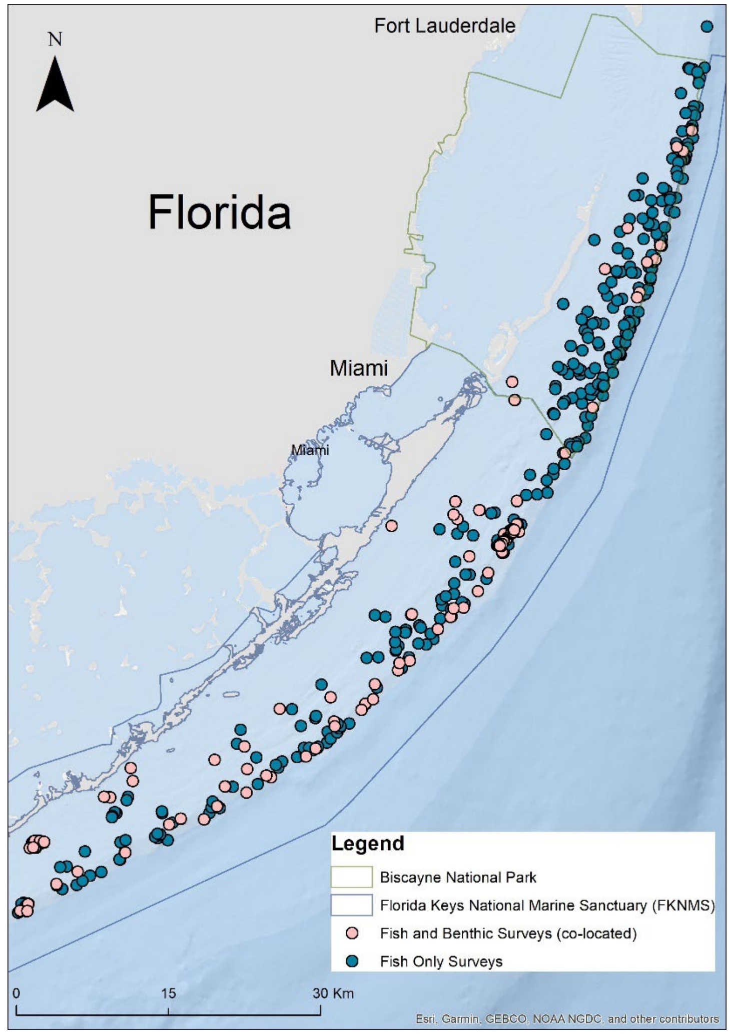


Figure 3. NCRMP survey sites sampled along the Florida reef tract in 2022.





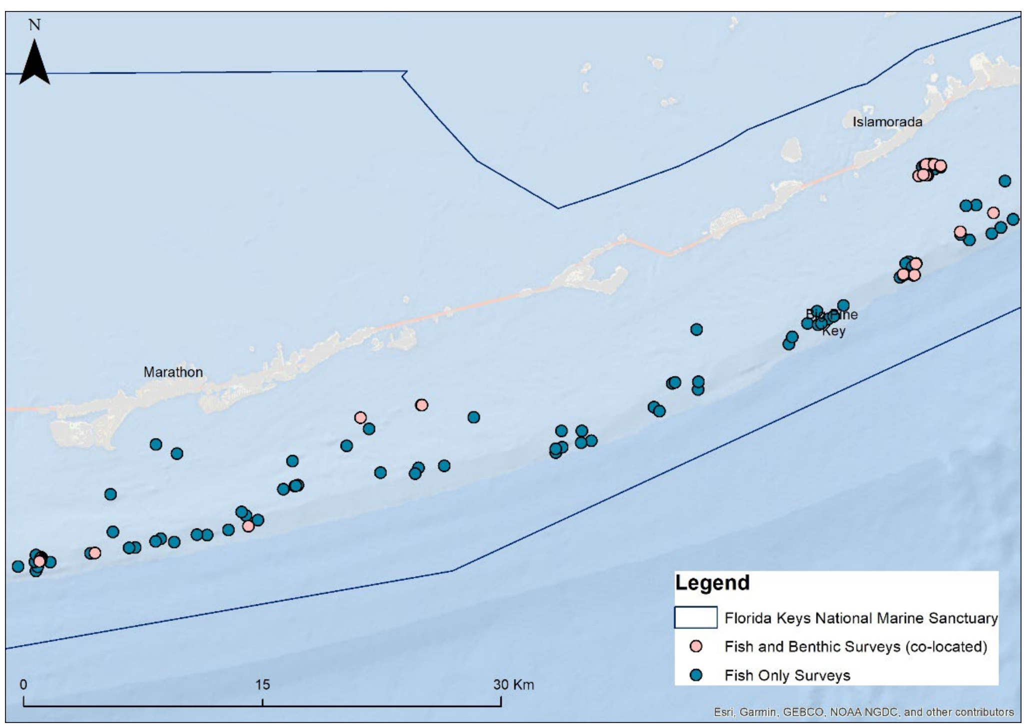
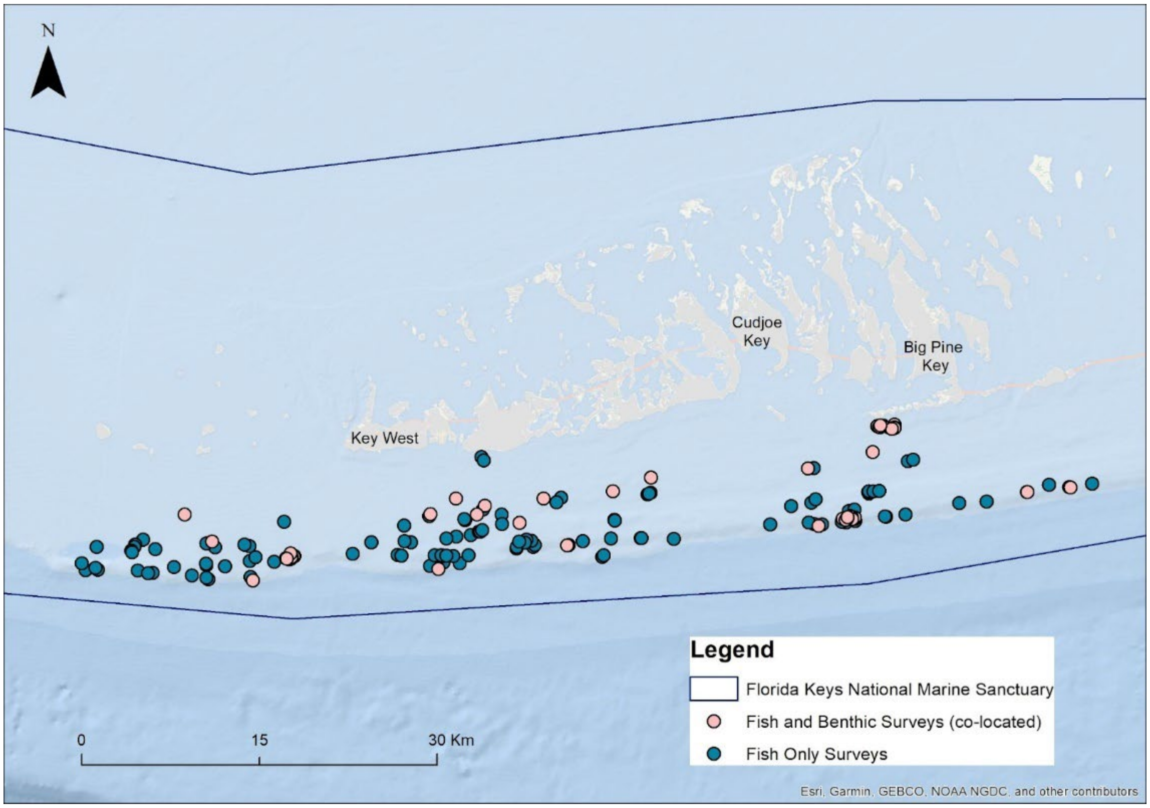


Figure 4. NCRMP survey sites sampled in Southeast Florida (top left), the Florida Keys – upper Keys region (top right), and the Florida Keys – middle Keys region (bottom) in 2022.



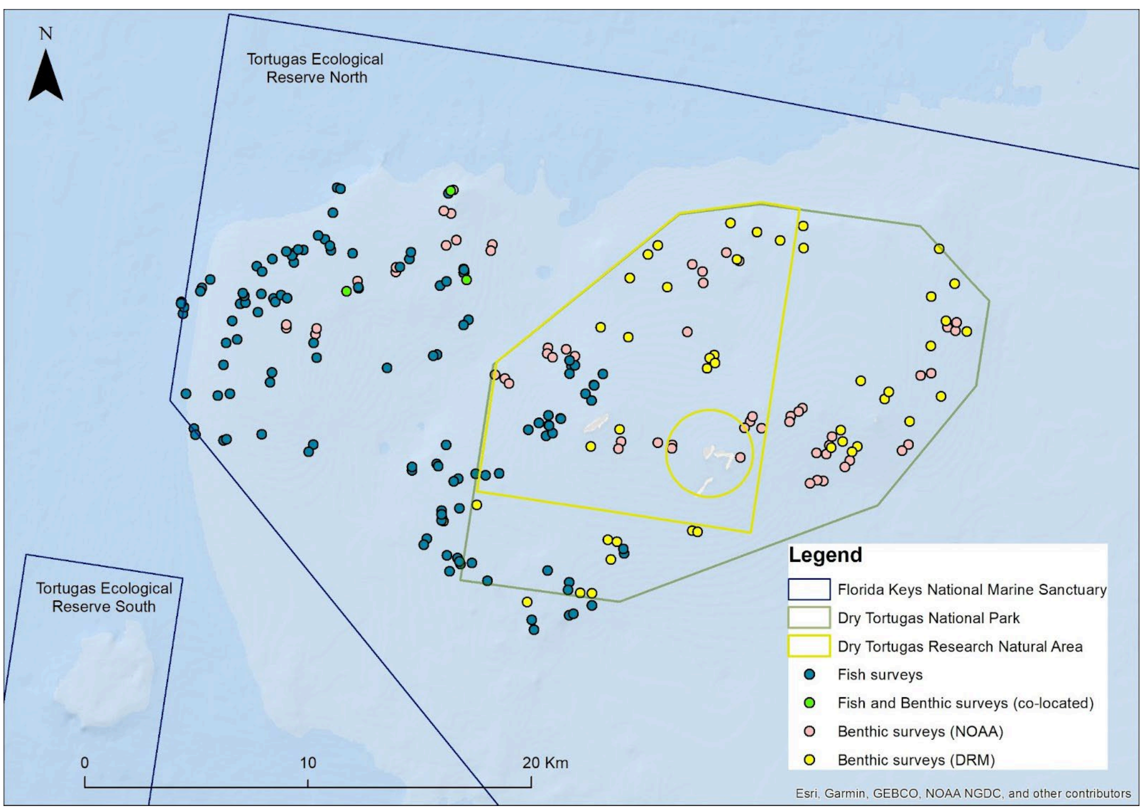


Figure 5. NCRMP survey sites sampled in the Florida Keys – lower Keys (top) and in the Dry Tortugas (bottom) in 2022. Note: DRM sites in the Dry Tortugas are shown because NCRMP (benthic community assessment) surveys were co-sampled with DRM (coral demographics) surveys during the DRM Tortugas cruise in 2022.

I. Fish

Typically, fishes are grouped together (e.g., guilds, trophic, genera) and presented as a single analysis metric (e.g., density, occurrence, biomass). However, these groups are often dominated by a single or a few species. When all species are combined, it can result in a misinterpretation of the data, as it is often assumed that each species equally contributes to the total. In Florida, two (Dry Tortugas, Florida Keys) or three (Southeast Florida) species of parrotfish make up approximately 75% of the total parrotfish density, highlighting the importance of analyzing and reporting species-specific information. For example, striped (*Scarus iseri*) and redband (*Sparisoma aurofrenatum*) parrotfish dominate the parrotfish taxonomic group in the Dry Tortugas as illustrated in Figure 6. This pattern was similar in the other Florida regions as well, although not shown graphically.

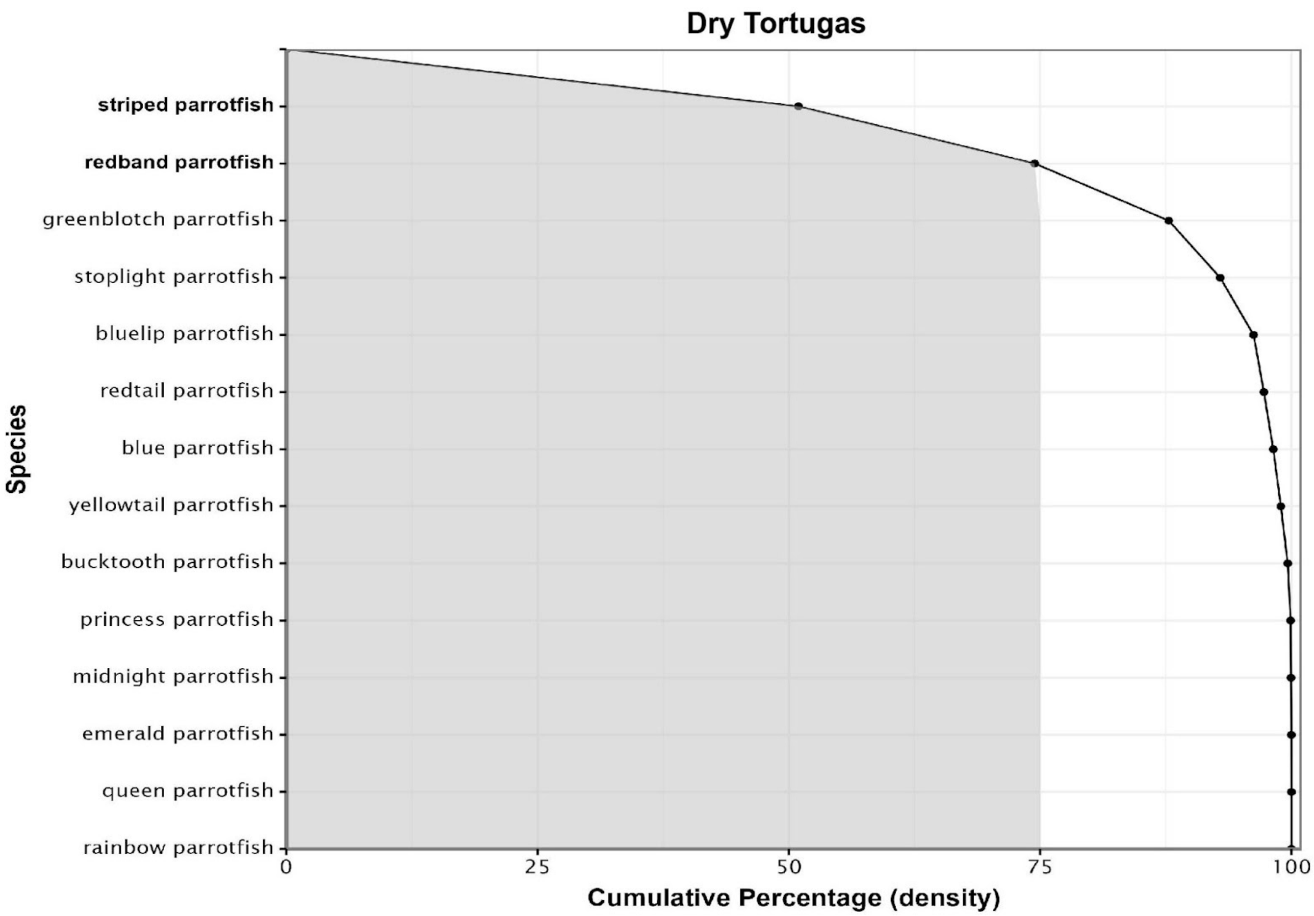


Figure 6. Cumulative density for parrotfishes in NCRMP sampling year 2022 in the Dry Tortugas. The two dominant species of parrotfish are in bold.

Species Occurrence

More fish species than the allocation species have CVs of density that are less than 20%. A 20% CV of density can be translated to the ability to statistically detect a 40% change.

Southeast Florida

In Southeast Florida, NCRMP fish survey results show that 48 individual species have CVs of density 20% or less in Southeast Florida (Figure 7). NCRMP does not allocate for species such as bicolor damselfish and slippery dick (*Halichoeres bivittatus*); however, each were seen in > 70% of surveys and had CVs of < 20% because of their ubiquitous nature.

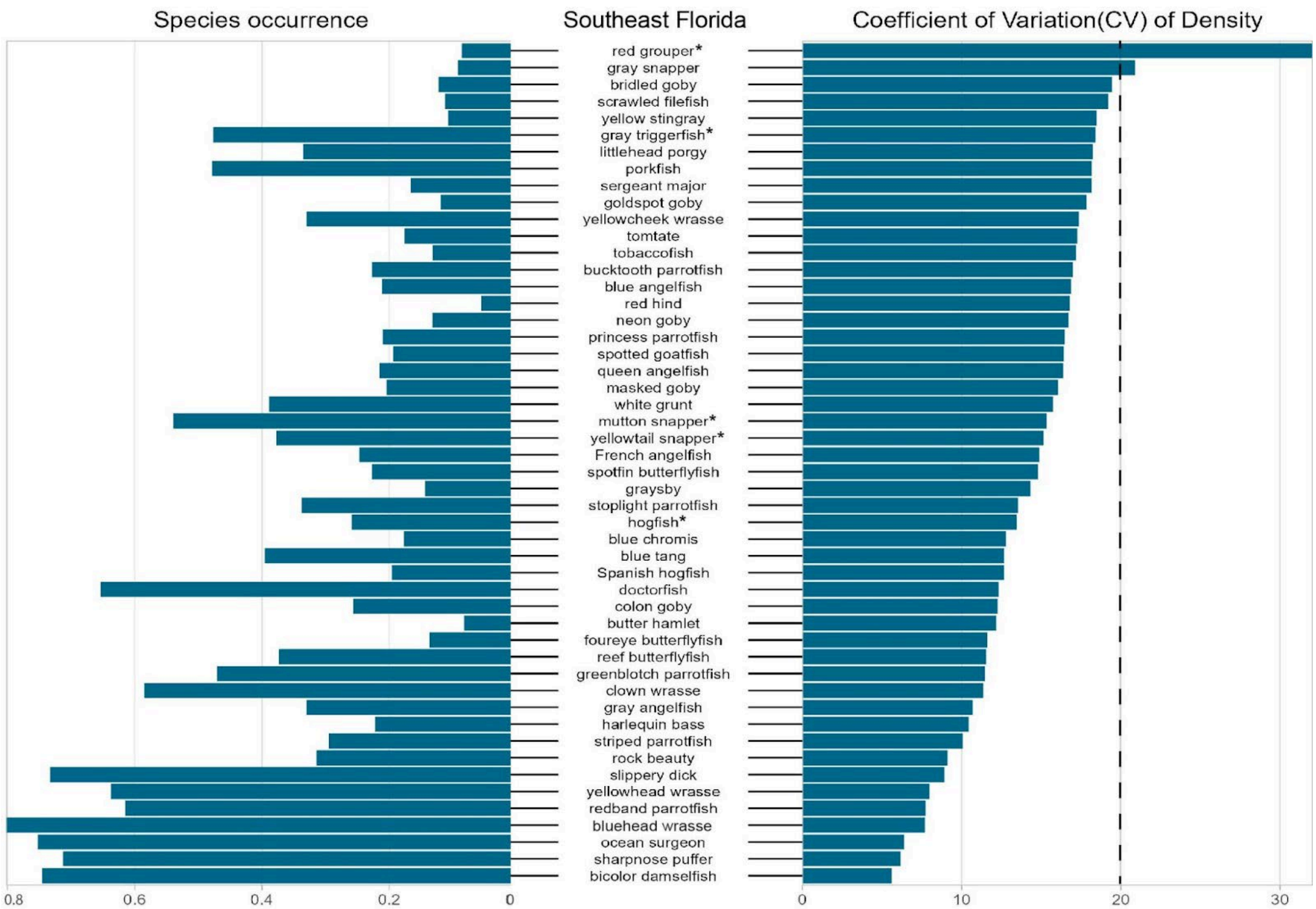


Figure 7. Occurrence of reef fish species with a coefficient of variation (CV) of density ≤30% and allocation species (*). Species are sorted by increasing CV of density in Southeast Florida in 2022. Dashed vertical line on the CV plot indicates the target CV of 20%.

