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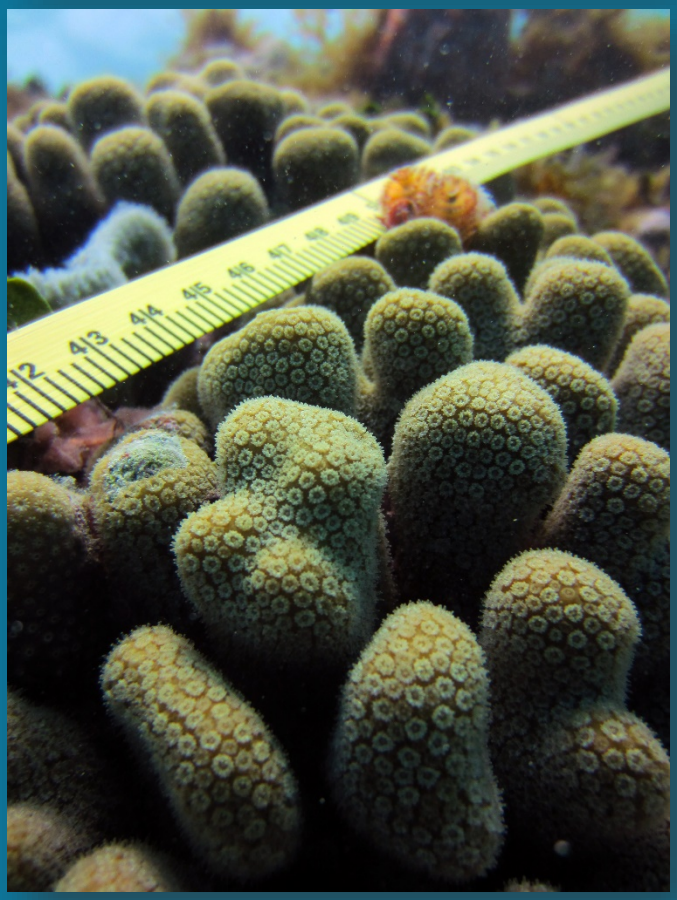

National Coral Reef Monitoring Program

Biological Monitoring Summary

U.S. Virgin Islands and Puerto Rico: 2019

June 2021

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 40

National Coral Reef Monitoring Program

Biological monitoring summary

U.S. Virgin Islands and Puerto Rico: 2019

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Disclaimer

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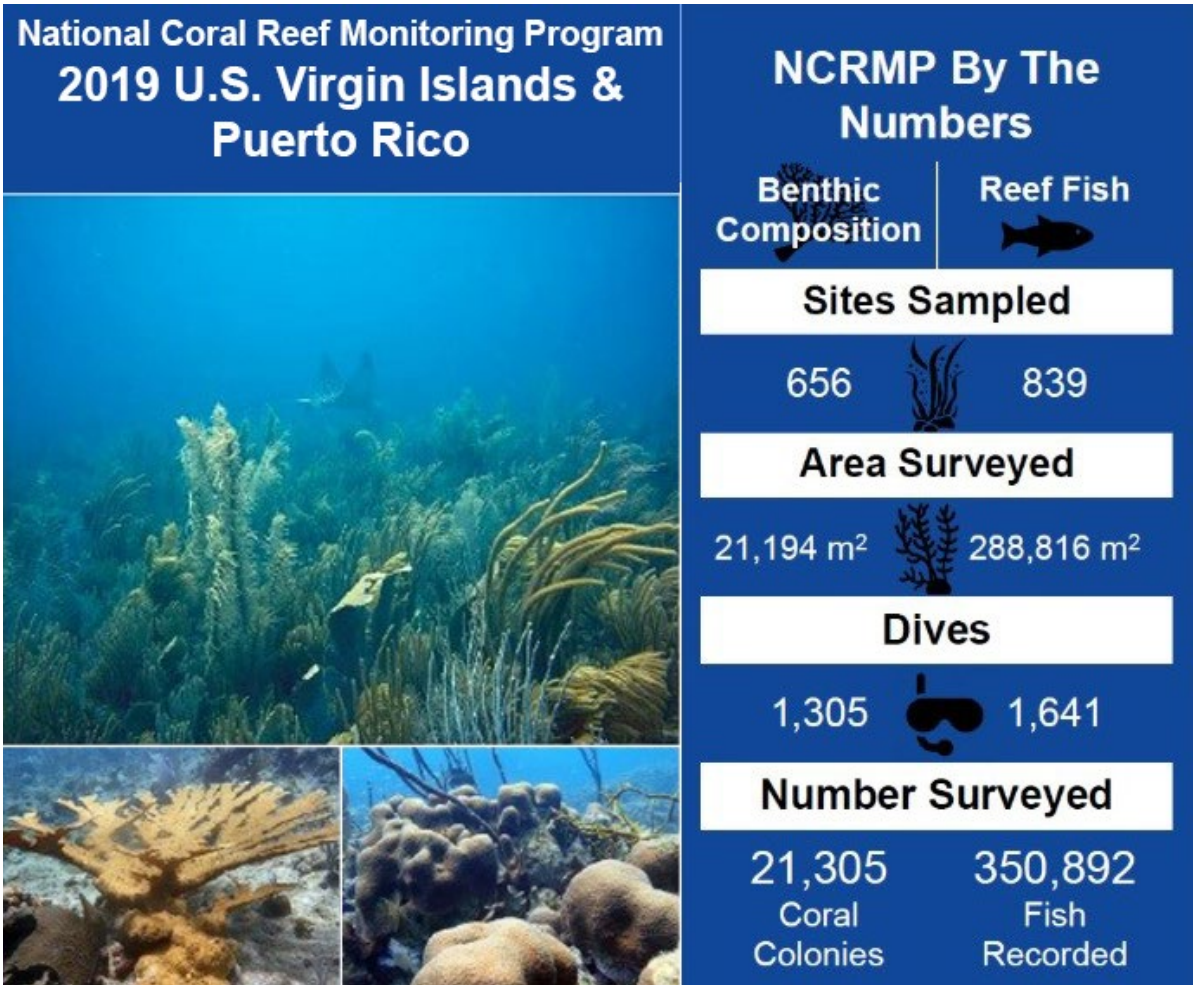
Acronyms

CRCP	Coral Reef Conservation Program
CV	Coefficient of variation
DNER	Puerto Rico Department of Natural and Environmental Resources
DPNR	USVI Department of Planning and Natural Resources
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FGBNMS	Flower Garden Banks National Marine Sanctuary
HJR	HJR Reefscaping, Inc.
LPI	Line Point Intercept
NCCOS	National Center for Coastal Ocean Services
NCEI	National Centers for Environmental Information
NCRMP	National Coral Reef Monitoring Program
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
OCM	Office of Coastal Management
RVC	Reef fish Visual Census
SCTLD	Stony Coral Tissue Loss Disease
SEFSC	Southeast Fisheries Science Center
TNC	The Nature Conservancy
UPR	University of Puerto Rico
USVI	United States Virgin Islands
UVI	University of the Virgin Islands
VI-CDAC	Virgin Island Coral Disease Advisory Committee

Executive Summary

NOAA's National Coral Reef Monitoring Program (NCRMP) conducts biological sampling for benthic communities (corals and algae) and fish populations in the U.S. Virgin Islands (USVI) and Puerto Rico every other year. In 2019, dive surveys occurred throughout summer and fall months on shallow-water (0–30 m) coral reefs. Data are used to inform coral and fish population management strategies, document the occurrence of endangered species and coral disease, and assist with local monitoring efforts. Information about NCRMP's methods, data, and data projects are available on the projects' website: https://www/coris.noaa.gov/monitoring/biological.html.



Summary

NCRMP provides large-scale data that can be used in partnership with local jurisdictional monitoring to support coral reef management. This report summarizes data collected by the biological sampling of shallow water coral reefs in the USVI and Puerto Rico in 2019 and highlights the NCRMP mission efforts accomplished by NOAA and the associated partners.

Sampling Overview

In 2019, sampling efforts occurred at the following locations and dates:

- St. Thomas and St. John, USVI: July 29–August 9, 2019
- St Croix, USVI: June 3–10, 2019
- Puerto Rico: July–December 2019

Partners involved in these efforts included:

- USVI
  - National Park Service (NPS)
  - The Nature Conservancy (TNC)
  - University of the Virgin Islands (UVI)
  - U.S. Environmental Protection Agency (EPA)
  - USVI Department of Planning and Natural Resources (DPNR)
- Puerto Rico
  - Coastal Survey Solutions
  - HJR Reefscaping (HJR)
  - Puerto Rico Department of Natural and Environmental Resources (DNER)
  - University of Puerto Rico (UPR)

Summary Points

Benthic Community

- Divers were on high alert for any signs of Stony Coral Tissue Loss Disease (SCTLD) during the 2019 missions. SCTLD was first reported in St. Thomas, USVI in January 2019 (Science News, 2019).
- NCRMP surveys were modified to add a site-level observation of SCTLD presence. Potential SCTLD sightings were photographed and provided to regional experts for disease identification.
- Coral cover declined by 1.5–5% in all three regions between 2013 and 2019.

Fish Community

- NCRMP fish data showed that a large number of fishery targeted and non-targeted surveyed fishes, presently 35–40 reef fish species, have CVs of 20% or better, meaning there are enough data to perform robust statistical analyses.
- In Puerto Rico and USVI regions, redband (*Sparisoma aurofrenatum*) and stoplight parrotfish (*Sparisoma viride*) dominate the parrotfish taxonomic group.
- Reefs in all locations are dominated by fishery non-targeted species of bicolor damselfish (*Stegastes partitus*) and bluehead wrasse (*Thalassoma bifasciatum*).

Introduction

Coral reefs are valuable ecosystems that provide people with goods and services including food, storm protection, and recreational opportunities. Despite their importance, coral reef ecosystems are in decline from a myriad of man-made and natural threats (Hughes and Tanner 2000; Knowlton 2001). In response to these threats, NOAA's Coral Reef Conservation Program (CRCP) established an integrated and focused monitoring effort with partners across the U.S.—the National Coral Reef Monitoring Program (NCRMP). 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 robust picture of U.S. coral reef ecosystem condition and the communities connected to them.

NCRMP biological monitoring provides an assessment over a broad spatial scale of the coral reef communities in U.S. jurisdictions. The overall goal is to evaluate the status and trends of coral reef fishes and benthic assemblages in the Atlantic, Caribbean, and Gulf of Mexico basins at a regional (or island) scale, and, as such, the survey design is optimized to generate data in a comprehensive approach. This design generates large-scale, regional status and trend information of U.S. shallow water (0–30 m) coral reef ecosystems. This large-scale context and perspective provides data used in partnership with local jurisdictional monitoring to supplement coral reef management. Biological sampling alternates every other year within the Atlantic, Caribbean, and Gulf of Mexico jurisdictions of the U.S. Virgin Islands (USVI): including St. Thomas, St. John and St. Croix; and Puerto Rico, Florida, and the Flower Garden Banks National Marine Sanctuary (FGBNMS; Figure 1).

Figure 1. Map of Atlantic regions sampled within NCRMP.

This report summarizes data collected by the biological sampling of shallow water coral reef ecosystems in the U.S. Virgin Islands and Puerto Rico in 2019. Data summaries for ecologically important metrics are generated for the individual missions to show trends over time. Full datasets for 2019 and previous years, can be obtained through NOAA's National Centers for Environmental Information (NCEI) database (see Appendix A for additional reference and archive information).

Methods

I. Sample Design

The NCRMP sample frame design uses a stratified random design approach for each region Puerto Rico includes the islands of Mona, Culebra and Vieques; and USVI consists of two subregions (1) St. Croix, and (2) St. Thomas and St. John. Details of the sample frame regions, protocol, methods, and definitions of the specific habitat types can be found in the Spatial Framework Protocols (NOAA NCCOS 2018). 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 and management zone, with sites distributed around the sampling region from nearshore to offshore to a maximum depth of 30 m.

Biological monitoring aims to sample a minimum number of sites each year in each region, based on the stratified random sample design. The total number of sites sampled may vary each year due to numerous factors, such as weather. Fish and Benthic sites are co-located, but may not be sampled concurrently during the same dive. The strength of data and trends will continue to increase as additional data are gathered in future years.

USVI's national parks are spatially explicit areas that offer seasonal closures on targeted species (i.e., recreational), and prohibit spearfishing and commercial fishing. In St. Croix, national parks include Buck Island Reef National Monument and Salt River Bay Ecological Reserve. In St. Thomas and St. John, national parks include Virgin Islands Coral Reef National Monument and Virgin Islands National Park. The majority of NCRMP sampling occurs outside of the national parks; however, the sampling design provides enough power to detect differences among fish densities inside versus outside. Although there are a number of spatially managed areas in Puerto Rico, there are no national parks. We designated the entire region as 'outside', and therefore did not make any 'inside' versus 'outside' comparisons.

II. Field Surveys

Benthic Communities

Benthic surveys were co-located with fish sites and along transects adjacent to the fish survey cylinders. Benthic communities were assessed using two components: the Benthic Assessment and the Coral Demographic protocols (NOAA NCCOS 2019a, b). The Benthic Assessment protocol includes: (1) benthic cover (%) estimates along a 15 m transect with the Line Point Intercept (LPI) method, (2) presence/absence of Endangered Species Act (ESA)-listed coral species, (3) abundance of key macroinvertebrates, and (4) a reef rugosity estimate (NOAA NCCOS 2019a; Figure 2a). At the same site, coral demographics were surveyed within a 10 x 1 m transect area (NOAA NCCOS 2019b). All coral colonies >4 cm were identified to species, measured to the nearest cm (length, width, height), and the proportion per colony of any present mortality (recent or old), disease, and/or bleaching (total, partial, paling) was estimated. 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 identified but no size or condition metrics are recorded.

The coral demographic surveys provide information on disease occurrence on individual coral colonies as presence or absence of coral disease on a colony, but does not identify the type or cause of disease. For more detailed information on coral diseases and identification, see Florida Keys National Marine Sanctuary Disease Identification Cards (https://floridakeys.noaa.gov/coral-disease/disease.html). Refer to NOAA NCCOS (2019a, b) for definitions on coral condition categories and identification.