Florida Keys

In the Florida Keys, NCRMP fish survey results show that 50 individual species have CVs of density that are 20% or less in the Florida Keys (Figure 8). NCRMP does not allocate for species such as blue tang and striped parrotfish (*Scarus iseri*); however, these species were observed in > 60% of surveys and have CVs of 20% or less due to their ubiquitous nature.

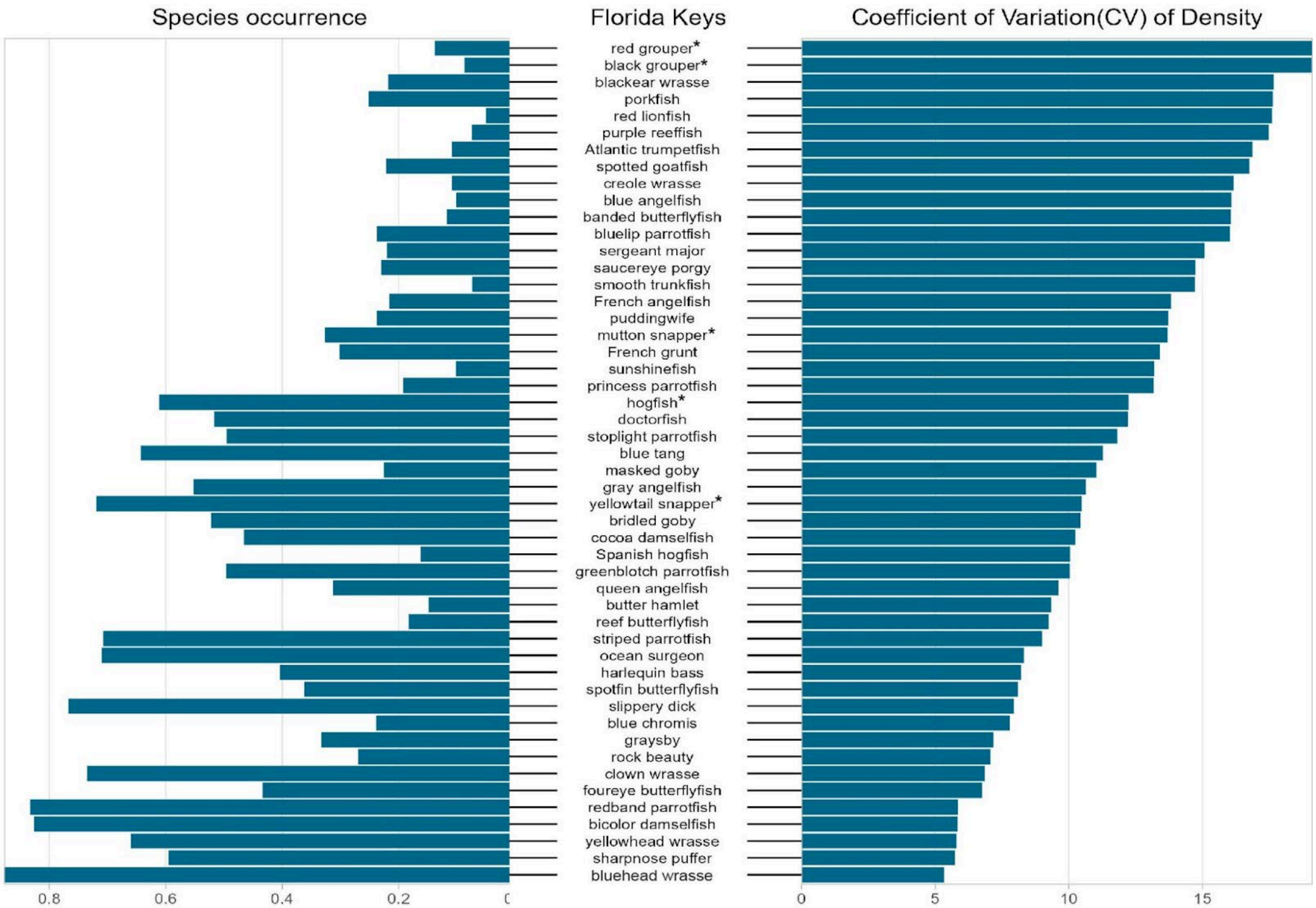


Figure 8. Occurrence of reef fish species with a coefficient of variation (CV) of density ≤20% and allocation species (*) with a target CV of 20%. Species are sorted by increasing CV of density in the Florida Keys, Florida in 2022.

Dry Tortugas

NCRMP fish survey results in the Dry Tortugas show that 38 individual species have CVs of density that are 20% or less (Figure 9). These CVs are quite good considering Covid-19 complications shortened both fish survey cruises in 2022. CVs of density of 20% or less often include > 40 individual species in the Dry Tortugas; similar results are anticipated when the 2023 make-up fish cruise data are incorporated into the dataset. While NCRMP did not allocate for species such as blue tang (*Acanthurus coeruleus*) and redband parrotfish (*Sparisoma aurofrenatum*), each were seen in > 75% of surveys and had CVs of < 20% because of their ubiquitous nature.

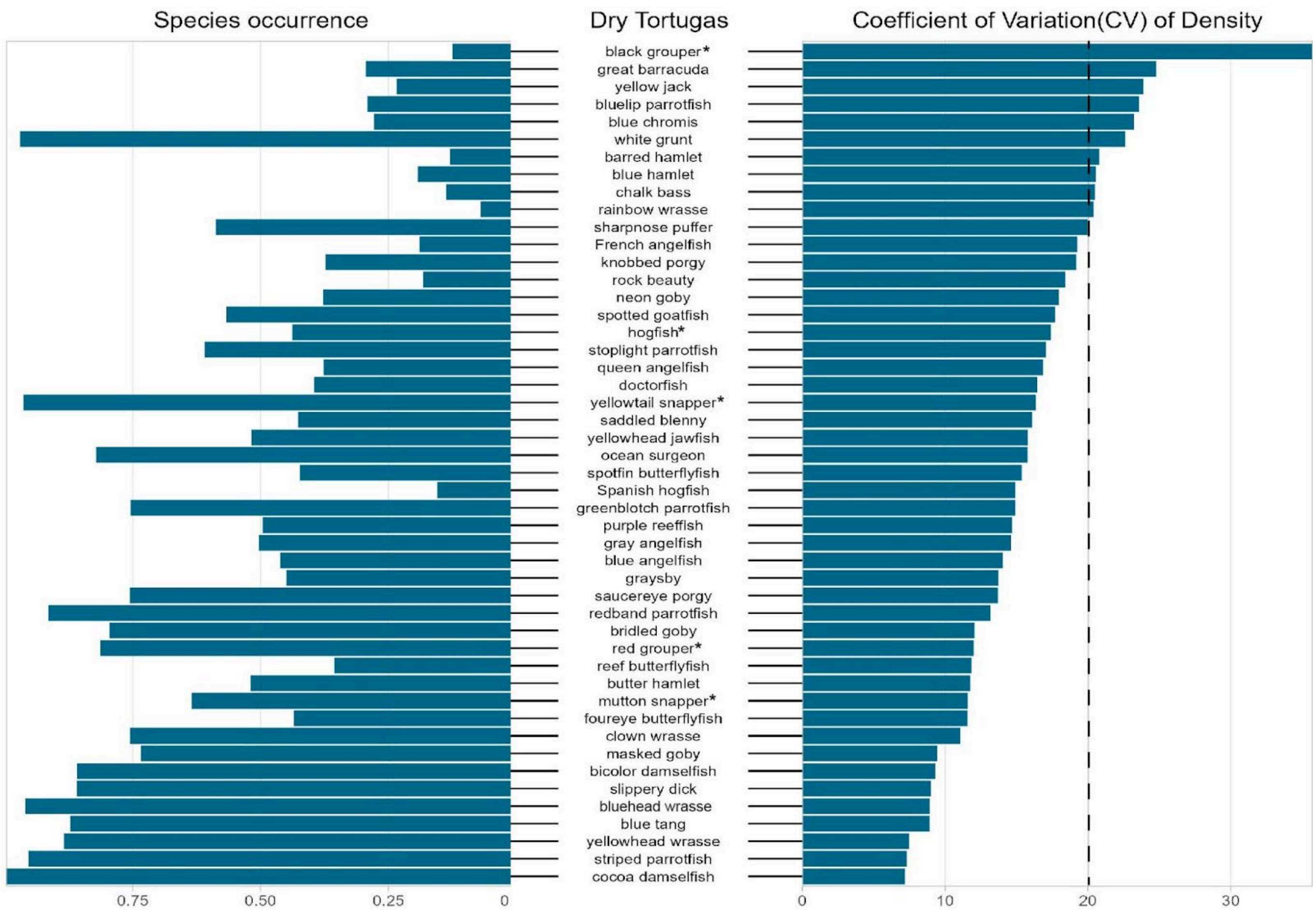


Figure 9. Occurrence of reef fish species with a coefficient of variation (CV) of density ≤ 25% and allocation species (*). Species are sorted by increasing CV of density in the Dry Tortugas, Florida in 2022. Dashed vertical line on the CV plot indicates the target CV of 20%.

Density

NCRMP's comprehensive sampling design strategy provides a broad, population-level perspective on the reef fish community. The fish community along Florida's coral reef is composed of fishery target and non-target species ranging from small, cryptic (e.g., gobies [Gobiidae], jawfish [Opistognathidae]) to larger, mobile fishes (e.g., great barracuda), and spans all trophic levels (Figure 10). NCRMP surveys capture a snapshot of these coral reef fish populations. Reporting temporal trends provides a comprehensive perspective of changes in reef fish populations. In particular, trend data can provide insight into how fishery target species respond to management actions including spatial management (e.g., national park boundaries, SPAs), fishing regulations (e.g., minimum size at capture, bag limits, and gear limitations), and natural events (e.g., hurricanes, El Niño).

Southeast Florida

In Southeast Florida, fishery target species, such as gray triggerfish, and non-target species, such as doctorfish (*Acanthurus chirurgus*) and yellowhead wrasse (*Halichoeres garnoti*), are common and numerous (Figure 10).

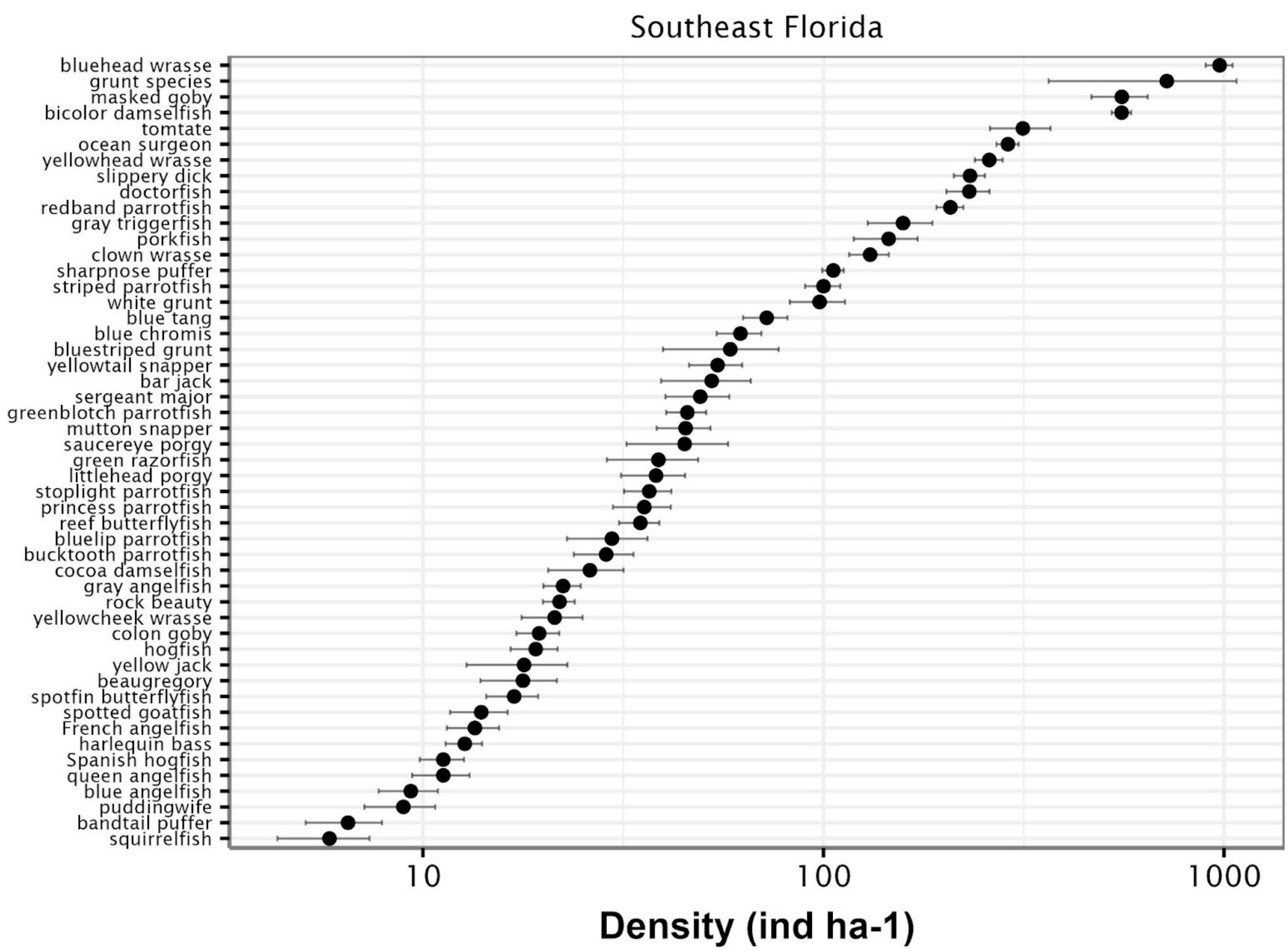


Figure 10. Mean density in Southeast Florida in 2022 of the top 50 (by occurrence) reef fish species. Fish densities (± SE) are presented on a log scale and show the number of fish per hectare.

Southeast Florida does not have any national parks or marine reserves that limit extractive fishing practices. Figure 11 shows statistical comparisons in density between 2018 and 2022 for the Southeast Florida reef tract (i.e., outside protection) for four species: hogfish, red grouper, mutton snapper, and yellowtail snapper. A significant difference in density was detected for hogfish between the 2018 and 2022 survey years.

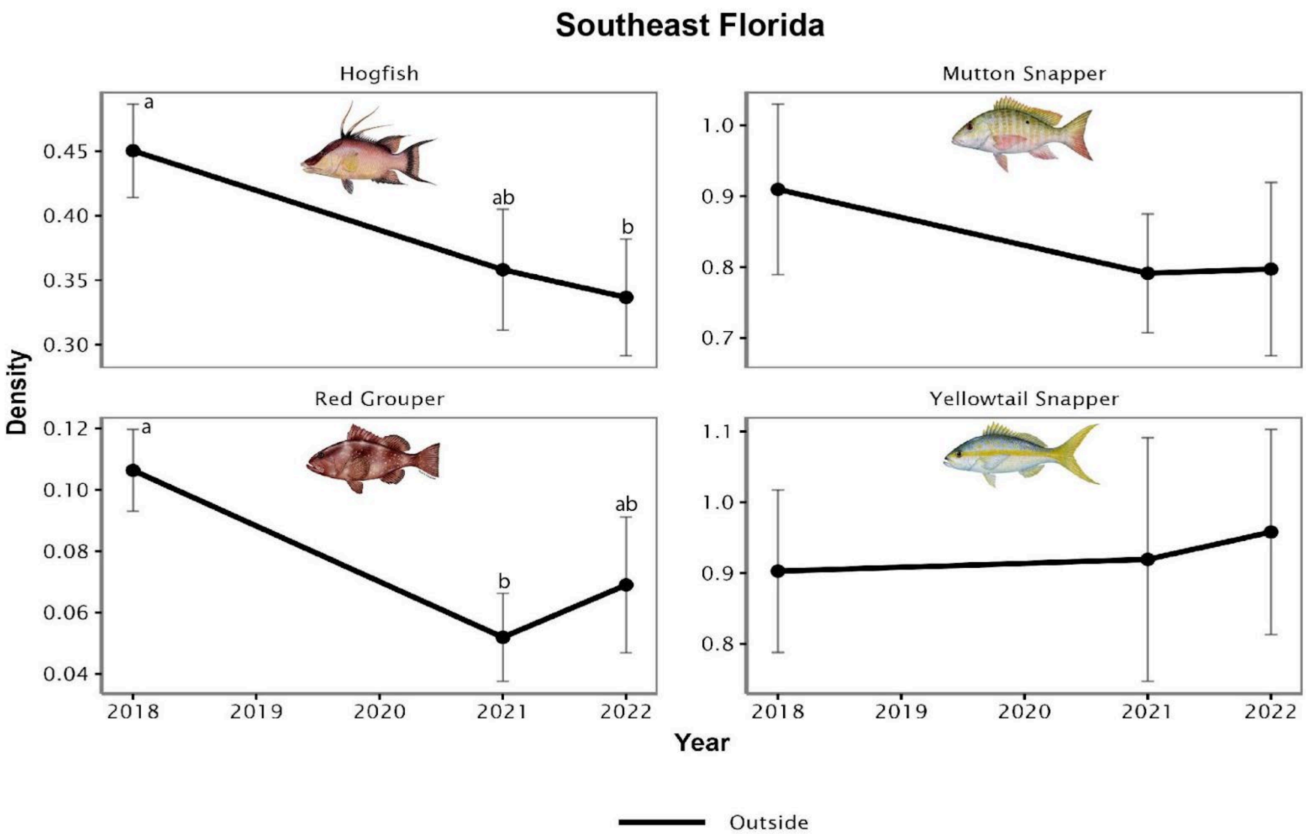


Figure 11. Density of hogfish, red grouper, mutton snapper, and yellowtail snapper by NCRMP survey year (2018 to 2022) in Southeast Florida. Densities are reported as the number of individuals per 177 $m^2 \pm$ SE, represent all life stages, and statistical significance (Tukey's two-tailed test), if present, is reported at $p < 0.05$ and different letters (i.e., a, b) denote differences between survey years. Note: y-axis varies by species.

Florida Keys

In the Florida Keys, the mean density (individuals ha-1) for the top 50 species by occurrence and fishery targeted species, such as yellowtail snapper, and non-targeted species, such as bluehead wrasse and striped parrotfish, are common and numerous (Figure 12).

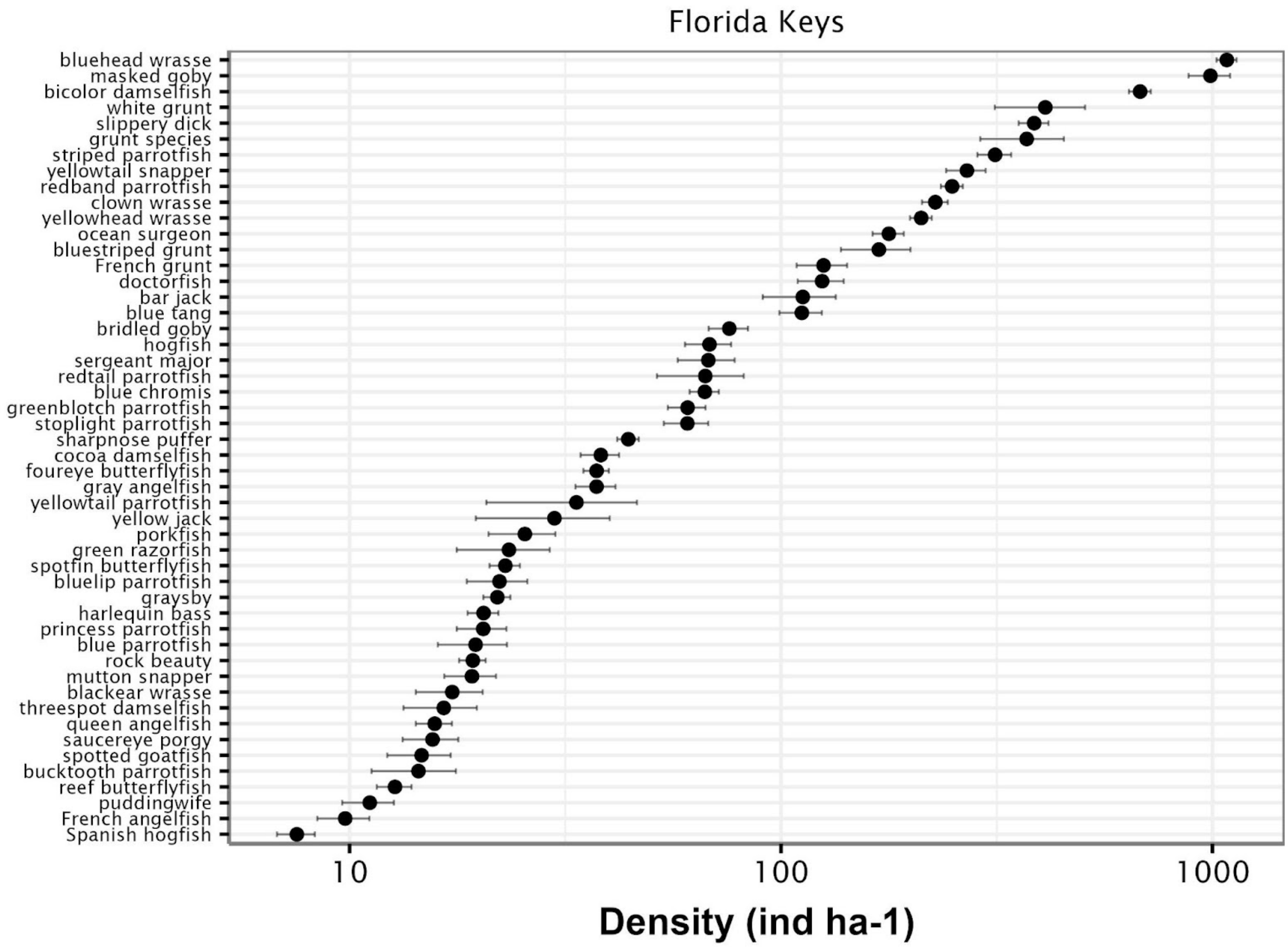


Figure 12. Mean density in the Florida Keys in 2022 of the top 50 (by occurrence) reef fish species. Fish densities (± SE) are presented on a log scale and show the number of fish per hectare.

The suite of allocation species (Table 2) is a representative and diverse group of fishery target species consisting of a snapper, grouper, and hogfish that are consistently observed in high enough numbers to detect change. The difference between inside (SPAs) and outside spatially managed areas was analyzed and two species, mutton snapper and hogfish, showed a significant difference in the Florida Keys (Table 2).

Table 2. Density of fishery target allocation species in the Florida Keys, both inside and outside of the SPAs in 2022. Densities are reported as number of individuals per 177 m^2 (± SE) and represent all life stages, and significance was accepted at $p < 0.05$ (*).

	Florida Keys		
Species	*Outside*		*Inside*
Red Grouper	**0.10** (0.02)		**0.10** (0.04)
Black Grouper	**0.06** (0.01)		**0.06** (0.02)
Mutton Snapper	**0.34** (0.05)	*	**0.18** (0.05)
Yellowtail Snapper	**4.70** (0.52)		**5.95** (0.73)
Hogfish	**1.22** (0.15)	*	**0.85** (0.13)

An NCRMP time series is shown for 2014 to 2022 for four species: hogfish, red grouper, mutton snapper, and yellowtail snapper and includes statistical comparisons, tested individually for each protected status (i.e., inside and outside of FKNMS protected areas), in density between adjacent years (Figure 13). Significant differences varied among species, between survey years, and between protection levels. For example, hogfish had significantly lower densities both inside and outside the protected areas in the most recent survey year (2022) compared to the first year reported, while yellowtail snapper densities were similar in 2014 and 2022 inside and outside of the protected areas (Figure 13).

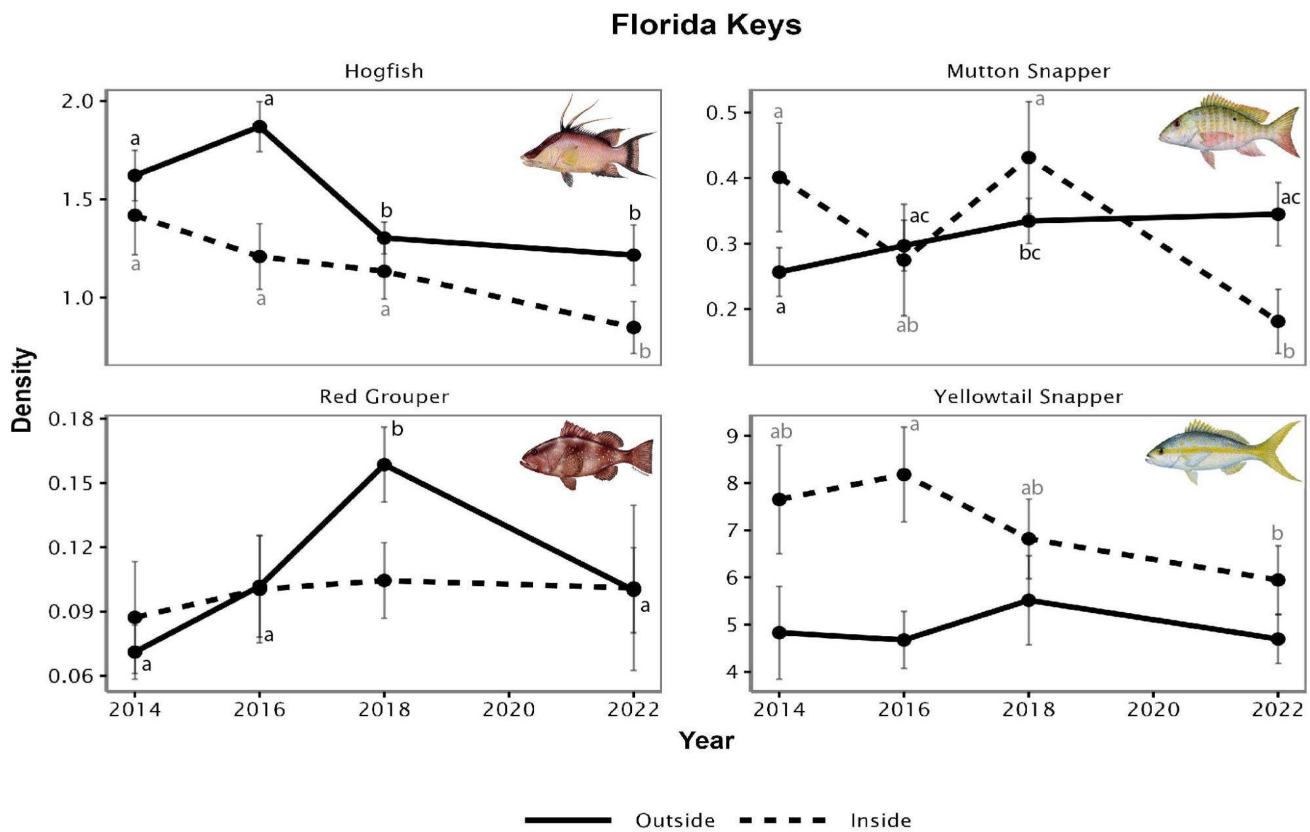


Figure 13. Density of hogfish, red grouper, mutton snapper, and yellowtail snapper by NCRMP survey year (2014 to 2022) in the Florida Keys. Densities are reported as the number of individuals per 177 m^2 ± SE and represent all life stages, and statistical significance (Tukey's two-tailed t-test), if present, is reported at $p < 0.05$, and different letters (i.e., a, b, c) denote a difference between survey years within each protected status. Protected status refers to sites inside (dashed line) or outside (solid line) of the Sanctuary Preservation Areas (SPAs). Note: y-axis varies by species.

Dry Tortugas

In the Dry Tortugas, the mean density (individuals ha-1) for the top 50 species by occurrence and fishery targeted species, such as yellowtail snapper, and non-targeted species, such as bluehead wrasse (*Thalassoma bifasciatum*) and striped parrotfish, are common and numerous (Figure 14).

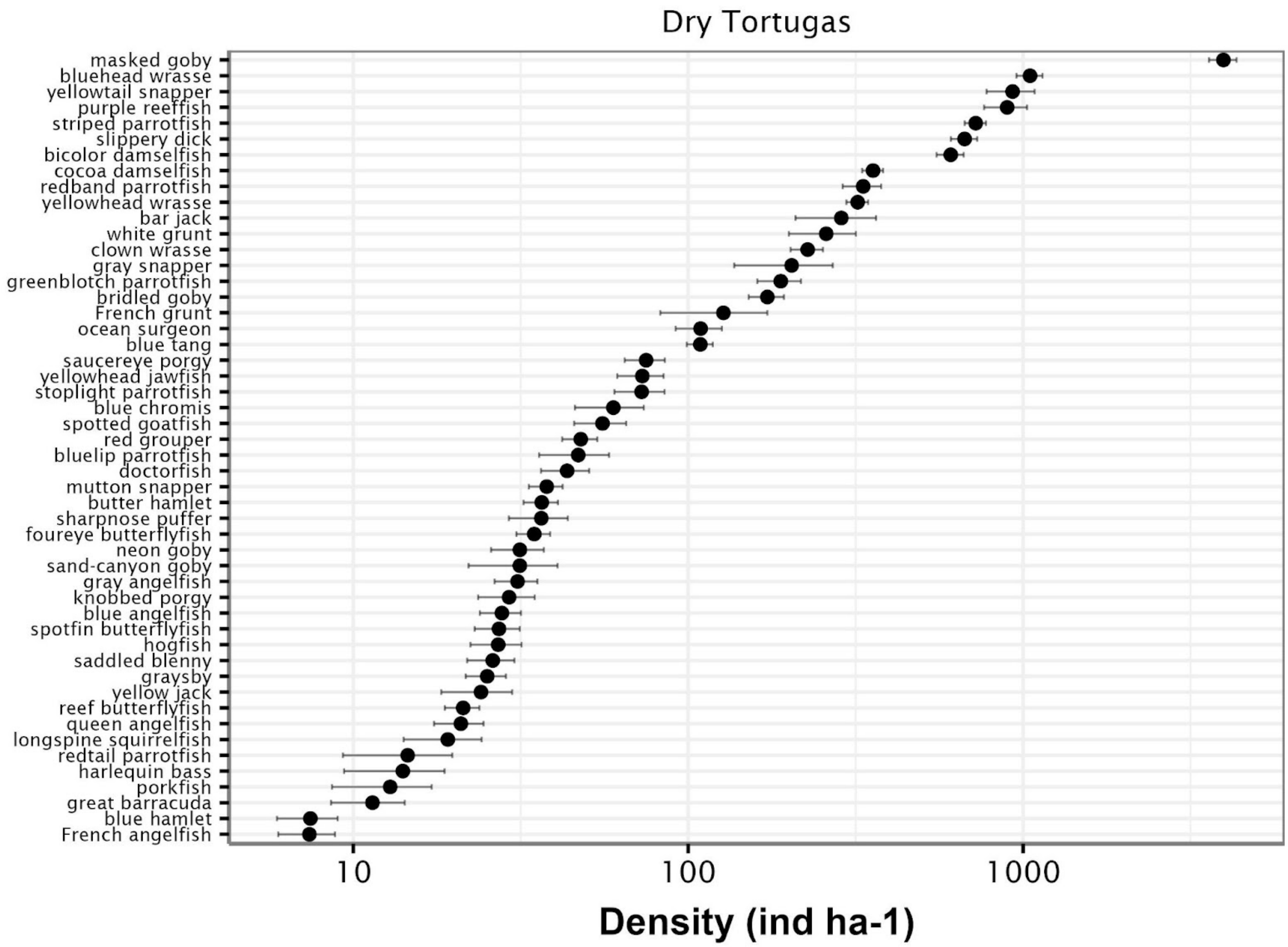


Figure 14. Mean density in the Dry Tortugas in 2022 of the top 50 (by occurrence) reef fish species. Fish densities (± SE) are presented on a log scale and show the number of fish per hectare.

The suite of allocation species (Table 3) is a representative and diverse group of fishery target species consisting of snapper, grouper, and hogfish that are consistently observed in high enough numbers to detect change. The difference between inside (Tortugas Ecological Reserve – North and DRTO) and outside spatially managed areas was analyzed, and two species, black grouper and mutton snapper, showed a significant difference in the Dry Tortugas (Table 3).

Table 3. Density of fishery target allocation species in the Dry Tortugas, both inside and outside of the Tortugas Ecological Reserve – North and Dry Tortugas National Park boundaries in 2022. Densities are reported as number of individuals per 177 m^2 (± SE) and represent all life stages, and significance was accepted at $p < 0.05$ (*).

	Dry Tortugas		
Species	*Outside*		*Inside*
Red Grouper	**0.90** (0.21)		**0.82** (0.11)
Black Grouper	**0.03** (0.02)	*	**0.12** (0.05)
Mutton Snapper	**0.24** (0.11)	*	**0.76** (0.09)
Yellowtail Snapper	**15.57** (4.90)		**16.56** (3.10)
Hogfish	**0.41** (0.13)		**0.49** (0.10)

Figure 15 shows statistical comparisons, tested individually for each protected status (i.e., inside and outside), in density between adjacent years for four species: hogfish, red grouper, mutton snapper, and yellowtail snapper. Significant differences varied among species, between years, and between protection levels; results may change when 2023 surveys are added to the Dry Tortugas dataset.

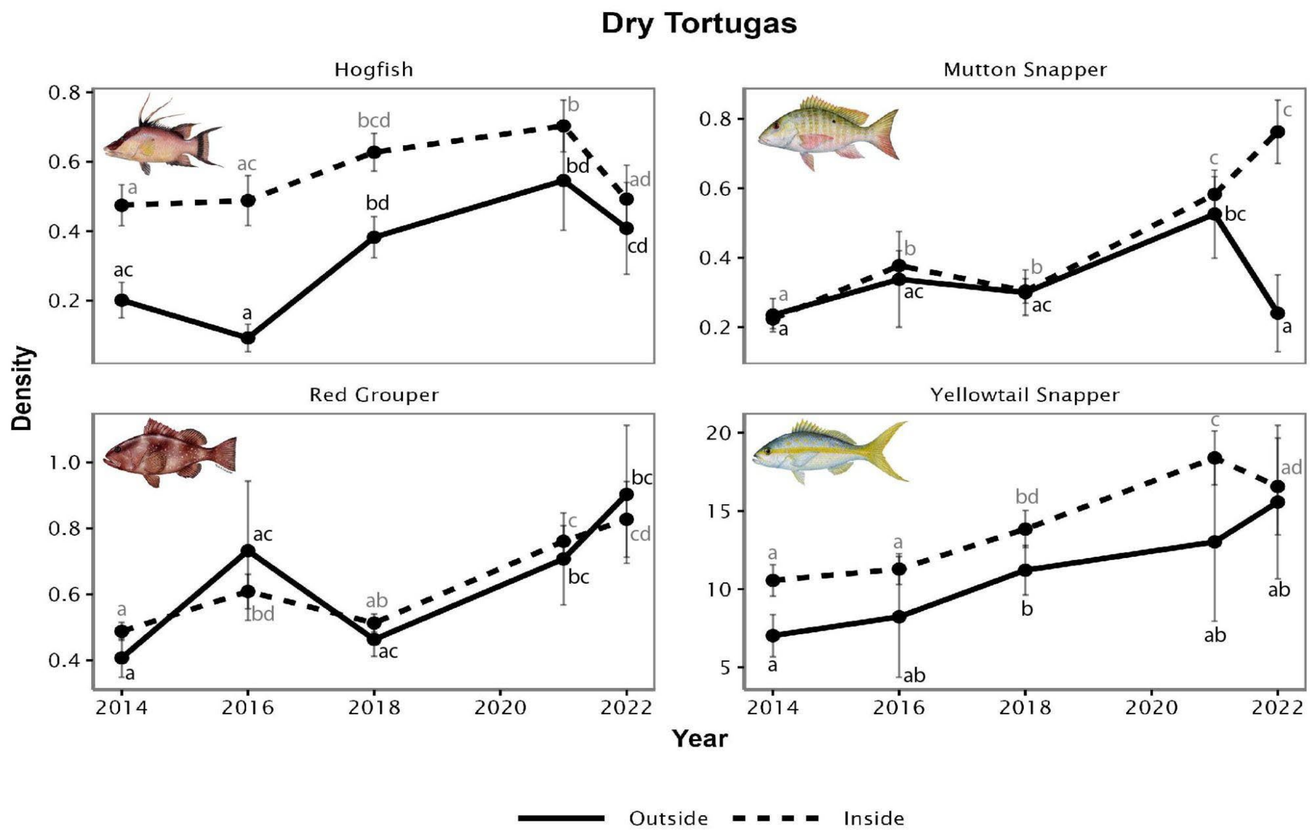


Figure 15. Density of hogfish, red grouper, mutton snapper, and yellowtail snapper by NCRMP survey year (2014–2022) in the Dry Tortugas. Densities are reported as the number of individuals per 177 m^2 ± SE and represent all life stages, and statistical significance (Tukey's two-tailed t-test), if present, is reported at $p < 0.05$ and different letters (i.e., a, b, c, d) denote a difference between survey years within each protected status. Protected status refers to sites inside (dashed line) or outside (solid line) of the Tortugas Ecological Reserve – North and Dry Tortugas National Park boundary. Note: y-axis varies by species.

Length Frequency

Length compositions provide a detailed description of the population structure for a selected fish species. These highly informative figures can show the length at which a fish species recruits to the coral reef from their nursery habitat, length classes that are selected by the local recreational and commercial fisheries, and the success of some fisheries management regulations (e.g., minimum length of capture). In general, populations typically consist of more younger, smaller fish than older, larger fish, and once fishes fully recruit to coral reef habitat (i.e., survey area), each subsequent length class should have fewer observed fish. A primary goal of fisheries management is to maintain enough large, mature fish to support successful reproduction to ensure both the health of the stock and future of the fishery.

Southeast Florida

Figures 16 and 17 show length composition distributions for hogfish, yellowtail snapper, mutton snapper, and red grouper for the sampling that occurred in 2022. Hogfish were more regularly observed < 35 cm and infrequently observed > 40 cm, the minimum length of capture in Florida state waters (Figure 16). This was similar for yellowtail snapper (< 30 cm) and red grouper (< 50 cm), which were frequently observed below their minimum length at captures (30 cm and 50 cm, respectively) and infrequently observed at larger sizes (Figure 17).

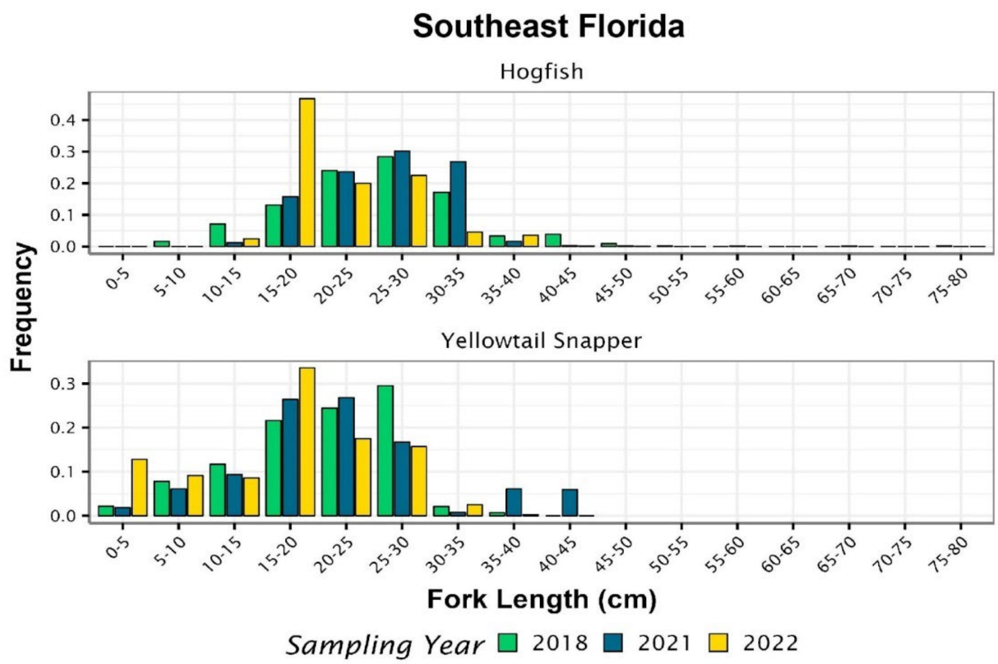


Figure 16. Relative length frequency of selected fishery target species hogfish (top) and yellowtail snapper (bottom) in Southeast Florida for the three most recent NCRMP sample years . Note: y-axis varies by species.