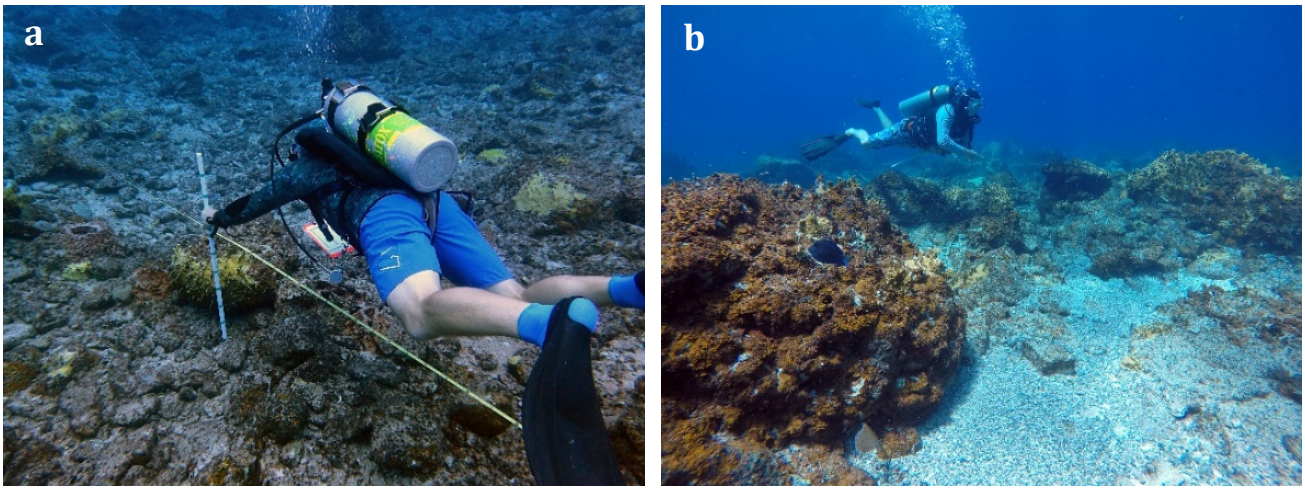


Figure 2. Examples of (a) a diver collecting benthic Line Point Intercept (LPI) data in St. John; and (b) a diver collecting Reef fish Visual Census (RVC) fish survey data in St. John. Photo credits: NOAA NCCOS

If coral disease was putatively Stony Coral Tissue Loss Disease (SCTLD), the surveyor photographed the colony and the NCRMP team shared photographs with regional coral disease experts for review and verification (NOAA NCCOS 2019b). Local partners were consulted prior to field sampling to develop a standard set of survey gear decontamination protocols for all surveyors to follow (NOAA ONMS 2019). Divers followed these decontamination protocols during the missions to prevent any potential transmission of SCTLD between sites through diving or sampling equipment.

Bleaching (total, partial, paling) presence is consistently recorded during NCRMP sampling; however, field sampling dates are do not always coincide with bleaching events. Therefore, peak bleaching events may be missed due to mission timing and seasonal variation. For example, in October 2019, a localized bleaching episode occurred in the USVI after completion of NCRMP sampling in August; this bleaching event is not represented in the NCRMP 2019 USVI data.

Fish Communities

The Reef fish Visual Census (RVC) is a stationary point count sampling protocol (NOAA NCCOS and NOAA SEFSC 2019) modified from Bohnsack and Bannerot (1986). A two diver team surveyed all fish within adjoining 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, counted, and fork length was measured to the nearest centimeter (Figure 2b). Data collected by the diver survey pair were averaged at the site level.

III. Analyses

Data Quality Assurance

NCRMP data quality standards are met using five primary approaches:

1) NCRMP surveyors demonstrate expertise in field identification prior to field surveys. Surveyors are trained in NCRMP methods through a) detailed training for new surveyors, and b) annual refresher training for repeat surveyors;
2) NCRMP fish surveyors calibrate length measurements using an All-Purpose Tool (APT), a one meter stick with a 30 cm perpendicular attachment on one side marked in 1 cm increments, during in-water training sessions prior to field sampling;
3) Reciprocal data checks following data collection at each site. Upon surveyors' return to the survey vessel after each dive, surveyors trade datasheets with their dive buddy and review to ensure all data were collected consistently and completely;
4) Divers enter their data into the online database and then compare their original datasheets with the database entries; and
5) Quality checks are applied to data after export from the database. Basic statistical analyses are conducted for quality checks (e.g., by species, by diver). Analyses scripts are open source and available at:

   Fish R package (Ganz and Blondeau 2015): https://github.com/jeremiaheb/rvc

   Benthic R package (Groves and Viehman 2019): https://github.com/shgroves/NCRMP_benthics

   Once the data are fully vetted through these quality checks, data are archived at NCEI and released publicly (Appendix A).

Analytical Methods

Benthic Communities

Coral demographic sampling within NCRMP targets a coefficient of variation (CV) of 20% or lower for the regionally specific sampling design. A 20% CV can be translated to the ability to statistically detect a 40% change in density. Therefore, a lower CV increases the ability to detect changes over time, such as coral density. The sample allocation is optimized for species that are identified as major reef-building species or those of interest to management.

Coral colony size is represented by the total 3-dimensional surface area of live coral tissue on coral colonies. This is not equivalent to either the volume or area of skeletal structure. The total surface area of the colony is calculated as half of an ellipsoid (note: no survey information is collected on colony morphology; inaccuracies are inherent in calculations due to morphological differences).

The overall surface area is calculated for each colony as:

$$SA = 2\pi \sqrt[p]{\frac{a^p b^p + a^p c^p + b^p c^p}{3}}$$

where $a = \frac{1}{2}$ colony maximum diameter, $b = \frac{1}{2}$ colony perpendicular diameter, $c = \frac{1}{2}$ colony height, and $p = 1.6$.

The surface area of live tissue on each colony is calculated as surface area of the colony less the surface area of mortality on each colony according to the equation:

$$SA_{adj} = SA - (SA \times \frac{M_{old} + M_{recent}}{100})$$

where M_{old} = old mortality and M_{recent} = recent mortality.

Fish Communities

NCRMP fish sampling similarly targets a minimum of 20% CV for the regionally specific sampling design species. In the Caribbean, the sample allocation selects for species that are targeted and non-targeted ecosystem species. The allocation species are all life stages of blue tang (*Acanthurus coeruleus*), foureye butterflyfish (*Chaetodon capistratus*), french grunt (*Haemulon flavolineatum*), coney (*Cephalopholis fulva*), red hind (*Epinephelus guttatus*), queen triggerfish (*Balistes vetula*), stoplight parrotfish (*Sparisoma viride*), and yellowtail snapper (*Ocyurus chrysurus*). Other more common reef fish species or fishes that share similar characteristics to the locally important and fishery targeted allocation species are similarly well-sampled. Additionally, a two-tailed T-test was performed for each species (inside versus outside), where appropriate (see Results section).

Results

Survey site locations for the 2019 sampling year are shown in Figure 3. Table 1 breaks down the number of sites sampled at each location by survey type from 2013–2019.

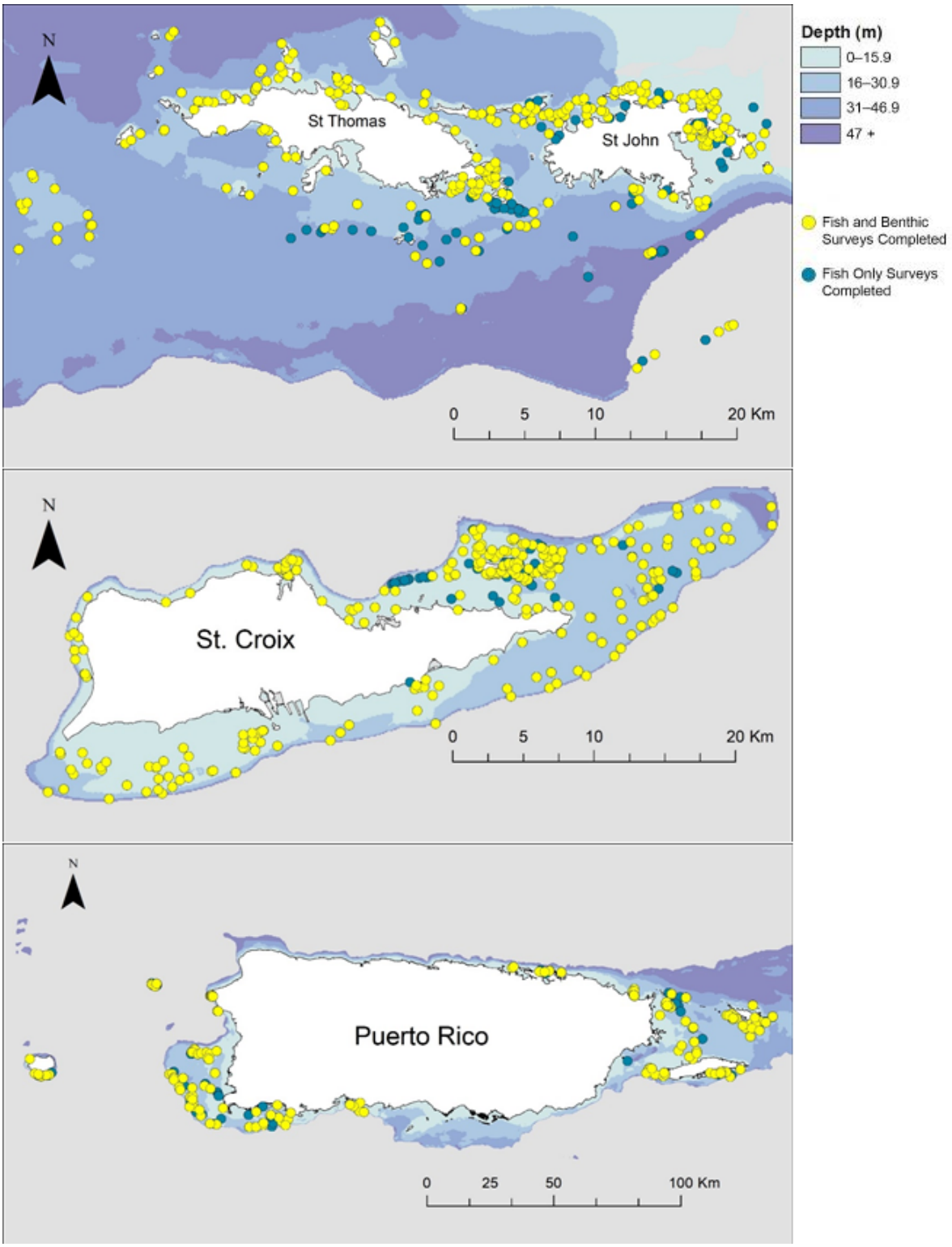


Figure 3. NCRMP survey sites sampled in St. Thomas and St. John (top), St. Croix (middle), and Puerto Rico (bottom) in 2019. Blue and yellow circles indicate survey locations. Legend shows bathymetric depth (m) gradients in each sample region along the mapped zone of the shelf edge. Grey zone indicates unmapped areas. Seven exploratory sites sampled St. John in 2019 were located outside of the mapped zone.

Table 1. Total NCRMP fish and benthic surveys completed by year in the U.S. Virgin Islands (USVI) and in Puerto Rico. 2013 USVI sampling includes only St. Thomas and St. John. Subsequent years of USVI sampling includes: St. Thomas, St. John, and St. Croix. In 2019, the NCRMP annual sampling schedule was revised to survey USVI and Puerto Rico in the same year.

	US Virgin Islands				Puerto Rico	
	St. Croix		St. Thomas/St. John			
Year	*Fish*	*Benthic*	*Fish*	*Benthic*	*Fish*	*Benthic*
2019	314	257	322	239	203	159
2017	181	175	239	235	-	-
2016	-	-	-	-	240	162
2015	239	139	255	168	-	-
2014	-	-	-	-	230	230
2013	-	-	283	283	-	-

I. Benthic Community Results

Coral and Macroalgae Cover

The Benthic Assessment surveys provide information on: 1) cover of biotic (e.g., coral, macroalgae, crustose coralline algae, sponges) and abiotic (e.g., hardbottom, softbottom) benthic habitat; 2) ESA-listed coral species detections at survey sites; 3) reef structural complexity; and 4) specific indicator species (i.e., Caribbean spiny lobster [*Panulirus argus*], queen conch [*Strombus gigas*], long-spined urchins [*Diadema antillarum*]). Benthic cover data are reported as percent cover by region both for a given sample year and, when applicable, as a trend analysis across years in each region.

The mean coral cover for all regions shows a declining trend over time (Figure 4a). In 2019, mean coral cover was approximately 5% or less in all regions (Puerto Rico: 5.08% ± 0.48, St. Thomas/John: 4.2% ± 0.37, St. Croix: 4.1% ± 0.32; Figure 4a). See Appendix (Figure A1) for mean coral cover stratified by habitat type. Figure 5a illustrates a rare high coral cover site in the USVI.

Macroalgae cover was variable between years and regions. In 2019, macroalgae cover varied between approximately 18–25% (Puerto Rico: 19.4% ± 1.95, St. Thomas/John: 25.2% ± 1.43, St. Croix: 17.9% ± 1.34; Figure 4b). 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 5b is an example of a high macroalgal site surveyed in the USVI.

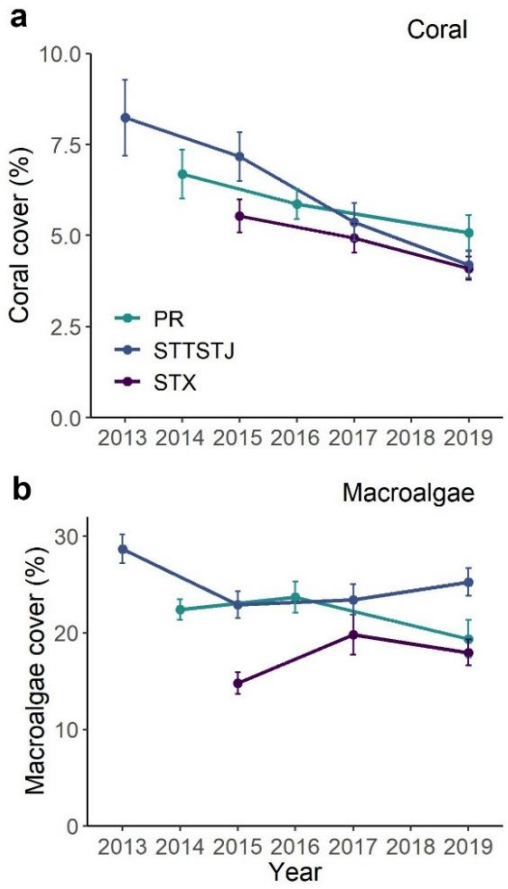


Figure 4. Mean (±SE) cover (%) for (a) corals and (b) macroalgae for each NCRMP sampling year in St. Thomas and St. John (blue), St. Croix (purple), and Puerto Rico (teal).