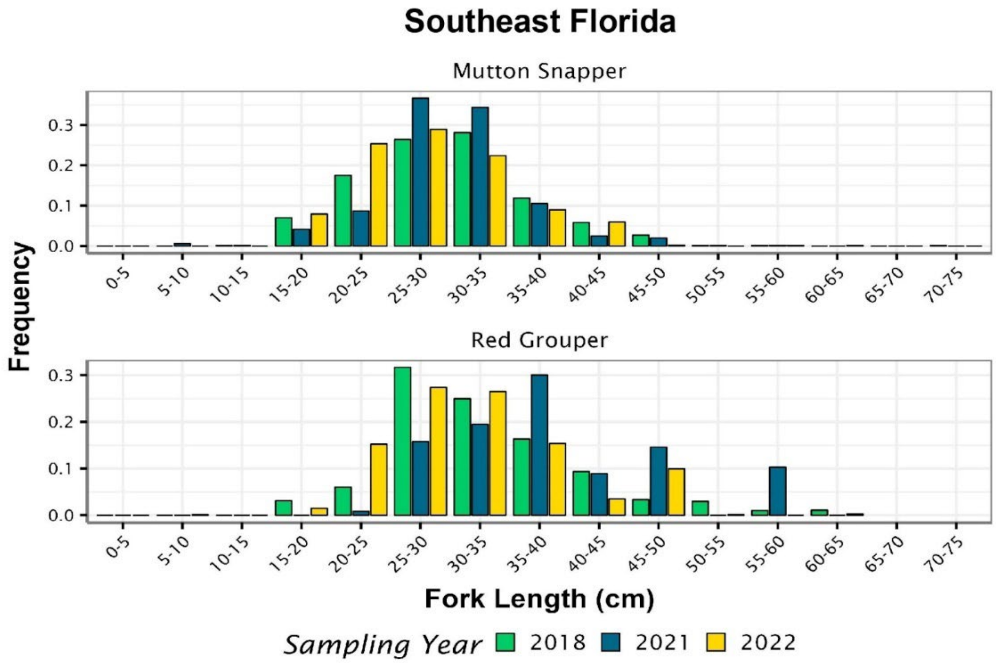


Figure 17. Relative length frequency of selected fishery target species mutton snapper (top) and red grouper (bottom) in Southeast Florida for the three most recent NCRMP sample years.

Florida Keys

Figures 18 and 19 show length composition distributions for hogfish, yellowtail snapper, mutton snapper, and red grouper for the sampling that occurred in 2022. Hogfish were more regularly observed < 35 cm and infrequently observed > 40 cm, the minimum length of capture in Florida state waters (Figure 18). This was similar for yellowtail snapper, which was frequently observed below its minimum length at capture (30 cm), and observations > 30 cm were limited. In contrast, while red grouper was more frequently observed below < 50 cm, comparatively more individuals were observed above their minimum length of capture (> 50 cm) (Figure 19).

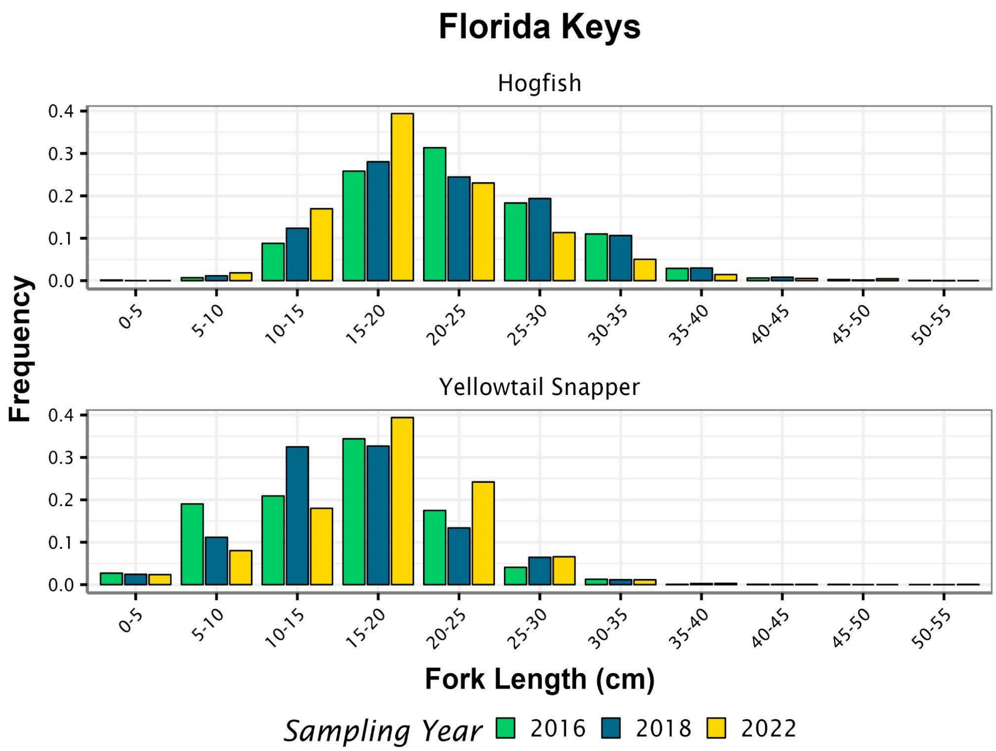


Figure 18. Relative length frequency of selected fishery target species hogfish (top) and yellowtail snapper (bottom) in the Florida Keys for the three most recent NCRMP sample years.

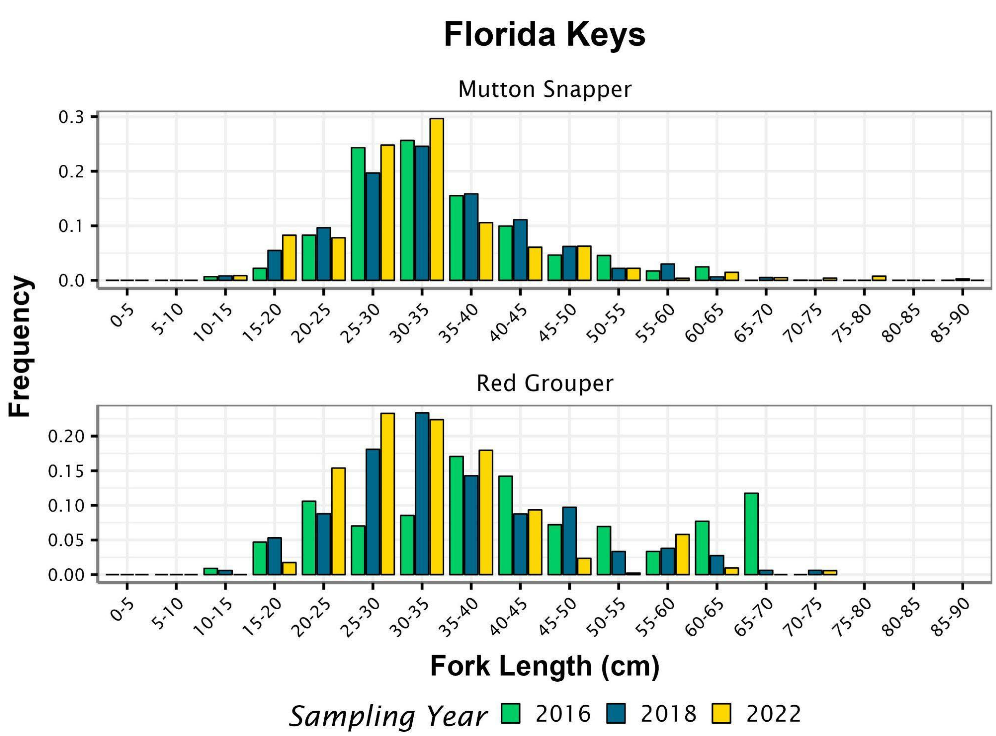


Figure 19. Relative length frequency of selected fishery target species mutton snapper (top) and red grouper (bottom) in the Florida Keys for the three most recent NCRMP sample years. Note: y-axis varies by species.

Dry Tortugas

Figures 20 and 21 show length composition distributions for hogfish, yellowtail snapper, mutton snapper, and red grouper for the sampling that occurred in 2022. The Dry Tortugas figures are preliminary; results may change as additional data collected in 2023 in this region are incorporated.

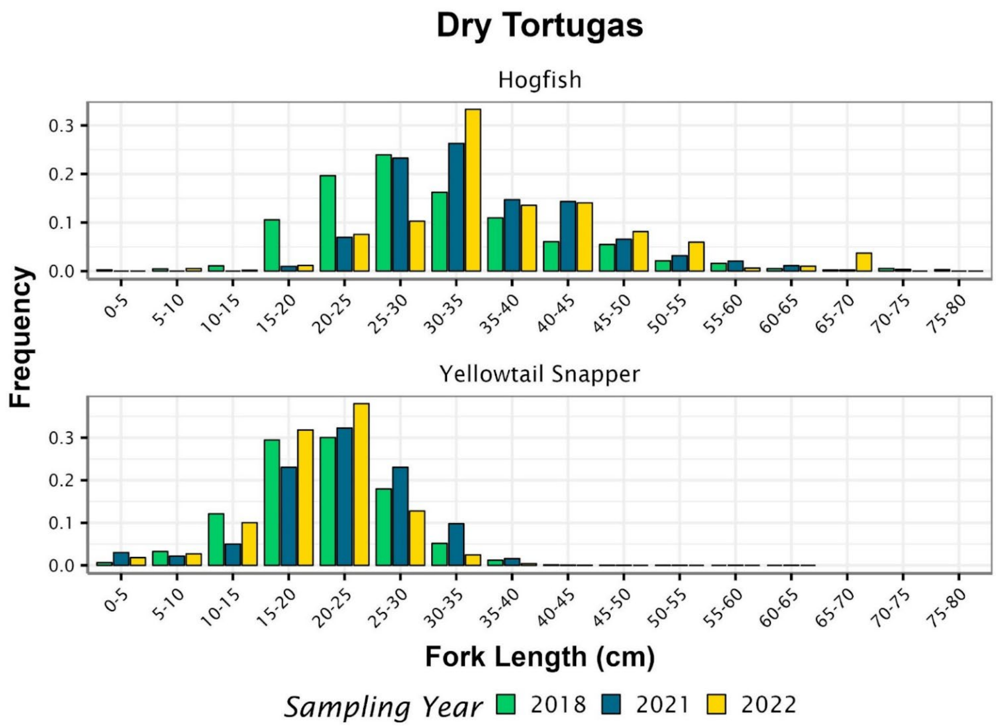


Figure 20. Relative length frequency of selected fishery target species hogfish (top) and yellowtail snapper (bottom) in the Dry Tortugas for the three most recent NCRMP sample years.

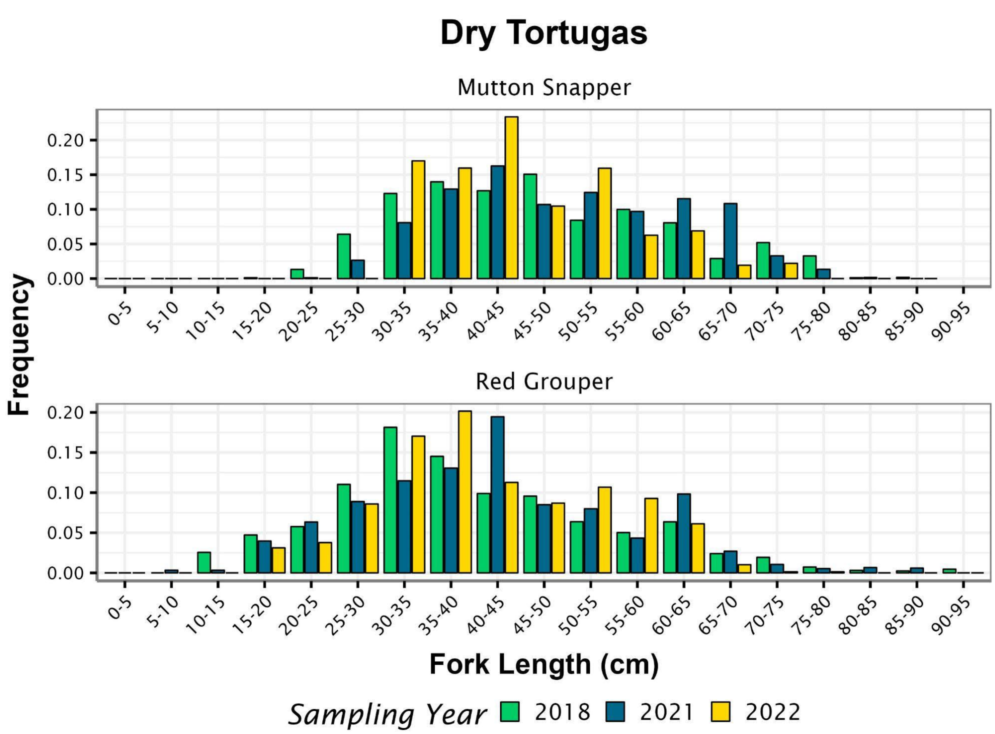


Figure 21. Relative length frequency of selected fishery target species mutton snapper (top) and red grouper (bottom) in the Dry Tortugas for the three most recent NCRMP sample years.

II. Corals and Benthic Communities

Overall coral cover has declined in each region since 2014, and macroalgal cover has varied between years (Figure 22). SCTLD has continued to spread across the entirety of Florida's coral reef tract from first detection in Southeast Florida in 2014 (Precht et al., 2016), in the Florida Keys in 2016 (Muller et al., 2020), and in the Dry Tortugas in 2021 (Grove et al., 2022; Dry Tortugas National Park, 2022). Coral disease, dominated by SCTLD, was widespread in the Dry Tortugas in 2022 surveys (Figure 23; Stein and Ruzicka, 2023). SCTLD continues to persist and cause extensive coral mortality throughout Florida's reef tract. Collaborative efforts across the Atlantic and Caribbean are researching and addressing the outbreak of the disease (McLaughlin and Wusinich-Mendez, 2022).

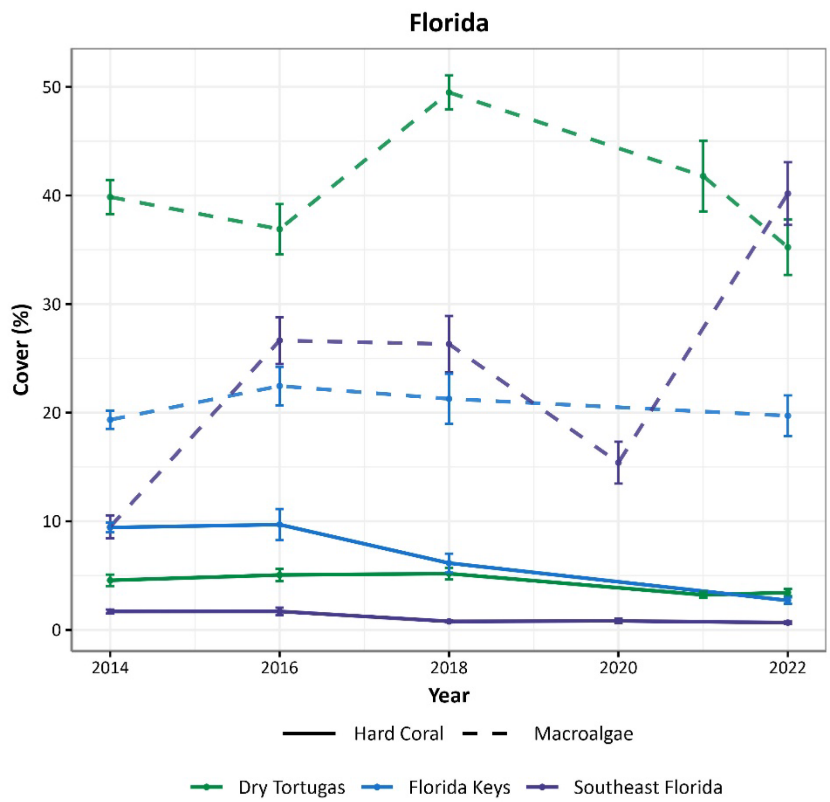


Figure 22. Overall cover (%) of corals (solid lines) and macroalgae (dashed lines) for each Florida region from 2014 to 2022 from NCRMP surveys.

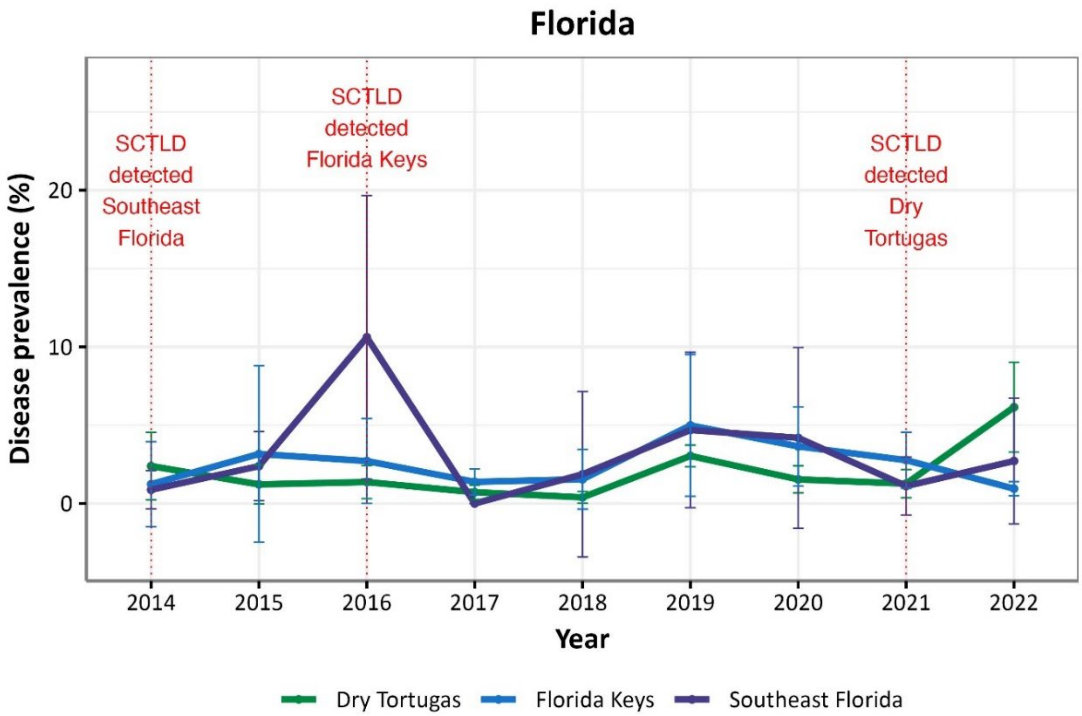


Figure 23. Mean prevalence (%) coral disease from 2014 to 2022 compiled from both NCRMP and DRM coral demographics data. Vertical dotted lines indicate when stony coral tissue loss disease (SCTLD) was first detected in each Florida region.

Coral and Macroalgal Cover

Southeast Florida

Mean coral cover in Southeast Florida has been consistently low over time since 2014 at < 2% with an additional decline observed between 2016 and 2018 (Figure 24). In 2022, mean coral cover was 0.67% ± 0.11. Macroalgae cover was highly variable between years (Figure 24). In 2022, macroalgae cover was 40.18% ± 2.89. However, macroalgae cover is strongly influenced by the timing of the sampling season, the habitat type surveyed, and the specific functional group or species of macroalgae.

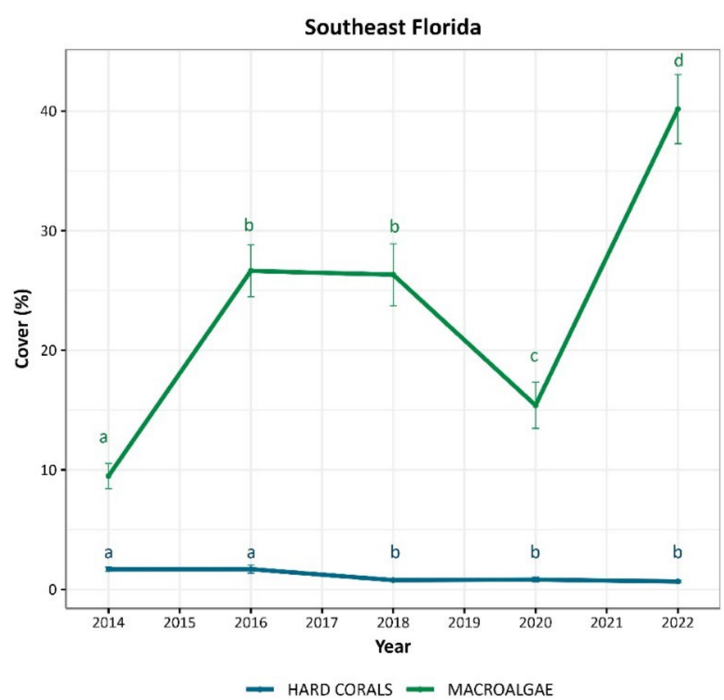


Figure 24. Mean coral and macroalgae percent cover ± SE in Southeast Florida from 2014 to 2022. Statistical significance (Tukey's two-tailed t-test), if present, is reported at $p < 0.05$, and different letters (i.e., a–d) denote a difference between survey years for hard coral and macroalgal cover, separately.

Florida Keys

In the Florida Keys, mean coral cover continued to decline (Figure 25). In 2022, mean coral cover was approximately 2.9% ± 0.29, a steep decline from 6.1% in 2018. Macroalgae did not significantly change between 2014–2022 (Figure 25). In 2022, macroalgae cover was 19.3% ± 1.86 (Figure 25). Results for 2020–2021 are not included due to the small sample size from Covid limitations.

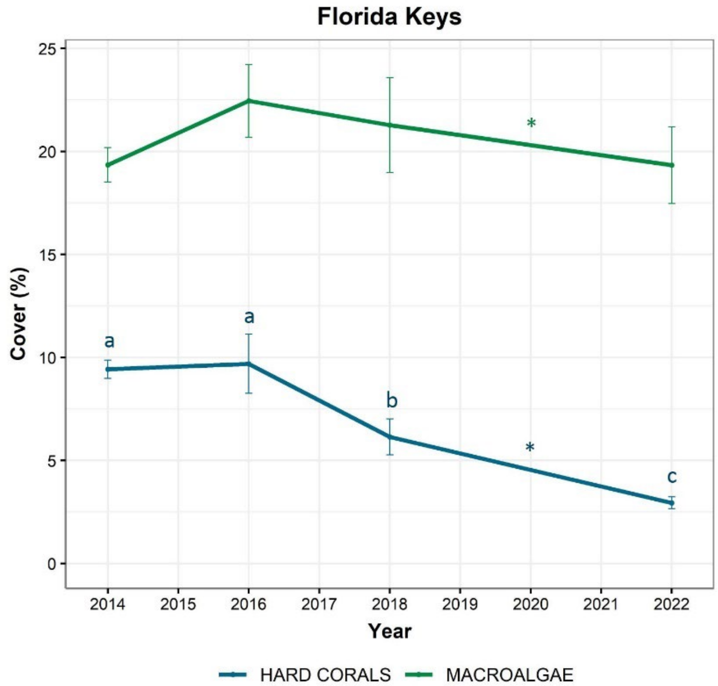


Figure 25. Mean coral and macroalgae percent cover ± SE in the Florida Keys from 2014 to 2022. Statistical significance (Tukey's two-tailed t-test), if present, is reported at $p < 0.05$, and different letters (i.e., a–d) denote a difference between survey years for hard coral and macroalgal cover, separately. An asterisk (*) indicates that insufficient sampling occurred due to Covid.

Dry Tortugas

In the Dry Tortugas, the mean cover of all coral species combined was consistently between 4%–5% from 2014 to 2018, but it declined significantly in 2021 and was approximately 3.4% ± 0.3 in 2022 (Figure 26). Macroalgae cover was variable but high (Figure 26). In 2022, macroalgae cover was 35.2% ± 2.6. However, macroalgae cover is strongly influenced by the timing of the sampling season, the habitat type surveyed, and the specific functional group or species of macroalgae.

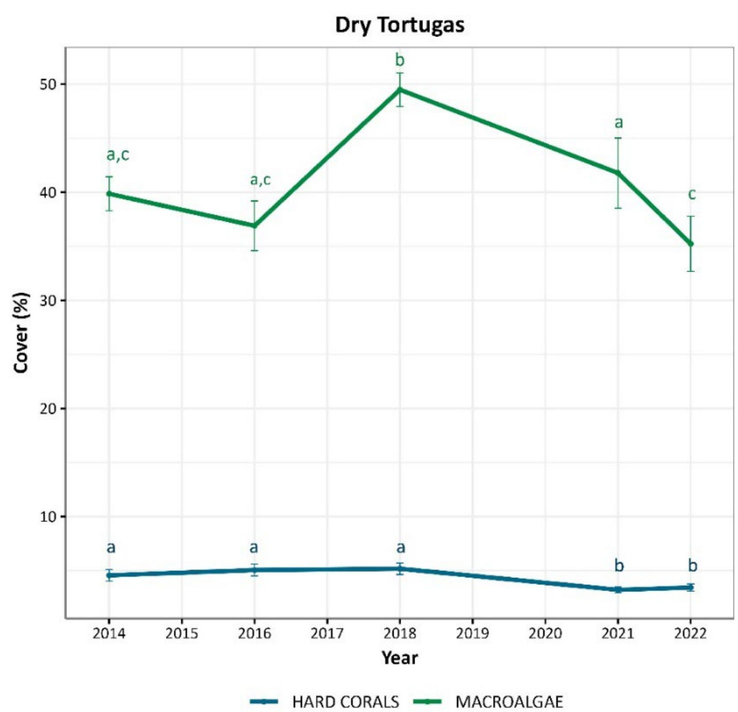


Figure 26. Mean coral and macroalgae percent cover ± SE in the Dry Tortugas from 2014 to 2022. Statistical significance (Tukey's two-tailed t-test), if present, is reported at $p < 0.05$, and different letters (i.e., a–c) denote a difference between survey years for hard coral and macroalgal cover, separately.

Species Occurrence

More coral species than the allocation species have CVs of density that are less than 20%. A 20% CV of density can be translated to the ability to statistically detect a 40% change. As coral species continue to decline from threats such as SCTLD, the frequency of occurrence declines, and more surveys are required to achieve a 20% CV.

Southeast Florida

For NCRMP in Southeast Florida in 2020, seven individual species had CVs of 20% or less: *Agaricia fragilis*, *Agaricia lamarcki*, *Madracis decactis*, *P. astreoides*, *Siderastrea radians*, *S. siderea*, *Stephanocoenia intersepta* (Figure 27). Of the six coral species used in allocations, four had a CV of 20% or less (*M. cavernosa*, *P. astreoides*, *P. strigosa*, *S. siderea*), and two did not meet CV targets (*M. meandrites*, *O. faveolata*). The most commonly encountered coral species were *S. siderea*, *P. astreoides*, *M. cavernosa*, and *S. intersepta* (Figure 27).

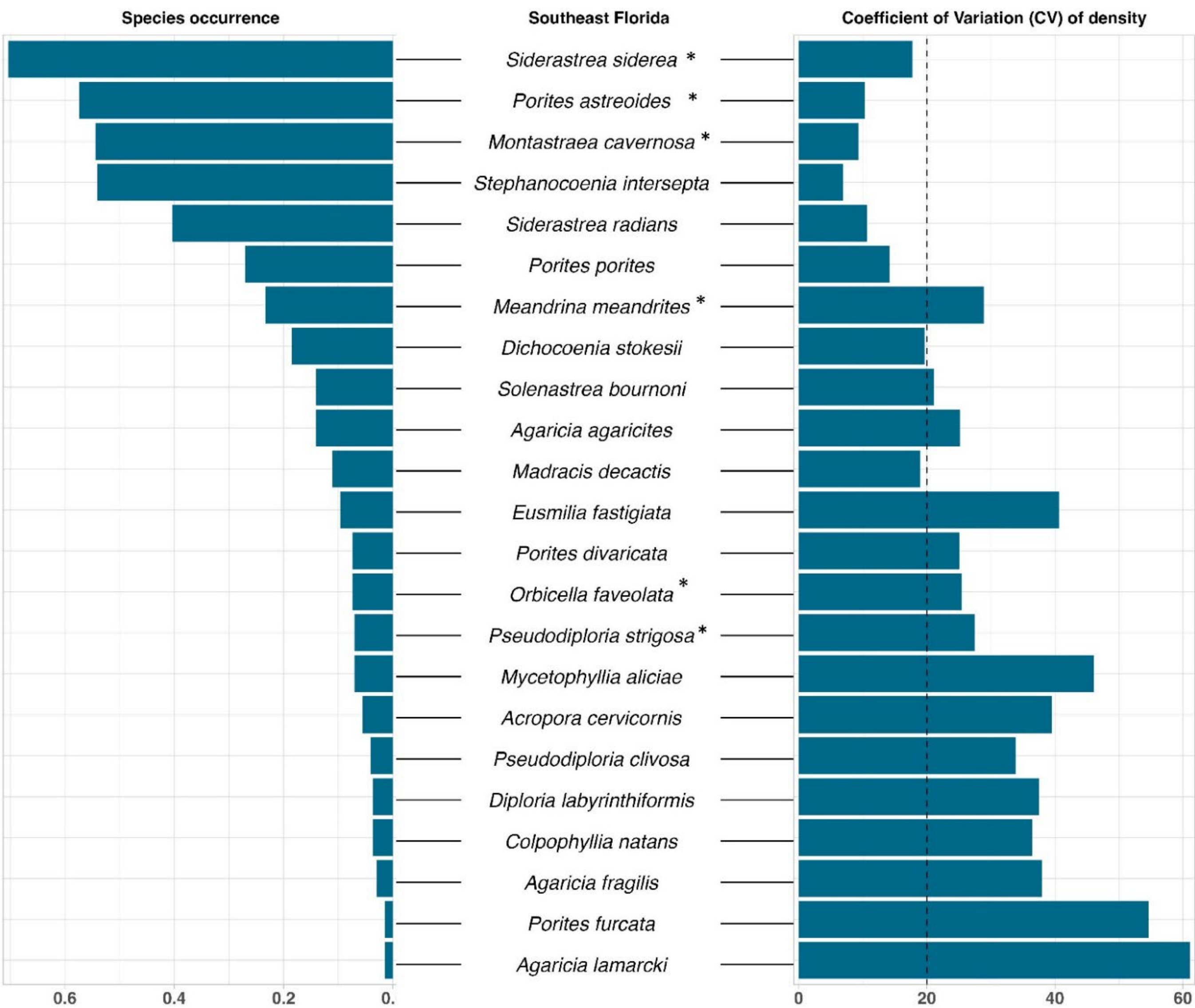


Figure 27. Coral species occurrence and coefficient of variation (CV) of density in coral demographics surveys in Southeast Florida in 2022. Species with an occurrence less than 0.01 are not shown. An asterisk (*) indicates the species was used in allocations. NCRMP and DRM data are included. Note: x-axis scale varies by metric.

Florida Keys

For the Florida Keys in 2022, eleven coral species met CV targets of 20% or less (Figure 28), based on combined NCRMP and DRM coral demographics data. All allocated species, except for *C. natans* and *P. strigosa*, met the CV targets*.* The coral species most commonly encountered were *S. siderea*, *P. astreoides*, *M. cavernosa*, and *S. intersepta* (Figure 28).

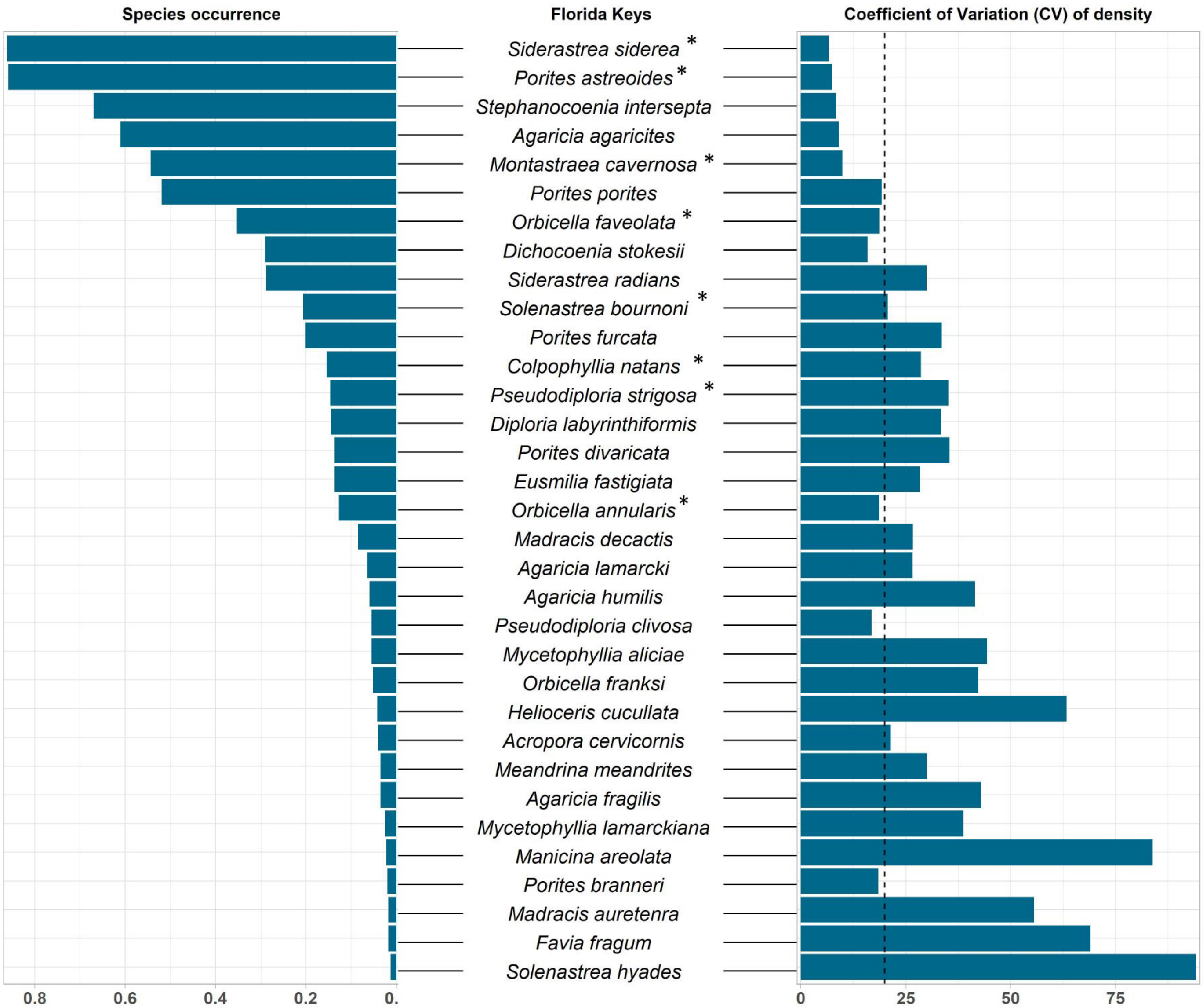


Figure 28. Coral species occurrence and coefficient of variation (CV) of density in coral demographics surveys in the Florida Keys in 2022. Species with an occurrence less than 0.01 are not shown. An asterisk (*) indicates the species was used in allocations. NCRMP and DRM data are included. Note: x-axis scale varies by metric.

Dry Tortugas

In the Dry Tortugas in 2022, 18 coral species had CVs of 20% or less based on combined NCRMP and DRM coral demographics data (Figure 29). All allocated species, except for *O. annularis*, had a CV of 20% or less, as did other species, including common species (e.g., *P. astreoides*). Only one *O. annularis* was surveyed in the Dry Tortugas in 2022; this may be related to a lower number of samples than normal on Tortugas Bank due to weather during the NCRMP benthic cruise (Figure 5. The coral species most commonly encountered were *S. siderea, P. astreoides*, *M. cavernosa*, and *S. intersepta* (Figure 29).

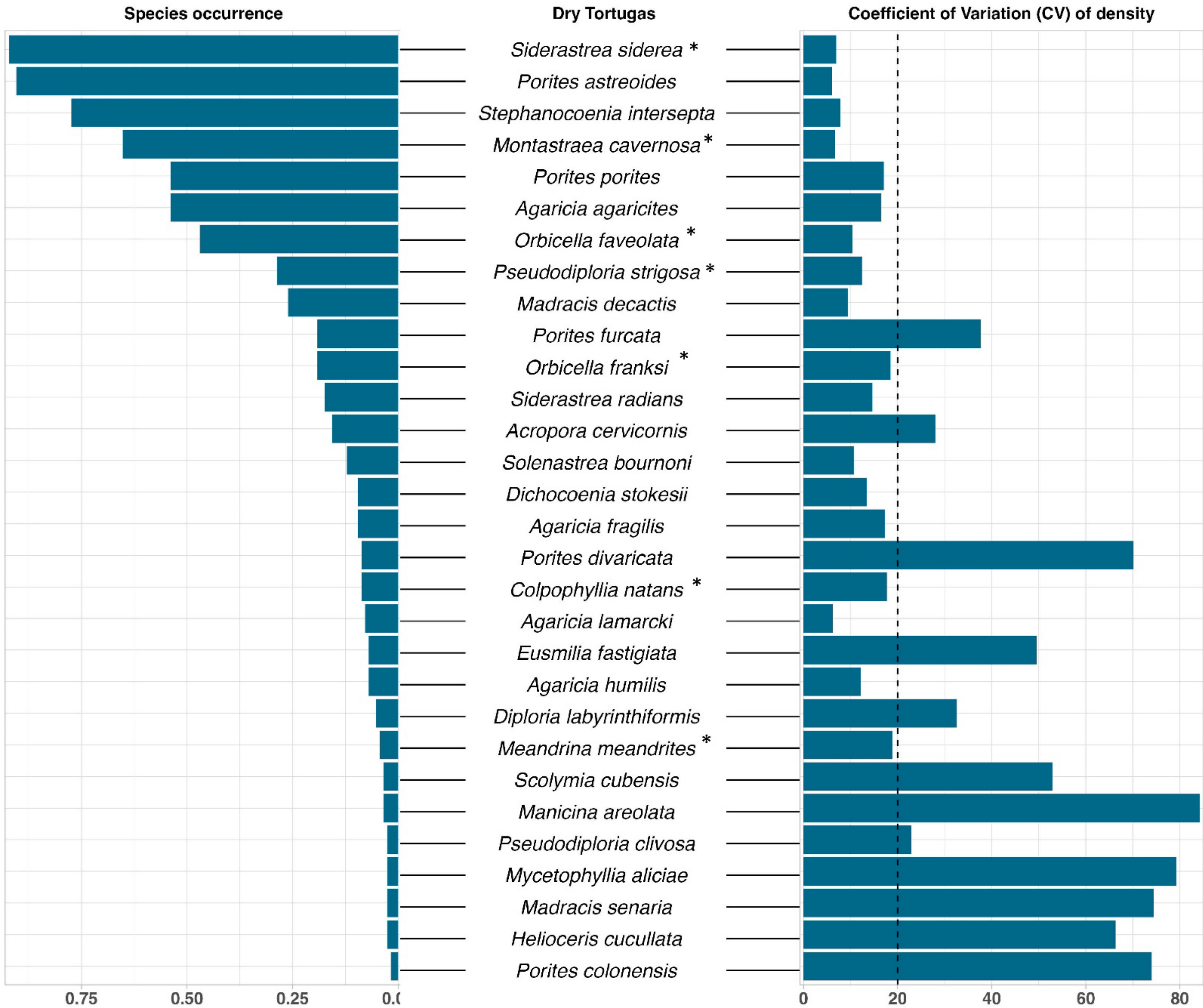


Figure 29. Coral species occurrence and coefficient of variation (CV) of density in coral demographics surveys in the Dry Tortugas in 2022. Species with an occurrence less than 0.01 are not shown. An asterisk (*) indicates the species was used in allocations. NCRMP and DRM data are included. Note: x-axis scale varies by metric.