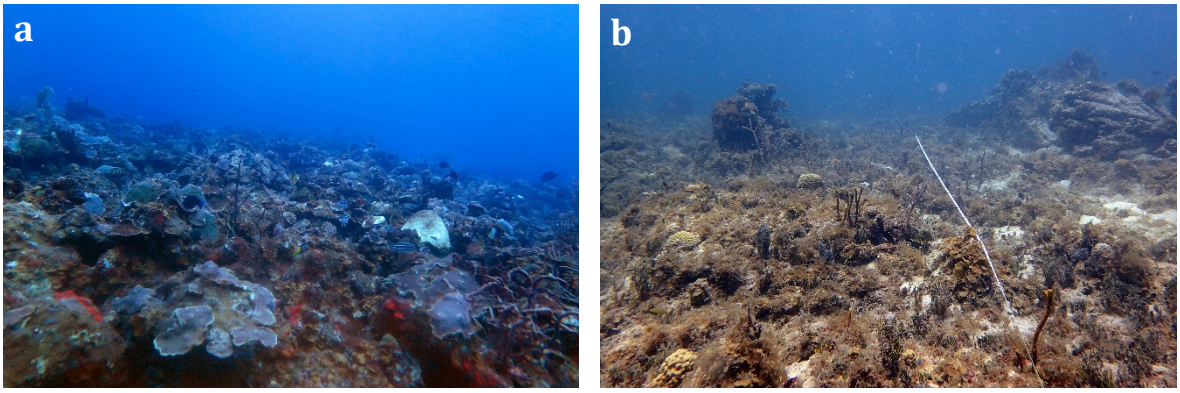


Figure 5. Examples of (a) a high coral cover site in the USVI, and (b) a high macroalgal cover site in the USVI. Photo credit: NOAA NCCOS

Coral Demographics

NCRMP coral demographic survey results show that approximately 8–14 individual species have CVs of 20% or better (Figures 6–8). However, as coral species continue to decline from threats such as SCTLD, the frequency of occurrence declines, making it more difficult to achieve a 20% CV.

The frequency of occurrence of coral species (reported as number of species observed by sites surveyed) and CV of density (Figures 6–8) illustrate that the species composition in each region is driven by the following most common coral species: *Porites astreoides, Siderastrea siderea, Agaricia agaricites, Montastraea cavernosa, Pseudodiploria strigosa*, and *Stephanocoenia intersepta*. Density is highly variable across species as well, and the most common species also have the highest density (Figure 9).

For ESA-listed coral species, the orbicellids (*Orbicella annularis, Orbicella franksi,* and *Orbicella faveolata*) were observed at over 40% of the 486 sites in the USVI where ESA-listed species presence was surveyed as part of the benthic assessment in 2019. Other ESA-listed species were observed at much lower frequencies (*Acropora cervicornis* = 4.1%, *Acropora palmata* = 9.1%, *Dendrogyra cylindrus* = 12%, and *Mycetophyllia ferox* = 2.7%). In Puerto Rico in 2019, orbicellids were observed at 18–34% of the 159 sites surveyed, and all other ESA-listed species were observed at lower frequencies (*A. cervicornis* = 12%, *A. palmata* = 5.7%, *D. cylindrus* = 28%, and *M. ferox* = 0.63%).

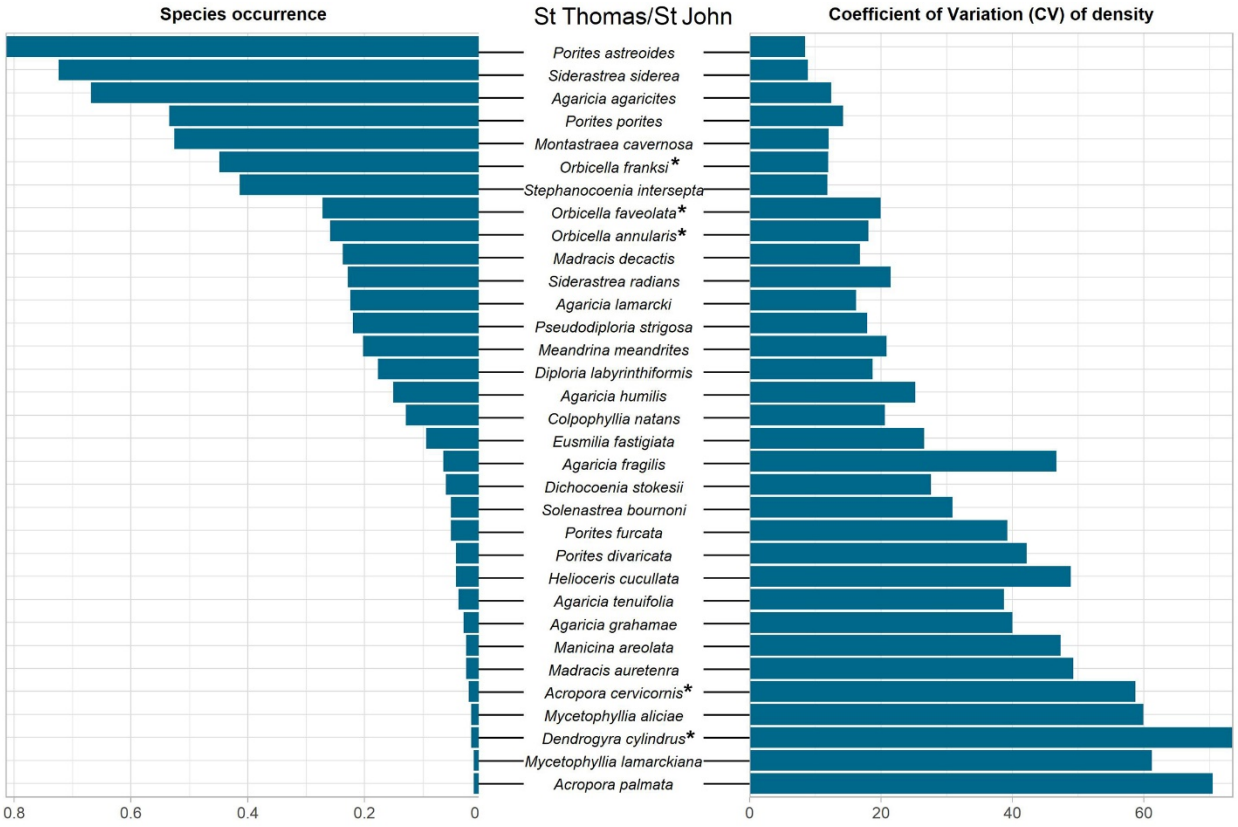


Figure 6. Occurrence of the top coral species sorted by increasing coefficient of variation (CV) of density in St. Thomas and St. John, USVI coral demographic surveys in 2019. Species with an occurrence less than 0.01 are not shown. * indicates ESA-listed species.

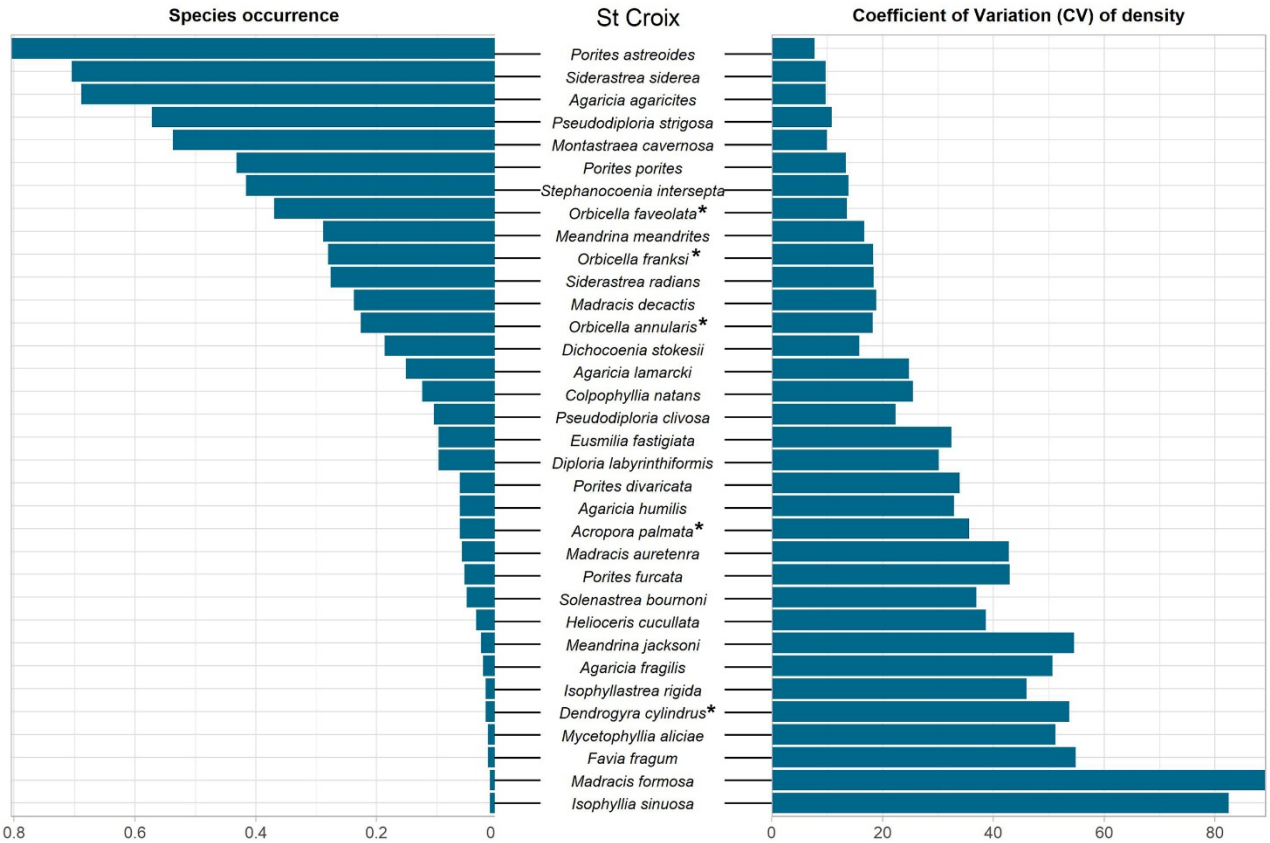


Figure 7. Occurrence of the top coral species sorted by increasing CV of density in St. Croix, USVI coral demographic surveys in 2019. Species with an occurrence less than 0.01 are not shown. * indicates ESA-listed species.

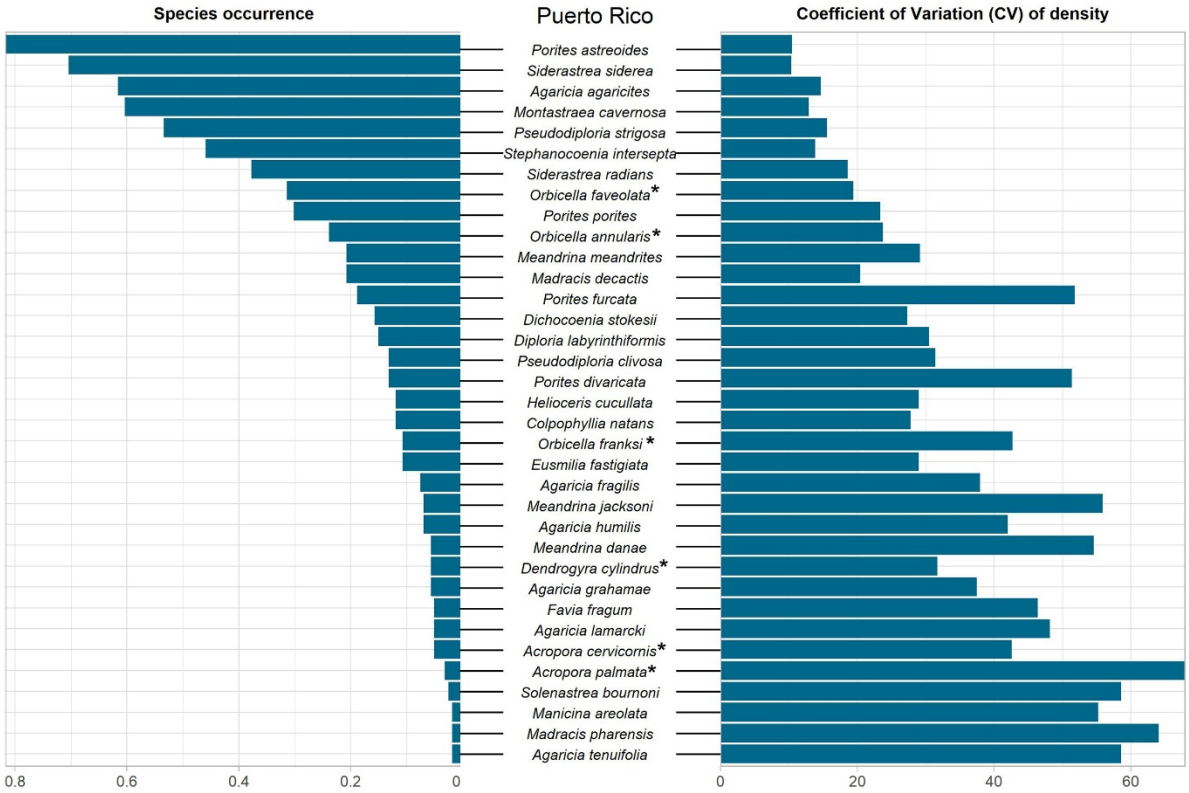


Figure 8. Occurrence of the top coral species sorted by an increasing CV of density in Puerto Rico coral demographic surveys in 2019. Species with an occurrence less than 0.01 are not shown. * indicates ESA-listed species.