Density and Size Composition

Colony size and mortality are important components of colony density. When partial mortality (either recent or old) increases on a coral colony to full mortality (100%), the completely dead coral colony is no longer part of the population, and, as such, is not included in NCRMP surveys. Coral mortality is a primary cause of declining coral density.

The subset of species shown in size composition figures was selected based on CV, ESA status, SCTLD susceptibility, and ecological value (e.g., reef building capability) for each region. Size composition figures are length frequency distributions using maximum diameter. Size compositions provide a detailed description of the population structure of a selected coral species and reflect the combination of demographic processes of recruitment, growth, and survival. Over time, coral colonies can remain in the same skeletal length class (due to partial mortality of coral tissue), transition to a larger length class (tissue survival and skeletal growth), or suffer total mortality over time (no longer surveyed). Individual colonies move backwards over time to a smaller size class only if colonies fragment. These highly informative figures can show juvenile input (growth and survival) to the adult length classes (≥ 4 cm), colonies that remain within length classes due to partial mortality, and the end result of growth and survival to larger sizes. Peak frequency in medium size length classes could signify a decrease in juvenile input into smaller size classes, a previous (episodic) recruitment event that resulted in large juvenile input into the population, or an accumulation of colonies over time due to partial mortality. Missing size classes may have resulted from a historical event where colonies suffered total mortality, cumulative effects of partial mortality, or a period of no recruitment into the adult population (Underwood and Koegh, 2001). In general, populations typically consist of a higher frequency of younger, smaller corals than older, larger colonies, and each subsequent length class normally has fewer observed corals.

Southeast Florida

In Southeast Florida, the mean density of corals has declined significantly since 2014 (Figure 30) and was 0.6 ± 0.04 corals/m^2 in 2022. Old mortality was variable between years, although the trend was relatively consistent with that of coral density until the increase in 2022 (Figure 30). Old mortality was 12.5% ± 2.38 in 2022.

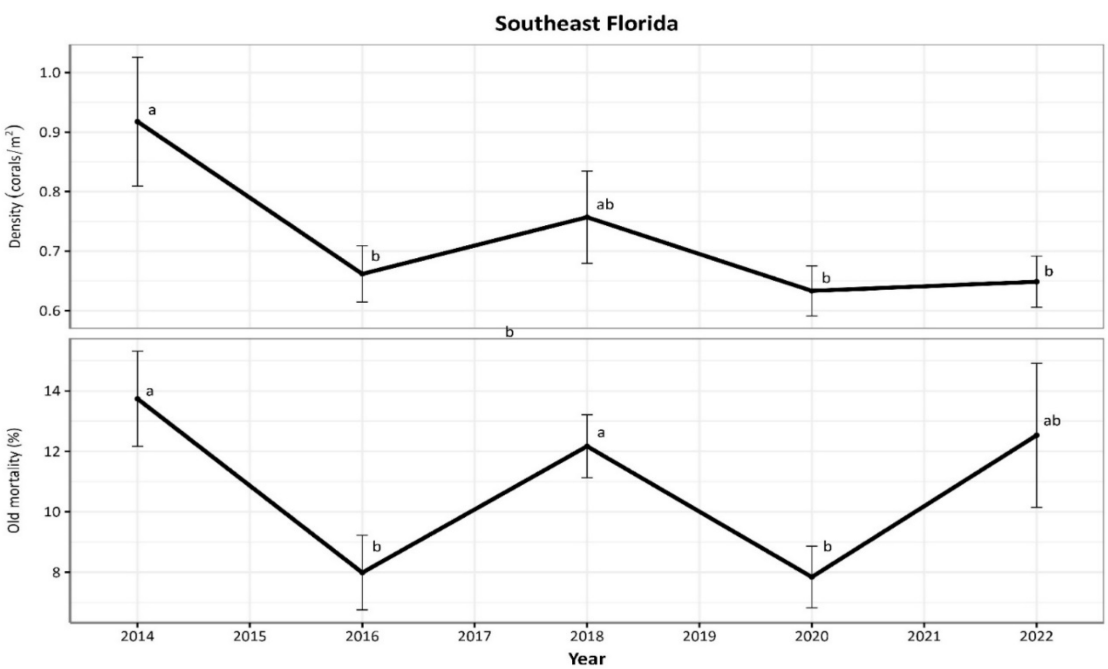


Figure 30. Mean coral density (corals/m^2; top) and old mortality (%; bottom) ± SE from 2014 to 2022 in Southeast Florida. Statistical significance (Tukey's two-tailed t-test), if present, is reported at $p < 0.05$, and different letters (i.e., a, b) denote a difference between survey years. NCRMP and DRM data are included. Note differences in y-axis scales.

In Southeast Florida in 2022, coral density was dominated by *S. siderea*, followed by *P. astreoides*, *S. intersepta*, *M. cavernosa*, and *S. radians* (Figure 31). The largest coral species by maximum skeletal dimension were *O. faveolata*, *M. cavernosa*, and *P. strigosa* (all between approximately 20–35 cm), and colonies of these species also had a relatively high percentage (approximately 10%–35%) of old mortality, as did *S. intersepta* and *P. clivosa*. *S. intersepta* and *Porites furcata* had a relatively high percentage (approximately 1%–3.5%) of recent mortality.

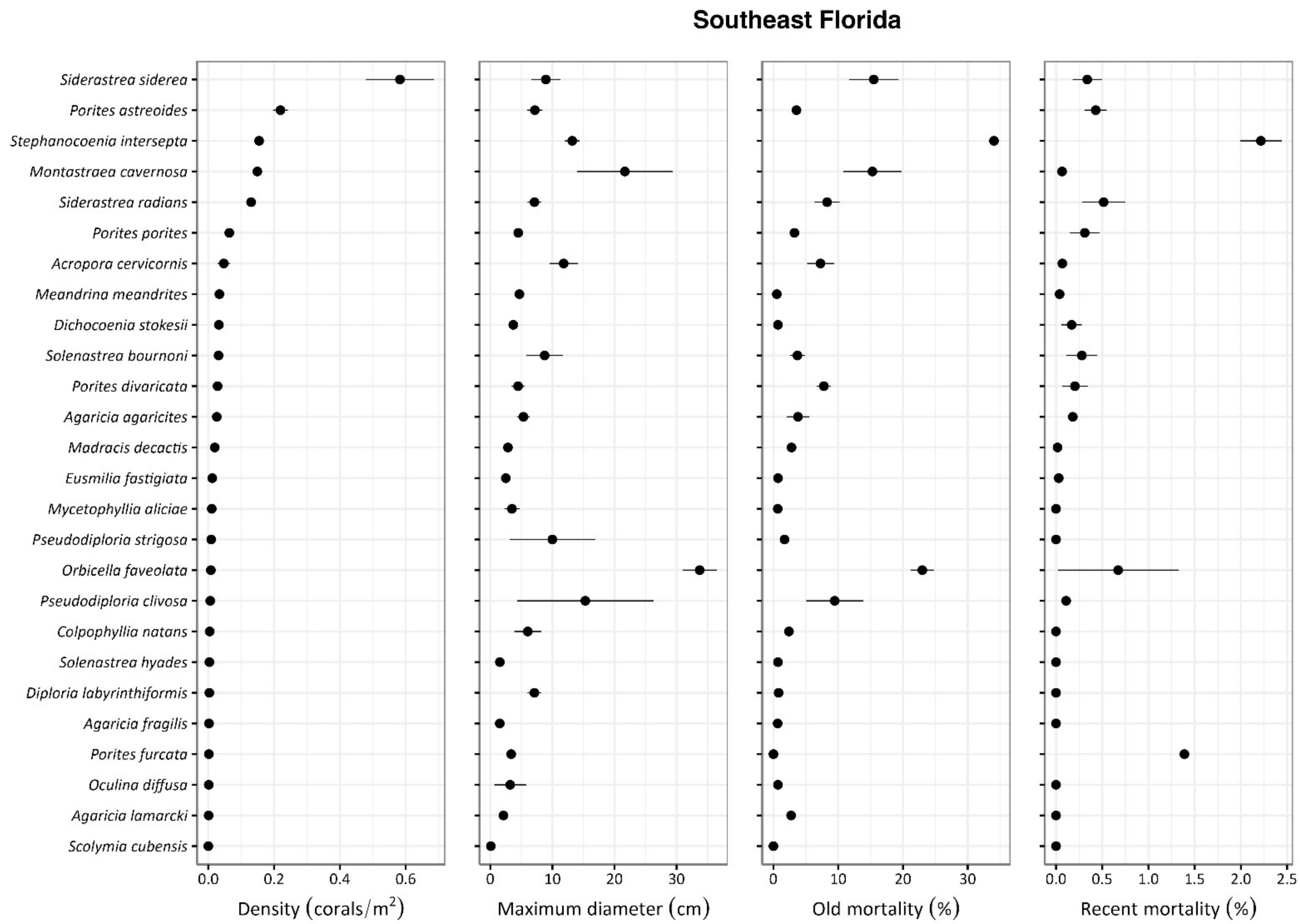


Figure 31. Mean density of corals (colonies/m²), maximum diameter (cm), percentage of old morality (%), and percentage of recent mortality (%) by coral species in Southeast Florida in 2022. Species are ordered in terms of decreasing density, and only species with densities above 0.01 are included. NCRMP and DRM data are included.

Figure 32 shows the length frequency distributions (bars) and old mortality by size (lines/points) for *M. meandrites*, *M. cavernosa*, *O. faveolata*, and *S. siderea* from 2014, 2018, and 2022. *M. meandrites*, a species highly impacted by SCTLD, showed decreases in all length classes except < 10 cm by 2022, and a decrease in the number of colonies surveyed between 2014 (n = 70), 2018 (n = 22), and 2022 (n = 47). This suggests mortality of large colonies between 2014 and 2018. The increase in small *M. meandrites* in 2022 indicates recruitment and/or survival. The percentage of old mortality was low for small colonies of *M. meandrites* in all years and was variable and low in larger sizes in 2014 (note larger sizes were not present or present only at low numbers in 2018 and 2022). For *M. cavernosa*, the length frequency distributions were relatively consistent from 2014 to 2022, and the overall number surveyed increased from 2014 (n = 97) to 2022 (n = 206), indicating continued recruitment and survival in small sizes. For *O. faveolata,* an ESA-listed species, the overall number of colonies did not change much over time. However, the number of larger colonies declined over time, and, in 2022, the size distribution was relatively even between size classes. For *S. siderea*, the numbers of colonies surveyed almost doubled from 2014 (n = 100) to 2022 (n = 236), and the population primarily consisted of small corals (< 15 cm), indicating recruitment and survival in small sizes. The percentage of old mortality increased with colony size. General trends for old mortality by species showed an increase in prevalence in larger size classes, although the signal was noisy (Figure 32).

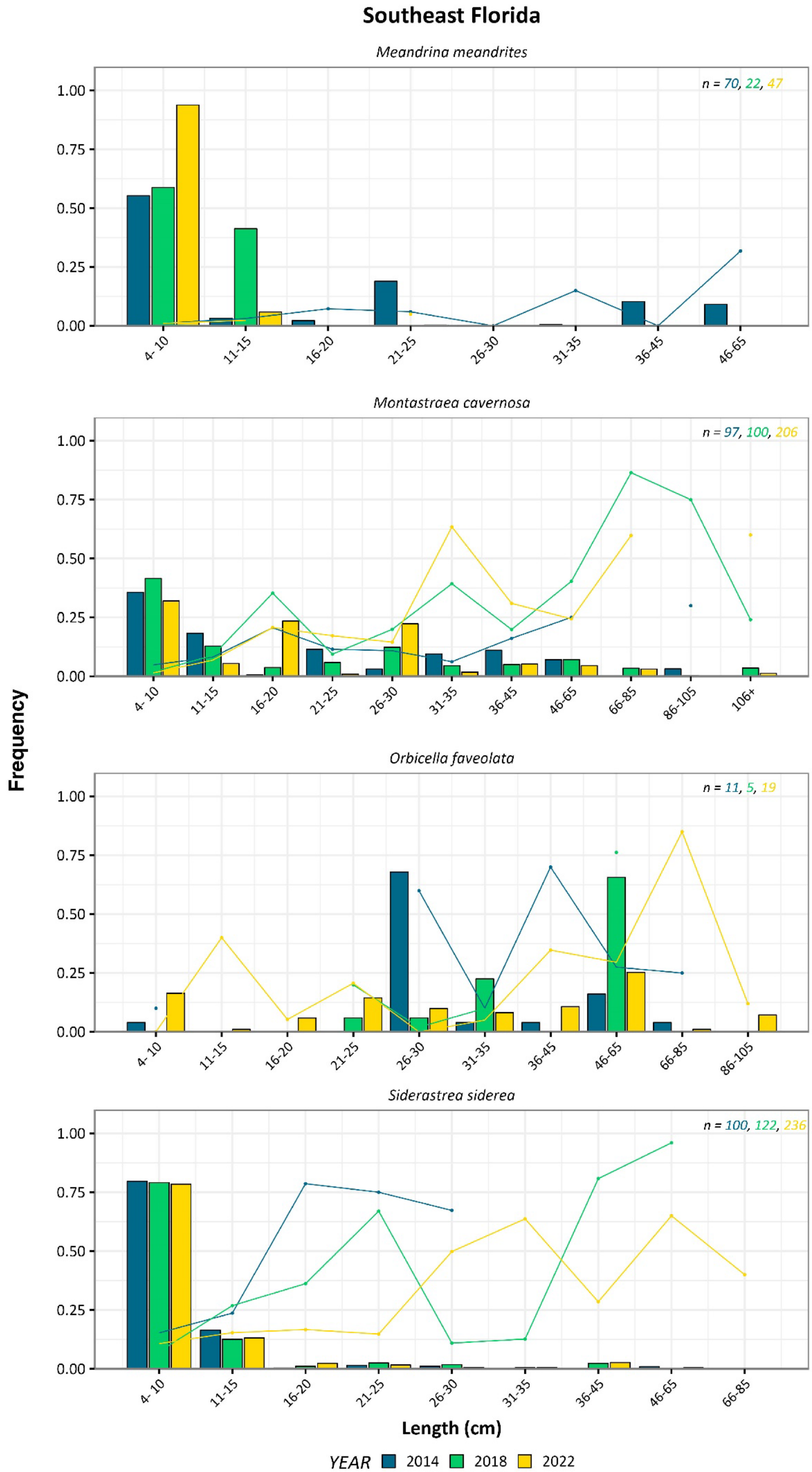


Figure 32. Relative length (maximum coral diameter) frequency (bars) and percentage of old mortality (lines, points) by colony size of select coral species in Southeast Florida for 2014, 2018, and 2022. NCRMP and DRM data are included. Note: gaps in lines indicate no data for specific year (color) and size class. Note: y-axis scale relates to both relative length frequency and percentage of old mortality (*100).

Florida Keys

Overall coral density in the Florida Keys declined from 2014–2022. In 2022, mean coral density was less than half of 2014 density (5.3 ± 0.2 corals/m^2 vs. 2.3 ± 0.3 corals/m^2; Figure 33). The percentage of old mortality on colonies trended downwards over time, generally consistent with the decline in coral density (Figure 33).

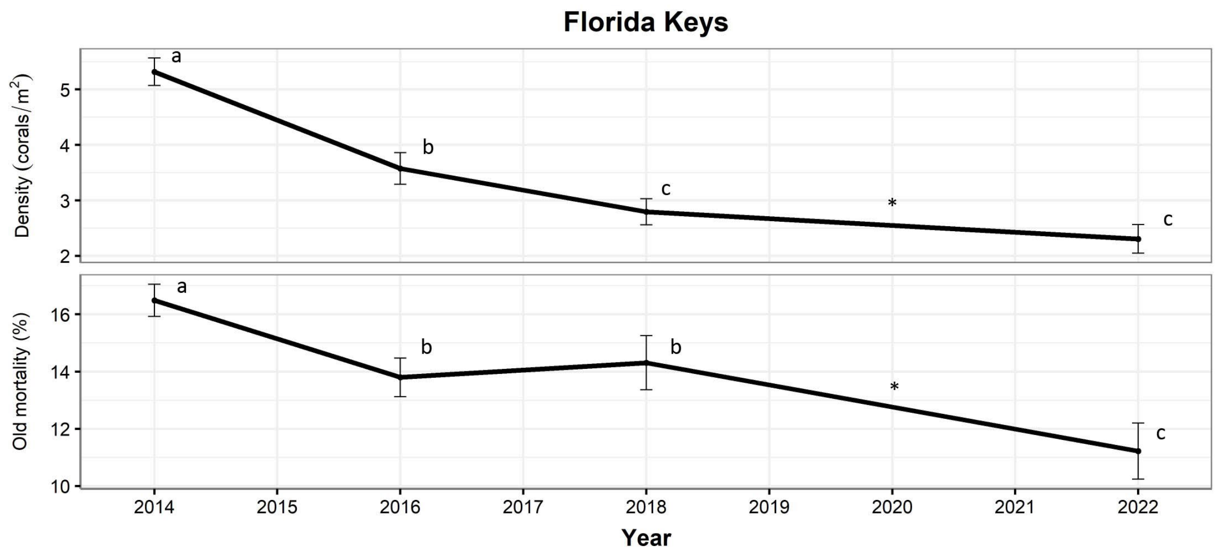


Figure 33. Mean coral density (corals per m^2; top) and old mortality (%; bottom) ± SE from 2014 to 2022 in the Florida Keys. Statistical significance (Tukey's two-tailed t-test), if present, is reported at $p < 0.05$, and different letters (i.e., a, b, c) denote a difference between survey years. NCRMP and DRM data are included. Note differences in y-axis scales.

The mean density of corals in the Florida Keys in 2022 was dominated by the following species: *S. siderea*, *P. astreoides*, *S. intersepta*, *A. agaricites*, and *M. cavernosa* (Figure 34), and all species had less than 3 colonies/m^2. The three orbicellids (*O. annularis*, *O. faveolata*, *O. franksi*) had the largest mean size in terms of maximum skeletal diameter (> 40 cm), although *O. annularis* and *O. faveolata* also showed two of the highest percentages of old mortality (i.e., reduced amount of live tissue on the coral skeletal structure) at approximately 35%–50%. Recent mortality by species was low (< 4%), with the highest percentages on *A. cervicornis* and *P. branneri*.

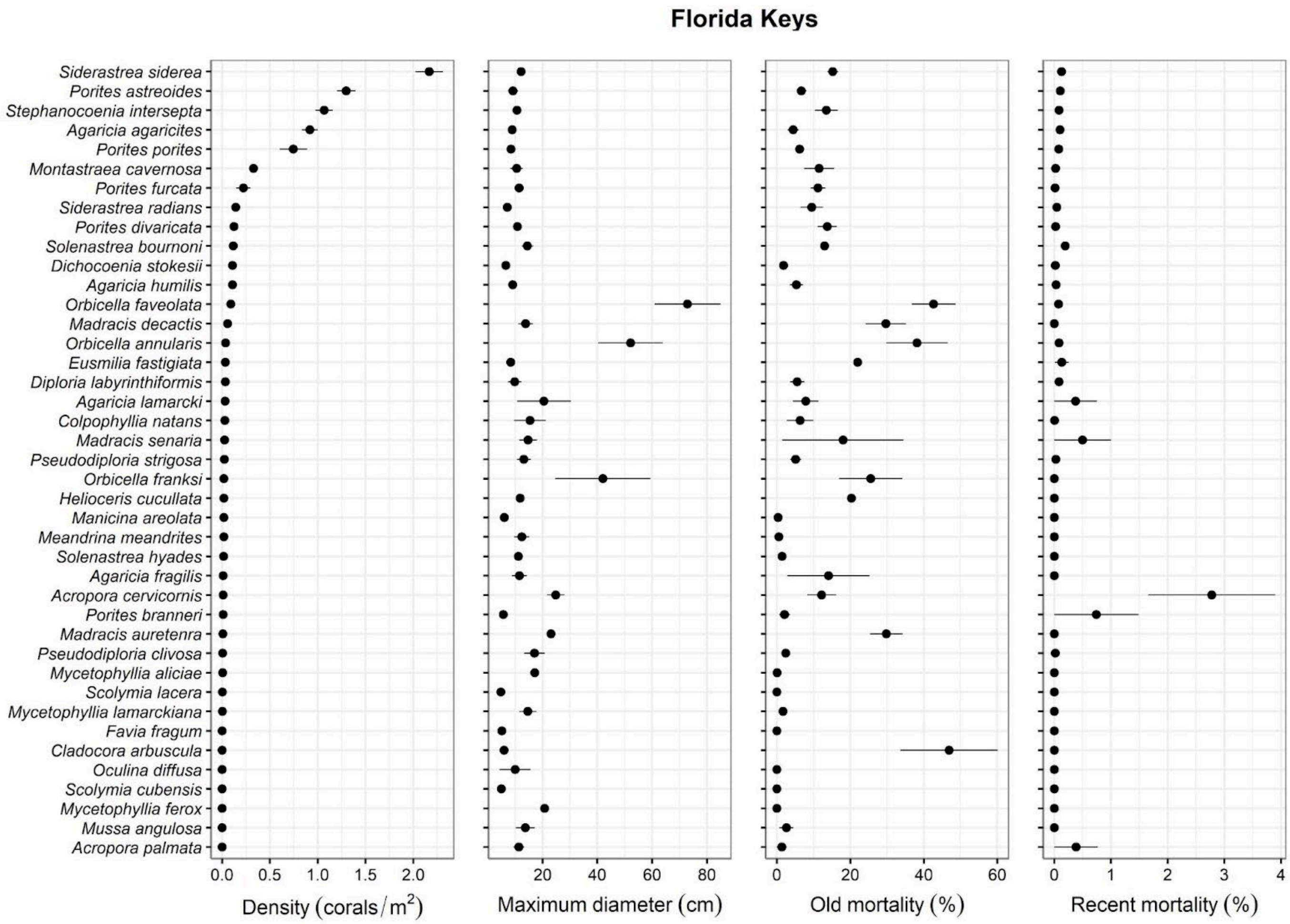
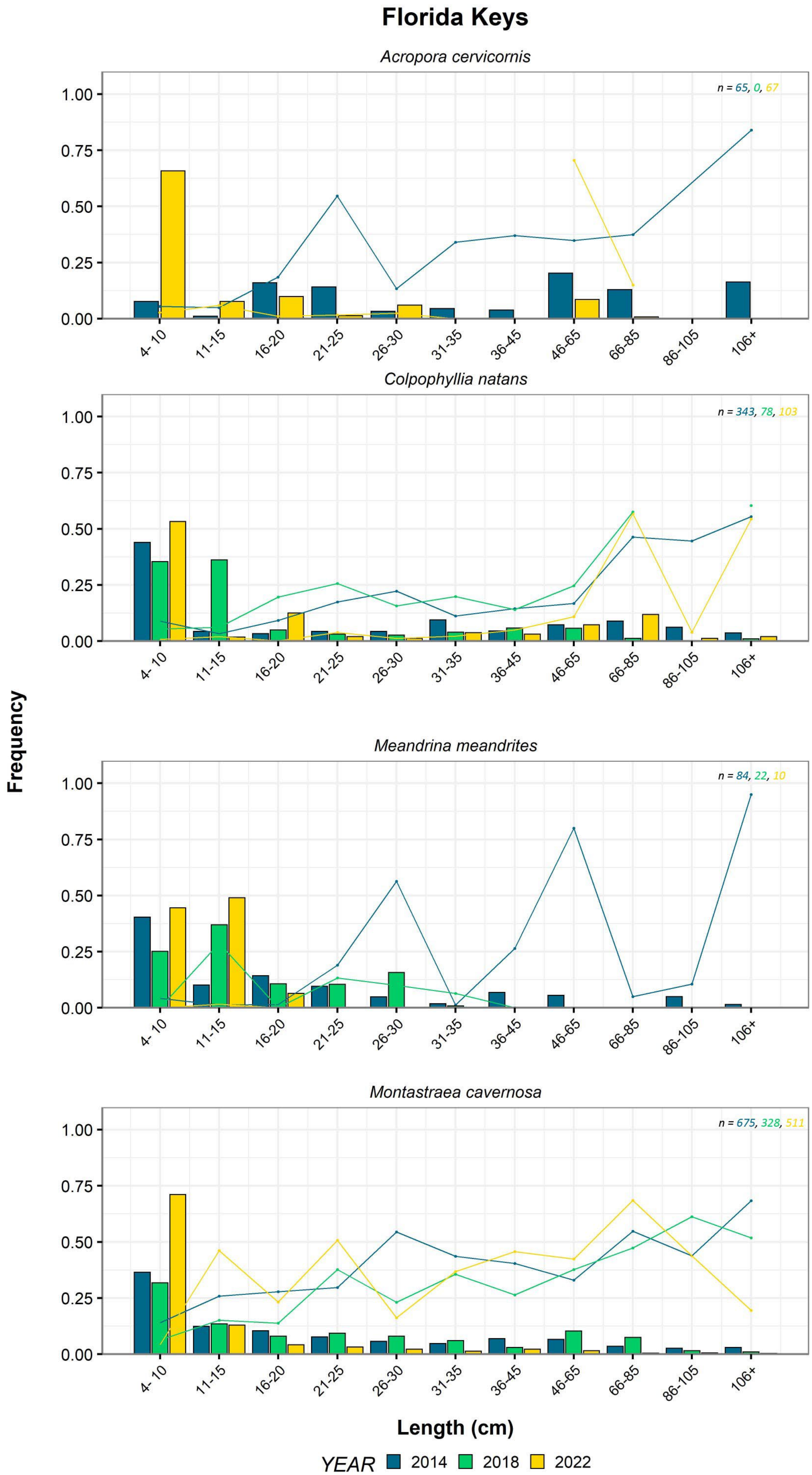


Figure 34. Mean density of corals (colonies/m²), maximum diameter (cm), percentage of old morality (%), and percentage of recent mortality (%) by coral species in the Florida Keys in 2022. Species are ordered in terms of decreasing density, and only species with densities above 0.01 are included. NCRMP and DRM data are included.

Figure 35 shows length frequency distributions for *A. cervicornis*, *C. natans*, *M. meandrites*, and *M. cavernosa* from 2014, 2018, and 2022. The proportion of colonies < 10 cm was higher in 2022 for all four species, indicating mortality in larger sizes in these species, and/or higher successful recruitment and survival in small size classes. In the Florida Keys, *A. cervicornis* had not been observed in NCRMP or DRM surveys since 2016 (year not shown) until 2022 M:IR surveys. In 2022, *A. cervicornis* colonies were observed only in M:IR sites, indicating that they were outplanted colonies, and were predominantly < 10 cm. Mortality was higher for large colonies than small colonies. *A. cervicornis*, *M. meandrites*, and *M. cavernosa* also showed a decrease in maximum colony length over time (Figure 35). The size frequency distribution of *C. natans* was relatively similar between 2014, 2018, and 2022; however, the overall number detected in NCRMP and DRM surveys decreased by over a third. All *M. meandrites* colonies surveyed in 2022 NCRMP and DRM surveys were ≤ 20 cm, a decrease in maximum size from previous years shown. The overall number of *M. meandrites* surveyed declined dramatically between 2014 (n = 84), 2018 (n = 22) and 2022 (n = 10). *M. cavernosa* had a relatively higher proportion of small colonies (4–10 cm) surveyed in 2022 than in 2014 or 2018, indicating potential recruitment and/or mortality of larger colonies. Mortality was relatively consistent across size classes > 10 cm.

Figure 35. Relative length (maximum coral diameter) frequency (bars) and percentage of old mortality (lines, points) by colony size of select coral species in the Florida Keys for 2014, 2018, and 2022. NCRMP and DRM data are included. Note: gaps in lines indicate no data for specific year (color) and size class. Note: y-axis scale relates to both relative length frequency and old mortality (*100).



Dry Tortugas

Overall coral density in the Dry Tortugas declined significantly between 2018 and 2022 (Figure 36). Mean coral density in 2022 was 1.6 ± 0.1 corals/m^2. Colony size and mortality are important components of colony density. The old mortality was significantly higher in 2016 but declined in 2018 and continued to slowly increase over time to 13.3% ± 1.0 in 2022 (Figure 36).

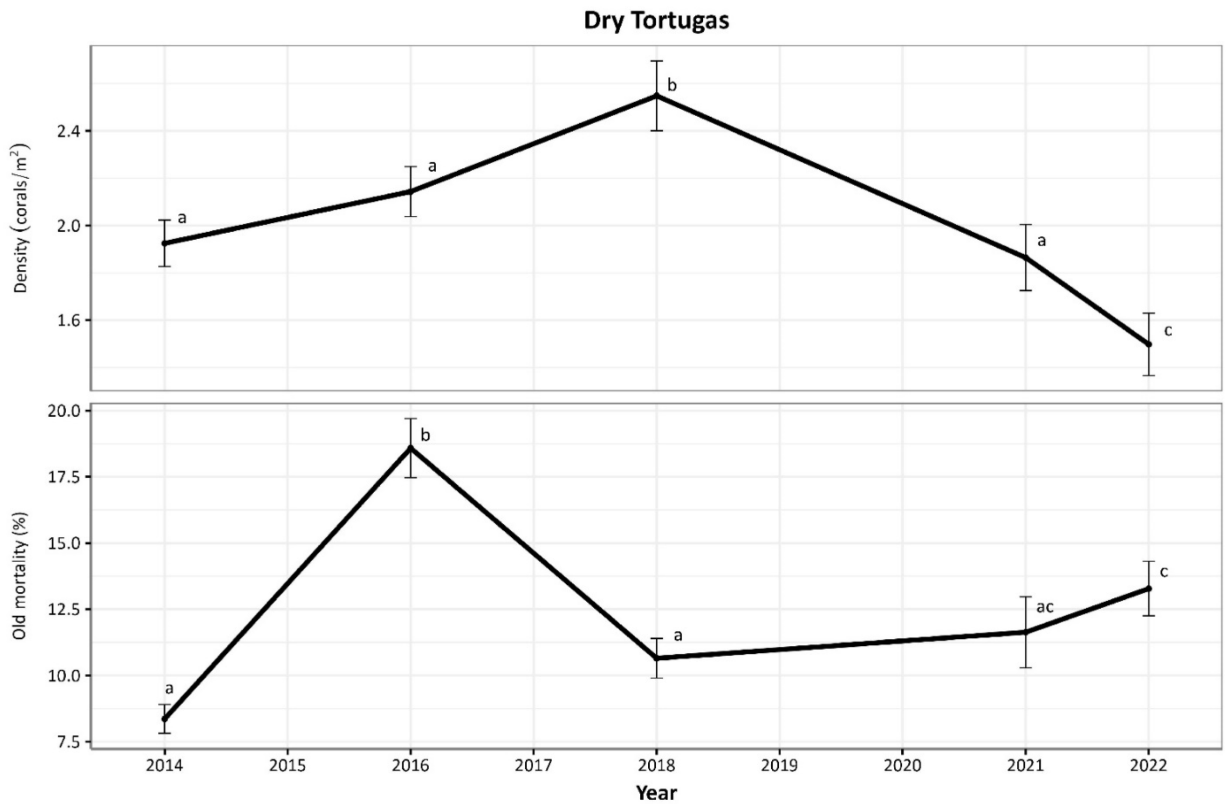


Figure 36. Mean coral density (corals/m^2) and old mortality (%) ± SE from 2014 to 2022 in the Dry Tortugas. Data include both NCRMP and DRM. Statistical significance (Tukey's two-tailed t-test), if present, is reported at $p < 0.05$, and different letters (i.e., a, b, c) denote a difference between survey years. Note: y-axis scale varies by metric.

In 2022, the mean density of corals in the Dry Tortugas was dominated by *S. siderea* and *P. astreoides* (Figure 37). The coral species with the largest maximum skeletal dimension (> 50 cm) were *O. faveolata* and *O. franksi*, both of which also had a higher percentage of old mortality than other species (approximately 30%–40%), along with *A. cervicornis*. Recent mortality was higher (approximately 1%–3%) on these two species as well as *S. siderea* and *M. cavernosa.*

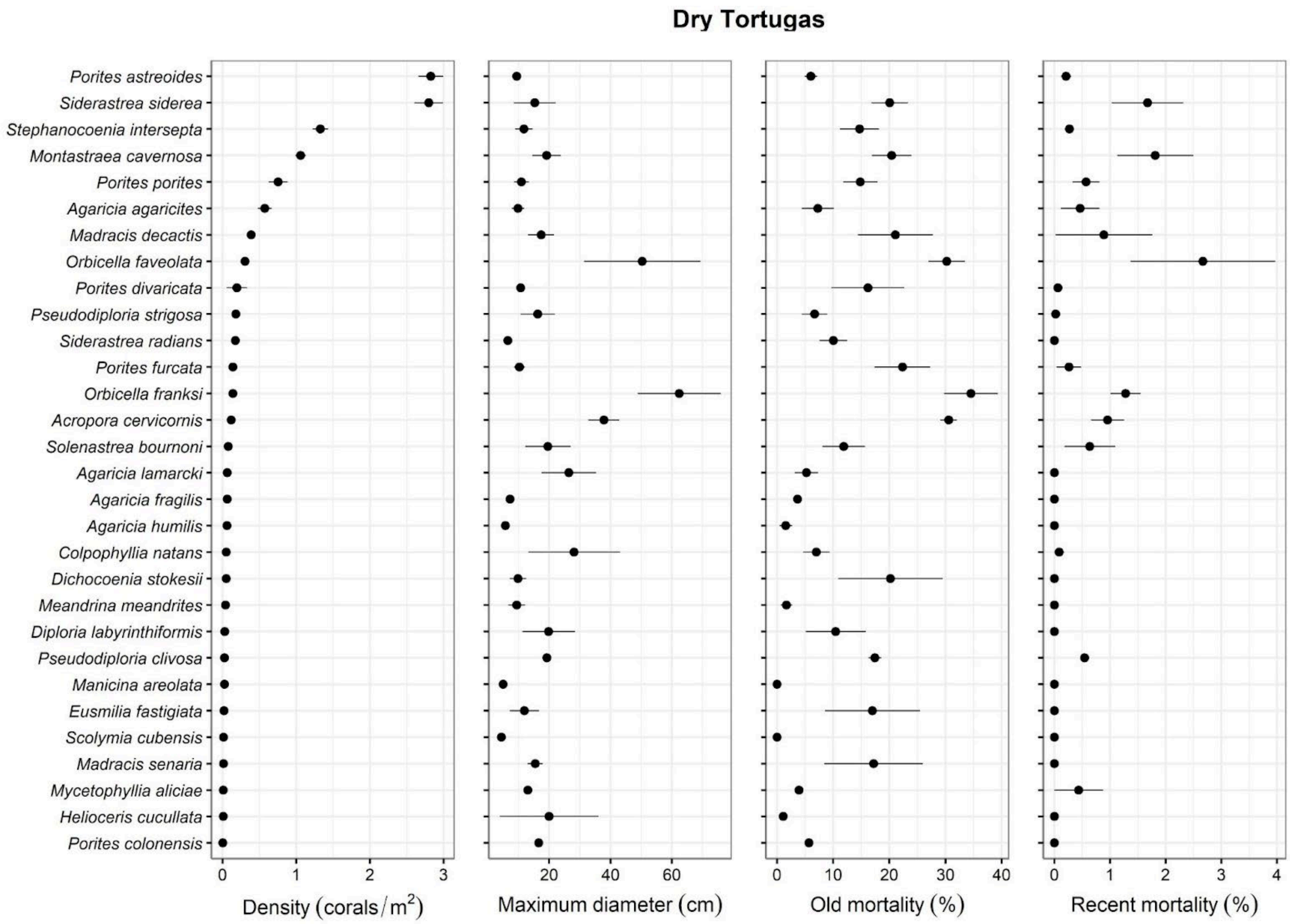
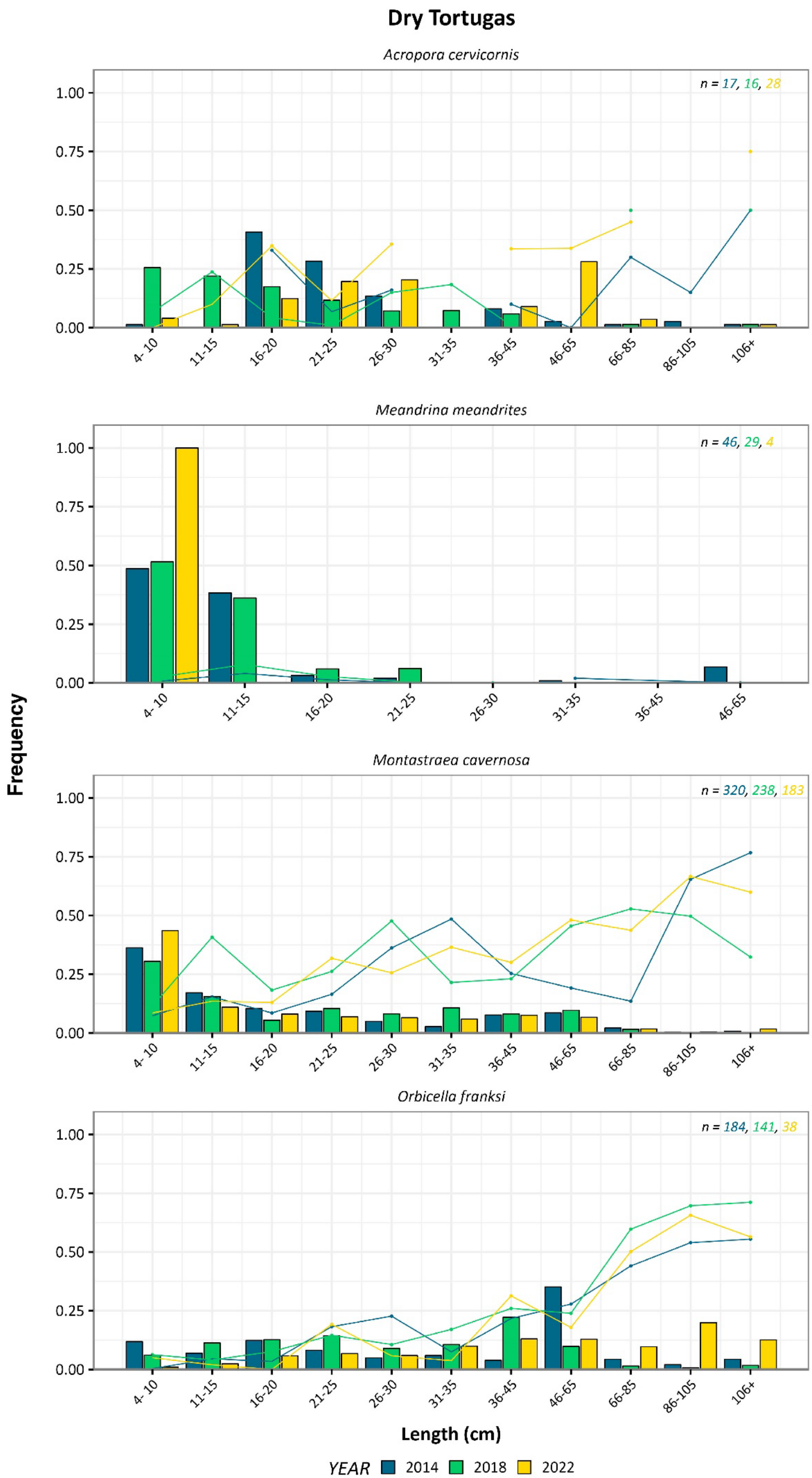


Figure 37. Mean density of corals (colonies/m²), maximum diameter (cm), percentage of old morality (%), and percentage of recent mortality (%) by coral species in the Dry Tortugas in 2022. Species are ordered in terms of decreasing density, and only species with densities above 0.01 are included. NCRMP and DRM data are included.