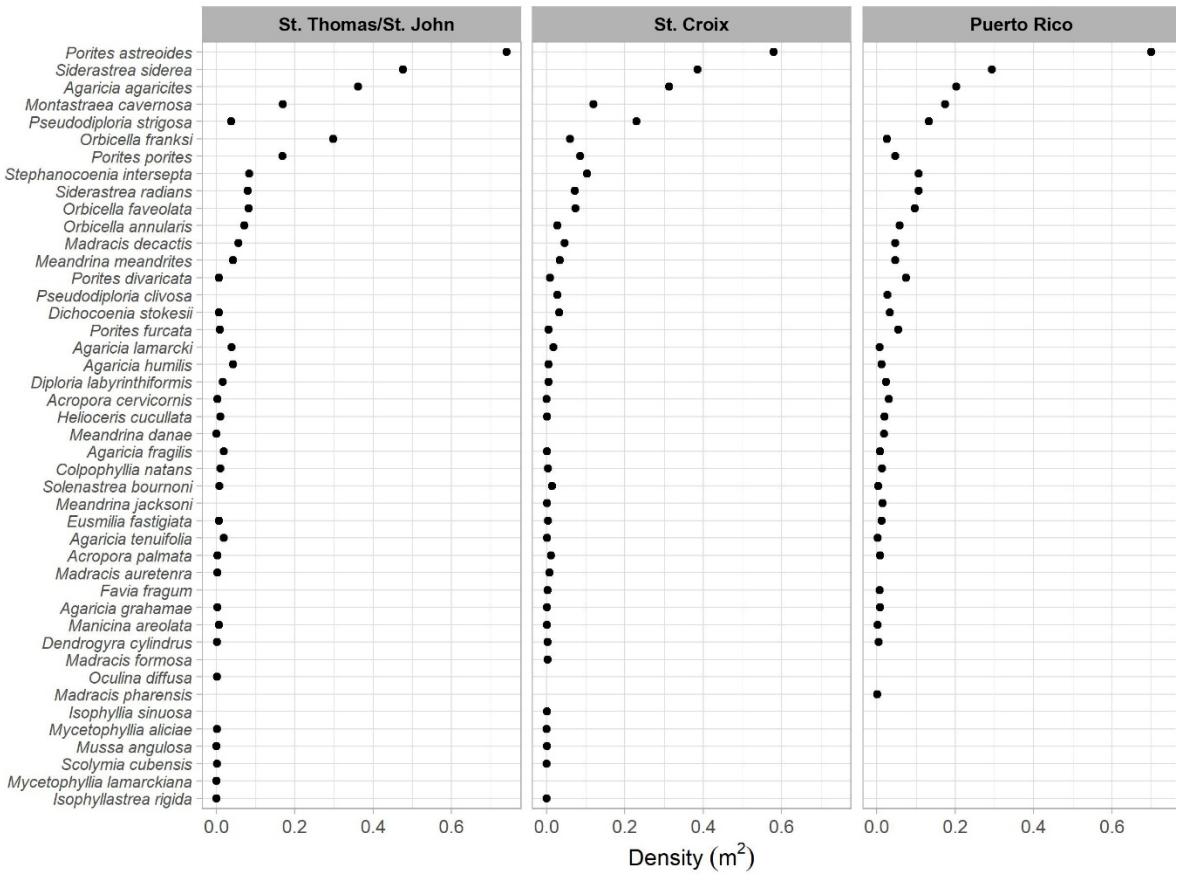


Figure 9. Mean coral density of species for each region in 2019. Approximately seven species (top of y-axis) drive the mean density in each region.

All three Caribbean regions show a decline in coral density over time (Figure 10a). Old mortality also declined in all three regions until 2017 when there was an increase in the USVI but continued decline in Puerto Rico (Figure 10b).

In Figure 10c, colony size is represented by the total 3-dimensional surface area of live coral tissue on coral colonies. In Puerto Rico and St. Thomas and St. John, coral colony size has gradually declined. In St. Croix, coral colony size was variable between years. Colony size is an important component of colony density. While small colonies collectively can lead to a high density (Figure 9), this does not equate with a high density of large, healthy, reef building corals.

Figures 11a and 11b illustrates the differences in recent versus old mortality in a coral demographics survey from Puerto Rico 2019 survey efforts; note the distinction between the uncolonized (Figure 11a) versus colonized (Figure 11b) coral skeleton.

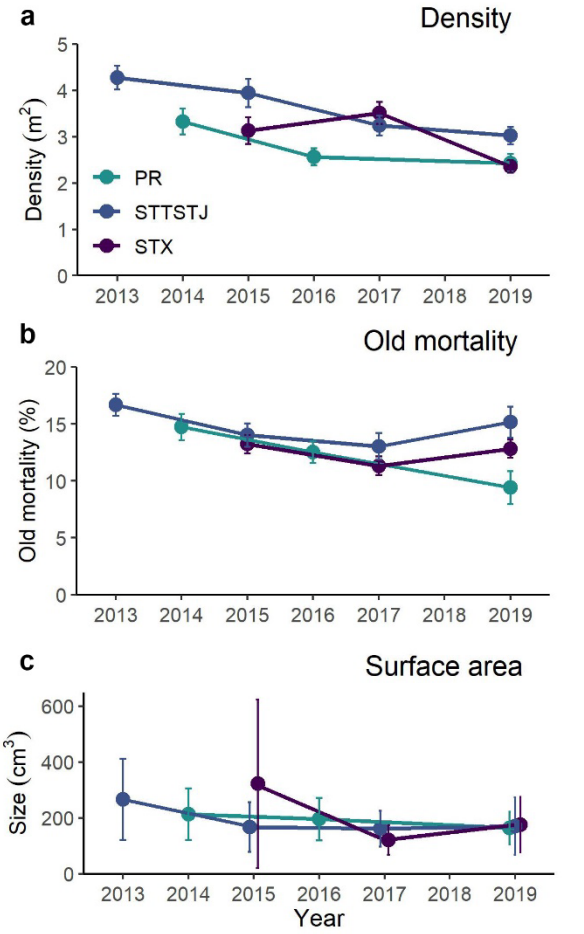


Figure 10. Mean (± SE) coral (a) density, (b) old mortality, and (c) 3-dimensional colony size for each NCRMP sampling year in St. Thomas and St. John (blue), St. Croix (purple), and Puerto Rico (teal).

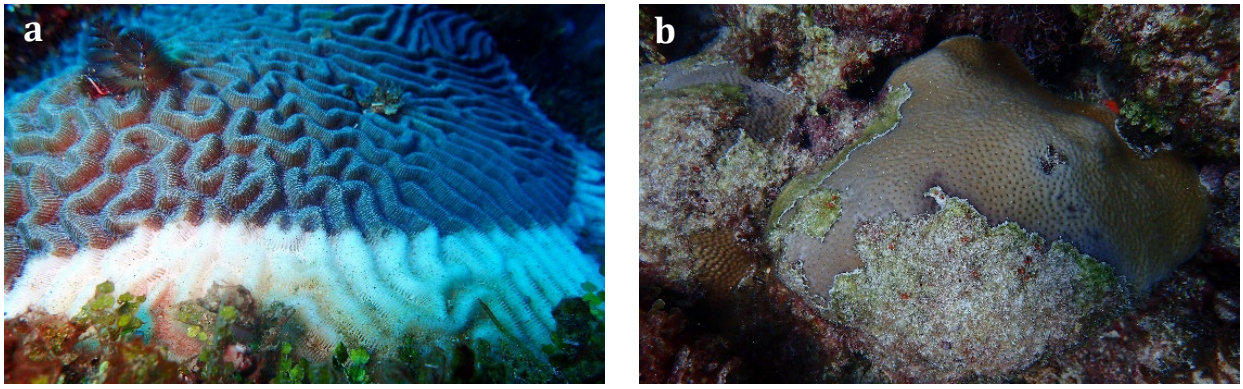


Figure 11. Examples of (a) recent mortality in *Colpophyllia natans* characterized by bright white skeleton and (b) old mortality in *Siderastrea siderea* colonies characterized by algal growth on the skeleton from Puerto Rico in 2019. Photo credit: NOAA NCCOS

Coral Bleaching and Disease

Bleaching and disease were present and recorded on a variety of coral species for the 2019 sampling year (Figure 12). Figures 13 and 14 show the bleaching and disease prevalence, respectively, by coral species for the 2019 sampling year. Prevalence here is defined as the mean percentage of corals with any bleaching/disease, out of the total number of corals by species for all sites. Orbicellids showed bleaching in all three regions in 2019 NCRMP sampling. *Siderastrea* spp. had a high prevalence of bleaching in all three regions (Figure 13). In St. Thomas and St. John, the highest bleaching prevalence observed in 2019 NCRMP sampling was on the coral species *Dichocoenia stokesii, Agaricia lamarcki,* and *Siderastrea* spp (Figure 13a). In St Croix, the highest bleaching prevalence was observed on *Agaricia grahamae*, *S. siderea* and *Favia fragum* (Figure 13b). In Puerto Rico, the highest bleaching prevalence was observed on *Diploria labyrinthiformis, O. annularis,* and *S. siderea* (Figure 13b).

Figure 12. Example of bleached *Madracis decactis* characterized by bright white live tissue from St. Croix in 2019. Photo credit: NOAA NCCOS

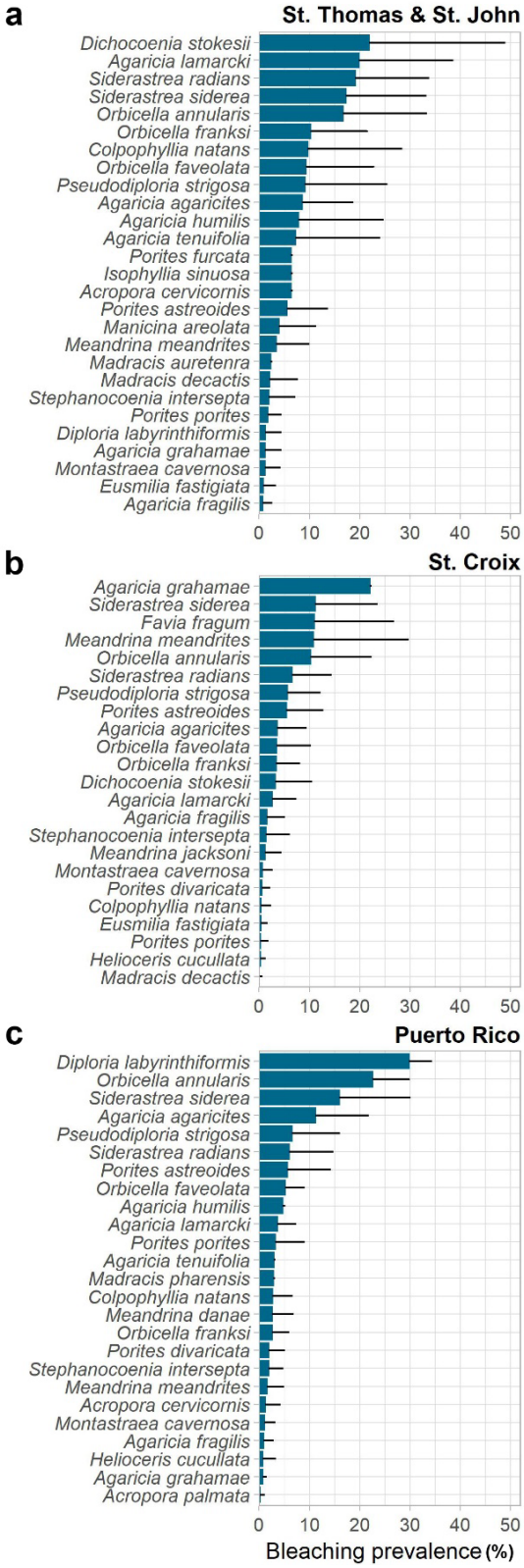


Figure 13. Mean bleaching prevalence (% ±SE) by coral species for (a) St. Thomas and St. John, (b) St. Croix, and (c) Puerto Rico in 2019. Species not listed had no bleaching detected in the NCRMP 2019 sampling season. Prevalence here is defined as the mean percentage of corals with any bleaching out of the total number of corals by species for all sites.

In St. Thomas and St. John, the highest prevalence of coral disease was observed in the coral species *Solenastrea bournoni, D. cylindrus*, and *A. palmata* (Figure 14a). In St. Croix, the highest disease prevalence was observed on *S. siderea, A. palmat*a, and *Madracis decactis* (Figure 14b). In Puerto Rico, *O. faveolata, S. siderea*, and *M. cavernosa* had the highest disease prevalence (Figure 14c).

At the time of NCRMP sampling in 2019, SCTLD had been observed in January of that year in St. Thomas (Figure 15); with no reports from Puerto Rico, St. John, or St. Croix (Martin 2019). By 2020, all regions have since documented SCTLD-associated coral mortality. For more information on SCTLD in the USVI, see Virgin Islands Coral Disease - VI CDAC (https://www.vicoraldisease.org/sctld-strike-teams). Collaborative efforts across the Atlantic and Caribbean are researching and addressing the outbreak of the disease. For more information on the SCTLD breakout and response efforts, see Stony Coral Tissue Loss Disease Dashboard (https://www.agrra.org/coral-disease-outbreak/#sctld-dashboard).

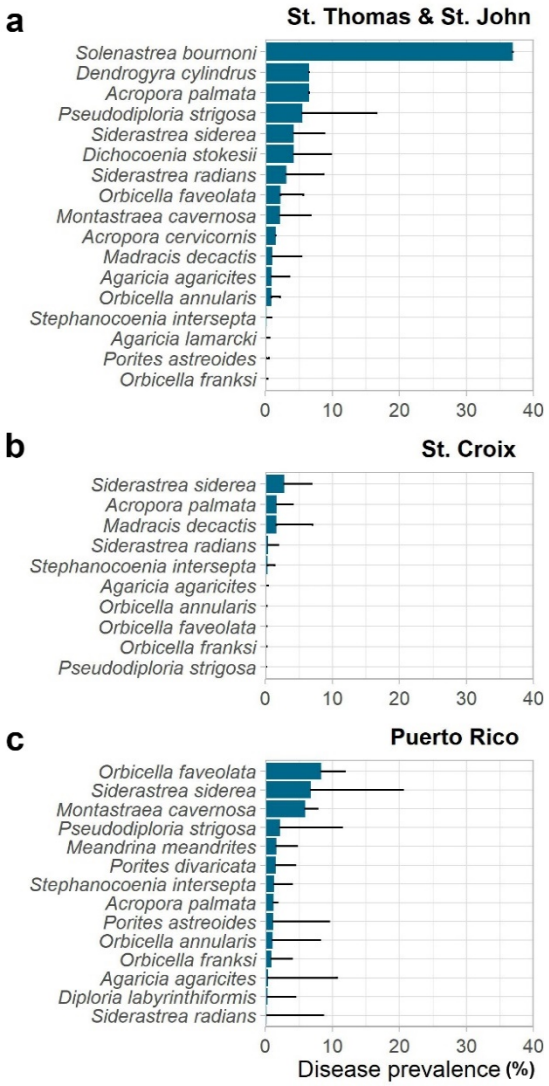


Figure 14. Mean disease prevalence (%, ±SE) by coral species for (a) St. Thomas and St. John, (b) St. Croix, and (c) Puerto Rico in 2019. Species not listed had no disease detected in the 2019 sampling season. Prevalence here is defined as the mean percentage of corals with any bleaching by species out of the total number of corals by species for all sites.