Figure 38 shows the length frequency distributions for *A. cervicornis*, *M. meandrites*, *M. cavernosa*, and *O. franksi* from 2014, 2018, and 2022. *A. cervicornis* had a smaller proportion of colonies < 20 cm and a higher proportion of mid-sized colonies (46–65 cm) in 2022 than in 2018, indicating a possible decrease in juvenile input (low frequency in 4- to 10-cm length class) and/or continued growth into larger size classes. While overall numbers of *A. cervicornis* surveyed were low, they did increase from 2014 (n = 17) to 2022 (n = 28). *M. meandrites* had a proportional decrease in all length classes except < 10 cm colonies, suggesting mortality of larger colonies, and the overall numbers surveyed declined from 2014 (n = 46) to 2022 (n = 4). *M. cavernosa* had consistent length frequency distributions between years. However, an increase in the percentage of colony mortality with size, and an overall decline in numbers of colonies surveyed from 2014 (n = 328) to 2022 (n = 183) suggests coral mortality across all size classes. *O. franksi* showed an increasing percentage of mortality on larger corals relatively consistently across all years, and an overall decline in corals surveyed from 2014 (n = 184) to 2022 (n = 38). A smaller proportion of small corals (> 25 cm) were observed in 2022 than in previous years, indicating limited recruitment and/or survival.

Figure 38. Relative length (maximum coral diameter) frequency (bars) and percentage of old mortality (lines, points) by colony size of select coral species in the Dry Tortugas for 2014, 2018, and 2022. NCRMP and DRM data are included. Note: gaps in lines indicate no data for specific year (color) and size class. Note: y-axis scale relates to both relative length frequency and old mortality (*100).



Coral Bleaching and Disease

Southeast Florida

In Southeast Florida in 2022, coral bleaching had a prevalence of 34.2% (± 17.4) on multiple coral species (Figure 39), including data from both NCRMP and DRM surveys. The coral species with the highest bleaching prevalence in 2022 surveys were *S. intersepta*, *S. siderea*, and *O. faveolata* (Figure 39). In Southeast Florida, NCRMP surveys were between June and October, and DRM surveys were between August and October (Stein and Ruzicka, 2023).

In Southeast Florida in 2022, coral disease prevalence was relatively low, at 2.7% (± 4.0), based on data from both NCRMP and DRM surveys. The highest prevalence of disease was on *A. cervicornis*, *S. radians*, and *O. faveolata* (Figure 39).

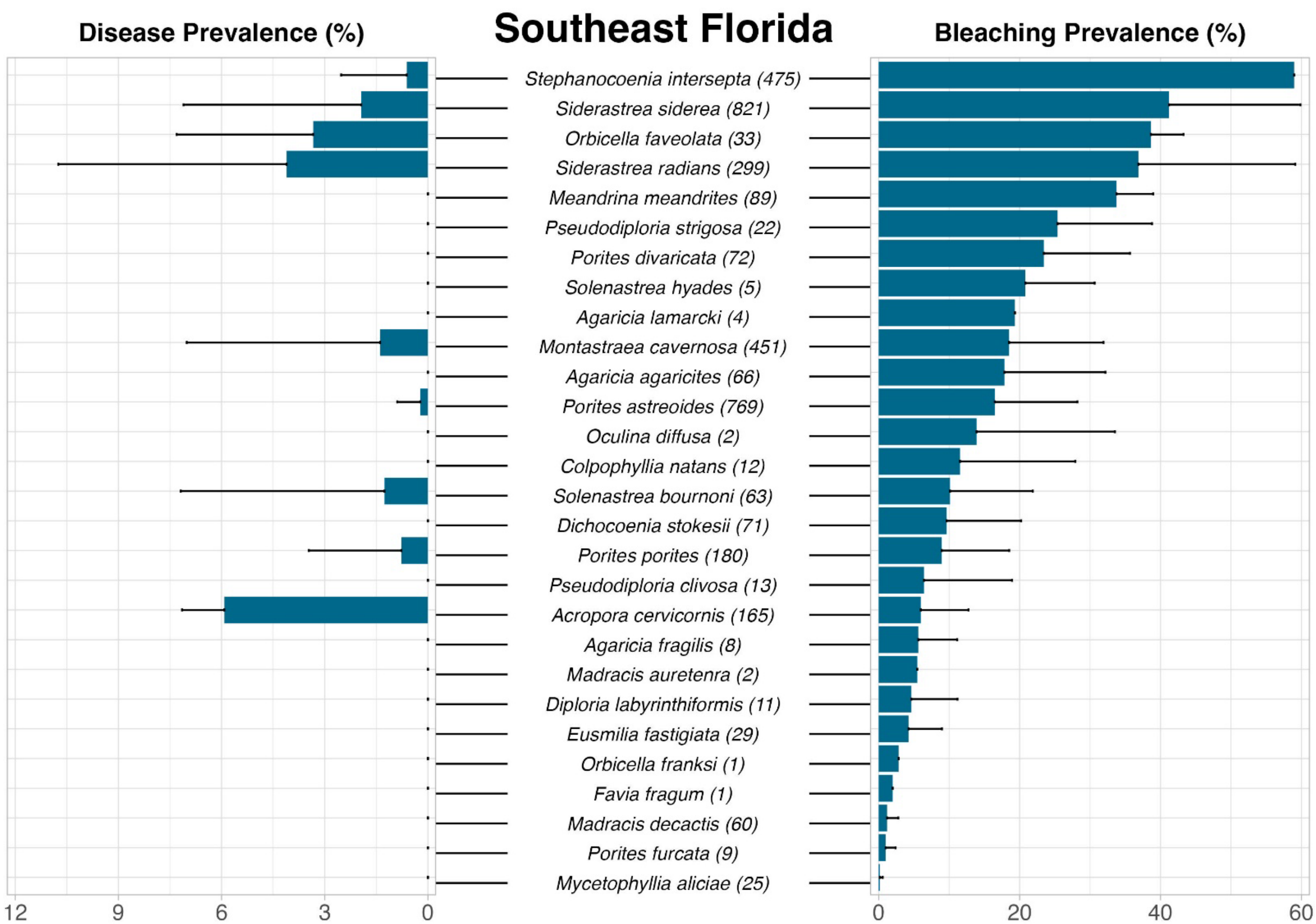


Figure 39. Mean disease prevalence (left) and bleaching prevalence (right) ± SE by coral species for Southeast Florida in 2022. The number of coral colonies observed by species are in parentheses. Only species with disease or bleaching observed in the 2022 NCRMP and 2022 DRM coral demographics surveys are included. Note: species are sorted in order of decreasing bleaching prevalence, and x-axis scale varies by metric.

Florida Keys

In the Florida Keys in 2022, bleaching had an overall prevalence of 29.5% (± 9.3), including data from both NCRMP and DRM surveys. Multiple coral species had high bleaching (20%–70%), with the highest prevalence on *A. agaricites*, *S. radians*, *and P. divaricata* (Figure 40). NCRMP surveys in the Florida Keys extended from July to October in 2022, with the exception of a few M:IR sites where sampling extended through December, and DRM surveys were largely from August to October, 2022 (Stein and Ruzicka, 2023).

In the Florida Keys in 2022, overall coral disease prevalence was relatively low, at 0.9% (± 0.5), with less than 5% by individual species, based on data from both NCRMP and DRM surveys. The species with highest disease prevalence were *D. labyrinthiformis*, *S. siderea*, and *S. intersepta* (Figure 40).

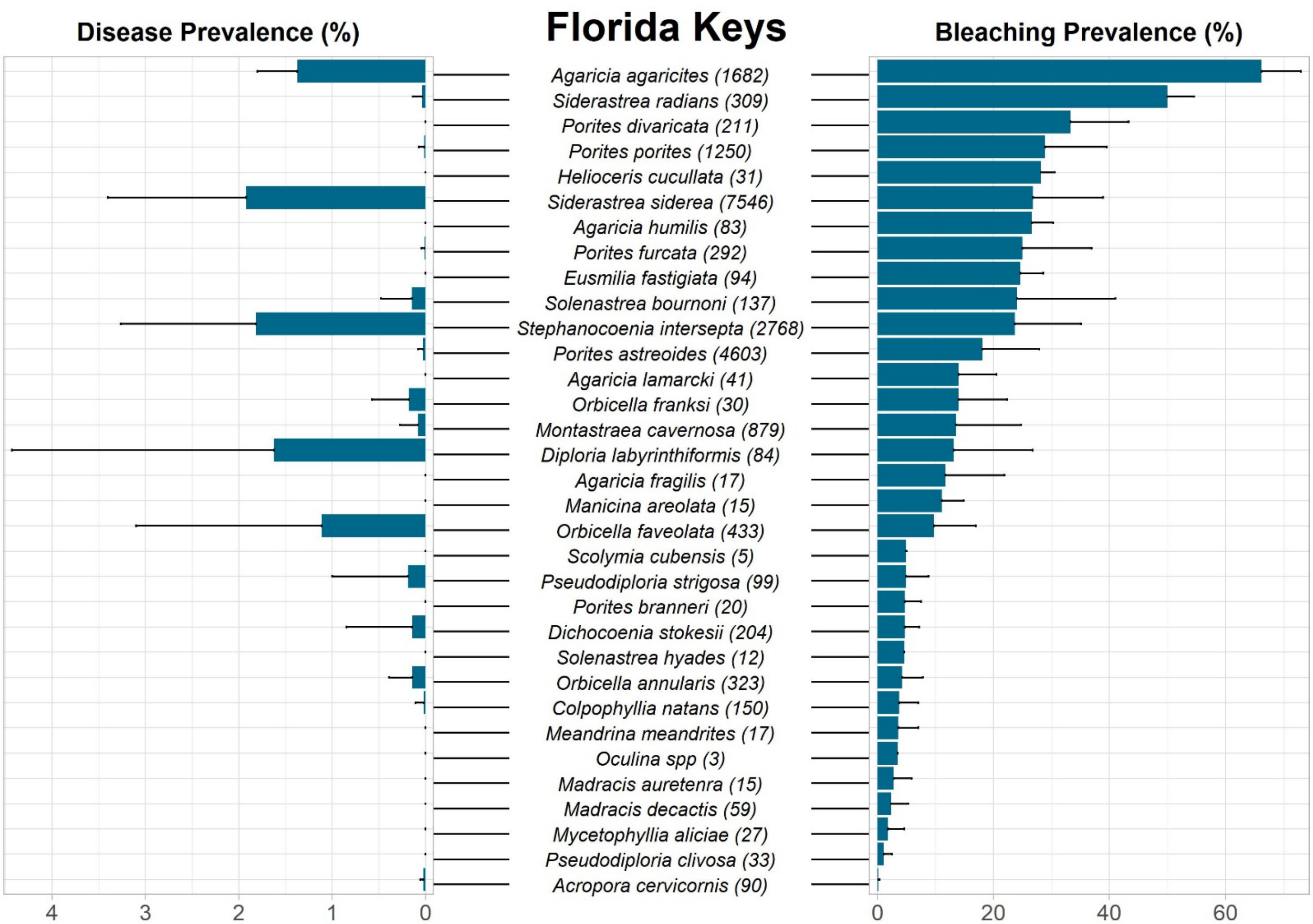


Figure 40. Mean disease prevalence (left) and bleaching prevalence (right) ± SE by coral species for the Florida Keys in 2022. The number of coral colonies observed by species are in parentheses. Only species with disease or bleaching observed in the 2022 NCRMP and 2022 DRM coral demographics surveys are included. Note: species are sorted in order of decreasing bleaching prevalence, and x-axis scale varies by metric.

Dry Tortugas

Both NCRMP and DRM 2022 surveys in the Dry Tortugas were in September, when water temperatures were highest, and just prior to Hurricane Ian's passage across the Dry Tortugas. Bleaching was highly prevalent at 29.3% (± 10.3), based on NCRMP and DRM survey data. The coral species observed with the highest bleaching prevalence were *A. agaricites*, *S. siderea*, and *O. faveolata* (Figure 41).

In the Dry Tortugas in 2022, coral disease was also highly prevalent, at 6.15% ± 2.9, based on both NCRMP and DRM surveys. The highest prevalence of coral disease was on *O. franksi*, *O. faveolata*, and *M. cavernosa* (Figure 41). Coral disease in the Dry Tortugas in 2022 was primarily SCTLD (Stein and Ruzicka, 2023).

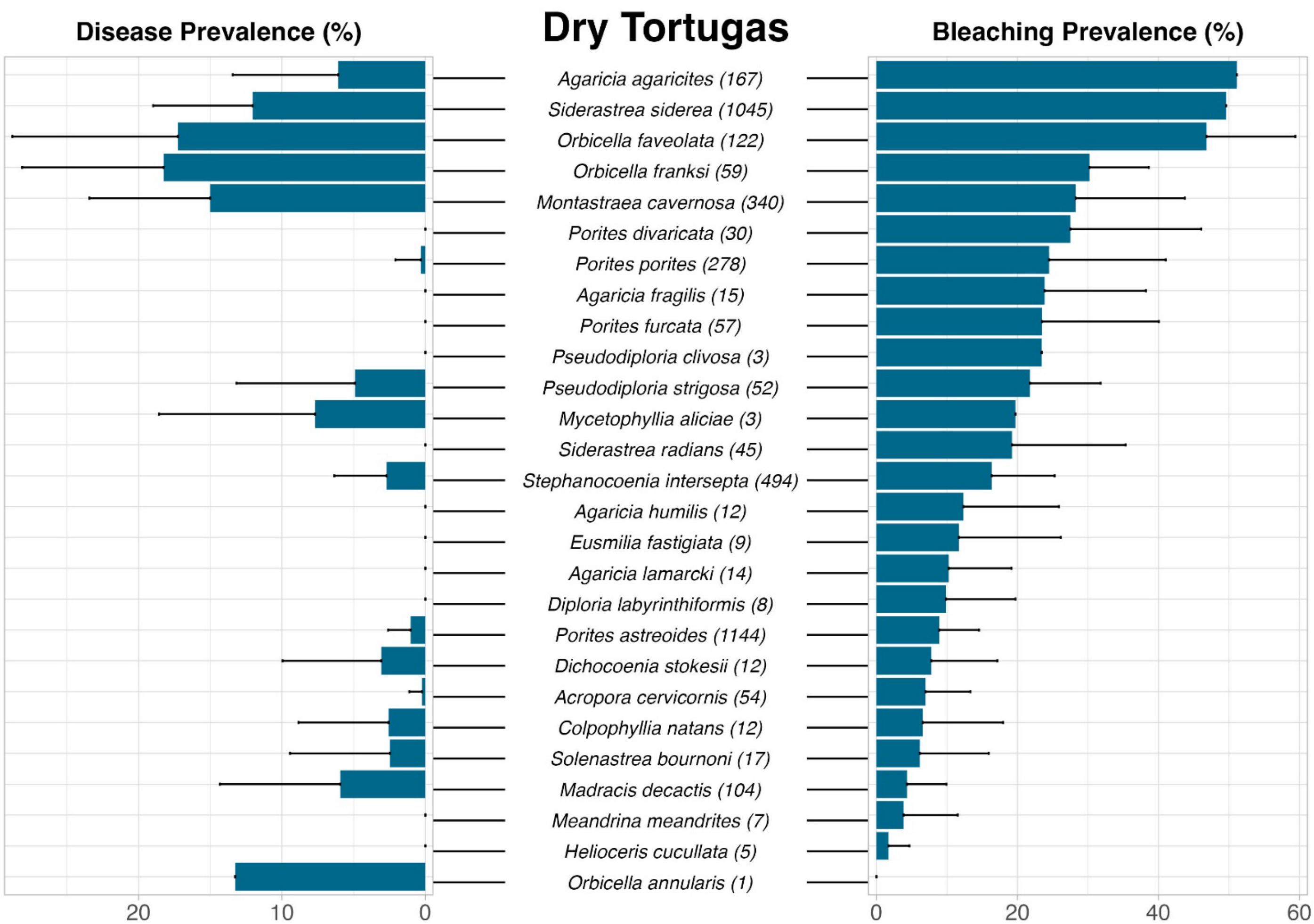


Figure 41. Mean disease prevalence (left) and bleaching prevalence (right) ± SE by coral species for the Dry Tortugas in 2022. The number of coral colonies observed by species are in parentheses. Only species with disease or bleaching observed in the 2022 NCRMP and 2022 DRM coral demographics surveys are included. Note: species are sorted in order of decreasing bleaching prevalence, and x-axis scale varies by metric.

Summary

NCRMP fish data showed that a large number of fishery targeted and non-targeted surveyed fishes, presently up to 50 reef fish species, have CVs of density that are 20% or less. This wide breadth of species regularly observed can be used to reliably monitor trends in species that are often overlooked by fishery-dependent surveys (e.g., smaller or ESA-listed species) yet are valuable components of the coral reef ecosystem (i.e., herbivores or prey species) and can be regionally important (e.g., ecotourism). In parrotfishes, two (Dry Tortugas, Florida Keys) or three (Southeast Florida) species made up 75% of the total regional parrotfish density, highlighting the importance of species-specific analyses, as opposed to broader groupings. Broader groupings such as "all parrotfishes" can unintentionally be misleading as it is often assumed that each species equally contributes to the results (e.g., density, trends); however, in the Dry Tortugas case, two out of the 14 parrotfish species observed are predominantly responsible for any results in a broader grouping. The importance of species-specific analyses generally extends to all fish groupings (e.g., groupers, snappers, damselfishes, angelfishes, etc.). In the Dry Tortugas, black grouper and mutton snapper density was significantly higher in the protected areas (DRTO and TNER-N) compared to unprotected areas in 2022. Within protected areas, mutton snapper densities have steadily and significantly increased from 2014 to 2022. In the Florida Keys, none of the fishery targeted species evaluated had significantly higher densities, and two species had significantly lower densities in the protected areas (SPAs) compared to unprotected areas in 2022. This could be related to a number of factors including, but not limited to, differences in habitat type and quality, small size of the protected areas, and lack of effective enforcement. In Southeast Florida, the only significant finding was a decline in hogfish density from 2018 to 2022. As a fishery-independent survey, NCRMP collects numbers and sizes on all observed fishes to the nearest centimeter and, generally, fishes were more commonly observed to be smaller than their minimum length of captures in all regions.

NCRMP surveys showed that coral cover in Florida continued to decline, particularly in the Florida Keys region. In every Florida region, combined NCRMP and DRM coral demographics data show that coral species that are highly susceptible to SCTLD, such as *M. meandrites*, have become increasingly rare and, as large colonies have died, population size distributions have shifted to higher proportion of smaller colonies than larger colonies. This may also indicate an influx (i.e., through recruitment and survival) into the ≥ 4 cm colony size surveyed by NCRMP. In every Florida region, combined NCRMP and DRM data show that a large number of coral species were sampled to CVs of density that are 20% or less. Together, these two complementary survey programs provide statistically robust population data to monitor trends and emphasize the benefits of federal-state collaboration. As declines in coral populations continue from SCTLD and coral bleaching, the number of survey sites may need to increase to maintain statistically robust CVs. A severe bleaching event is now underway at the time of writing this report in 2023; note that this report includes data only up to 2022. As restoration efforts, such as M:IR in the Florida Keys, continue to scale up, NCRMP surveys should continue to include data on coral populations, benthic communities, and fish populations and communities from restoration sites to compare restoration efforts to the broader regional populations. For example, 2022 NCRMP M:IR surveys included data on outplanted *A. cervicornis* corals, a species that has not otherwise been encountered in Florida Keys NCRMP or DRM surveys since 2016.

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Appendix: Supplemental Information

NCEI Data Package References:

- **Florida Benthic Collections** (all years):

NOAA National Centers for Coastal Ocean Science; NOAA Southeast Fisheries Science Center (2022). National Coral Reef Monitoring Program: Assessment of coral reef benthic communities in Florida [indicate subset used]. NOAA National Centers for Environmental Information. Dataset. doi: 10.7289/v5xw4h4z

- **2022 Florida Benthic Data:**

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- **Florida Fish Collections** (all years):

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