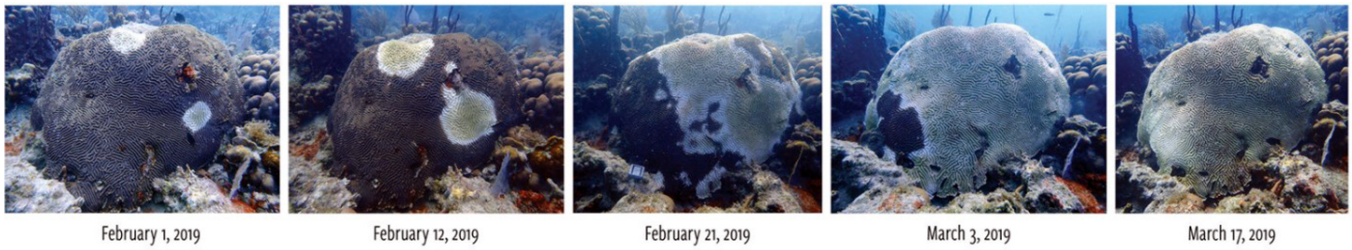


Figure 15. Photo progression series of Stony Coral Tissue Loss Disease in St. Thomas, USVI illustrating the rapid progression of the disease. Photo credit: Sonora Meiling (University of the Virgin Islands).

II. Fish Community Results

Fish Species Occurrence

Even though NCRMP does not specifically target all the species in the sampling design, NCRMP fish survey results show that approximately 35–40 individual species have CV's of 20% or better. A 20% CV can be translated to the ability to statistically detect a 40% change, therefore, a lower CV increases our ability to detect differences. NCRMP does not allocate for species such as bicolor damselfish (*Stegastes partitus*) and spotted goatfish (*Pseudupeneus maculatus*), each seen in >75% of surveys in St. Thomas and St. John (Figure 16) even though they meet the CV criteria of 20% or better because regularly ubiquitous species such as these do not provide strong statistical power in analyzing differences in fish species metrics. Similarly, in both St. Croix (Figure 17) and Puerto Rico (Figure 18) data show that the yellowhead wrasse (*Halichoeres garnoti*) and slippery dick (*Halichoeres bivittatus*) are each highly ubiquitous species that meet the CV criteria of 20% or better, highlighting the importance of allocating for species that meet the CV criteria but are often under sampled due to lower occurrence on the reefs.

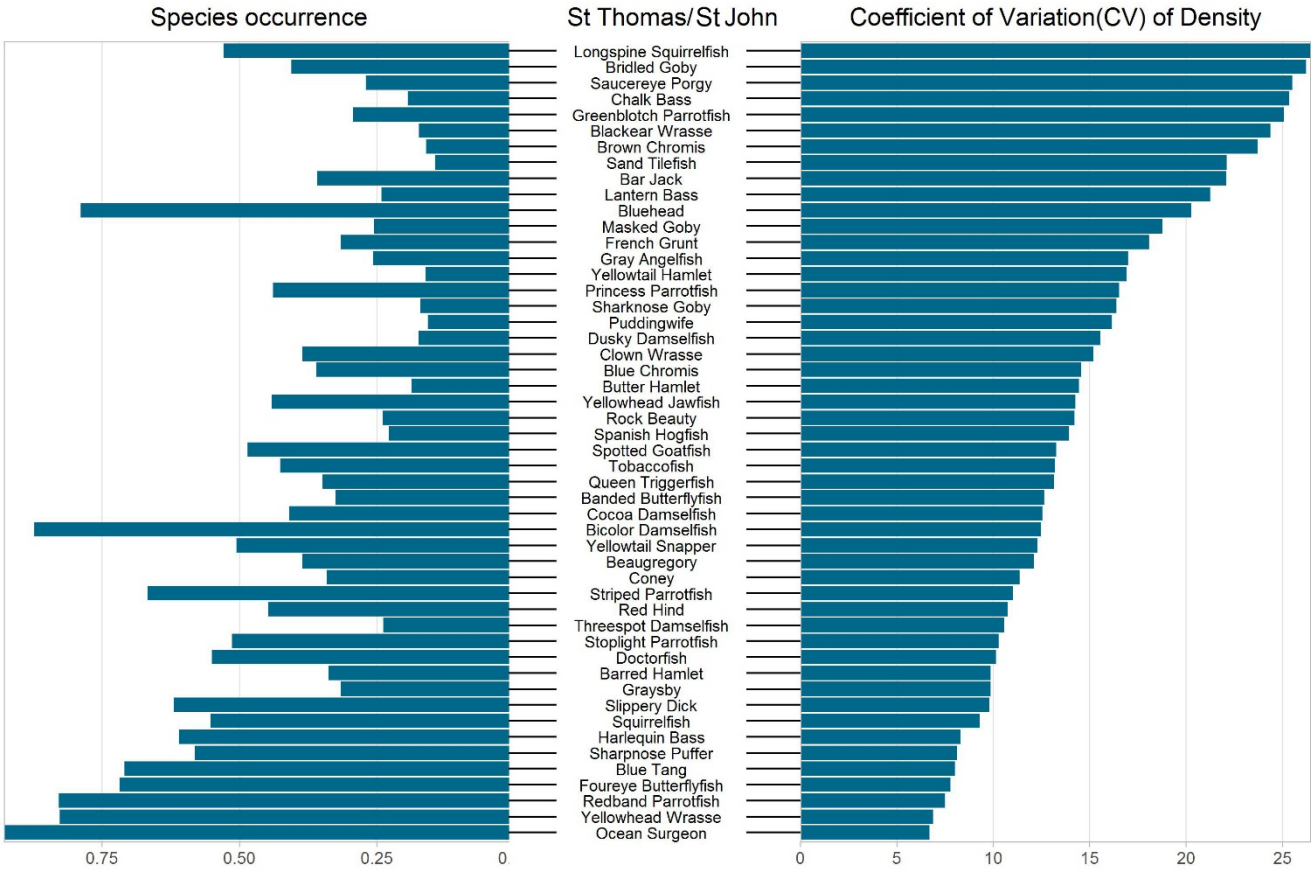


Figure 16. Occurrence of the top 50 reef fish species sorted by increasing CV of density in St. Thomas and St. John, USVI in 2019.

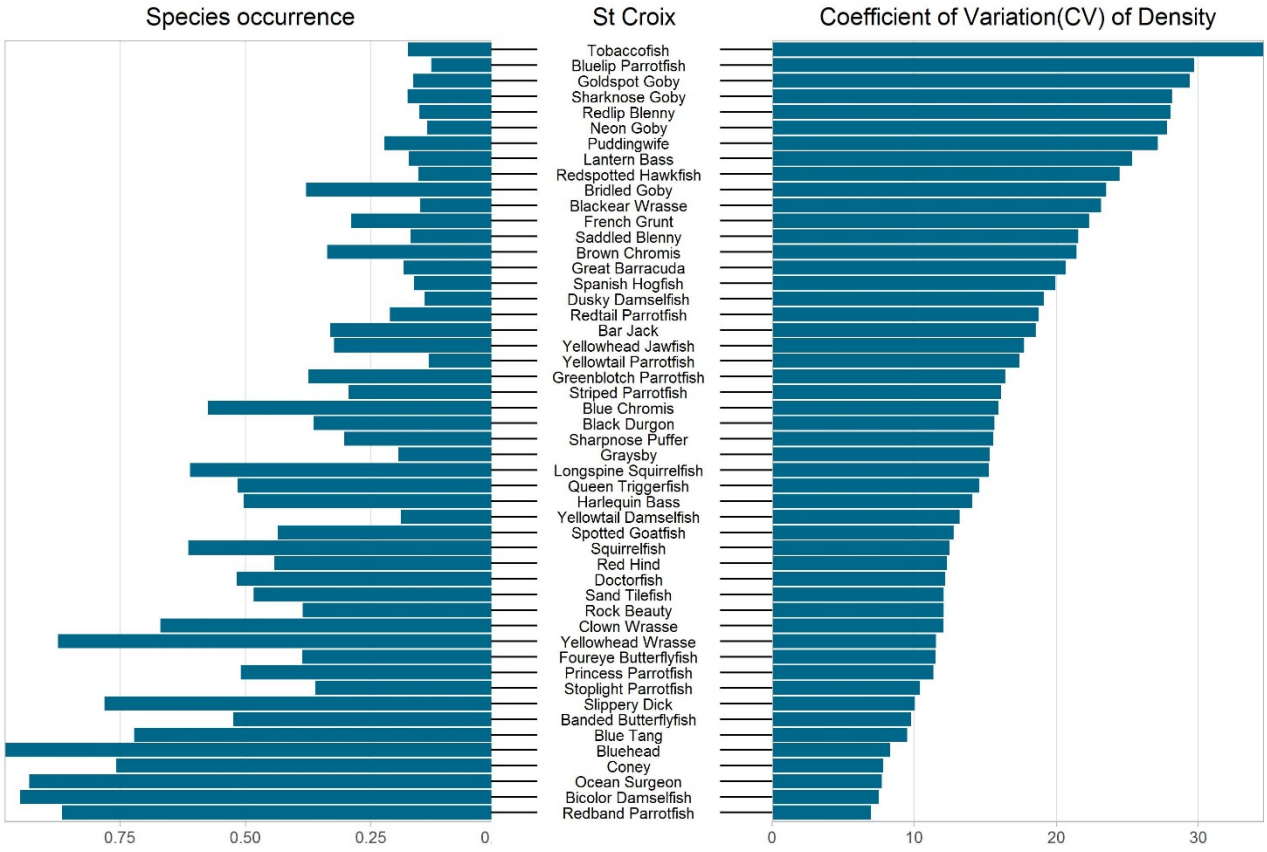


Figure 17. Occurrence of the top 50 reef fish species sorted by increasing CV of density in St. Croix, USVI in 2019.

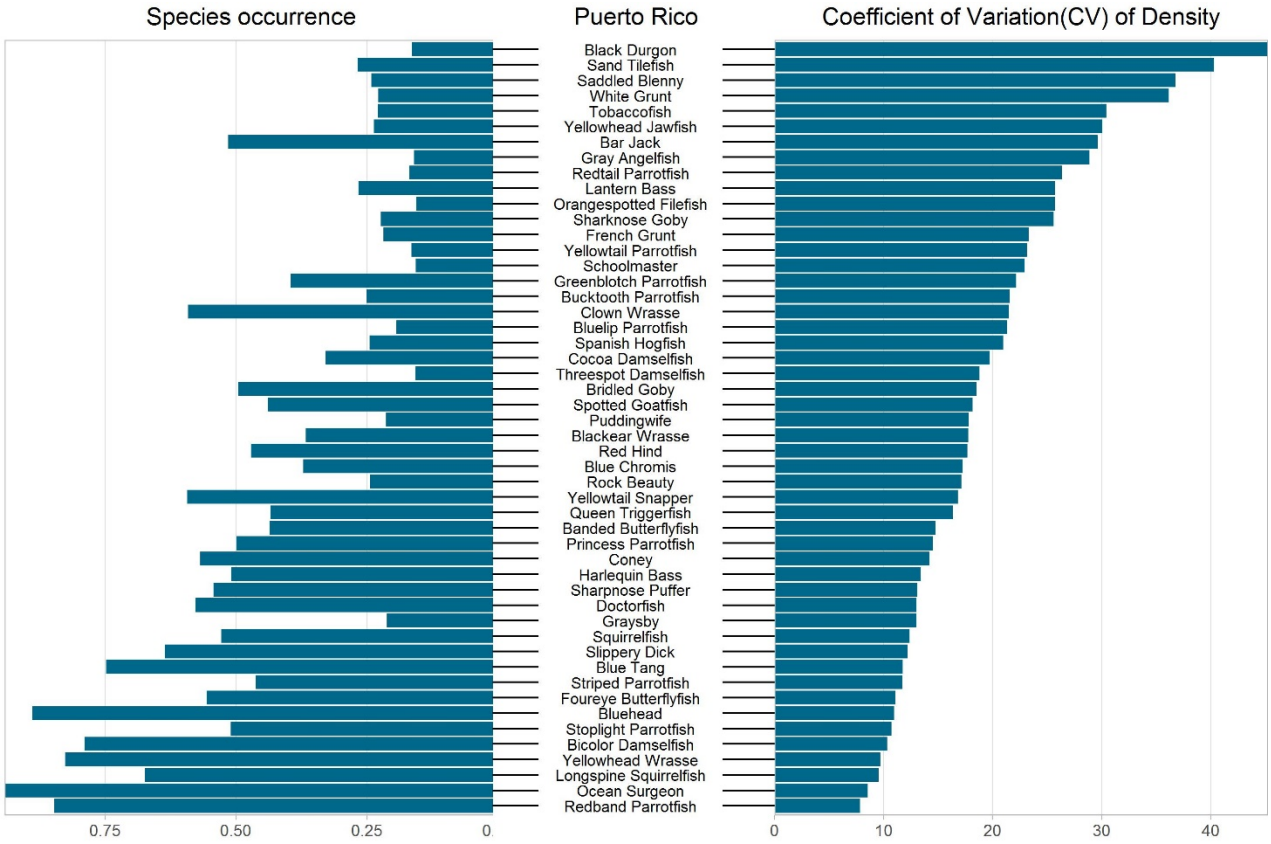


Figure 18. Occurrence of the top 50 reef fish species sorted by increasing CV of density in Puerto Rico in 2019.

Fish Density

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 the U.S. Caribbean, one (USVI) or two (Puerto Rico) species of parrotfish make up 50% of the total parrotfish density, highlighting the importance of analyzing and reporting species-specific information. Redband (*Sparisoma aurofrenatum*) and stoplight parrotfish dominate the parrotfish taxonomic group in Puerto Rico as illustrated in Figure 19. The pattern was similar in the USVI regions.

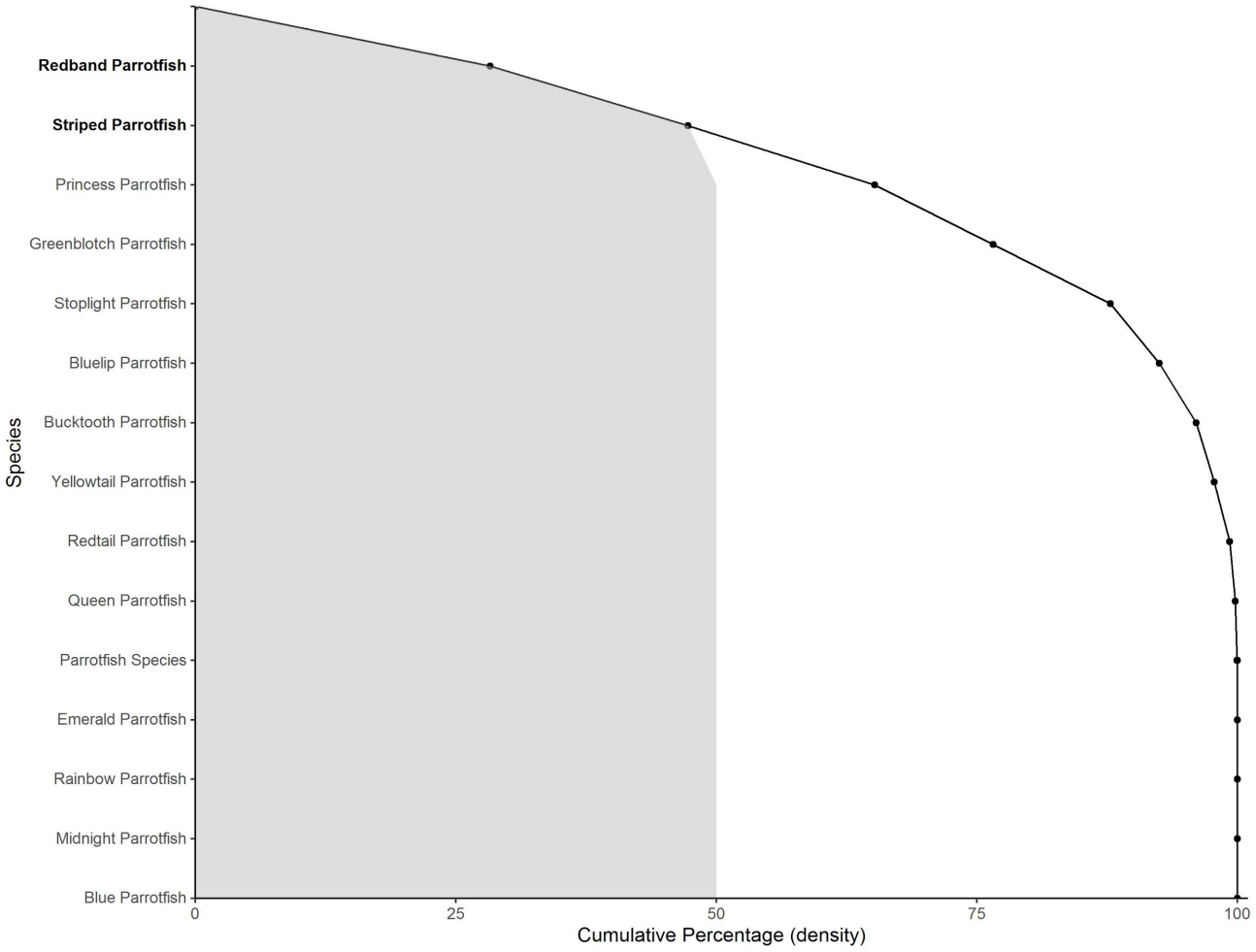


Figure 19. Cumulative density for parrotfishes in NCRMP sampling year 2019 in Puerto Rico. The two dominant species of parrotfish are in bold.

NCRMP's comprehensive sampling design strategy provides a broad, population-level perspective on the reef fish community. This community 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., barracuda [*Sphyraena barracuda*]), and spans all trophic levels. Figure 20 shows the mean density (individuals ha^{-1}) for the top 50 species in 2019 in each region and illustrates the similarities in species composition on the reefs in these three regions, with all three locations dominated by fishery non-targeted species of bicolor damselfish and bluehead wrasse (*Thalassoma bifasciatum*).

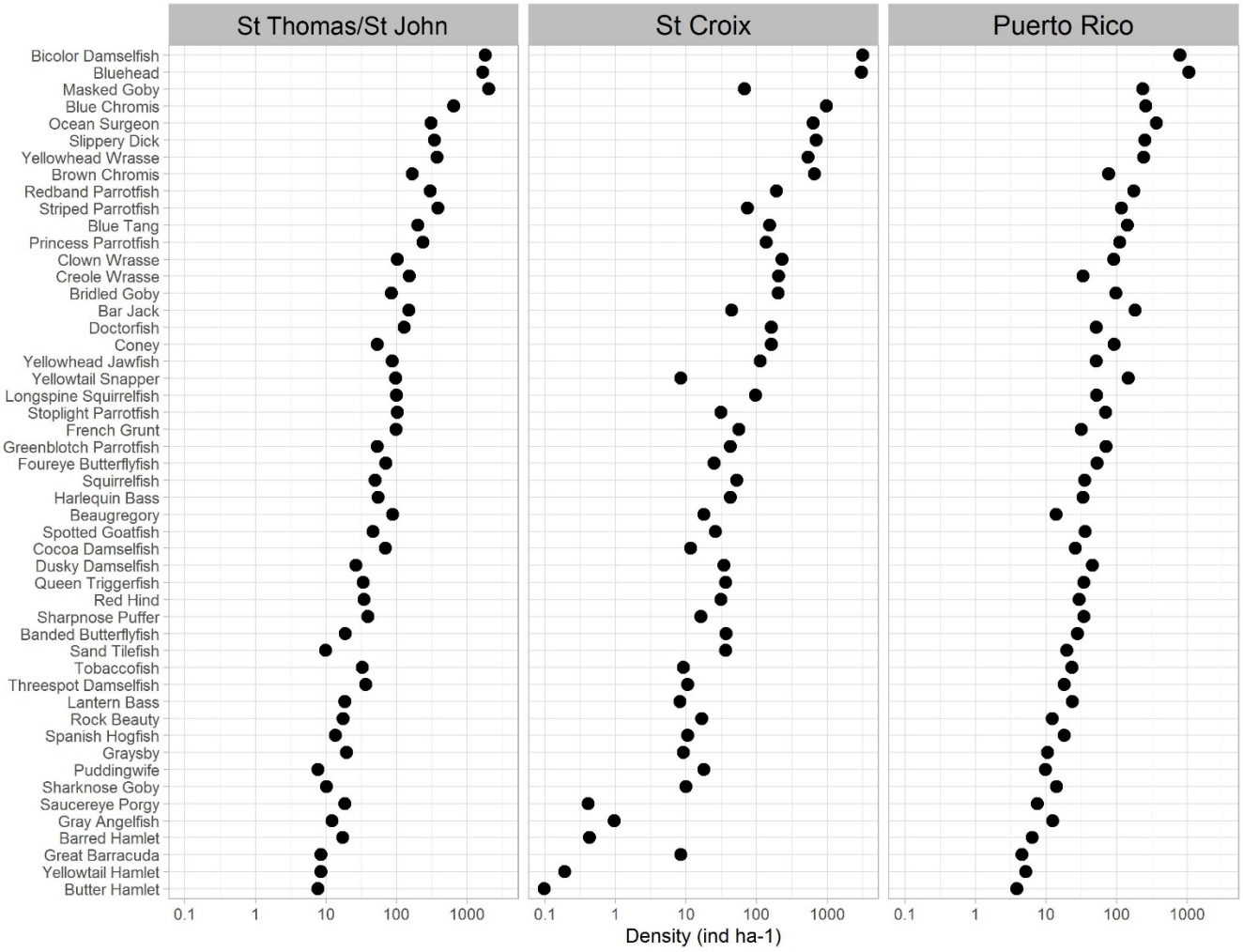


Figure 20. Mean density by region in 2019 of the top 50 (by occurrence) reef fish species. Fish densities are presented on a log scale and show the number of fish per hectare.

Differences between inside and outside spatially managed areas in these regions were analyzed (see Introduction for managed area descriptions). Table 2 illustrates how there are significant differences between managed versus unmanaged zones for some of the allocation species. Three of the seven species showed significant differences between inside and outside national parks in St. Thomas/St. John and St. Croix (coney, queen triggerfish, and red hind).

Table 2. Density of selected fishery target species by region, both inside and outside of national park boundaries in USVI and for Puerto Rico in 2019. Densities are reported as, number of individuals per 177 m^2 ±SE, represent all life stages, and significance (Tukey's two-tailed t-test) was accepted at $p < 0.05$ (*).

	St. Thomas / St. John			St. Croix			Puerto Rico
Species	*Outside*		*Inside*	*Outside*		*Inside*	*Outside*
Stoplight Parrotfish	5.37 (0.47)		4.46 (0.66)	3.30 (0.34)	*	4.24 (0.38)	3.09 (0.24)
Coney	1.06 (0.10)	*	0.18 (0.05)	2.95 (0.30)	*	1.65 (0.24)	1.63 (0.23)
Yellowtail Snapper	1.69 (0.25)		1.78 (0.32)	0.12 (0.04)		0.46 (0.24)	2.56 (0.43)
Queen Triggerfish	0.65 (0.09)	*	0.20 (0.04)	0.66 (0.10)	*	0.44 (0.10)	0.61 (0.10)
Red Hind	0.65 (0.08)	*	0.36 (0.05)	0.57 (0.09)	*	0.34 (0.07)	0.52 (0.09)
Gray Snapper	0.40 (0.20)		0.20 (0.10)	0.09 (0.06)		0.00 (0.00)	0.04 (0.03)
Mutton Snapper	0.14 (0.04)		0.13 (0.04)	0.08 (0.03)		0.09 (0.05)	0.05 (0.02)
Hogfish	0.03 (0.02)		0.02 (0.01)	0.00 (0.00)		0.00 (0.00)	0.08 (0.02)

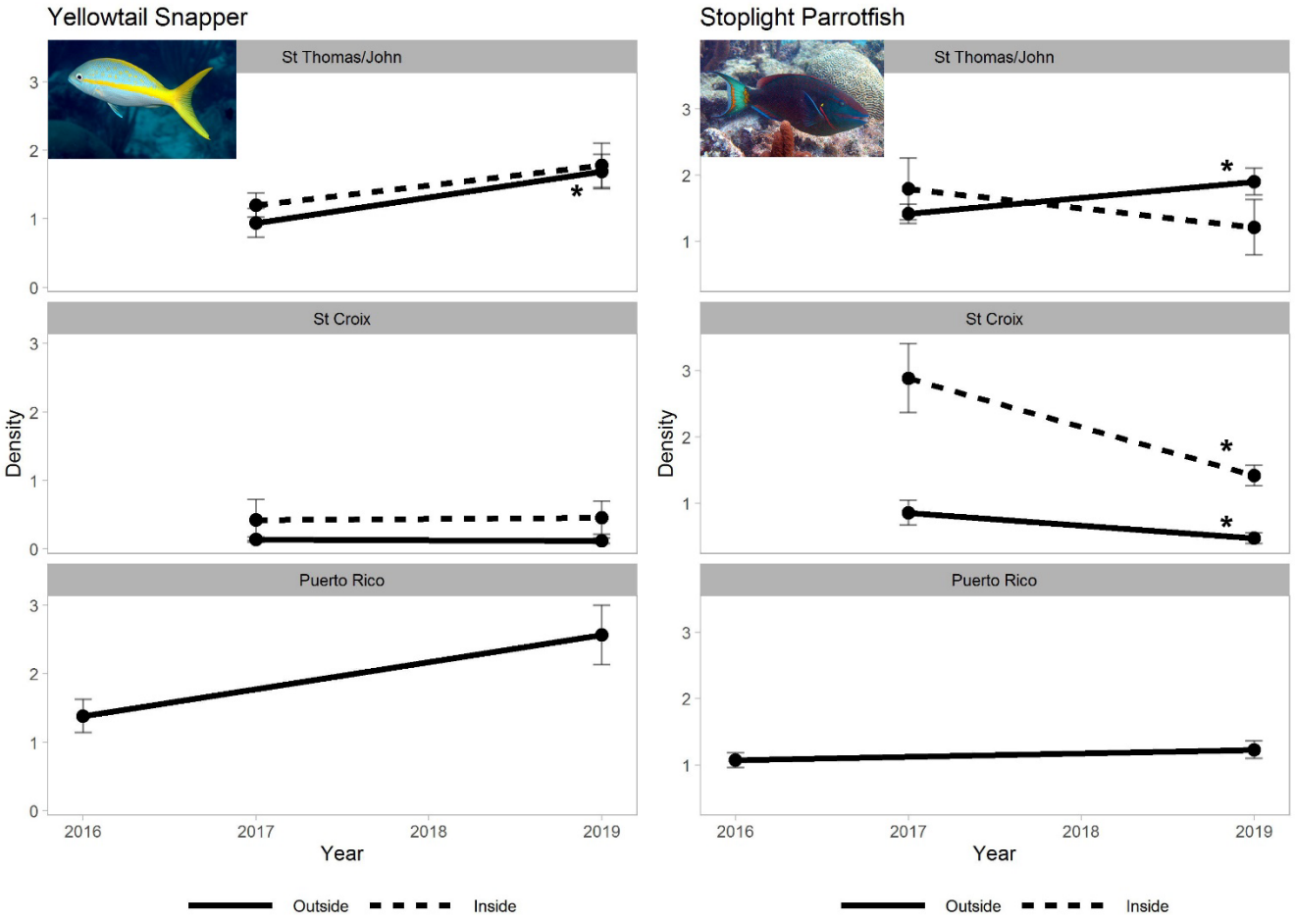


Figure 21. Density of yellowtail snapper and stoplight parrotfish by region and year. Densities are reported as the number of individuals per 177 m^2 ± SE, represents all life stages, and significance (Tukey's two-tailed t-test) was reported by year at $p < 0.05$ (*). Protected status refers to sites inside or outside of a USVI national park boundary. Photo credit: Jiangang Luo (UM-RSMAS; yellowtail snapper) and NOAA NCCOS (stoplight parrotfish).

NCRMP surveys capture an annual snapshot of coral reef fish populations. Reporting annual trends over time provides a more 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), fishing regulations (e.g., minimum size at capture, bag limits, and gear limitations) and natural events (e.g. hurricanes). The suite of species (Table 2) are a representative and diverse group of fishery target species consisting of a snapper, grouper, triggerfish and parrotfish that are consistently observed in high enough numbers to detect change. Figures 21 and 22 show statistical comparisons, tested individually for each protected status, in density between years. Species-specific densities of these select species (Figure 21) resulted in a significant difference in yellowtail snapper and stoplight parrotfish between years outside parks in St. Thomas/St. John. As in Table 2, stoplight parrotfish resulted in significant differences both inside and outside the parks in St. Croix between sample years.

Similarly, queen triggerfish and red hind resulted in significant differences (Table 2) outside the parks in St. Thomas/St. John between sample years. In St. Croix, red hind resulted in a significant difference in density between years both inside and outside parks (Figure 22).

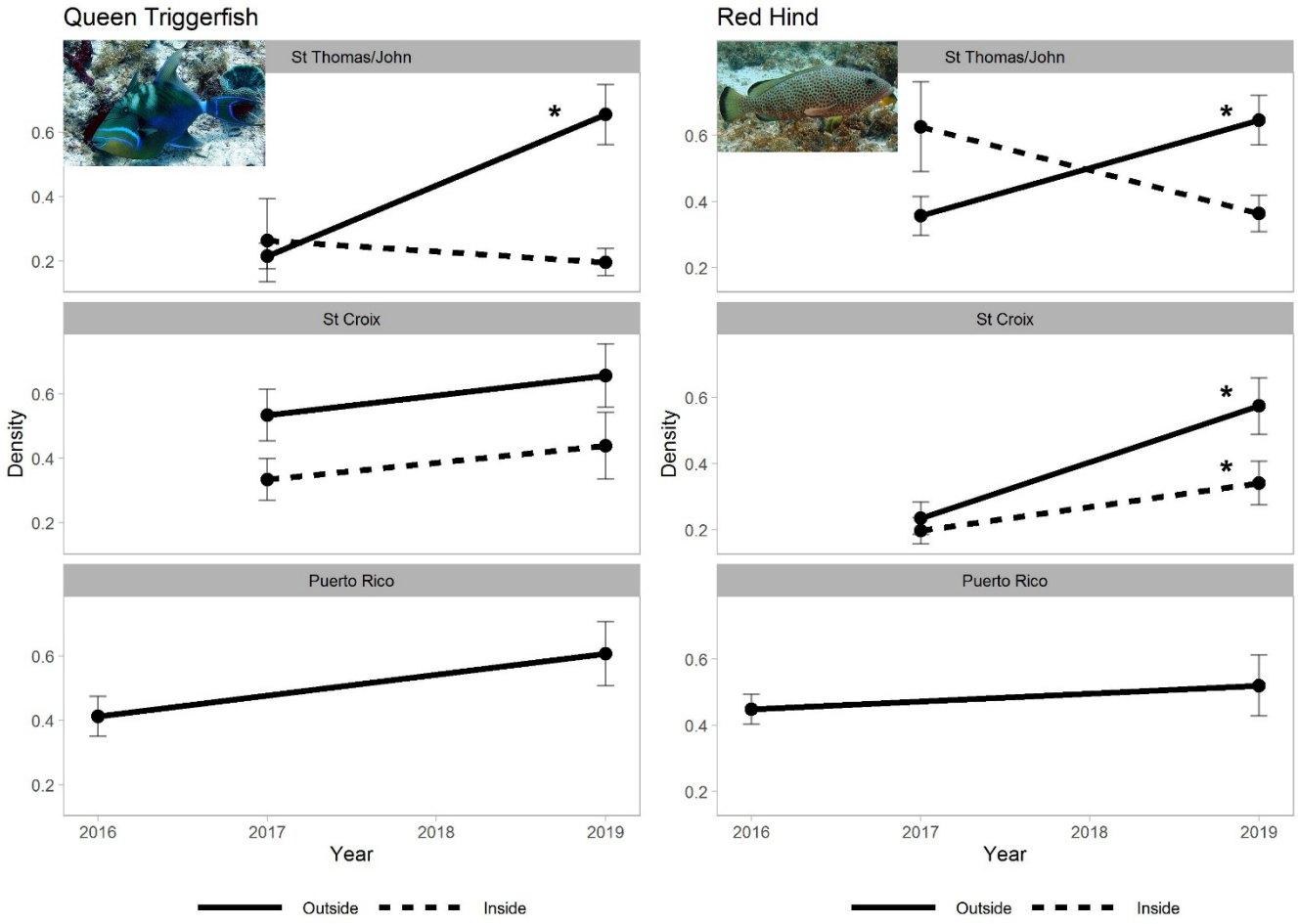


Figure 22. Density of queen triggerfish and red hind by region and year. Densities are reported as number of individuals per 177 m^2 ± SE and significance (Tukey's two-tailed t-test) is reported by year at $p < 0.05$ (*). Protected status refers to sites inside or outside of a USVI national park boundary. Photo credit: NOAA NCCOS

Fish Length Frequency

Length compositions provide a detailed description of a selected fish's population structure. 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 the fishery, each subsequent length class should have less 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. The suite of species in Figures 23 and 24 are a representative and diverse group of fishery target species that are subject to different management regulations. Length frequency figures show that fewer red hind are observed at >30 cm in all regions (Figure 23). While larger individuals of this species are observed less often, it is encouraging that we readily observe size classes above their published length-at-maturity (21.5 cm; Sadovy et al. 1994). In Figure 24, stoplight parrotfish are similarly observed at multiple size classes ranging from small (5–10 cm) to large (30–35 cm) in all three regions.

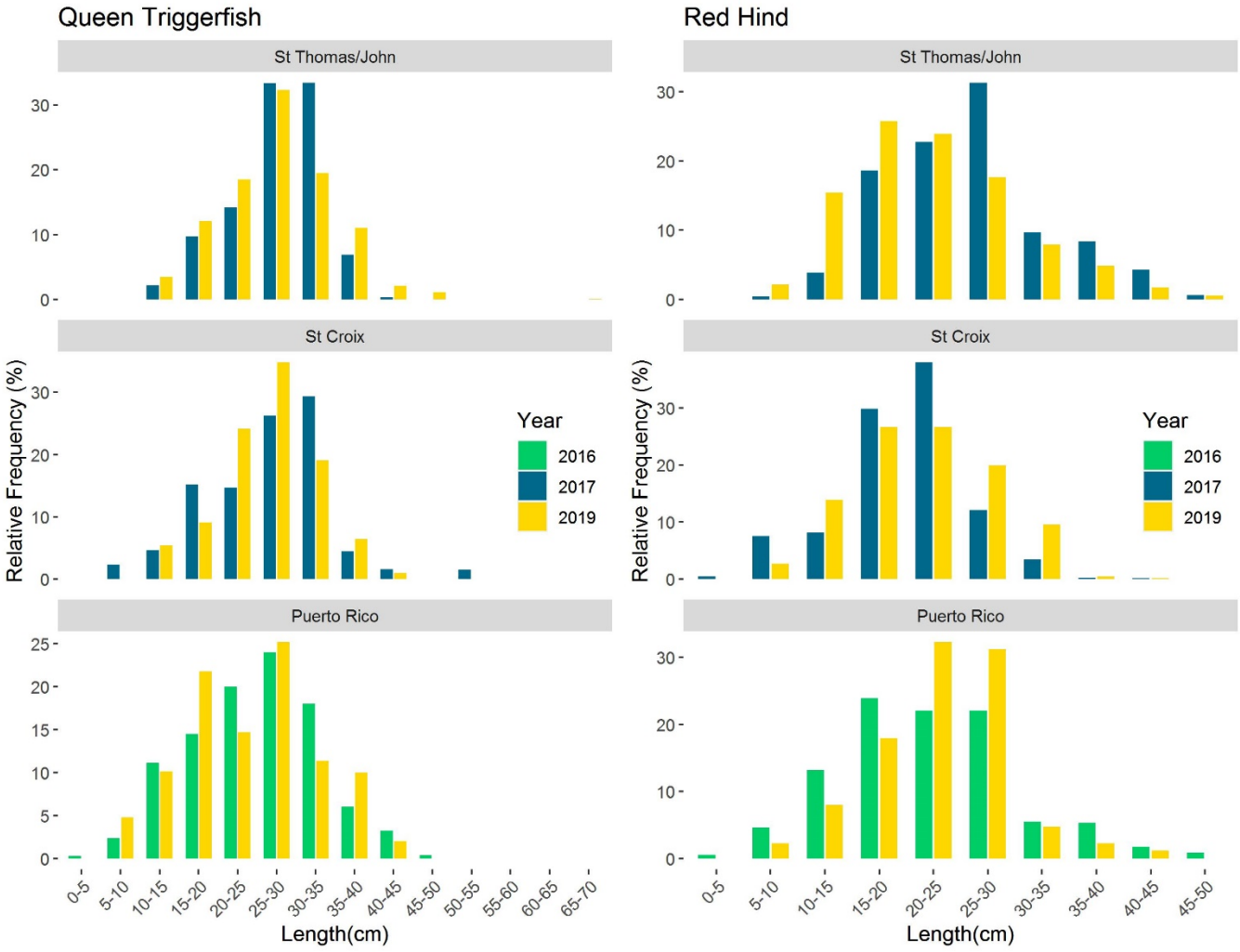


Figure 23. Length frequency of selected fishery target species including queen triggerfish (left) and red hind (right) for each region and most recent NCRMP sample years.

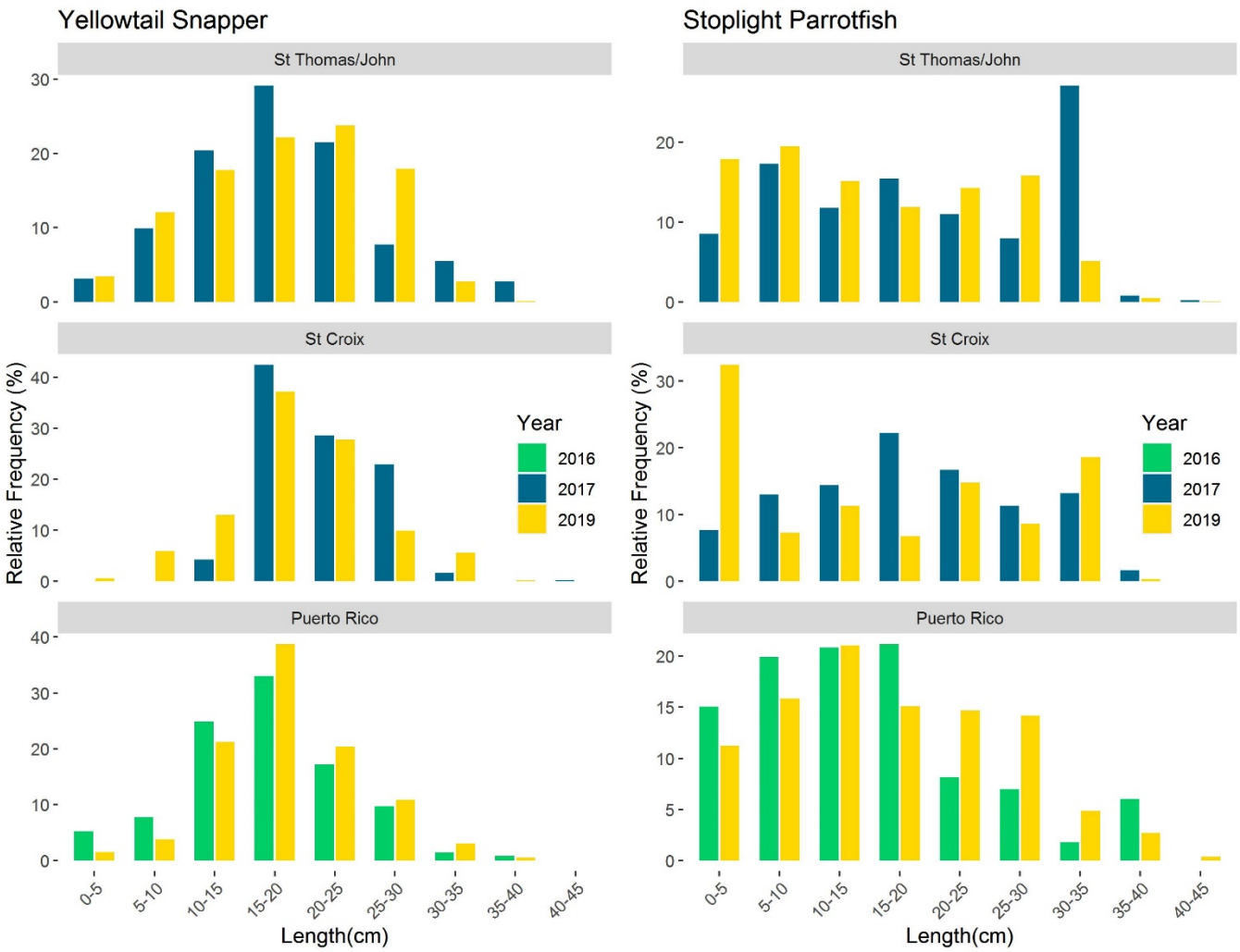


Figure 24. Length frequency of selected fishery target species including yellowtail snapper (left) and stoplight parrotfish (right) for each region and most recent NCRMP sample years.

Summary

NCRMP successfully surveyed over 800 sites in 2019. SCTLD continues to spread throughout the Caribbean and cause widespread coral mortality. SCTLD observations will continue to be included in NCRMP monitoring efforts to support the tracking and remediation efforts led by territorial and commonwealth partners. While mean coral cover shows declines in all regions over time, mean macroalgae cover was highly variable in all regions over time. Bleaching prevalence was reported in 2019 and affected multiple species in each region (Figure 13), even though NCRMP did not sample during a fall bleaching event in the USVI. Coral disease also showed varying prevalence among species in each region. While all three regions showed a steady decline in old mortality during the majority of the monitoring program, this is unlikely to be an indication of improving reef conditions. As large coral colonies continue to lose living tissue and become colonized by other organisms, the extent of the original colony becomes harder to determine and the remaining sections of living tissue can appear as many smaller colonies. One might think this would lead to a corresponding increase in coral density, however, the concurrent decline of coral density in all regions may suggest that these colonies are dying rapidly and being removed from the population, rather than persisting with large sections of colonized coral skeleton.

NCRMP fish data showed that a large number of fishery targeted and non-targeted surveyed fishes, presently 35–40 reef fish species, have CVs of 20% or better. 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), in addition to the regional species of interest. In parrotfishes, one (USVI) or two (Puerto Rico) species made up 50% of the total regional parrotfish density, highlighting the importance of species-specific analyses, as opposed to broader groupings. The importance of species-specific analyses generally extends to all fish groupings (e.g., groupers, snappers, damselfishes, angelfishes, etc.). In the USVI, density of selected fishery-target species (Table 2) varied inside and outside of the national parks with three (St. Thomas and St. John) or four (St. Croix) of the eight selected species having significant differences. Some species had higher densities outside of the spatial protection which could be related to a number of factors including differences in habitat type and quality, time series (more RVC data in future years), and lack of effective enforcement. For fishery-targeted species, it is critical to have estimates of both number and size for management (e.g., setting fishery regulations that allow for a species to reproduce before becoming available for capture). As a fishery-independent survey, NCRMP collects numbers and sizes on all observed fishes to the nearest cm. Selected length frequency graphs showed that in all three regions queen triggerfish, red hind, yellowtail snapper, and stoplight parrotfish were observed from 5 cm to 50 cm (Figures 24–25). Generally, fishes were most common from 15 cm to 30 cm, presumably before capture by the fishery, except for stoplight parrotfish, which was more similarly observed among all size classes.

References

Bohnsack, J., and S. Bannerot. 1986. A Stationary Visual Census Technique for Quantitatively Assessing Community Structure of Coral Reef Fishes. NOAA National Marine Fisheries Service. NOAA Technical Report NMFS 41. 15 pp.

Ganz, H., and J. Blondeau. 2015. Reef Visual Census statistical package in R (website). R package version 1.0.0. Available online: https://github.com/jeremiaheb/rvc (Accessed 19 February 2021)

Groves, S., and S. Viehman. 2019. NCRMP benthics statistical package in R (website). R package version 1.0.0. Available online: https://github.com/shgroves/NCRMP_benthics (Accessed 19 February 2021)

Hughes, T., and J. Tanner. 2000. Recruitment Failure, Life Histories, and Long-Term Decline of Caribbean Corals. Ecology 81(8): 2250–2263. doi: 10.2307/177112

Knowlton, N. 2001. The future of coral reefs. Proceedings of the National Academy of Sciences 98 (10): 5419–5425. doi: 10.1073/pnas.091092998

Kramer, P.R., L. Roth, and J. Lang. 2019. Map of Stony Coral Tissue Loss Disease Outbreak in the Caribbean (website). ArcGIS Online. Online: https://www.agrra.org (Accessed 19 February 2021)

Martin, C. 2019. A mysterious coral disease is ravaging Caribbean reefs. ScienceNews: Magazine of the Society for Science & the Public. July 7, 2019. Online: https://www.sciencenews.org/article/mysterious-coral-disease-ravaging-caribbean-reefs (Accessed 19 February 2021).

NOAA ONMS. 2019. Coral Disease Decontamination Protocol. NOAA National Ocean Service, Office of National Marine Sanctuaries, Florida Keys National Marine Sanctuary. Online: https://nmsfloridakeys.blob.core.windows.net/floridakeys-prod/media/docs/coral-disease-decontamination-protocol.pdf (Accessed 19 February 2021)

NOAA NCCOS. 2019a. National Coral Reef Monitoring Program (NCRMP)—Benthic Assessment Protocols for the Atlantic Region: U.S. Caribbean, Florida and the Gulf of Mexico: 2019 for the Atlantic Region: U.S. Caribbean, Florida and Gulf of Mexico. NOAA National Ocean Service, National Center for Coastal Ocean Services. 26 pp. Online: https://www.nodc.noaa.gov/archive/arc0159/0218548/3.3/data/0-data/NCRMP_PR_2019_Fish/NCRMP_PR_2019_Fish/Documentation/NCRMP_BenthicAssessment_Protocols_2019.pdf (Accessed 19 February 2021)

NOAA NCCOS. 2019b. National Coral Reef Monitoring Program (NCRMP)—Coral Demographic Protocols for the Atlantic Region: U.S. Caribbean, Florida and the Gulf of Mexico: 2019. NOAA National Ocean Service, National Center for Coastal Ocean Services. 23 pp. Online: https://www.nodc.noaa.gov/archive/arc0158/0217139/2.2/data/0-data/NCRMP_PR_2019_Benthics/NCRMP_PR_2019_Benthics/Documentation/NCRMP_CoralDemographic_Protocol_2019.pdf (Accessed 19 February 2021)

NOAA NCCOS and NOAA SEFSC. 2019. National Coral Reef Monitoring Program (NCRMP)—Reef Visual Census (RVC) Fish Survey Protocol for the Atlantic Region: U.S. Caribbean, Florida and the Gulf of Mexico: 2019. NOAA National Ocean Service, National Centers for Coastal Ocean Science. 18 pp. Online: https://accession.nodc.noaa.gov/0218548/data/0-data/NCRMP_PR_2019_Fish/NCRMP_PR_2019_Fish/Documentation/NCRMP_RVC_Protocol_2019.pdf (Accessed 19 February 2021)

NOAA NCCOS. 2018. NCRMP Sample Frame Development Protocols for U.S. Caribbean and FGBNMS. NOAA National Center for Coastal Ocean Services. 12 pp. Online: https://www.nodc.noaa.gov/archive/arc0101/0157633/7.7/data/0-data/Atlantic/Biological/Caribbean_Gulf-of-Mexico/NCRMP_Protocol_SampleFrame%20Protocol_2016.pdf (Accessed 19 February 2021)

Roth, L., P.R. Kramer, E. Doyle, and C. O'Sullivan. 2020. Caribbean SCTLD Dashboard (website). ArcGIS Online. Online: https://www.agrra.org (Accessed 19 February 2021)

Sadovy, Y., A. Rosario, and A. Román. (1994) Reproduction in an aggregating grouper, the red hind, *Epinephelus guttatus*. pp. 269–286. In: E.K. Balon, M.N. Bruton, and D.L.G. Noakes (eds.), Women in ichthyology: an anthology in honour of ET, Ro and Genie. Developments in Environmental Biology of Fishes 15(15). Springer, Dordrecht. doi: 10.1007/978-94-011-0199-8_21

Appendix: Supplemental Information

NCEI data package references:

U.S. Virgin Islands

- **USVI Benthic Collections** (all years):
  NOAA National Centers for Coastal Ocean Science; NOAA Southeast Fisheries Science Center (2018). National Coral Reef Monitoring Program: Assessment of coral reef fish communities in Puerto Rico. [indicate subset used]. NOAA National Centers for Environmental Information. Dataset. https://doi.org/10.7289/v5t72frz. Accessed [date].
- **2019 USVI Benthic Data:**
  National Centers for Coastal Ocean Science (NCCOS) and Southeast Fisheries Science Center (SEFSC) (2020). National Coral Reef Monitoring Program: Assessment of coral reef benthic communities in the U.S. Virgin Islands from 2019-06-08 to 2019-08-09 (NCEI Accession 0215460). [indicate subset used]. NOAA National Centers for Environmental Information. Dataset. https://accession.nodc.noaa.gov/0215460. Accessed [date].
- **USVI Fish Collections** (all years):
  NOAA National Centers for Coastal Ocean Science (2018). National Coral Reef Monitoring Program: Assessment of coral reef fish communities in the U.S. Virgin Islands. [indicate subset used]. NOAA National Centers for Environmental Information. Dataset. https://doi.org/10.7289/v5f769mm. Accessed [date].
- **2019 USVI Fish Data:**
  National Centers for Coastal Ocean Science (NCCOS) and Southeast Fisheries Science Center (SEFSC) (2020). National Coral Reef Monitoring Program: Assessment of coral reef fish communities in Puerto Rico from 2019-07-18 to 2019-12-29 (NCEI Accession 0218548). [indicate subset used]. NOAA National Centers for Environmental Information. Dataset. https://accession.nodc.noaa.gov/0216069. Accessed [date].

Puerto Rico

- **Puerto Rico Benthic Collections** (all years):
  NOAA National Centers for Coastal Ocean Science; NOAA Southeast Fisheries Science Center (2018). National Coral Reef Monitoring Program: Assessment of coral reef benthic communities in Puerto Rico. [indicate subset used]. NOAA National Centers for Environmental Information. Dataset. https://doi.org/10.7289/v5pg1q23. Accessed [date].
- **2019 Puerto Rico Benthic Data**:
  National Centers for Coastal Ocean Science (NCCOS) and Southeast Fisheries Science Center (SEFSC) (2020). National Coral Reef Monitoring Program: Assessment of coral reef benthic communities in Puerto Rico from 2019-07-18 to 2019-12-29 (NCEI Accession 0217139). [indicate subset used]. NOAA National Centers for Environmental Information. Dataset. https://www.ncei.noaa.gov/archive/accession/0217139. Accessed [date].

- **Puerto Rico Fish Collections** (all years):
  NOAA National Centers for Coastal Ocean Science; NOAA Southeast Fisheries Science Center (2018). National Coral Reef Monitoring Program: Assessment of coral reef fish communities in Puerto Rico. [indicate subset used]. NOAA National Centers for Environmental Information. Dataset. https://doi.org/10.7289/v5t72frz. Accessed [date].
- **2019 Puerto Rico Fish Data**:
  National Centers for Coastal Ocean Science (NCCOS) and Southeast Fisheries Science Center (SEFSC) (2020). National Coral Reef Monitoring Program: Assessment of coral reef fish communities in Puerto Rico from 2019-07-18 to 2019-12-29 (NCEI Accession 0218548). [indicate subset used]. NOAA National Centers for Environmental Information. Dataset. https://accession.nodc.noaa.gov/0218548. Accessed [date].

NCRMP Local Partner Programs:

NCRMP provides a broad geographic context to supplement local monitoring efforts and studies of tropical reef ecosystems. For more information on local partner programs in these regions, see:

Territorial Coral Reef Monitoring Program (TCRMP)
https://sites.google.com/site/usvitcrmp/

Puerto Rico Long-Term Coral Reef Monitoring Program
https://www.ncei.noaa.gov/archive/accession/0204647

Habitat types by region and year

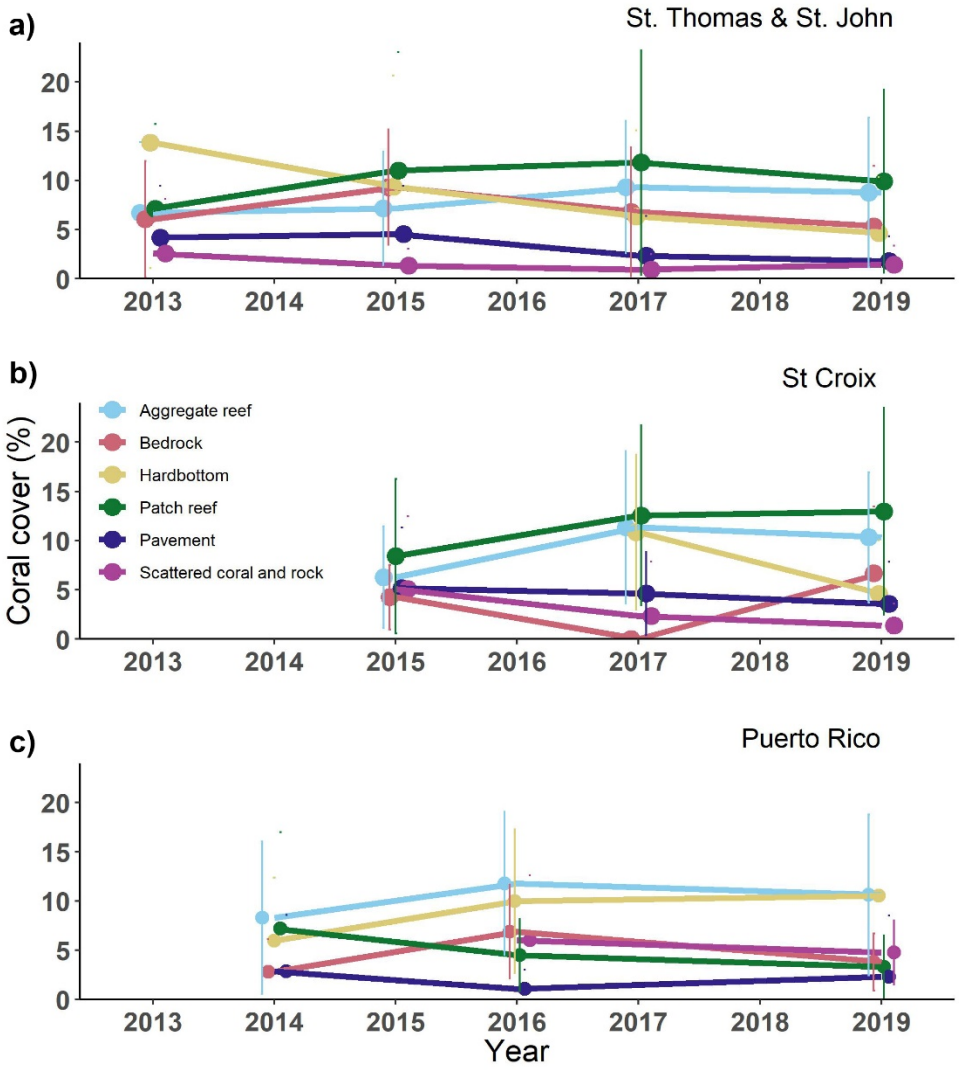


Figure A1. Mean hard coral cover for the six sampled habitat types (aggregate reef, bedrock, hardbottom, patch reef, pavement, and scattered coral and rock) for each NCRMP sampling year in (a) St. Thomas and St. John, (b) St. Croix, and (c) Puerto Rico.

U.S. Department of Commerce

Gina Raimondo, *Secretary*

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National Ocean Service

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